Waste Water Treatment System: Design and Operation Report

Permit-Review Level

NorthMet Project

Prepared for
Poly Met Mining, Inc.

Version 2

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Certification

I hereby certify this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota.

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Acronyms

CIP	Clean-in-Place
CPS	Central Pumping Station
FEIS	Final Environmental Impact Statement
FEIS	Final environmental impact statement
FTB	Flotation Tailings Basin
GCL	geosynthetic clay liner
GSF	greensand filter
HCEQ	High Concentration Equalization
HDPE	high-density polyethylene
HDS	high-density sludge
HRF	Hydrometallurgical Residue Facility
LBC	limestone bed contactors
LCEQ	Low Concentration Equalization
LSI	Langlier saturation index
MnDOT	Minnesota Department of Transportation
MPCA	Minnesota Pollution Control Agency
MPP	Mine to Plant Pipelines
NF	nanofiltration
NPDES	National Pollutant Discharge Elimination System
P50	50th percentile (median)
P90	90th percentile
RO	reverse osmosis
RTH	Rail Transfer Hopper
SDS	State Disposal System
VSEP	vibratory shear-enhanced process
WWTS	Waste Water Treatment System

1.0 Introduction

This Waste Water Treatment System (WWTS) Design and Operations Report (Design Report) describes the proposed permit-review level design and operation of the WWTS for the Poly Met Mining, Inc. (PolyMet) NorthMet Project (Project). The primary components of the WWTS for the Project will include the Equalization Basin Area at the Mine Site, the Mine to Plant Pipelines (MPP), the WWTS building, which is located at the Plant Site and will house the process equipment for the treatment trains. Large Figure 1 through Large Figure 3 show the proposed location of the WWTS and other prominent Project features.

The design and operation of the WWTS has been developed as an integrated system to address the goals of the overall water management strategy for the Project. These goals include:

- Maximize beneficial reuse of mine water in the Beneficiation Plant
- Treat tailings basin seepage to meet all applicable state and federal standards before it is discharged
- Reduce the overall mercury loading to the St. Louis River watershed
- Minimize hydrologic impacts of the Project

To achieve these goals, the Project waste water treatment strategy is integrated across the Mine and Plant Sites, as illustrated on Figure 1-1, which shows key flows. Maximizing re-use of mine water minimizes the water appropriation needs for the Project from Colby Lake. Collection of Flotation Tailings Basin (FTB) seepage for the influent stream to the tailings basin seepage treatment train of the WWTS also allows for mercury removal through adsorption to tailings before the water is treated in the WWTS, thereby minimizing the need for additional mercury treatment. WWTS discharge will consist of treated water from the tailings basin seepage treatment train and will replace flow collected by the FTB seepage capture systems, with a goal to maintain average annual flow at pre-project hydrologic conditions along multiple sub-watersheds around the Tailings Basin.

The WWTS will use greensand filtration and membrane separation to remove metals and sulfate from mine water and tailings basin seepage. Additional membrane separation will be used to concentrate these constituents into a reduced flow volume. Chemical precipitation will be used to remove these constituents from the high-strength flows from some waste rock stockpiles and the concentrated solutions from the membrane separation processes. Permeate from the primary membrane separation process will be chemically stabilized prior to discharge to the environment.

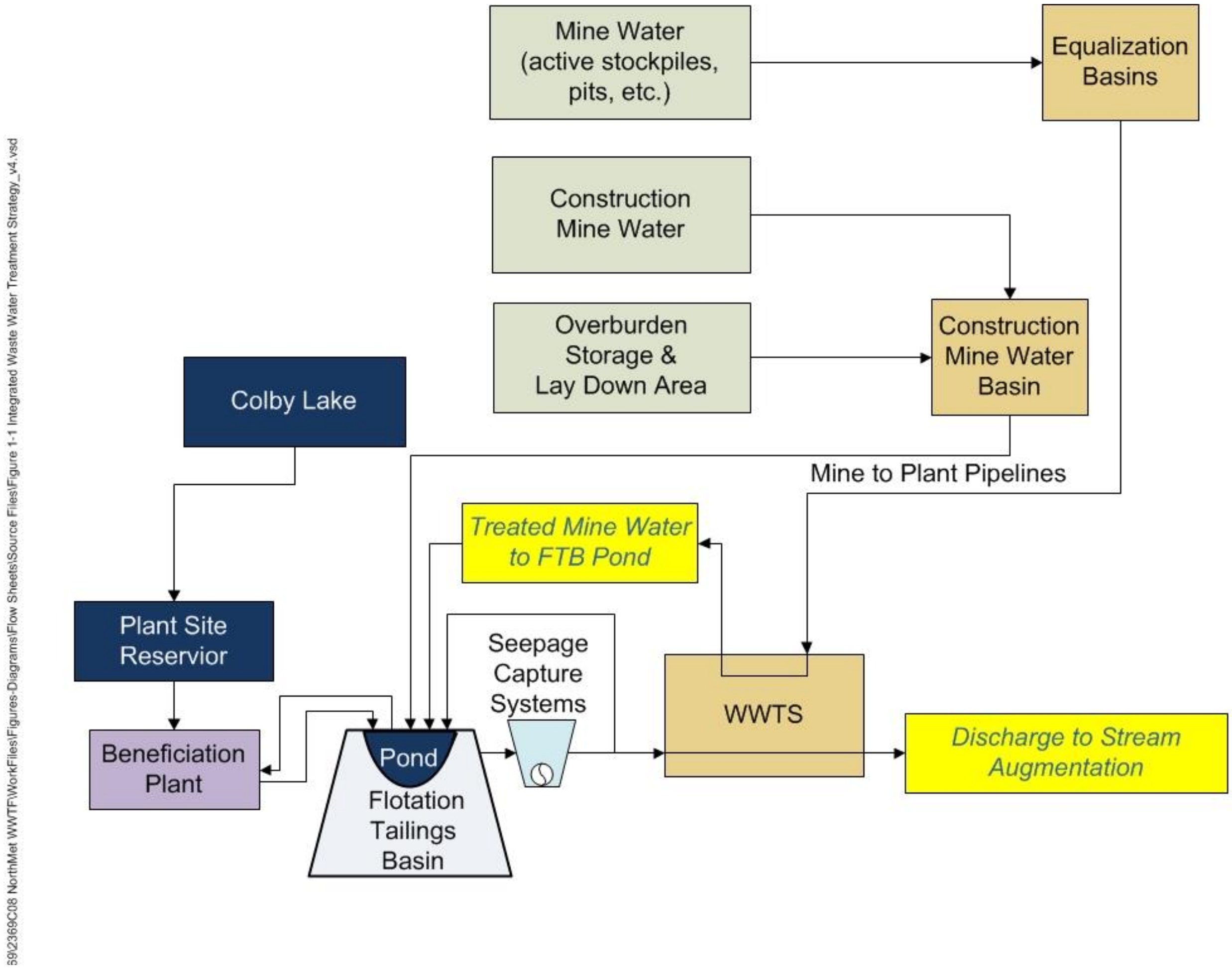


Figure 1-1 Waste Water Treatment System Overview: Operations

1.1 Purpose and Outline

The purpose of this Design Report is to document the design basis for waste water treatment for the Project in support of NPDES/SDS permitting.

The outline of this report is:

Section 1.0	Introduction, purpose, and outline.
Section 2.0	Description of the information used to design the waste water treatment system, including flow and water quality information from the GoldSim model simulations used to support the FEIS, operational requirements for the Project, pilot-testing, bench testing, equipment vendors, and published data.
Sections 3.0	Description of the basis for selection of components for the tailings basin seepage treatment train, iterative modeling to determine optimal component configuration,

	and preliminary design and operational plans for the tailings basin seepage treatment train.
Section 4.0	Description of the basis for selection of components for the mine water treatment trains, iterative modeling to determine optimal component configuration, and preliminary design and operational plans for the mine water treatment trains.
Section 5.0	Description of the chemical usage and handling for the WWTS, based on the results of the design and modeling work presented in Section 3.0 and Section 4.0.
Section 6.0	Description of the WWTS relocations that have been incorporated into the Project.

2.0 Waste Water Treatment System Design Information and Data

The permit-review level design of the WWTS is based on:

- influent flow and water quality estimates from GoldSim modeling and operational requirements for the Project
- effluent flow and water quality treatment targets based on the projected NPDES/SDS Permit requirements
- pilot-test data
- bench test data
- equipment vendor data
- published data

These data sources are described in the following paragraphs.

2.1 Tailings Basin Seepage Influent Flow and Water Quality

Tailings basin seepage influent flow and load information is based on the GoldSim model simulations of Plant Site water quality and quantity conducted in support of the NorthMet Project and Land Exchange Preliminary Final Environmental Impact Statement (FEIS, Reference (1)). GoldSim is a probabilistic model framework that uses Monte Carlo simulation to quantify the uncertainty in the various aspects of the model system. The model is run many times, with model results expressed as probability distributions. Full GoldSim model results are presented in the Water Modeling Data Package – Volume 2, Plant Site (Reference (2)). Attachment A contains additional details on the derivation of design values for tailings basin seepage influent flow and water quality using the GoldSim data.

2.1.1 Tailings Basin Seepage Treatment Train Inputs

The tailings basin seepage treatment train will receive seepage collected by the FTB seepage capture systems. Initially, approximately 60% of the seepage will be recycled to the FTB Pond, with approximately 40% of the seepage being treated at the WWTS and discharged to the environment. As operations continue, the fraction of seepage to be treated at the WWTS and discharged will increase to approximately 50%. The distribution of the FTB seepage flow will depend on several factors, but the discharge goal will be to augment the receiving streams (Trimble Creek, Unnamed Creek, and Second Creek) within 20% of their natural average annual flow (conditions before the implementation of the pumpback systems, which are short-term mitigation measures as part of the Cliffs Erie L.L.C. Consent Decree) (Section 5.2.2.1.2 of Reference (1)). The general strategy for routing water from the FTB seepage capture systems to the WWTS will be to route more concentrated seepage sources to the WWTS and send less concentrated seepage back to the FTB Pond.

In this document, the “FTB” means the newly constructed NorthMet Flotation Tailings Basin, the “LTV Steel Mining Company (LTVSMC) tailings basin” means the existing former LTVSMC tailings basin, and the ”Tailings Basin” means the combined LTVSMC tailings basin and the FTB, which is built over approximately half of the LTVSMC tailings basin. Once operational, most of the water that becomes seepage from the Tailings Basin originates at the FTB Pond and then flows through the Tailings Basin by gravity. The primary inflows to the FTB Pond are direct precipitation and runoff from surrounding areas; return process water from the beneficiation process; treated mine water from the WWTS; seepage collected by the FTB Seepage Containment System and the FTB South Seepage Management System (collectively referred to as the FTB seepage capture systems); construction mine water and Overburden Storage and Laydown Area (OSLA) water from the Mine Site, and make-up water from Colby Lake. A more detailed description of the water balance for the FTB Pond is provided in Attachment A and in the Water Modeling Data Package – Volume 2, Plant Site (Reference (2)).

2.1.2 GoldSim Influent Flow Projections

Section 2.1 of Attachment A summarizes the estimated quantity of seepage to be treated at the WWTS over the 20-year operational life for the Project. This amount includes the volume required to augment flow and maintain the hydrologic conditions of local streams. The 90th percentile (P90) annual average and maximum monthly flows from the GoldSim model were used as the design inflow for WWTS tailings basin seepage treatment modeling and design for the first seven years of operation. The maximum treatment rate needed for the first seven years of operation is estimated to at approximately 2,000 gallons per minute (gpm). From Mine Year 8 to Mine Year 20, the maximum treatment rate is estimated at 4,000 gpm. Flow rates will fluctuate annually, as the Project is built out, and seasonally, based on precipitation.

The overall tailings basin seepage treatment train design flow incorporates estimated influent flows from GoldSim modeling and flows of internal recycle streams within the tailings basin seepage treatment train operations, as described in Section 3.3.2.

2.1.3 Tailings Basin Seepage Treatment Train Influent Water Quality Projections

As part of pilot-testing conducted in support of tailings basin seepage treatment train design, water quality data were collected from SD004, an existing seep from the LTVSMC tailings basin, and a pilot well installed near SD004, both of which provided source water for the pilot-test. These data are summarized in the Plant Site Waste Water Treatment Plant Pilot-Testing Report (Attachment B). These feed water sources for the pilot-test were selected from areas known to generally have more than 250 mg/L of sulfate in the groundwater and surface water and to be indicative of the starting water quality from the FTB seepage capture systems. The actual pilot-test well sulfate water quality ranged from 92 to 470 mg/L; therefore, the pilot-test feed water quality is considered a conservative estimate of Mine Year 1 water quality for the tailings basin seepage treatment train influent.

Over time, seepage through the Flotation Tailings will influence the quality of the water collected by the FTB seepage capture systems. Therefore, after Mine Year 1, the GoldSim projections of constituent concentrations over the life of the mine (Large Table 1 of Attachment A) were used to estimate influent water quality. GoldSim modeling produced probabilistic water quality estimates for the tailings basin seepage influent. As described in Attachment A, these estimates were converted from a probabilistic form into a deterministic form to support design of the tailings basin seepage treatment train, with the selection of the P90 constituent concentrations.

2.2 WWTS Discharge Treatment Targets

The discharge from the WWTS must meet applicable water quality discharge limits. The treatment targets for the WWTS discharge are shown in Table 2-1. These represent possible discharge limits based on current state and federal rules that were used to evaluate preliminary design and modeling. Actual limits will be established in the NPDES/SDS Permit.

Table 2-1 WWTS Discharge Treatment Targets Used for Design

Parameter	Target	Basis
Metals/Inorganics (total in µg/L, except where noted)		
Aluminum	125	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Antimony	31	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Arsenic(1,2)	10	Federal Drinking Water Standard (Primary MCLs)
Barium(5)	2,000	Minnesota Groundwater Standards (HRL, HBV, or RAA)
Beryllium(5)	4	Federal Drinking Water Standard (Primary MCLs)
Boron	500	Minnesota Rules, part 7050.0224 Class 4A (chronic standard)
Cadmium(2,3)	2.5	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Chromium(4)	11	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Cobalt	5	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Copper(2,3)	9.3	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Iron(5)	300	Federal Drinking Water Standard (Secondary MCLs)
Lead(2,3)	3.2	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Manganese(5)	50	Federal Drinking Water Standard (Secondary MCLs)
Mercury(2,6)	1.3 (ng/L)	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Nickel(3)	52	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Selenium	5	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Silver	1	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Thallium	0.56	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Zinc(2,3)	120	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)

Parameter	Target	Basis
General Parameters (total, except where noted)		
Chloride	230 (mg/L)	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Fluoride(5)	2 (mg/L)	Federal Drinking Water Standard (Secondary MCLs)
Hardness(6)	100 (mg/L)	Hardness target chosen to establish targets for metals with a hardness-based standard
Oxygen, Dissolved(7)	>5.0 (mg/L)	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
pH(2)	6.5-8.5 (SU)	Minnesota Rules, part 7050.0222 Class 2B (chronic standard) Minnesota Rules, part 7050.0224 Class 4A (chronic standard)
Solids, Total Suspended(2,7)	15 (mg/L)	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Sodium	60% of cations	Minnesota Rules, part 7050.0224 Class 4A (chronic standard)
Sulfate	10 (mg/L)	Internal performance operating limit(8)
Whole Effluent Toxicity, (WET)(7)	Meet acute and chronic standards	Minnesota Rules, part 7050.0240

(1) Minnesota Rules, part 7050.0222 Class 2B standard for arsenic is 53 µg/L.
(2) Parameter with an effluent limit guideline in 40 CFR 440, which is less stringent than the listed target.
(3) Surface water standard based on hardness, value shown assumes hardness of 100 mg/L.
(4) The Chromium (+6) standard of 11 µg/L is used rather than the total Chromium standard to be conservative.
(5) Treatment target used in design, but does not have a promulgated surface water quality standard.
(6) Minnesota Rules, part 7050.0223 Class 3C standard for hardness is 500 mg/L.
(7) Treatment target anticipated to be achieved in WWTS discharge, but not modeled.
(8) PolyMet plans to implement an internal performance operating limit of 10 mg/L for sulfate, as described in Appendix D of Volume I of the NPDES/SDS Permit Application.

2.3 Mine Water Treatment Trains Influent Flow and Water Quality

Mine water flow and load information is based on the results of the GoldSim model simulations of Mine Site water quality and quantity conducted in support of the Project FEIS, as presented in the Water Modeling Data Package – Volume 1, Mine Site (Reference (3)). Additional information developed to describe the Mine Site hydrology and proposed Mine Site dewatering operations were also considered. Attachment C presents additional details on the derivation of the design values for mine water treatment trains influent flow and water quality.

2.3.1 Mine Water Treatment Trains Inputs

The mine water treatment trains will receive mine water from pit dewatering, seepage from waste rock and ore stockpiles, and drainage from areas of the Mine Site that PolyMet has agreed to manage as mine water. The mine water treatment trains will also receive secondary membrane concentrate flows from the tailings basin seepage treatment train. A more detailed description of the inputs to the mine water treatment trains is presented in Reference (3).

Mine water to be treated by the WWTS mine water treatment trains will consist of two general types of flows. The first flow type is characterized by high flow volumes with relatively low concentrations of dissolved metals and sulfate. These high-volume, low-concentration flows will originate from the mine pits, the haul roads, the Category 1 Stockpile Groundwater Containment System, and the Rail Transfer Hopper. The second flow type is characterized by lower flow volumes with higher concentrations of dissolved metals and sulfate. These low-volume, high-concentration flows generally include drainage from the temporary waste rock stockpiles, Ore Surge Pile, and the secondary membrane concentrate from the tailings basin seepage treatment train.

The distinction between these two types of flows is the basis for the parallel use of two separate mine water treatment trains as detailed in Section 4.0. High-volume, low-concentration flows will be routed to the Low Concentration Equalization (LCEQ) Basins and then to the mine water membrane separation treatment train. Low-volume, high-concentration flows will be routed to the High Concentration Equalization (HCEQ) Basin and then to the mine water chemical precipitation treatment train.

2.3.2 Mine Water Treatment Trains Influent Flow Projections

Section 2.1 of Attachment C provides a summary of the estimated quantity of mine water to be treated at the mine water treatment trains over the 20-year operational life of the Project.. Mine water flows will initially report to either the LCEQ Basins or the HCEQ Basin, which will moderate the flowrates that will need to be conveyed to the WWTS for treatment. Over the operational phase of the Project, mine water flows are generally proportional to the footprint of the active mine pits and stockpiles, with the peak mine water flows to the equalization basins occurring around Mine Year 10. Flow rates will also fluctuate seasonally, influenced by precipitation and snowmelt. The annual variation in flow, including the spring flood (snowmelt), average summer, and average winter flow rates, are further discussed in Section 3 of Attachment C.

The overall mine water treatment design flow incorporates estimated mine water flows during the spring flood in Mine Year 10, flows of internal recycle streams, and pond sizing considerations, as detailed in Section 4 of Attachment C and summarized in Section 4.3.2. Flows include stockpile drainage from Category 1, Category 2/3, and Category 4 Waste Rock Stockpiles, the Ore Surge Pile, mine pit dewatering, drainage from the Rail Transfer Hopper and load-out area, haul roads, and secondary membrane concentrate from the tailings basin seepage treatment train.

The GoldSim modeling results indicate that the peak mine water flow to the LCEQ and HCEQ Basins occurs around Mine Year 10 with a secondary peak around Mine Year 14.

2.3.3 Mine Water Treatment Trains Influent Water Quality Projections

GoldSim modeling was used to produce probabilistic water quality estimates for the mine water routed to the WWTS over the life of the mine. As described in Attachment C, these estimates were converted from a probabilistic form into a deterministic form to support design of the mine water treatment trains. Separate influent water quality design bases were selected for the LCEQ Basins and the HCEQ Basin, as shown in Table 10 of Attachment C. GoldSim projections of the P90 constituent concentrations over the life of the mine (Large Tables 2 and 3 of Attachment C) were used as the starting point to estimate influent water quality to the LCEQ Basins and HCEQ Basin. GoldSim results were also adjusted to take into account the relationship between flow rate and parameter concentration (Section 5 of Attachment C).

2.4 Treated Mine Water Treatment Targets

Because the effluent from the mine water treatment trains (treated mine water) will be delivered to the FTB Pond, for the purpose of designing the waste water treatment systems, it is considered an internal waste stream. Because the treated mine water will not be discharged to the environment, the treatment targets for the treated mine water were selected to:

- Establish mass reduction values for the treated mine water to maintain the long-term water quality of the FTB Pond for use in the Beneficiation Plant, and
- Maintain overall water quality in the FTB Pond to manage the water quality of tailings basin seepage, which will be the influent to the tailings basin seepage treatment train.

The treatment targets that were used to evaluate preliminary design and modeling for the treated mine water are listed in Table 2-2. Some of these targets differ from WWTS discharge treatment targets. For example, the treated mine water treatment targets have a less stringent target for water hardness, which translates into less stringent targets for metals with hardness-based criteria. In addition, the treated mine water treatment target for sulfate is the federal secondary MCL rather than the 10 mg/L internal performance operating limit used for the WWTS discharge. The secondary MCL was selected as a target, because it is close to the current water quality in the FTB Pond.

Table 2-2 Treated Mine Water Treatment Targets Used for Design

Parameter	Target	Basis
Metals/Inorganics (total in µg/L, except where noted)		
Aluminum	125	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Antimony	31	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Arsenic(1,2)	10	Federal Drinking Water Standard (Primary MCLs)
Barium	2,000	Minnesota Groundwater Standards (HRL, HBV, or RAA)
Beryllium	4	Federal Drinking Water Standard (Primary MCLs)
Boron	500	Minnesota Rules, part 7050.0224 Class 4A (chronic standard)
Cadmium(2,3)	5.1	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Chromium(4)	11	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Cobalt	5	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Copper(2,3)	20	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Iron	300	Federal Drinking Water Standard (Secondary MCLs)
Lead(2,3)	10.2	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Manganese	50	Federal Drinking Water Standard (Secondary MCLs)
Nickel(3)	113	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Selenium	5	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Silver	1	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Thallium	0.56	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Zinc(2,3)	260	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
General Parameters (total, except where noted)		
Chloride	230 (mg/L)	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Fluoride	2 (mg/L)	Federal Drinking Water Standard (Secondary MCLs)
Hardness(5)	250 (mg/L)	FEIS modeling assumption
Sodium	60% of cations	Minnesota Rules, part 7050.0224 Class 4A (chronic standard)
Sulfate	250 (mg/L)	Federal Drinking Water Standard (Secondary MCLs)

(1) Minnesota Rules, part 7050.0222 Class 2B standard for arsenic is 53 µg/L.
(2) Parameter with an effluent limit guideline in 40 CFR 440, which is less stringent than the listed target.
(3) Surface water standard based on hardness, value shown assumes hardness of 250 mg/L.
(4) The Chromium (+6) standard of 11 µg/L is used rather than the total Chromium standard to be conservative.
(5) Minnesota Rules, part 7050.0223 Class 3C standard for hardness is 500 mg/L.

2.5 Pilot-Test Data

To aid in the design of the waste water treatment system, three pilot-tests were conducted to evaluate the performance of key components of the proposed treatment operations – greensand filtration, primary membrane separation, and secondary membrane separation.

- Plant Site Waste Water Treatment Plant Pilot-Testing Program (Attachment B) was conducted between May and December 2012 using a blend of SD004 water and water from a pilot well located in the northwest corner of the LTVSMC tailings basin, which is a high concentration area of the groundwater capture zone from the Tailings Basin. The set-up, operation, and results of this testing work are described in Attachment B.

- Additional pilot-testing (Reverse Osmosis Pilot-Test Report, Attachment D) was conducted between January and July 2013 using water from the Area 5 NW Pit to represent mine water. A summary of the set-up, operation, and results from the Reverse Osmosis Pilot-Test Report are included in Attachment D. The Reverse Osmosis Pilot-Test Report focused on primary (GE AG membrane) and secondary (Hydranautics ESPA-1) reverse osmosis (RO) membranes.
- The final round of pilot-testing (Waste Water Treatment Facility Pilot-Testing Program; Attachment E) was conducted from July 2013 through October 2013. This test also used water from the Area 5 NW Pit as the influent and incorporated additional membrane types into the membrane separation testing process, including primary (GE HL4040FM NF) and secondary (Dow NF-270) nanofiltration (NF) membranes. The set-up, operation, and results of this testing are included in Attachment E.

The results of the pilot-testing provide the basis for establishing design inputs for important components of the WWTS, including:

- achievable recovery for primary and secondary membrane equipment
- observed rejection rates for metals and sulfate by the primary and secondary membranes

Pilot-testing results also demonstrated reliable achievement of treatment targets with the primary membrane separation equipment. Additional details of the design that were derived from the pilot-test results are discussed in Section 3.0 and 4.0.

2.6 Bench Test Data

Chemical precipitation bench tests were conducted on secondary membrane concentrate from two of the pilot-tests (Attachment D and Attachment E). These bench tests used secondary membrane concentrate as feed because their high salt content represents a worst-case scenario from a chemical precipitation standpoint. The objectives of these bench tests were:

- to confirm the operating conditions (i.e., pH, solids content) suggested by PHREEQC for precipitation and adsorption of metals and sulfate in the chemical precipitation process
- to confirm the reaction time required to achieve the desired removal efficiencies for metals and sulfate in the chemical precipitation process
- to evaluate if pretreatment is necessary to counteract effects of antiscalants in the concentrates prior to chemical precipitation
- to evaluate the critical settling velocities for sludges formed during chemical precipitation

Bench testing results demonstrated that chemical precipitation can be used to achieve removal of sulfate and metals from the secondary membrane concentrate.

Bench testing also was conducted to provide an estimate of the chemical addition requirements needed to stabilize the tailings basin seepage treatment primary membrane permeate prior to being discharged to the environment. The set-up, operation, and results of this work are included in Attachment B, and are used as the basis of design for the effluent stabilization components of the tailings basin seepage treatment train in Section 3.0.

2.7 Equipment Vendor Data

For the purposes of membrane design, equipment vendor projections for membrane recovery and constituent rejection were used in conjunction with membrane rejections observed during pilot-tests to model the anticipated, long-term performance of the proposed treatment systems, as designed. These vendor projections were obtained by providing feed water quality and quantity estimates for various design years to the membrane manufacturers.

In the case of some parameters, limited vendor data exist; therefore, pilot-testing was conducted to supplement the vendor data, as documented in Section 2.5, 3.0, and 4.0.

Membrane treatment projections and preliminary cut-sheets for treatment processes that were obtained from the vendors are included in Attachment F and Attachment G.

2.8 Published Data

For the purposes of calculating removal efficiencies for metals and sulfate and for calculating appropriate chemical dosages in the chemical precipitation and effluent stabilization equipment, published data regarding solubility of target phases was obtained from the Minteq version 4 database distributed with the U.S. Geological Survey PHREEQC model. These removal efficiencies were checked against bench testing data.

2.9 Space Requirements

The WWTS building and associated access will require a site location with at least four acres. The Pre-Treatment Basin will require additional space. For the permit-level design, a four-acre site south of the FTB with an adjacent area at a lower elevation is proposed. Alternative locations may need to be considered during the final design phase if additional space requirements are identified or other Project operations limit the space available south of the FTB.

The proposed Equalization Basin Area is located south of Dunka Road and southwest of the proposed Rail Transfer Hopper. The Equalization Basin Area needs to have adequate space for the equalization basins, Construction Mine Water Basin, Central Pumping Station, and Construction Mine Water Pumping Station.

3.0 Tailings Basin Seepage Treatment Train Design and Operation

The purpose of the tailings basin seepage treatment train at the WWTS is to treat tailings basin seepage for discharge to the environment when discharge is required to augment flows of the receiving streams or when the Project has excess water that cannot be recycled or stored in the FTB. During operations, WWTS discharge will be routed to streams north (Trimble Creek), south (Second Creek), and west (Unnamed Creek) of the Tailings Basin. This discharge will maintain the stream flow by replacing recharge that will be cut off by the FTB seepage capture systems. PolyMet plans to tailings basin seepage treatment train in two phases, with the first build-out covering Mine Years 1 to 7, when influent flow is at half its ultimate rate, as described in Section 2.1.2. The second phase of the tailings basin seepage treatment train build-out, which will be ready for operation at the beginning of Mine Year 8, will expand the tailings basin seepage treatment train to the full design flow rate.

The process of designing the tailings basin seepage treatment train at the WWTS consisted of four interrelated activities. First, basic components of the tailings basin seepage treatment train were selected based on characteristics of the Project, treatment objectives, and available water treatment technology (Section 3.1). Second, the components were iteratively modeled to develop an optimized system configuration that will achieve water quality treatment objectives (Section 3.2). Third, the system configuration was developed into a preliminary design that satisfies operational design considerations such as reliability and flexibility, with details such as membrane types, pond sizes, recycle streams, and chemical additions, to produce an effluent that will meet the proposed treatment objectives (Section 3.3). Fourth, preliminary (permit-review level) plans were developed for tailings basin seepage treatment train operation (Section 3.4). The scope of this section includes modeling and preliminary design through Mine Year 20 of the tailings basin seepage treatment train.

3.1 Selection of Tailings Basin Seepage Treatment Train Components

Selection of treatment components for the tailings basin seepage treatment train was driven primarily by the sulfate treatment target of 10 mg/L. In particular, the primary reverse osmosis membrane separation process was selected for the purpose of achieving the sulfate target.

The four basic treatment components that were selected for use at the tailings basin seepage treatment train include:

- Pretreatment using greensand filtration (GSF), to remove constituents that could harm the primary membrane separation units.
- Primary membrane separation, to remove dissolved constituents.
- Secondary membrane separation, to reduce the volume of the primary membrane separation concentrate and increase the sulfate concentration in the concentrate for subsequent chemical precipitation at the mine water chemical precipitation train.

- Stabilization, to reduce corrosivity and toxicity, and adjust the pH of primary membrane separation permeate before it is discharged to the environment.

The primary membrane separation process will be used to separate dissolved constituents (solutes) from water by applying pressure to drive water molecules across the membrane and away from the dissolved constituents. During this process, clean water (permeate) passes through the membrane, while a concentrated brine solution (concentrate) is retained by the membrane. Membranes used in the primary membrane separation process will include both RO membranes and nanofiltration (NF) membranes. NF membranes use the same RO process (i.e., reversal of osmotic diffusion by applying energy) as RO membranes and are specifically designed for the retention of many of the constituents of interest for this Project, including sulfate and divalent metals. The percentage of a given solute that is retained by the membrane separation process is termed the rejection, and is expressed as a percentage of the feed concentration. The percentage of the feed water volume that permeates the membrane is termed the recovery. In this document, mass-based rejections are used, which express the percentage of solute mass that is retained by the membrane, and incorporate both rejection and recovery.

While pilot-testing has demonstrated that the primary membrane separation process is capable of achieving the sulfate target using either RO or NF membranes (Attachment B, Attachment D, and Attachment E), the system will use a combination of both membrane types. The reasons for including this level of robustness in the tailings basin seepage treatment train design include:

- RO membranes reject slightly more sulfate than NF membranes, and thus may provide a benefit for future performance if membrane rejection declines with age,
- NF membranes are less subject to silica fouling, and thus may provide a benefit for future system operation if silica concentrations increase, and
- NF membranes allow passage of a higher percentage of sodium and chloride, thereby reducing the potential for these salts to cycle up within the water management components of the Project including the mine water treatment trains at the WWTS, the FTB Pond, and the FTB seepage capture systems.

Reliable operation of the primary membrane separation process will require adequate pre-treatment to remove potential membrane foulants, such as iron and manganese. Greensand filtration was selected as the pretreatment technology for this purpose. Greensand filtration also provides the added benefit of removal of some other metals, such as copper and arsenic, as demonstrated in the Waste Water Treatment Facility Pilot-Testing Program (Attachment E).

Further treatment of the primary membrane concentrate via a secondary membrane separation system was included in the design of the tailings basin seepage treatment train, because it will:

- Decrease the volume of concentrate that will need to be treated by the mine water chemical precipitation train.

- Increase the concentration of sulfate in the concentrate prior to routing to the mine water chemical precipitation train, which will increase the mass of sulfate that can be removed.

NF membranes (Dow NF 270) were selected for the secondary membrane separation system, because this will help to lower the ratio of sodium to sulfate in the concentrate relative to RO membranes. Lowering the sodium to sulfate ratio reduces the effective solubility limit for sulfate, thereby improving the precipitation of sulfate in the mine water chemical precipitation train. A more detailed description of this effect is included in the presentation of the chemical precipitation modeling in Section 3.2.5.

The permeate from the secondary membrane separation process will be routed back to a dedicated set of NF membranes within the primary membrane separation unit operation to provide polishing of sulfate and other constituents that may permeate the secondary membrane separation due to the high feed concentrations.

Stabilization will be employed to prepare the primary membrane separation permeate for discharge to the environment. This step is needed because testing of the primary membrane permeate during pilot-testing showed that it is potentially corrosive due to its low concentrations of dissolved solids and high concentrations of dissolved carbon dioxide (gases permeate the membrane). The low concentrations of dissolved solids and high concentrations of dissolved carbon dioxide can also result in the potential for toxicity to aquatic organisms from exposure to unstabilized membrane permeate. In the tailings basin seepage treatment train process design, stabilization via limestone contactor was selected to contribute alkalinity and hardness to the effluent, thereby reducing its corrosivity and toxicity. Degassing was also included to further stabilize the effluent by off-gassing residual dissolved carbon dioxide. Additional controls to modulate the temperature, pH, or the dissolved oxygen content of the treated water prior to discharge to the environment will also be contemplated during detailed and final design, if necessary.

3.2 Modeling of Tailings Basin Seepage Treatment Train

The components described above were combined into an overall process that was iteratively modeled, varying the process based on interim results, to select an optimal system configuration. The following section describes the modeling method that was used to optimize the design and the results obtained from that modeling. Models were run for Mine Years 1, 7, 8, 10, 15, and 20.

3.2.1 Modeling Framework

Tailings basin seepage treatment process modeling used a combination of two modeling software packages; GoldSim and PHREEQC (collectively termed GoldPHREEQC). GoldSim is used to simulate flows of water and solute mass between unit processes. Physical separation processes, such as greensand filtration and membrane filtration, are achieved in GoldSim by specifying the fractions of water and solute mass routed to filtrate/permeate and backwash/concentrate. Chemical processes, such as pH adjustment and effluent stabilization, are accomplished via the use of PHREEQC water quality modeling software as a subroutine to GoldSim. GoldSim provides solution composition and chemical dose to PHREEQC, which computes solution composition and pH after equilibration, and provides that information to GoldSim for routing to the next unit process. This method computes the required chemical dose and accounts for the solute mass added with treatment chemicals.

One of the primary design activities for the tailings basin seepage treatment train was to determine the optimal proportion of different membrane types (i.e., RO or NF) within the primary membrane separation treatment step. Because influent tailings basin seepage quality is estimated to change over time, the modeling framework allows for adjustment of the amount of feed flow routed to these two different membrane types to balance the positive aspects of each of these components.

3.2.2 Model Inputs

Inputs to the GoldPHREEQC process model of the tailings basin seepage treatment train included:

- Influent flow volumes and influent design water quality as described in Section 2.1
- Greensand filtration removal rates as determined by pilot-testing
- Membrane recovery and rejection rates as determined by pilot-testing

Table 3-1 summarizes the tailings basin seepage water quality used in models, as described in Attachment A. Charge balancing was necessary because the influent for geochemical modeling and process design must be electrically neutral. While the GoldSim water quality modeling for the FEIS produced probabilistic water quality estimates for concentrations of each constituent, it did not consider the need to balance the overall combination of these constituents within the solution. While this provided a conservative assessment of several constituents of interest for the purposes of environmental review, the results cannot be used in subsequent GoldPHREEQC modeling without correcting for the charge imbalance. Therefore, to prepare the GoldSim results for use in waste water treatment modeling, the solution charge was balanced by adjusting alkalinity, assuming a pH of 7.5.

Table 3-1 Tailings Basin Seepage Water Quality Used in Process Model

Parameter	Units	Mine Year 1(1)	Mine Year 7	Mine Year 8	Mine Year 10	Mine Year 15	Mine Year 20
P90 Annual Average Flow	gpm	1,937.0	2,000.0	2,868.0	3,900.0	3,525.0	2,282.0
pH	std units	7.5	7.5	7.5	7.5	7.5	7.5
Silver	µg/L	0.1	0.3	0.3	0.2	0.2	0.2
Aluminum	µg/L	11.4	12.7	11.4	10.0	11.4	5.1
Alkalinity[2]	mg/L as HCO_3^-	347.0	131.1	153.3	454.6	762.0	1,117.8
Arsenic	µg/L	3.7	14.1	18.3	24.2	45.7	67.5
Boron	µg/L	245.9	276.4	245.1	216.8	229.0	122.5
Barium	µg/L	171.7	48.5	33.7	26.5	26.3	20.7
Beryllium	µg/L	0.2	0.4	0.5	0.4	0.5	0.4
Inorganic Carbon(2)	mg/L as HCO_3^-	342.0	135.5	159.1	476.2	798.6	1,168.2
Calcium	mg/L	37.6	87.1	88.6	90.3	168.8	288.5
Cadmium	µg/L	0.1	0.8	1.0	1.3	2.4	4.0
Chloride	mg/L	18.8	24.2	25.0	24.5	24.4	30.6
Cobalt	µg/L	2.1	21.0	22.3	24.4	40.7	75.9
Chromium	µg/L	0.5	3.6	4.9	6.0	7.1	7.6
Copper	µg/L	8.1	232.3	327.1	395.1	534.1	602.3
Fluoride	mg/L	3.9	2.1	1.8	1.4	1.2	1.4
Iron	µg/L	1,229.0	8,375.6	7,353.2	2,847.0	2,357.7	547.0
Potassium	mg/L	7.6	15.3	17.6	21.0	31.1	38.7
Magnesium	mg/L	63.9	102.0	95.5	87.0	99.4	98.5
Manganese	µg/L	300.0	899.9	910.4	829.8	898.2	814.2
Sodium	mg/L	59.0	73.0	71.9	69.0	77.7	113.4
Nickel	µg/L	11.6	256.1	283.4	343.8	563.7	965.8
Lead	µg/L	1.1	12.1	20.1	31.7	53.9	67.8
Antimony	µg/L	0.4	6.0	6.6	8.0	12.9	20.7
Silicon(3)	mg/L	34.8	34.8	34.8	34.8	34.8	34.8
Selenium	µg/L	0.50	1.7	1.9	2.0	3.5	6.0
Sulfate	mg/L	168.0	650.5	610.3	336.3	358.2	431.8
Thallium	µg/L	0.1	0.2	0.2	0.2	0.2	0.2
Vanadium	µg/L	3.9	6.1	7.2	8.0	9.2	9.4
Zinc	µg/L	10.5	49.9	65.4	86.6	163.3	253.6

Source: Reference (2)

(1) Mine Year 1 water quality based on SD004 seep water quality from pilot-test. Water quality for other Mine Years based on FEIS model.

(2) Alkalinity and inorganic carbon concentrations calculated based on charge balance to achieve pH 7.5.

(3) Silicon lowered to 34.75 mg/L to allow for 75% system recovery.

3.2.3 Treatment Objectives

Treatment objectives for the tailings basin seepage treatment train are to meet WWTS discharge treatment targets and produce a stable effluent.

The WWTS discharge must meet applicable water quality discharge limits. The treatment targets for the WWTS discharge are shown in Table 2-1. Actual limits will be established in the NPDES/SDS Permit.

The tailings basin seepage treatment train will be designed to produce a stable effluent that achieves two effluent stability measurements:

- Langelier Saturation Index (LSI) ≥ 0 (or as high as practicable)
- Calcium carbonate saturation index (SI) > 0

As noted in Section 3.1, effluent stability is an issue because permeate from the primary membrane separation process will have a low pH and limited buffering capacity. Because the membrane separation process will remove most of the dissolved constituents from water, the permeate will likely contain inadequate divalent minerals for discharge, with low amounts of calcium and alkalinity. Additionally, the primary membrane permeate will contain elevated concentrations of dissolved carbon dioxide. The carbon dioxide is formed from the reaction of antiscalant chemicals, which are added to the primary membrane separation feed water to protect the membranes, with bicarbonate alkalinity already present in the feed water.

3.2.4 Model Construct

The overall flow sheet for the tailings basin seepage treatment train is shown on Large Figure 4.

The GoldPHREEQC model represents waste water unit processes with model nodes that are connected to simulate the process flow. The model tracks the movement of water and solute mass through each unit process. At the inlet and outlet of each unit process, the concentrations of solutes are computed, and solution conditions, such as pH and ionic strength, are determined by PHREEQC. The process model includes a number of internal recycle streams, thus the models were run through a sufficient number of iterations to allow constituent concentrations to achieve steady state. Steady state conditions were also confirmed via mass balance calculations. The following sections describe how each unit process was represented in the GoldPHREEQC model.

3.2.4.1 Pre-Treatment Basin

The pre-treatment basin is modeled as a pass-through for all flow and mass. While some removal of iron and, potentially, other constituents is anticipated in the pre-treatment basin, no removal was assumed for the purposes of process modeling, which is a conservative assumption. Effluent from the pre-treatment basin is routed to the greensand filter.

3.2.4.2 Greensand Filtration

For the greensand filter (GSF), flow is apportioned to the filtrate and backwash in accordance with the estimated duration, rate, and frequency of backwashing. Solute mass is apportioned between the filtrate and backwash in accordance with specified mass removal efficiencies, which are based on observed values from the pilot-testing:

- Plant Site Waste Water Treatment Plant Pilot-testing Program (Attachment B) removal efficiencies were used for arsenic and iron, because influent iron concentrations from this pilot-test most closely match projected full-scale influent iron concentrations. The removal mechanism for arsenite is expected to be sorption to iron particles, so arsenite removal is closely linked to iron removal. Total arsenic removal was conservatively assumed to be equal to arsenite removal.
- Reverse Osmosis Pilot-Test Report (Attachment D) removal efficiencies were used for manganese, because influent manganese concentrations from this pilot-test most closely match projected full-scale influent manganese concentrations.
- Waste Water Treatment Facility Pilot-Testing Program (Attachment E) removal efficiencies were used for cobalt, copper, lead, nickel, and zinc, because these metals were spiked into pilot feed water in this pilot-test to reflect projected full-scale concentrations.

These removal efficiencies are listed in Table 3-2. Those constituents that are not anticipated to be removed by the filter are assigned a mass removal efficiency equivalent to the flow proportion, such that their concentrations are the same in the filtrate and backwash.

Backwash from the greensand filter is routed back to the FTB Pond. Filtrate from the greensand filter is routed to the primary membrane separation process and apportioned to the two potential membrane types. The ratio of this division was selected via optimization based on what was required to achieve the sulfate effluent water quality target in a given year.

Table 3-2 Greensand Filter Mass-based Removal Efficiencies used in Tailings Basin Seepage Treatment Process Model

Species	Value	Source
Arsenic (based on arsenite)	99.3%	Plant Site Waste Water Treatment Plant Pilot-Testing Program(1)
Cobalt (II)	98.53%	Waste Water Treatment Facility Pilot-Testing Program(2)
Copper (II)	94.19%	Waste Water Treatment Facility Pilot-Testing Program(2)
Iron (III)	99%	Plant Site Waste Water Treatment Plant Pilot-Testing Program(1)
Lead (II)	89.63%	Waste Water Treatment Facility Pilot-Testing Program(2)
Manganese (II)	85%	Reverse Osmosis Pilot-Test Report(3)
Nickel (II)	86.90%	Waste Water Treatment Facility Pilot-Testing Program(2)
Selenium (Selenate)	5%	default to flow
Zinc	97.81%	Waste Water Treatment Facility Pilot-Testing Program(2)
All Other Metals	5%	default to flow

(1) Attachment B
(2) Attachment E
(3) Attachment D

3.2.4.3 Primary Membrane Separation

For primary membrane separation, flow is separated into permeate and concentrate in accordance with specified recovery values, based on pilot-testing results and vendor data for GE AG series RO membranes and GE Muni-400 NF membranes (Large Table 1 and Large Table 2). Solute mass was apportioned between permeate and concentrate in accordance with specified mass-based rejections. Vendor projections reported here were based on a 3-year membrane life and average of projections at 35˚F and 75˚F.

For primary NF membranes, a recovery of 80% was assumed based on vendor projections that were confirmed with pilot-testing results (Attachment B). For primary RO membranes, 75% recovery was assumed based on vendor projections. This is a conservative assumption, as pilot-testing demonstrated 80% recovery with the RO membranes (Attachment B).

Solutes that are not anticipated to be rejected by the membranes were assigned a rejection value equivalent to one minus the recovery; such that the concentration of those solutes will be the same in both permeate and concentrate. Rejections used in the modeling for other solutes for RO membranes were based on vendors' data (Attachment F) and Reverse Osmosis Pilot-Test Report results (pilot results for GE AG membranes, described in Attachment D). Rejections used in the modeling for NF membranes were based on vendors' data (Attachment F) and Plant Site Waste Water Treatment Plant Pilot-Testing Program results (Attachment B). Rejection values used in modeling were the lower of either the pilot values (Attachment B or Attachment E) or the average of the pilot and manufacturer values.

Large Table 1 and Large Table 2 show the RO and NF mass-based rejections used in the tailings basin seepage treatment process model.

Permeate from the primary membrane separation process was combined and routed to effluent stabilization. The primary membrane separation process concentrates were also combined and then pH-adjusted to below 6.5 using carbon dioxide, and routed to the secondary membrane separation process as described below.

3.2.4.4 Secondary Membrane Separation

For modeling the secondary membranes, flow was apportioned between permeate and concentrate using a recovery value of 85% based on pilot-testing of Dow NF-270 membranes (Attachment E). Solute mass was apportioned to either permeate or concentrate in accordance with specified mass-based rejection values.

Permeate from the secondary membrane separation process was blended with the feed to the primary membrane separation process feed and was specifically directed to the NF membranes. Concentrate from the secondary membrane separation process was routed to the head of the mine water chemical precipitation train for treatment.

Table 3-3 summarizes mass-based rejection values for the secondary membrane separation system obtained from vendors and from pilot-testing. In order to reflect the limitations of both estimation methods, the design uses the lower of either the vendor data or the average of the vendor data and the pilot results. For constituents not well characterized in the pilot-test, vendor results were used.

Table 3-3 Secondary Membrane (VSEP) Mass-Based Rejections Used in Process Model

Parameter	Vendor-Projected Rejection[1]	Pilot-Test Rejection, Average[2]	Estimated Rejection for Modeling Tailings Basin Seepage VSEP
Ag	98.9%	--	98.9%
Al	93.5%	--	93.5%
As	93.3%	50.6%	50.6%
B	48.3%	--	48.3%
Ba	99.3%	95.7%	95.7%
Be	48.3%	--	48.3%
Ca	99.2%	94.3%	94.3%
Cd	98.9%	--	98.9%
Cl	88.4%	13.0%	13.0%
Co	98.9%	95.1%	95.1%
Cr	98.6%	--	98.6%
Cu	83.3%	96.6%	89.9%
F	88.4%	--	88.4%
Fe	99.9%	--	99.9%
K	89.7%	--	89.7%
Mg	100.0%	95.6%	95.6%
Mn	98.6%	--	98.6%
Na	92.2%	55.4%	55.4%
Ni	98.0%	95.7%	95.7%
Pb	98.9%	98.5%	98.5%
Sb	98.0%	--	98.0%
Se	98.9%	97.7%	97.7%
Si	97.2%	29.8%	29.8%
SO_4	99.5%	98.0%	98.0%
Tl	98.0%	--	98.0%
V	95.0%	--	95.0%
Zn	85.8%	94.9%	90.4%

(1) Based on mass balance projections from New Logic

(2) Pilot-testing results from Waste Water Treatment Facility Pilot-Testing Program as documented in Attachment E.

3.2.4.5 Effluent Stabilization

Primary membrane separation permeate will be stabilized using limestone bed contactors (LBCs) and gas stripping to provide hardness and alkalinity and to remove excess dissolved carbon dioxide. These processes involve manipulation of carbonate chemistry, and were modeled using PHREEQC and thermodynamic data from the Minteq.v4 database. In the case of calcite addition, the added reagents were allowed to equilibrate with solution conditions in a closed system, with the resulting solution chemistry returned to GoldSim for routing to the next unit process. In the case of degassing, the solution was allowed to equilibrate with a near-atmospheric (CO_2 partial pressure = 10^{-3} atmospheres) boundary condition in PHREEQC, with the resulting solution chemistry returned to GoldSim for mass accounting and reporting.

3.2.5 Tailings Basin Seepage Treatment Train Process Modeling Results

Overall, the results of tailings basin seepage treatment process modeling show that the system can achieve the treatment objectives. Tailings basin seepage treatment process modeling results are summarized in Attachment H. Attachment H contains a schematic diagram illustrating nodes represented in the model, along with tables summarizing the modeled water quality and flow at annual average P90 and peak flow P90 projections. Node labels correspond to columns in the tables. Tables in Attachment H present results for the following scenarios:

- Mine Year 1 P90 Annual Average Flow, P90 FEIS Water Quality
- Mine Year 1 P90 Peak Flow, P90 FEIS Water Quality
- Mine Year 7 P90 Annual Average Flow, P90 FEIS Water Quality
- Mine Year 7 P90 Peak Flow, P90 FEIS Water Quality
- Mine Year 8 P90 Annual Average Flow, P90 FEIS Water Quality
- Mine Year 8 P90 Peak Flow, P90 FEIS Water Quality
- Mine Year 10 P90 Annual Average Flow, P90 FEIS Water Quality
- Mine Year 10 P90 Peak Flow, P90 FEIS Water Quality
- Mine Year 15 P90 Annual Average Flow, P90 FEIS Water Quality
- Mine Year 15 P90 Peak Flow, P90 FEIS Water Quality
- Mine Year 20 P90 Annual Average Flow, P90 FEIS Water Quality
- Mine Year 20 P90 Peak Flow, P90 FEIS Water Quality

The output tables include estimates of blended WWTS discharge quality (row 12 of each table).

The primary system function that determined the arrangement of treatment components in the model was sulfate removal. In Mine Year 8, all of the forward flow through the primary membrane separation process would need to be routed to RO membranes (no primary NF flow except recycle of secondary membrane permeate) to meet the sulfate target. To be conservative regarding the secondary membrane capacity required and the quality of secondary membrane concentrate water, models for Mine Years 1, 7, and 8 were operated with only RO membranes treating the forward flow through the primary membrane separation process. For Mine Years 10, 15, and 20, the primary membrane feed was divided between RO and NF units. The fraction of feed flow routed to the primary RO membranes for these years was selected by completing multiple modeling runs, which determined that routing between 60 and 80% of the flow to the primary RO membranes could achieve the sulfate effluent target.

The modeling results also provide information on the quantity and quality of internal flows that affect the design of all treatment trains of the WWTS. Within the tailings basin seepage treatment train, recycle flows routed to the FTB Pond total 200 gpm in Mine Year 10. The tables in Attachment H also present the estimated quantity and quality of secondary membrane concentrate for routing to the mine water chemical precipitation train for treatment. This quantity and quality was used as an input to the mine water treatment process model, described in Section 4.2.2. As described in Section 4.2, multiple modeling runs for optimization of the mine water treatment trains resulted in the identification of sodium concentrations in the chemical precipitation influent as a factor influencing sulfate mass removal at the mine water chemical precipitation treatment train.

During tailings basin seepage treatment train operation, the same model used for this process design can be populated with observed feed quality, membrane rejection values, and recoveries to aid in the anticipation of any necessary adjustments to either the proportion of membrane types within the system or the frequency of replacement of any particular membrane type. Additionally, as more advanced membrane formulations come to market in the future, the model can be used to assess their relative benefit to system operation and performance. Through tandem use of the tailings basin seepage treatment train and mine water treatment trains models during operation, potential impacts of observed tailings basin seepage treatment train operation on mine water treatment trains performance, or vice versa, can also be evaluated to anticipate any adjustments that may be required within the system.

3.3 Tailings Basin Seepage Treatment Train Design

The tailings basin seepage treatment train design was developed based on the system configuration that modeling demonstrated is able to achieve treatment objectives. Large Figure 4 displays a treatment schematic of the WWTS and more detail is provided in the WWTS Permit Application Support Drawings, Attachment I. Design requirements for major equipment were based on applicable design standards and are provided in Attachment J. Design considerations, design bases for flow and water quality, and the major components included in the system design are described in the following sections.

3.3.1 Design Considerations

In addition to treatment objectives, the tailings basin seepage treatment train was also designed to be reliable, adaptable, and as compact as possible as described below.

3.3.1.1 Reliability

The tailings basin seepage treatment train must be reliable, user-friendly, and robust to minimize downtime and operation and maintenance costs. Control systems will be incorporated into the design and operation to enable smooth interactions between equipment components and simplify operation of the system. The membrane systems will also be highly automated, requiring little operator input on a daily basis.

Redundancy of key features will be included to improve reliability. The greensand filters, secondary membranes, and permeate stabilization in the tailings basin seepage treatment train will be designed with sufficient redundancy to be able to treat the design capacity with the largest single unit within each individual process out of service. The primary membrane system in the tailings basin seepage treatment train will be designed to treat the design flow with one two-stage, 2x1 membrane array out of service on each skid. Pumping stations will be designed to treat the design flow with the largest unit out of service. For example, a pumping station with a design capacity of 2,000 gpm will be designed with two 2,000 gpm pumps. Adding a third 2,000 gpm pump will increase the design capacity of the system to 4,000 gpm.

Additionally, if WWTS discharge does not meet NPDES/SDS Permit limits for any reason, then the effluent can be conveyed to the FTB Pond for a short time rather than discharged to the environment, while system improvements are completed to achieve compliance.

3.3.1.2 Adaptive Management

The tailings basin seepage treatment train design and treatment processes can be adapted, as necessary, to meet the actual conditions encountered during the Project. As described in Attachment A, tailings basin seepage water quantity and quality routed to the WWTS are anticipated to vary substantially over the course of the Project. To accommodate variable influent quantity and quality, the tailings basin seepage treatment train design is modular such that additional treatment capacity or unit processes can be brought on or offline to handle fluctuations in required treatment capacity. Further, while pilot-testing with tailings basin seepage provides an accurate estimate of the initial water quality to be treated, the composition of this water source will vary over time with input from the treated mine water and ore beneficiation and processing. For these reasons, treatment equipment will be selected such that component operation may be modified to account for changes in influent quantity and quality.

The primary membrane separation process will be designed to use spiral-wound membranes. The standard sizing of spiral-wound membrane filtration technology allows the use of the same equipment infrastructure with minor modifications to house interchangeable membrane elements and different membrane types (i.e., RO and NF membranes). This provides a degree of flexibility in terms of the ratio of NF to RO capacity that can be put into place within a given equipment footprint. This flexibility also offers opportunities to upgrade membrane elements if new products that may be developed in the future provide an advantage from a performance or operational standpoint.

Flexibility in tailings basin seepage treatment train operation will also allow operators to adjust to changing or unforeseen conditions. For example, operators can bypass units and/or processes that are not required to meet discharge requirements, or adjust the proportion of flow between the different primary membrane separation types (RO and NF units). Also, chemical feed systems will be designed to offer the operational flexibility necessary to accommodate changing water chemistry.

The tailings basin seepage treatment train is designed for adaptive water management based on flows and loads. As operational data are accumulated, the system can be expanded or the treatment trains modified to accommodate changing requirements. Specific modifications that could be incorporated, if necessary, include:

- Primary membrane modules – Primary membrane modules can be replaced with modules of different removal capability if treatment requirements change. The design for the housing of the RO and NF membrane modules has been standardized (i.e., 8-inch diameter, spiral wound), allowing replacement of existing modules with modules of different capability, or even different manufacturer. The membrane sheets, which comprise the separation function of the modules, are constantly being refined. New products with improved or more targeted capabilities are brought to market regularly.

- Primary membrane proportioning – Two different types of primary membranes (RO and NF) are provided in the initial design. The flow apportionment between these two membrane types can be varied depending on water quantity and quality. Because the NF membrane allows a higher percentage of sodium and chloride to pass through the membrane than the RO membrane (a desired outcome for improving chemical precipitation performance), the highest percentage of flow which can be treated through the NF while still allowing the blended permeate to meet the discharge standard is preferred.

- Effluent recycle to FTB Pond – If the WWTS discharge fails to meet discharge standards, the effluent can be temporarily recycled to the FTB Pond. The FTB Pond can also serve as an equalization basin, for a limited time, to for allow repair or modification of the treatment system.

- FTB seepage capture systems feed source – As noted previously, the general strategy for routing water from the FTB seepage capture systems to the tailings basin seepage treatment train at the WWTS will be to route more concentrated seepage sources to the WWTS and less concentrated seepage to the FTB Pond. However, there is some flexibility to adjust the blend of sources routed to the WWTS to balance mass removal, system performance, and system operation if needed due to changes in seepage quality.

3.3.2 Tailings Basin Seepage Treatment Train Flow Design Basis

The tailings basin seepage treatment train flow design basis is as previously described in Section 2.1.2 and detailed in Attachment A and ranges from 2,000 gpm in Mine Years 1 through 7 to 4,000 gpm in Mine Years 8 through 20.

3.3.3 Tailings Basin Seepage Influent Water Quality Design Basis

The tailings basin seepage treatment train influent water quality design basis has been determined using the methods described in Attachment A and summarized in Section 2.1.3. The tailings basin seepage treatment train influent water quality design basis is the same as the values used in the input the tailings basin seepage treatment model as described in Section 3.2.2 and summarized in Table 3-1.

3.3.4 Pre-Treatment Basin

The Pre-Treatment Basin will be designed to allow soluble iron to precipitate when exposed to atmospheric conditions, thereby reducing the iron load to the GSF. Seepage from the FTB seepage capture systems will be routed to the Pre-Treatment Basin and dosed with a flocculant chemical, if necessary. The water in the Pre-Treatment Basin will then be pumped to the GSF units. If a flocculant is used, the specific flocculant chemical and dose that will be added will be determined during final design. Periodically, settled iron sludge will be dredged from the basin and sent to the FTB Pond.

The Pre-Treatment Basin is sized to provide 18 hours of detention time at the ultimate design flow. The 18-hour detention time was selected to provide adequate oxidation and settling time for the iron precipitate. The basin will be designed to fit within existing site contours and will have a composite liner consisting of HDPE (high-density polyethylene) underlain by a geosynthetic clay liner to protect groundwater.

A lift station will be installed on the west end of the Pre-Treatment Basin to pump effluent to the GSF. The lift station will be sized for three 2,000-gpm pumps. Two pumps will be provided initially to deliver the design flow with one pump out of service. It is anticipated that a third pump will be added by Mine Year 8 to provide the ultimate design capacity of 4,000 gpm with one pump out of service.

The preliminary design of the Pre-Treatment Basin is presented in Table 3-4.

Table 3-4 Pre-Treatment Basin Preliminary Design

Item	Preliminary Design
Hydraulic residence time (HRT)	18 hours (at 4,000 gpm)
Volume	4.54 Million Gallons (MG)
Liner	Composite Liner (high density polyethylene (HDPE) and geosynthetic clay liner)
Flocculant Addition	In line, at treatment building
Lift Station Design Capacity	2,000 gpm (initial build-out) 4,000 gpm (ultimate build-out)
Lift Station Pumps	Two pumps, 2,000 gpm each (initial build-out) Three pumps, 2,000 gpm each (ultimate build-out)

3.3.5 Greensand Filtration

"Greensand filter" is a term that refers to a media filter with an oxidation process. The specific media that will be used for the filter, which could be greensand or other media with an oxidative coating, will be determined during final design based on site-specific information. GSF are used to remove iron, manganese, and total suspended solids that will foul the primary membrane separation units if not removed. GSF media is typically silica sand coated with manganese oxide. Sodium permanganate will be added as a pretreatment to the GSF influent to oxidize dissolved manganese and iron for increased removal and to maintain the charge on the media to allow contact oxidation of manganese. GSF units will be backwashed using filtrate from parallel on-line GSF units.

Table 3-5 summarizes the GSF preliminary design for the two build-outs.

Table 3-5 Tailings Basin Seepage Treatment Train: Greensand Filter Preliminary Design

Parameter	Value
Build-out 1 Capacity (Mine Year 1)(1)	2,000 gpm
Build-out 2 Capacity (Mine Year 8)(1)	4,000 gpm
Loading Rate	3.5 gpm/ft^2 to 4.9 gpm/ft^2
Sodium Permanganate Dose	1.65 mg/L
Backwash Volume (each cycle)	12-15 gpm/ft^2
Backwash Cycle Time	15-25 minutes
Maximum Pressure Differential	7 psi

(1) Attachment A

3.3.6 Primary Membrane Separation

The primary membrane system for the tailings basin seepage treatment train will be a conventional, spiral wound membrane configuration, with multiple membranes operating in series and parallel configuration to provide the needed capacity. This system will be designed to operate on a continuous basis while isolated elements are removed from the process for periodic cleaning or maintenance.

The individual primary membrane separation elements will consist of a combination of RO and NF membrane types as described in Section 3.1. Within these two membrane types, a wide variety of different manufacturers' membranes could be used in the primary membrane separation process. The membranes that have been demonstrated to be effective with site-specific water include:

- GE AK90-LE low-pressure RO as reported in the Plant Site Waste Water Treatment Plant Pilot-testing Program (Attachment B)
- GE AG90 low-pressure RO as reported in the Reverse Osmosis Pilot-Test Report (Attachment D)
- GE HL4040FM NF as reported in the Waste Water Treatment Facility Pilot-Testing Program (Attachment E)
- Dow NF-270 NF as reported in the Waste Water Treatment Facility Pilot-Testing Program (Attachment E)

The membranes that will be used in the primary membrane separation system will be selected during the final design process based on demonstrated ability to remove the constituents of interest for this Project and to meet the effluent requirements established in the NPDES/SDS Permit. Additional details for both the primary membrane units are described below.

3.3.6.1 Primary RO Membrane Separation System

Table 3-6 summarizes the design criteria for the primary RO membranes during the first and second build-outs.

It is anticipated that the primary RO capacity will be expanded to 2,230 gpm by Mine Year 8.

Table 3-6 Tailings Basin Seepage Treatment Train: Primary RO Membrane Preliminary Design

Parameter	Value
Build-out 1 Capacity (Mine Year 1)(1)	1,890 gpm
Build-out 2 Capacity (Mine Year 8)(1)	2,230 gpm
Recovery	75%
Flux	16 gallons per square foot per day (gfd)
Sodium Bisulfite Dose	1 ppm
Pre-treatment	Antiscalant, Sodium bisulfite

(1) GoldPHREEQC Tailings Basin Seepage Treatment Train Model Simulations, July 2015

The RO membranes will be cleaned periodically using manually initiated caustic and acid Clean-in-Place (CIP) procedures.

3.3.6.2 Primary NF Membrane Separation System

Table 3-7 summarizes the preliminary design of the NF portion of the primary membrane separation systems during the two phases of build-outs. The NF portion of the primary membrane separation system will have the capability to receive both a fraction of the tailings basin seepage treatment train GSF effluent, as well as permeate from the secondary membranes. During Build-out 1, it is anticipated that the NF portion of the primary membrane separation units will only be used to treat secondary membrane permeate, with all of the tailings basin seepage treatment train influent from the GSF units routed to primary RO membranes. This is needed to accommodate a modeled spike in the influent sulfate concentration occurring in Mine Year 7.

In the second build-out, a portion of primary membrane feed will also be routed to primary NF membranes.

Table 3-7 Tailings Basin Seepage Treatment Train - Primary NF Membrane Preliminary Design

Parameter	Value
Build-out 1 Capacity (Mine Year 1)(1)	504 gpm
Build-out 2 Capacity (Mine Year 8)(1)	2,360 gpm
Recovery	80%
Flux	16 gfd
Sodium Bisulfite Dose	1 ppm
Pre-treatment	Antiscalant, Sodium bisulfite

(1) GoldPHREEQC Tailings Basin Seepage Treatment Train Model Simulations, July 2015

3.3.7 Secondary Membrane Separation

The secondary membrane system will reduce the volume of the primary membrane separation concentrate using a flat-sheet, vibratory shear-enhanced process (VSEP). The secondary membranes will operate in a batch-mode with a declining flux rate to produce the secondary membrane concentrate and the secondary membrane permeate. Table 3-8 summarizes the preliminary design of the secondary membrane system during the two build-outs. The design includes the exclusive use of NF membranes in the VSEP modules because pilot-testing demonstrated a significantly higher achievable flux relative to RO membranes. Justification supporting use of a secondary membrane system and the selection of NF membranes are outlined in Section 3.1.

Table 3-8 Tailings Basin Seepage Treatment Train- Secondary Membrane Preliminary Design

Parameter	Value
Build-out 1 Capacity (Mine Year 1)(1)	580 gpm
Build-out 2 Capacity (Mine Year 8)(1)	1,030 gpm
Flux	60 gfd
Filtrate Recovery Rate	85%
Cleaning Waste Generation Rate	5% of feed
Pre-Treatment	Antiscalant, Sodium bisulfite, Carbon dioxide to pH <6.0
Batch Volume	20,000 gallons

(1) GoldPHREEQC Tailings Basin Seepage Treatment Train Model Simulations, July 2015

The secondary membrane concentrate will be routed to the mine water treatment trains for chemical precipitation treatment, while the secondary membrane permeate is routed back to dedicated NF-type primary membrane separation units, as described previously.

During pilot-testing, the secondary membranes experienced a negligible decline in flux. Antiscalant and acid were added to the secondary membrane influent to minimize fouling. While the influent was being dosed with antiscalants only, acid cleanings were more effective than either basic cleaning or hot water flushes. These results suggest that acid-soluble minerals were limiting the recovery of the membrane. When both acid and antiscalants were added to the influent, basic cleanings were more effective at restoring recovery. Therefore, the capability to conduct acid and basic cleanings, as well as hot water flushes, will be included in the design.

The actual membranes used in the secondary membrane treatment system will be selected during the final design phase to optimize the performance of the chemical precipitation process for the removal of the constituents of interest for this Project and to meet the effluent requirements established in the NPDES/SDS Permit.

3.3.8 Permeate Stabilization

Primary membrane separation permeate will be stabilized using limestone bed contactors (LBCs) and gas stripping (degasifiers) to provide hardness and alkalinity and to remove excess dissolved carbon dioxide. "Limestone bed contactor" is a term that refers to a fixed-bed contactor containing minerals, not limited to limestone, used to stabilize membrane effluent. The specific design of the contactor will be determined during final design. Degasifiers will remove excess carbon dioxide downstream of the LBCs and bring the pH back into the treatment target range.

Table 3-9 summarizes design information for the permeate stabilization system during Phase 1. It is anticipated that effluent stabilization capacity will be increased to approximately 3,650 gpm by Mine Year 8.

Table 3-9 Tailings Basin Seepage Treatment Train: Permeate Stabilization System Preliminary Design

Parameter	Value
Configuration	Single-cell pressure vessel
Build-out 1 Capacity(1)	1,820 gpm
Build-out 2 Capacity(1)	3,650 gpm
Hydraulic Loading Rate, LBCs	1-5 gpm/ft^2
Empty Bed Contact Time	2.5 – 5 min
LBC Dimensions	3 units, 8-ft diameter 21-ft long horizontal tanks
Degasifier loading rate	20 gpm/ft^2
Degasifier dimensions	2 units, 6 ft x 6 ft

(1) GoldPHREEQC Tailings Basin Seepage Treatment Train Model Simulations, July 2015

3.4 Tailings Basin Seepage Treatment Train Operation

This section describes key aspects of tailings basin seepage treatment train operations, including management of effluent, internal waste streams, and byproducts.

3.4.1 WWTS Discharge

Effluent from the tailings basin seepage treatment train will be collected in the Treated Water Storage Tank. This WWTS discharge water will be pumped from this tank to stream augmentation outfalls, as described in Section 5.3.1 of Reference (4).

3.4.2 Tailings Basin Seepage Treatment Train Byproduct Streams

The tailings basin seepage treatment train will produce byproduct streams as a result of filter and membrane cleaning. Media and membrane filtration systems will be designed with redundant units such that maximum flow rates can be treated with some units taken offline for cleaning or maintenance. Cleaning or backwashing of filtration units will be conducted on a rolling basis, with a portion of the units offline for cleaning at any given time. The details and fate of these streams is outlined in Table 3-10. Detailed estimates of CIP water quality can be found in Attachment B.

Table 3-10 Tailings Basin Seepage Treatment Train: Byproduct Streams Description and Fate

Stream	Treatment Process	Constituents	Build-out 1 Max Year Production Rate (Mine Year 7 P90 Average)[(1)]	Build-out 2 Max Year Production Rate (Mine Year 10 P90 Average)[(1)]	Reports to	Fate
Clean-in-Place Membrane Waste	Primary Membranes	MC1, MC4, trace Fe and Mg	474,000 gal/year	916,000 gal/year	Flotation Tailings Basin	Tailings Basin Solids (Fe), Sludge (Mg)
	Secondary Membranes	NLR 404, NLR 505, Na, trace other salts	24,000 gal/day	44,000 gal/day	Flotation Tailings Basin	NF permeate (Na)
Greensand Filter Backwash[(1)]	Greensand Filter	COD, Fe, Ca, Mg, Mn, Si, Na	144,000 gal/day	281,000 gal/day	Flotation Tailings Basin	Tailings Basin Solids (COD, Fe, Mn) Sludge (Ca, Mg) NF Permeate, (Na) NF permeate or sludge (Si)

Source: GoldPHREEQC Tailings Basin Seepage Treatment Train Model Simulations, July 2015

(1) Exact cleaning volumes may be changed in final design or plant startup

4.0 Mine Water Treatment Trains Design and Operation

The mine water treatment trains will treat mine water so it can be used in the Beneficiation Plant. During operations, treated mine water from the mine water treatment trains will be piped to the FTB Pond. The purpose of the mine water treatment trains is to maintain the overall water quality in the FTB Pond at or below treatment targets and to manage the water quality of groundwater seepage from the FTB.

As with the tailings basin seepage treatment trains, the process of designing the mine water treatment trains consisted of four interrelated activities. First, basic components of the mine water treatment trains were selected, based on characteristics of the Project, treatment objectives, and available water treatment technology (Section 4.1). Second, the components were modeled to identify an optimized system configuration that will achieve water quality treatment objectives (Section 4.2). Third, the system configuration was developed into a preliminary design that satisfies operational design considerations such as reliability and flexibility, with details such as membrane types, pond sizes, and recycle streams (Section 4.3). Fourth, preliminary (permit-review level) plans were developed for mine water treatment trains operation (Section 4.4). The scope of this section includes modeling and preliminary design of the mine water treatment trains from Mine Year 1 to Mine Year 10.

4.1 Selection of Mine Water Treatment Components

Selection of the components for the mine water treatment trains was driven by the treatment objectives for water routed back to the FTB Pond and the variable characteristics of the influent streams. Early in the evaluation of alternatives, the concept for segregation of the mine water influent streams was incorporated into the design. This facilitated the use of two treatment trains – a Chemical Precipitation Train to treat low-volume, high-concentration influent, and a Membrane Separation Train to treat high-volume, low-concentration influent. Four basic treatment components were selected for use in the mine water treatment trains:

- Chemical precipitation, to remove dissolved constituents from flows with high concentrations.
- Pre-treatment by greensand filtration (GSF), to remove constituents that could harm the primary membrane separation units.
- Primary membrane separation, using NF-type membranes, to remove dissolved constituents from flows with low concentrations.
- Secondary membrane separation, to reduce the volume of the primary membrane concentrate and further remove dissolved constituents from chemical precipitation effluent.

Chemical precipitation will be conducted using a three-step process that was selected based on the need to remove metals, sulfate, and residual calcium from the low-volume, high-concentration influent. The three-step process will provide the flexibility to operate the metals precipitation process at a lower pH (lime dose) than the sulfate precipitation process. This separation will allow for the optimization of metals removal in the first step and sulfate removal in the second step.

While some mine water sources will have sulfate concentrations sufficiently high to facilitate chemical precipitation, other sources will require concentration prior to precipitation to facilitate removal of sulfate. A combination of primary and secondary membranes separation in series was selected to concentrate these dilute (high-volume, low-concentration) mine water streams. Each stage of membrane separation will produce a permeate and a concentrate. From both stages, the permeate will be routed to the Central Pumping Station (CPS) for blending with the chemical precipitation effluent and conveyance to the FTB Pond. The concentrate from the primary membrane separation units will be sent to the secondary membrane separation system, while the concentrate from the secondary membrane separation units will be sent to the chemical precipitation treatment train. Nanofiltration (NF) membranes were selected for both the primary and secondary membrane separation processes because they reduce the ratio of sodium to sulfate in the concentrate, thereby improving sulfate precipitation.

Depending on the effluent sulfate concentration from the chemical precipitation process and the volume of other more dilute streams, some amount of additional treatment may be required at times to achieve the effluent sulfate target. To further enhance sulfate removal by the system and achieve the effluent sulfate target, a portion of the chemical precipitation effluent can be routed to the secondary NF membranes.

4.2 Modeling of Mine Water Treatment Trains

The components described above were combined into an overall process that was iteratively modeled, varying the process based on interim results, to select the optimal system configuration. The following section describes the modeling method that was used to optimize the design and the results obtained from that modeling. Models were run for Mine Years 1, 2, 3, 6, 7, and 10 to reflect years at the beginning and end of two NPDES/SDS Permit periods and years immediately before and after the second and third build-outs. For each Mine Year, three different flow conditions (peak, summer, and winter) were modeled.

4.2.1 Modeling Framework

Mine water treatment process modeling used the GoldPHREEQC method as described in Section 3.2.1.

One of the primary design objectives for the mine water treatment trains was to determine the optimal proportion of primary membrane concentrate and chemical precipitation effluent to be routed to the secondary membranes. The modeling framework allowed for adjustment of these proportions to determine the amount of secondary membrane capacity required to achieve treatment objectives. During peak flow conditions, secondary membrane treatment capacity is occupied by relatively more primary membrane concentrate and relatively less chemical precipitation effluent. These proportions transition to relatively more chemical precipitation effluent and less primary membrane concentrate as flows from the mine pits moderate through the summer and into the winter months, achieving lower concentrations in treated mine water during these times than during peak flow conditions (i.e., spring snowmelt). Changing the proportions of chemical precipitation effluent and primary membrane concentrate that are routed to the secondary membranes allows for:

- optimum use of the secondary NF membrane capacity while enabling treated mine water treatment targets to be met on a 12-month rolling average basis, and
- increased hydraulic loading consistency through chemical precipitation equipment between high flow and low flow periods

During winter operation, it is desirable to maintain flow through chemical precipitation equipment to facilitate more reliable accommodation of increased flows during the spring peak event. Because source flows are low during winter months, primary membrane concentrate was routed directly to the chemical precipitation equipment during winter months to maintain a higher hydraulic loading to the equipment. This allows for more of the secondary membrane separation equipment to be used only for second-pass treatment of chemical precipitation effluent in the winter.

4.2.2 Model Inputs

Inputs to the GoldPHREEQC process model of the mine water treatment trains included:

- Influent flow volumes and influent design water quality as described in Section 2.23
- Greensand filtration removal rates as determined by pilot-testing
- Membrane recovery and rejection rates as determined by pilot-testing
- Modeled quantity and quality of secondary membrane concentrate from the tailings basin seepage treatment trains that will be routed to the mine water chemical precipitation train
- Chemical addition required to achieve target pH for chemical precipitation processes
- Chemical precipitation removal efficiencies observed during bench testing

Large Table 3 and Large Table 4 summarize the quality and quantity of the mine water influent flows based on the charge-balanced results from the evaluation of the GoldSim model results for the Mine Site, as described in Section 2.3 and Attachment C. Flow rates for the P90 average annual, summer, winter, and the peak for each equalization basin for each Mine Year are included in the tables. The average annual, summer, and winter flow rates are based on GoldSim modeling results for the Mine Site. Peak flow rates are based on the equalization basin effluent flow rate required to maintain the required freeboard in equalization basins during spring snowmelt periods, which was developed based on operational needs for mining.

As noted previously, charge balancing was necessary because the influent for geochemical modeling and the mine water treatment trains design model must be electrically neutral, while the probabilistic water quality estimates for concentrations of each constituent in the GoldSim model were not constrained by this requirement. The LCEQ Basin water was charge balanced using alkalinity, assuming a pH of 7.0. The

HCEQ Basin water could not be balanced with alkalinity due to the high concentrations of sulfate present. Instead, this flow was balanced with calcium assuming a pH of 5.0.

The number of days during each Mine Year when the mine water treatment trains is projected to receive mine water at each of the three flow conditions is outlined in Table 4-1.

Table 4-1 Duration of Flow Periods for Mine Years 1-10

	Mine Year									
	1	2	3	4	5	6	7	8	9	10
Days at Peak Flow	242	229	218	223	235	232	30	30	30	30
Days at Summer Flow	0	0	0	0	0	0	185	185	185	185
Days at Winter Flow	123	136	147	142	130	133	150	150	150	150

Source: Attachment C

4.2.3 Treatment Objectives

Treatment objectives for the mine water treatment trains are to meet treatment targets as shown in Table 2-2. Because treated mine water will be reused in the Project operations, it is considered an internal waste stream for the purpose of design. The treatment targets were selected to meet overall Project objectives, as described in Section 2.4.

4.2.4 Model Construct

The overall flow sheet for the mine water treatment trains is shown on Large Figure 4.

The GoldPHREEQC model represented waste water unit processes with model nodes that are connected to simulate the process flow. The model tracks the movement of water and solute mass through each unit process. Some recycle flows internal to the chemical precipitation units were not accounted for in the model, but are calculated and presented with model results in Attachment K. At the inlet and outlet of each unit process, the concentrations of solutes were computed and solution conditions, such as pH and ionic strength, were determined by PHREEQC. The following sections describe how each unit process was represented in the GoldPHREEQC model.

4.2.4.1 Equalization Basins

Equalization basins were modeled as pass-through systems for flow and mass. While some removal of iron and metals may occur in the equalization basins, none was assumed for the purposes of process modeling, which was a conservative assumption. Effluent from the LCEQ Basins was routed to the GSF, while effluent from the HCEQ Basin was routed to the chemical precipitation process.

4.2.4.2 Chemical Precipitation

The combined, three-step chemical precipitation process included high-density sludge (HDS) metals precipitation, sulfate precipitation, and calcite precipitation. In each of these processes, GoldSim routed water, solute mass, and reagent mass into the reactor, computed the resulting concentrations, and exported the interim results to PHREEQC. PHREEQC was then used to calculate the solution chemistry based on the solids phases formed and report back to GoldSim. GoldSim then apportioned the mass between effluent (clarifier overflow) and sludge (clarifier underflow). Those reagents indicated below as contingencies can be implemented in the model to assess a response to unanticipated conditions, but were not included in the modeling that was the basis for design.

The following sections describe the modeling of each chemical precipitation process in more detail. The source of thermodynamic data for these processes was the Minteq.v4 database.

High Density Sludge Precipitation

In this process, reagents that could be added included lime and ferric sulfate (contingency, if needed to supplement influent iron). The process also included recycle of iron oxyhydroxides for adsorption of metals. The pH for this precipitation reaction was set in the model between 10.5 to 11 to facilitate removal of metals to meet the treated mine water treatment targets. Phases that precipitate in this process, if present at concentrations above their respective solubilities, include metal hydroxides, metal carbonates, gypsum, barium sulfate, calcite, magnesium hydroxide, and calcium hydroxide (to limit lime solubility). A mixed hydroxide of magnesium, nickel, and cobalt was also included in the model based on bench testing results. The model also included adsorption of metals to iron oxyhydroxide surfaces.

The model included a routine to account for the occupation of available sites on the iron sludge at high recycle rates. The GoldSim portion of the model was used to compute a sludge age parameter based on the target sludge concentration in the reactor and iron inputs (i.e., mass in reactor feed and mass in ferric sulfate inputs, if used). This parameter represented the number of influent volumes contacted by a given mass of iron sludge. This parameter was output to PHREEQC, which equilibrated the iron surfaces with the appropriate volume of feed prior to returning the water quality results to GoldSim.

The model included some provisions to better-match modeled behavior with bench testing results. These were represented as mass removal efficiencies specified in GoldSim, and include:

- Selenium removal of 30%
- Manganese removal of 99%

Effluent from the high density sludge precipitation process was routed to sulfate precipitation. The mass of constituents reporting to sludge was recorded.

Sulfate Precipitation

In this process, chemicals that could be added included lime and hydrochloric acid (contingency to counter high sodium concentrations). Lime was added to achieve a reactor pH between 12 and 12.5. Phases that precipitate in this process, if present at concentrations above their respective solubilities, include metal hydroxides, metal carbonates, gypsum, barium sulfate, calcium carbonate, magnesium hydroxide, mixed magnesium-nickel-cobalt hydroxide, and calcium hydroxide (to limit lime solubility).

The model also included some provisions to better-match modeled behavior with bench testing results. These were represented as mass removal efficiencies specified in GoldSim and included:

- Selenium removal of 50%
- Antimony removal of 95%
- Aluminum removal of 99.9%

Effluent from the sulfate precipitation process was routed to calcite precipitation. The mass of constituents reporting to the sludge was recorded.

Calcite Precipitation

Effluent from the sulfate precipitation system will have a high pH and high concentrations of calcium, both of which are undesirable during conveyance of treated mine water to the FTB Pond. Thus, calcite precipitation was modeled downstream of sulfate precipitation. In this process, carbon dioxide was added to adjust pH to between 10 and 10.5 to precipitate excess calcium. Phases that precipitate in this process, if present at concentrations above their respective solubilities, include metal hydroxides, metal carbonates, and calcium carbonate.

Scavenger addition was evaluated as a contingency to improve removal of metals including cobalt, copper, and nickel, in which case removal efficiencies of 50% were assigned for each of the three metals in accordance with bench testing observations. However, this contingency was not used for the modeling described in this report, which is a conservative assumption.

Recarbonation

A second step of carbon dioxide addition was included after calcite has been removed. Carbon dioxide was added to adjust pH to between 6 and 7 to reduce corrosion during transport.

A portion of the calcite precipitation effluent was routed to the secondary membranes for further treatment, while the remainder was blended with primary and secondary membrane permeates for routing to the FTB Pond.

4.2.4.3 Greensand Filtration

The greensand filter (GSF) receives relatively dilute influent from the LCEQ Basins. Within the GSF, flow was apportioned to the filtrate and backwash in accordance with the estimated duration, rate, and frequency of backwashing. Solute mass was apportioned between the filtrate and backwash in accordance with specified mass removal efficiencies, which were based on average observed pilot-testing values (Table 4-2). These efficiencies were based on observed values from the pilot studies:

- Plant Site Waste Water Treatment Plant Pilot-Testing Program removal efficiencies were used for iron and manganese, because influent iron and manganese concentrations from this pilot most closely match projected full-scale influent iron and manganese concentrations.

- WWTF Pilot No. 2 removal efficiencies were used for cobalt, copper, lead, nickel, and zinc, because these metals were spiked into pilot feed water in this pilot-test to demonstrate removal efficiencies.

- The arsenic removal efficiency value of 74% was a conservative assumption based on the average pilot rejections for arsenite observed in the Plant Site Waste Water Treatment Plant Pilot-testing Program (99%) and in the Waste Water Treatment Facility Pilot-Testing Program (69%). The projected iron concentration in greensand filter effluent was between the iron concentrations observed in the Plant Site Waste Water Treatment Plant Pilot-Testing Program and the Waste Water Treatment Facility Pilot-Testing Program, so the arsenite removal efficiency is also expected to be between the observed values for the two pilot-tests.

Those constituents that were not anticipated to be removed by the filter were assigned a mass removal efficiency equivalent to the backwash flow proportion of 5%, such that their concentrations were the same in the filtrate and backwash.

Table 4-2 Greensand Filter Mass-based Removal Efficiencies Used in Mine Water Treatment Trains Process Model

Species	Value	Source
Arsenic (based on arsenite)	74%	Plant Site Waste Water Treatment Plant Pilot-Testing Program and Waste Water Treatment Facility Pilot-Testing Program(1,2)
Cobalt (II)	98.53%	Waste Water Treatment Facility Pilot-Testing Program(2)
Copper (II)	94.19%	Waste Water Treatment Facility Pilot-Testing Program(2)
Iron (III)	99%	Plant Site Waste Water Treatment Plant Pilot-Testing Program(1)
Lead (II)	89.63%	Waste Water Treatment Facility Pilot-Testing Program(2)
Manganese (II)	95%	Plant Site Waste Water Treatment Plant Pilot-Testing Program(1)
Nickel (II)	86.90%	Waste Water Treatment Facility Pilot-Testing Program(2)
Selenium (Selenate)	5%	default to flow
Zinc	97.81%	Waste Water Treatment Facility Pilot-Testing Program(2)
All Other Metals	5%	default to flow

(1) Attachment B
(2) Attachment E
(3) Attachment D

Backwash from the GSF was routed to the backwash settling tank. This process allowed settling of solids, with decant (supernatant) being returned to the greensand filter feed tank at the head of the mine water filtration train. The precipitate (settled solids) was routed to the first unit of the chemical precipitation train to supplement iron needs for the HDS process. The backwash flow was apportioned as a 50/50 split between supernatant and settled solids. Solutes removed by the GSF were apportioned to the solids in accordance with their removal efficiency.

Filtrate from the GSF was routed to the primary membrane separation unit.

4.2.4.4 Primary Membrane Separation

For primary membrane separation, flow was apportioned between the permeate and concentrate in accordance with specified recovery values, based on the pilot-testing results and vendor data. Solutes that were not anticipated to be rejected by the membrane were assigned a rejection value equivalent to one minus the recovery, such that the concentration of the solute will be the same in the permeate and concentrate. Rejection values used in modeling are presented in Table 4-3. Solute mass was apportioned to the permeate and concentrate in accordance with specified mass-based rejections. Vendor projections reported here were based on GE Muni-400NF membranes and a 3-year membrane life and average of projections at 35˚F and 75˚F. Solute rejection is known to change with membrane age. Rejection values used in modeling were the lower of either the pilot-test results (Attachment E) or the average of the vendor data and the pilot-test results.

Table 4-3 Primary Membrane (NF) Mass-based Rejections used for Mine Water Treatment Process Model

Parameter	Vendor-Projected Rejections (GE)(1)			Pilot-Test Rejection, Average(2)	Estimated Rejections for Modeling Mine Water Treatment Train NF		
	Mine Year 1	Mine Year 5	Mine Year 10		Mine Year 1(3)	Mine Year 5(3)	Mine Year 10(3)
Ag	39.17%	36.89%	39.5%	--	39.17%	36.89%	39.5%
Al	94.44%	94.28%	94.3%	--	94.44%	94.28%	94.3%
Alk	51.60%	45.87%	48.6%	48.80%	48.80%	47.34%	48.7%
As	98.50%	98.50%	98.5%	99.40%	98.95%	98.95%	99.0%
B	29.24%	28.87%	17.7%	--	29.24%	28.87%	17.7%
Ba	87.06%	85.32%	86.6%	93.50%	90.28%	89.41%	90.1%
Be	94.47%	94.31%	94.3%	--	94.47%	94.31%	94.3%
Ca	84.70%	87.15%	87.8%	92.60%	88.65%	89.88%	90.2%
Cd	94.45%	94.31%	94.3%	--	94.45%	94.31%	94.3%
Cl	71.97%	72.68%	70.4%	9.40%	9.40%	9.40%	9.40%
Co	94.45%	94.30%	94.3%	99.90%	97.17%	97.10%	97.1%
Cr	94.46%	94.28%	94.3%	--	94.46%	94.28%	94.3%
Cu	not given	not given	not given	93.80%	93.80%	93.80%	93.8%
F	38.56%	35.77%	37.2%	--	38.56%	35.77%	37.2%
Fe	100.00%	100.00%	100.0%	--	100.00%	100.00%	100.0%
K	60.24%	55.44%	57.9%	59.00%	59.00%	57.22%	58.4%
Mg	94.45%	94.33%	94.3%	94.80%	94.63%	94.56%	94.6%
Mn	84.50%	100.00%	78.6%	97.80%	91.15%	97.80%	88.2%
Na	39.38%	37.42%	39.5%	57.60%	48.49%	47.51%	48.5%
Ni	94.45%	94.31%	94.3%	99.80%	97.13%	97.06%	97.1%
Pb	94.44%	94.30%	94.3%	99.40%	96.92%	96.85%	96.8%
Sb	94.45%	94.31%	94.3%	--	94.45%	94.31%	94.3%
Se	94.46%	94.33%	94.3%	99.20%	96.83%	96.76%	96.8%
SiO_2	not requested	not requested	not requested	24.10%	24.10%	24.10%	24.1%
SO_4	94.46%	94.33%	94.3%	99.00%	96.73%	96.67%	96.7%
Tl	94.68%	94.32%	94.3%	--	94.68%	94.32%	94.3%
V	94.45%	94.31%	94.3%	--	94.45%	94.31%	94.3%
Zn	not given	not given	not given	98.40%	98.40%	98.40%	98.4%

(1) Based on GE projections for Muni-400 NF membranes (same expected performance as HL4040FM membranes according to GE)

(2) Pilot-testing results from Attachment E; testing of GE HL4040FM membranes

(3) Estimated rejections for Mine Year 1 were used for Mine Year 1 and Mine Year 2. Estimated rejections for Mine Year 10 were used for Mine Year 9 and Mine Year 10. Estimated rejections for Mine Year 5 were used for Mine Year 3 through Mine Year 8.

4.2.4.5 Secondary Membrane Separation

The modeled secondary membrane system received feed from primary membrane system concentrate and chemical precipitation system effluent. The proportions of these flows that were routed to secondary membrane separation was dependent on seasonal flows and treatment required to meet treatment targets on a 12-month rolling average basis. Secondary membrane feed was pH-adjusted to below 6.5 in the model to minimize membrane scaling. Secondary membrane recovery of 80% was selected based on pilot-test results.

For secondary membrane separation, modeled flow was apportioned to either the permeate or the concentrate in accordance with the specified recovery value. Solute mass was apportioned to either the permeate or the concentrate in accordance with specified mass-based rejection values. Solute rejection is known to change with membrane age. Rejection values used in modeling were the lower of either the pilot-test results (Attachment H) or the average of the pilot-test results and vendor data.

Secondary membranes receiving primary membrane concentrate (termed VSEP A) were modeled separately from those receiving the slipstream of chemical precipitation effluent (VSEP B). This convention was adopted for clarity of cause and effect in the results. In actual operation, the secondary membranes could receive a blend of primary membrane concentrate and chemical precipitation effluent, with the net result being equivalent to the model construct.

Permeate from the secondary membranes was blended with chemical precipitation effluent and primary membrane separation permeate for routing to the FTB Pond. Concentrate from the secondary membrane separation units was routed to the mine water chemical precipitation train.

Table 4-4 Secondary Membrane (VSEP) Mass-based Rejections Used in Mine Water Treatment Process Model

Parameter	Vendor-Projected Rejections(1)		Pilot-Test Rejection, Average(2)	Estimated Rejection for Modeling Mine Water Treatment Train VSEP	
	Mine Year 1(3)	Mine Year 4(3)		Mine Year 1(3)	Mine Year 4(3)
Ag	96.07%	95.96%	--	96.86%	96.86%
Al	99.36%	99.36%	--	99.49%	99.49%
Alk	--	--	39.8%	39.8%	39.8%
As	65.56%	65.56%	50.60%	50.60%	50.60%
B	15.00%	15.00%	--	20.00%	20.00%
Ba	93.75%	93.75%	--	95.00%	95.00%
Be	15.00%	15.00%	--	20.00%	20.00%
Ca	89.33%	89.33%	94.30%	94.30%	92.88%
Cd	97.41%	97.41%	--	97.93%	97.93%
Cl	13.34%	13.33%	13.00%	13.00%	21.84%
Co	97.77%	97.77%	95.10%	95.10%	95.10%
Cr	89.33%	89.33%	--	91.46%	91.46%
Cu	98.76%	98.76%	96.60%	96.60%	96.60%
F	40.00%	40.00%	--	52.00%	52.00%
Fe	96.00%	96.00%	--	96.80%	96.80%
K	62.67%	62.66%	--	70.14%	70.14%
Mg	76.00%	76.00%	95.60%	80.80%	88.20%
Mn	74.66%	74.53%	--	79.73%	79.73%
Na	66.67%	66.67%	55.40%	55.40%	64.37%
Ni	74.14%	74.15%	95.70%	95.70%	87.51%
Pb	97.34%	97.33%	98.50%	98.50%	98.19%
Sb	94.67%	94.67%	--	95.74%	95.74%
Se	90.67%	90.67%	97.70%	97.70%	95.12%
SiO_2	90.67%	90.67%	--	92.54%	61.17%
SO_4	85.33%	85.33%	98.00%	98.00%	93.13%
Tl	94.73%	94.68%	--	95.78%	95.78%
V	86.67%	86.67%	--	86.67%	86.67%
Zn	94.67%	94.67%	94.90%	94.67%	94.67%

(1) Based on VSEP bench testing of NF-270 membranes

(2) Pilot-testing results from Attachment E

(3) Mine Year 1 rejections used for model Mine Years 1 and 2, Mine Year 4 rejections used for model Mine Years 3 and 5.

4.2.5 Mine Water Treatment Process Modeling Results

Results indicate that the mine water treatment process design is capable of achieving treated mine water treatment targets on a 12-month rolling average basis (refer to Section 4.2.1 for details regarding this approach). Attachment KAttachment K presents a schematic diagram illustrating nodes represented in the model, along with one table summarizing the 12-month rolling average results and a series of tables summarizing the modeled water quality and flow. Node labels correspond to rows in the tables. The first table for each scenario shows projected concentrations at each node, and the second table for each scenario shows flow balance and sludge production. Each page represents a model run for the following scenarios:

- Mine Year 1 Peak Flow, 90th percentile (P90) Annual Average Water Quality (Spring Operation)
- Mine Year 1 P90 Annual Average Flow, P90 Annual Average Water Quality
- Mine Year 1 Average Winter Flow, P90 Annual Average Water Quality (Winter Operation)
- Mine Year 2 Peak Flow, P90 Annual Average Water Quality (Spring Operation)
- Mine Year 2 P90 Annual Average Flow, P90 Annual Average Water Quality
- Mine Year 2 Average Winter Flow, P90 Annual Average Water Quality (Winter Operation)
- Mine Year 3 Peak Flow, P90 Annual Average Water Quality (Spring Operation)
- Mine Year 3 P90 Annual Average Flow, P90 Annual Average Water Quality
- Mine Year 3 Average Winter Flow, P90 Annual Average Water Quality (Winter Operation)
- Mine Year 4 Peak Flow, P90 Annual Average Water Quality (Spring Operation)
- Mine Year 4 P90 Annual Average Flow, P90 Annual Average Water Quality
- Mine Year 4 Average Winter Flow, P90 Annual Average Water Quality (Winter Operation)
- Mine Year 5 Peak Flow, P90 Annual Average Water Quality (Spring Operation)
- Mine Year 5 P90 Annual Average Flow, P90 Annual Average Water Quality
- Mine Year 5 Average Winter Flow, P90 Annual Average Water Quality (Winter Operation)
- Mine Year 6 Peak Flow, P90 Annual Average Water Quality (Spring Operation)
- Mine Year 6 P90 Annual Average Flow, P90 Annual Average n Water Quality
- Mine Year 6 Average Winter Flow, P90 Annual Average Water Quality (Winter Operation)
- Mine Year 7 Peak Flow, P90 Annual Average Water Quality (Spring Operation)

- Mine Year 7 P90 Annual Average Flow, P90 Annual Average Water Quality
- Mine Year 7 Average Winter Flow, P90 Annual Average Water Quality (Winter Operation)
- Mine Year 7 Average Summer Flow, P90 Annual Average Water Quality (Winter Operation)
- Mine Year 8 Peak Flow, P90 Annual Average Water Quality (Spring Operation)
- Mine Year 8 P90 Annual Average Flow, P90 Annual Average Water Quality
- Mine Year 8 Average Winter Flow, P90 Annual Average Water Quality (Winter Operation)
- Mine Year 8 Average Summer Flow, P90 Annual Average Water Quality (Winter Operation)
- Mine Year 9 Peak Flow, P90 Annual Average Water Quality (Spring Operation)
- Mine Year 9 P90 Annual Average Flow, P90 Annual Average Water Quality
- Mine Year 9 Average Winter Flow, P90 Annual Average Water Quality (Winter Operation)
- Mine Year 9 Average Summer Flow, P90 Annual Average Water Quality (Winter Operation)
- Mine Year 10 Peak Flow, P90 Annual Average Water Quality (Spring Operation)
- Mine Year 10 P90 Annual Average Flow, P90 Annual Average Water Quality
- Mine Year 10 Average Winter Flow, P90 Annual Average Water Quality (Winter Operation)
- Mine Year 10 Average Summer Flow, P90 Annual Average Water Quality (Winter Operation)

The output tables include estimates of blended treated mine water quality routed to the FTB Pond (row 30 of each table).

The primary system function that determined the arrangement of treatment components in the model was sulfate and selenium removal in Mine Year 10. The primary mechanism used to achieve this function was the control of the VSEP capacity needed for second pass treatment of the chemical precipitation effluent. The fraction of the chemical precipitation effluent requiring second-pass treatment via secondary membrane separation was selected via multiple modeling runs, with the objective of leveling the usage of the in-place secondary membrane capacity throughout the year to achieve the treatment targets on a 12-month rolling average basis.

Based on the model results, the fraction of secondary membrane feed flow from primary membrane concentrate versus second pass chemical precipitation effluent varied seasonally. For example, during Mine Year 10, 833 gpm of secondary membrane capacity is required to treat:

- 499 gpm from primary membrane concentrate and 334 gpm from chemical precipitation effluent in peak flow conditions

- 435 gpm from primary membrane concentrate and 397 gpm from chemical precipitation effluent in summer flow conditions
- 0 gpm from primary membrane concentrate and 594 gpm from chemical precipitation effluent in winter flow conditions (primary membrane concentrate will be routed directly to chemical precipitation in winter conditions)

The treatment target for sodium is to have sodium constitute less than 60% of cations in treated mine water. Using the model, it was not always possible to meet both the hardness treatment target of 250 mg/L and the sodium target of 60% of cations in all Mine Years after Mine Year 1. This is because reducing the percent of cations constituted by sodium was achieved by retaining additional calcium in the effluent, but retaining additional calcium resulted in exceedance of the hardness target. These sodium exceedances occurred even though calcium was added to charge balance HCEQ Basin influent.

4.3 Mine Water Treatment Trains Design

Design of the mine water treatment trains was developed based on the system configuration that was shown during modeling to achieve treatment objectives. Large Figure 4 displays a treatment flow sheet of the mine water treatment trains and more detail is provided in the WWTS Permit Application Support Drawings (Attachment I). The system will be designed such that excess treatment capacity (normally in reserve for peak loading events) can be used for enhanced sulfate removal during low-flow periods. Design requirements for major equipment was based on applicable design standards and are provided in Attachment LAttachment L. Design considerations, design bases for flow and water quality, and the major components included in the system design are described in the following sections.

4.3.1 Design Considerations

In addition to treatment objectives, the mine water treatment trains will also be designed to be reliable, adaptable, and as compact as possible as described below.

4.3.1.1 Reliability

The mine water treatment trains must be reliable, user-friendly, and robust to minimize downtime and operation and maintenance costs. Reliability issues will be partially mitigated through the inclusion of equipment to assure continuity of treatment. Control systems will be incorporated into the design and operation to enable smooth interactions between equipment components and simplify operation of the system. Clarification units will be designed to treat the design flow split evenly through two parallel units. The membrane systems will also be highly automated, requiring little operator input on a daily basis.

Redundancy of key features will be included to improve reliability. The greensand filters and secondary membranes in the mine water membrane treatment train will be designed with sufficient redundancy to be able to treat the design capacity with the largest single unit within each individual process out of service. The primary membrane systems will be designed to treat the design flow with one two-stage, 2x1 membrane array out of service on each skid. The chemical precipitation units will be designed in two trains each capable of treating 50% of the design flow. Pumping stations will be designed to treat the design flow with the largest unit out of service. For example, a pumping station with a design capacity of 225 gpm could be designed with two 225 gpm pumps. Adding a third 225 gpm pump will increase the design capacity of the system to 450 gpm.

4.3.1.2 Adaptive Management

The mine water treatment processes can be adapted, as necessary, to meet the actual conditions encountered during the Project. As described in Attachment C, mine water quantity and quality are anticipated to vary substantially over the course of the Project. Water quantity and quality of mine water influent will be dependent on the degree and quality of drainage from the waste rock stockpiles and the amount and quality of mine pit dewatering. Further, because the actual water that will be generated will not be available until after the mine operations are initiated, there are limited opportunities for pilot-testing. While pilot-testing with Area 5 pit water (Attachment B and Attachment E) provides a basis for design, the composition of this water source will likely vary from the actual water that will be realized as mine water. For these reasons, treatment equipment will be selected such that component operation may be modified to account for unforeseen changes in reaction kinetics, sludge characteristics, or other factors that may modify the underlying chemistry in the process units. Flexibility in operation of the mine water treatment trains will allow operators to adjust to these changing or unforeseen conditions.

To accommodate variable influent quantity and quality, the mine water membrane treatment train design will be modular such that additional treatment capacity or unit processes can be brought online to handle fluctuations in required treatment capacity. This will be particularly important during spring snowmelt conditions when PolyMet may choose to dewater the mine pits over a three-day period. Alternatively, at low flows, treatment could be accomplished using fewer units. The primary spiral-wound membranes are produced in standard sizes universal to the spiral-wound membrane industry, which provides additional operational flexibility. Thus, there will be opportunity to upgrade membrane elements if new products developed in the future provide an advantage from a performance or operational standpoint.

Additional potential operational flexibility includes:

- Operators could bypass units and/or processes that are not required to meet discharge requirements.
- The proportions of primary membrane concentrate and chemical precipitation effluent routed to secondary membranes could be adjusted.
- Chemical feed systems will be designed to offer the operational flexibility necessary to accommodate changing water chemistry.

The mine water treatment trains will be designed for adaptive water management based on flows and loads. As operational data are accumulated, the system can be expanded or the flow path modified to accommodate changing requirements. Specific modifications that could be incorporated, if necessary, include:

- Equalization – Three equalization basins at the Mine Site will be provided for equalizing flows into two mine water treatment trains at the WWTS. Providing a third basin allows flexibility in equalizing flows that will vary depending on mining or construction activities in operation at any given time. Thirteen different flow sources are routed to the equalization basins. Based on constituent concentrations, these flows can be routed to either the mine water membrane treatment (typically lower strength), or the mine water chemical precipitation train (typically higher strength).

- Primary membrane modules – Replacement of primary membrane modules with modules of different removal capability can be accomplished if treatment requirements change. The housing of RO and NF membrane modules has been standardized (i.e., 8-inch diameter, spiral wound) allowing replacement of existing modules with modules of different capability, or even different manufacture. The membrane sheets which comprise the separation function of the modules are constantly being refined by membrane manufacturers. New products with improved or more targeted capabilities are brought to market regularly.

- Chemical precipitation train – The mine water chemical precipitation train will include three stages, each with multiple points for chemical addition. As water quality and quantity changes, the chemical addition can be modified to best accommodate the new conditions.

- Primary membrane concentrate routing – In winter months, influent flow from the HCEQ Basin is lower than the design range of the chemical precipitation equipment. In response, primary membrane concentrate can be routed directly to the chemical precipitation train to maintain design hydraulic loading of these units.

- Chemical precipitation effluent routing – Effluent from the chemical precipitation train is routed to the chemical precipitation effluent tank where it can be conveyed to the FTB Pond or to the secondary membrane feed tank, depending on the required level of treatment during that season and the available secondary membrane capacity. Water from the chemical precipitation effluent tank can also be used in the carbon dioxide system, or at the filter press for flush water. As noted in the modeling, routing more of the primary membrane concentrate directly to the chemical precipitation train increases the available capacity for secondary membrane treatment of chemical precipitation effluent in the winter.

- Secondary membrane modules – Secondary membrane trains can be populated with additional modules to accommodate additional recycle treatment if needed, or to provide for expanded capacity in the future.

4.3.2 Mine Water Flow Design Basis

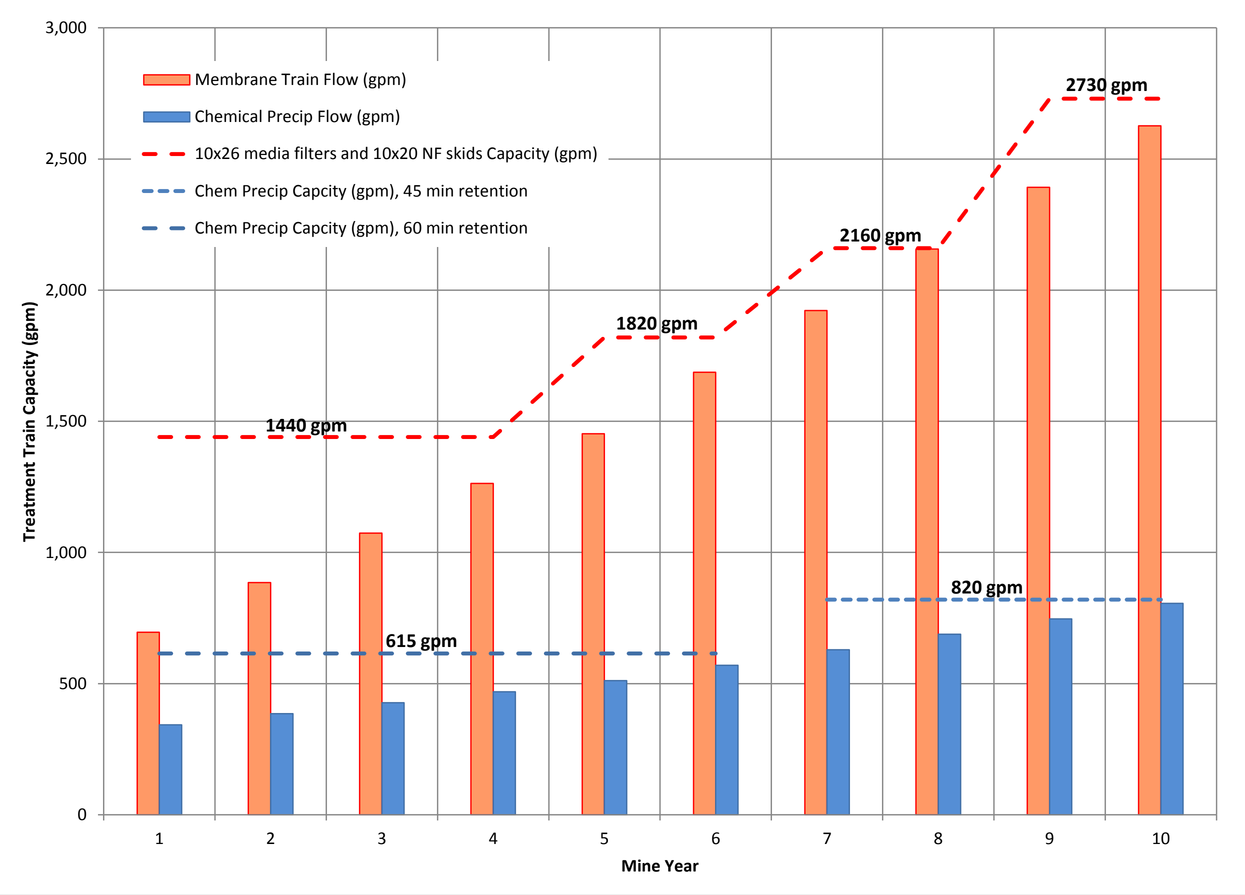
The mine water influent flow design basis is as previously described in Section 2.3.2 and detailed in Attachment C. Mine water influent flows from the both equalization basins vary seasonally. Influent flow from the LCEQ Basins and HCEQ Basin is expected to peak around Mine Year 10 and again around Mine Year 14. The design basis influent flow for each of the mine water treatment trains is determined from the spring flood event flow rates, which are greater than the annual average flow rates, and correspond to the peak flows used in the model.

4.3.3 Mine Water Influent Water Quality Design Basis

The mine water influent quality design basis was determined using methods described in Attachment C and summarized in Section 2.3.3. The mine water influent quality design basis is the same as the water quality inputs to the model as described in Section 4.2.2 and summarized in Large Table 3 and Large Table 4.

4.3.4 Mine Water Treatment Trains Build-out Schedule

Figure 4-1 shows an overview of the anticipated construction build-out of the mine water membrane treatment train and the chemical precipitation train, based on the peak influent flow and loading rates in each Mine Year.



Source: GoldPHREEQC Mine Water Treatment Model Simulations, July 2015

Figure 4-1 **Mine Water Chemical Precipitation and Membrane Treatment Trains Construction Build-out**

The chemical precipitation train will be constructed with adequate tank capacity for each year of operation. At least 50% of the chemical precipitation treatment capacity will be constructed in Mine

Year 1. The additional capacity will be installed as needed to meet project requirements, prior to Mine Year 5, depending on the observed flows and treatment performance. Starting in Mine Year 7, the operating hydraulic residence time in each reactor of the chemical precipitation train will be decreased from 60 minutes to 45 minutes, resulting in an increased hydraulic treatment capacity. The capacity required for the chemical precipitation train in Mine Year 10 includes the flow sources and quantities outlined in Table 4-5.

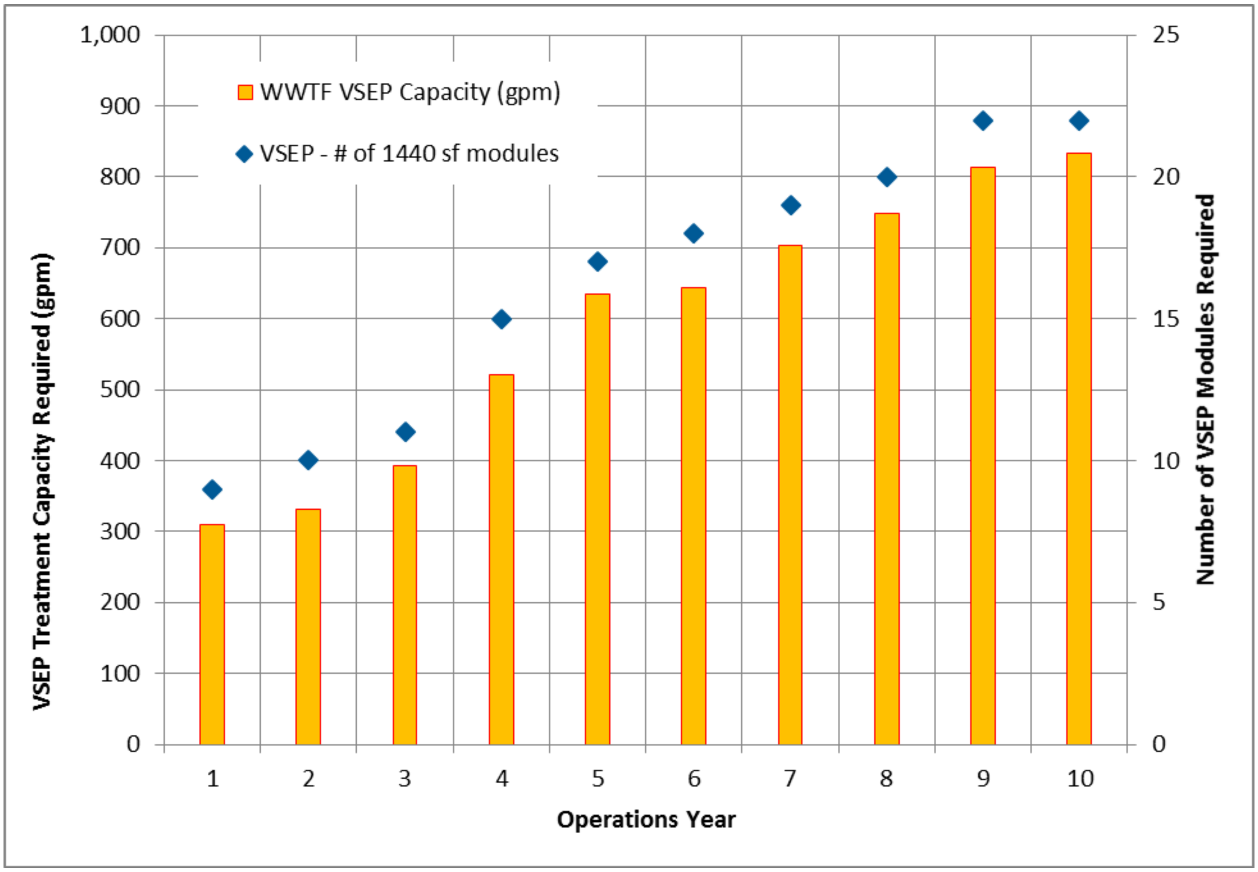
Table 4-5 Mine Water Chemical Precipitation Train Capacity Required in Mine Year 10

High Concentration Equalization Basin Outlet, gpm	Tailings Basin Seepage Train VSEP Concentrate, gpm	Mine Water VSEP Concentrate, gpm	Mine Water Greensand Filter Backwash Solids, gpm	Total Flow, gpm
368	158	167	65.7	760

Source: GoldPHREEQC Mine Water Treatment Train Model Simulations, July 2015

The membrane separation treatment train can be expanded by adding filters and membrane module skids operating in parallel with the initially constructed units.

Large Table 4 shows an overview of the anticipated construction build-out of the mine water secondary membrane separation system. As described in more detail in the following sections, build-out of this treatment process will include additional membrane modules for the two treatment trains initially constructed.



Source: GoldPHREEQC Mine Water Treatment Model Simulations, July 2015

Figure 4-2 **Mine Water Treatment Secondary Membrane Construction Build-out**

4.3.5 Central Pumping Station

The CPS will receive mine water and construction mine water from numerous sources within the Mine Site. Upon entering the CPS, these flows will be conveyed by gravity to the LCEQ Basins, HCEQ Basin, or the Construction Mine Water Basin. Water from the HCEQ Basin and LCEQ Basins will flow by gravity to the lift stations (described below) which will be located in the CPS, and then be conveyed to chemical precipitation and membrane separation treatment trains at the WWTS as described below.

4.3.6 Mine Water Chemical Precipitation Train

The mine water chemical precipitation train will remove metals and sulfate from high-concentration mine water. Mine water routed through the chemical precipitation treatment train will pass from the HCEQ Basin at the headworks (Section 4.3.6.1), then through a three-stage chemical precipitation system. The chemical precipitation system (Section 4.3.6.2) will be two parallel trains of three chemical reactor-clarifier systems operated in series to remove metals, sulfate, and excess calcium. Metals and sulfate will be removed by adding lime, while the excess calcium will be removed by adding carbonate using carbon dioxide. Metal and sulfate chemical precipitation reactors will be of the same design and size, allowing the flexibility to use any reactor for either metals or sulfate removal. Providing identical chemical precipitation reactors will also simplify operations and maintenance as the same replacement components and procedures can be used for identical units.

Most effluent from the chemical precipitation train will be routed to the FTB Pond. Some effluent from the chemical precipitation train will be recycled to the secondary membrane system, as described in Section 4.3.7.4. The chemical precipitation processes will produce solid residuals in the form of sludges, which will be managed using sludge pumping, storage, and filter press equipment (Section 4.3.6.3).

4.3.6.1 Headworks

The headworks will consist of the HCEQ Basin and lift station at the Mine Site.

High Concentration Equalization Basin

The HCEQ Basin will equalize the flow of high-concentration, low-volume waste water to the WWTS. It will be sized to contain the one-month spring snowmelt event in Mine Year 10 to prevent overfilling (Section 4.0 of Attachment C). The HCEQ Basin will have a densely-compacted embankment consisting of Common Fill 1, which will have a maximum 6-inch diameter rock size and be free of organic material. Above the embankment will be a geocomposite liner consisting of a geosynthetic clay liner (GCL) overlain by a 60-mil HDPE liner that will extend continuously beneath the CPS and the LCEQ basins, as described below. The liner system will be overlain with a 1-foot protective sand layer and 1-foot layer of Minnesota Department of Transportation (MnDOT) Class V riprap on the side slopes. The HCEQ Basin will have three vertical feet of freeboard above the design volume shown in Table 4-6. Table 4-6 summarizes preliminary design information for the HCEQ Basin.

Table 4-6 High Concentration Equalization Basin Preliminary Design

Parameter	Value
Volume	31.4 acre-feet
Spring Snowmelt Pumping Rate (30 days), Mine Year 10	604 gpm
Mean Summer Average Flow Rate (Beginning on Day 30), Mine Year 10	341 gpm
Minimum Required Pumping Rate to Prevent Overfilling, Mine Year 10	368 gpm
Liner Construction	GCL overlain by 60-mil HDPE 1-foot sand layer 1-foot MnDOT Class V Riprap on side slopes

Source: Attachment C

Lift Station

The lift station for pumping mine water from the HCEQ Basin at the Mine Site to the WWTS at the Plant Site will be housed within the CPS and will be capable of meeting the maximum pumping requirements during the 30-day spring snowmelt event followed by 30 days of the mean summer flow conditions with one pump out of service.

The lift station will be provided with three pumps, each capable of pumping 50% of the design flow. The pumps will cycle based on basin water depth.

4.3.6.2 Metals, Sulfate, and Calcite Precipitation Equipment

This system will comprise a set of rapid-mix tanks, high-density sludge reactors, and clarifiers for each process (HDS, sulfate precipitation, and calcite precipitation).

The first stage of chemical precipitation will remove metals, including nickel, copper, and cobalt using lime addition to a high-density sludge metals precipitation system. Lime will be dosed to achieve the target pH range for metals removal. The system will include provisions to recycle settled sludge from the clarifier to the reactor to maintain a high sludge concentration to facilitate the co-precipitation of iron and metals. While the preliminary design includes provisions for the addition of ferric sulfate (to supplement iron concentration in the reactor), polymer coagulant (to achieve the desired solids settling in the clarifiers), and a scavenger for metals polishing after the HDS process, it is anticipated that these supplemental chemicals will not be required. Removed metals will exit the system as a sludge that will be dewatered and hauled to the Hydrometallurgical Residue Facility (HRF) at the Plant Site or disposed in a permitted solid waste facility (Section 4.3.6.3).

The second stage of chemical precipitation will remove sulfate, by adding more lime to precipitate gypsum. Lime will be dosed to achieve the target pH range for gypsum precipitation. The gypsum precipitation system will comprise rapid mix tanks, high-density sludge reactors, and clarifiers. The system will include pumps and piping for recycling settled sludge from the clarifier to the reactor to provide nucleation sites for gypsum precipitation, thereby enhancing precipitation kinetics. Removed sulfate will exit the system as gypsum sludge that will be dewatered and hauled to the HRF at the Plant Site or disposed in a permitted solid waste facility.

The second stage of the chemical precipitation system will also include provisions to add hydrochloric acid to the feed for the purposes of lowering sulfate solubility in the reactor, if necessary. While the amount of hydrochloric acid that can be fed will be limited by the allowable chloride in the effluent, the addition of hydrochloric acid can be used to counteract elevated levels of sodium in the feed, and can be a cost-effective alternative to increased secondary membrane capacity. The design will also include provisions for the addition of polymer coagulant to assist with solids removal in the clarifiers, however, it is anticipated that polymer coagulant will not be required.

The third stage of chemical precipitation will remove excess calcium and adjust pH, using a recarbonation/calcite precipitation system. The recarbonation/calcite precipitation system will comprise a rapid mix tank with carbon dioxide injection and a solids-contact clarifier to provide for excess calcium removal. Carbon dioxide will be fed to the system in a carrier water stream to facilitate good mixing and minimize clogging of diffusers with scale. Carbon dioxide will be dosed to achieve the target pH range for calcite precipitation. Precipitated calcium carbonate will be removed from the waste water in the solids contact clarifier. The excess calcium removed will exit the system as calcite sludge, which will be dewatered and hauled to the HRF or disposed in a permitted solid waste facility. An in-line carbon dioxide injection point downstream of the solids contact clarifier will provide final neutralization of the chemical precipitation effluent meet effluent targets for pH.

Clarifiers will be designed to meet applicable Minnesota Pollution Control Agency (MPCA) guidelines as listed in the *Settling Review Checklist* (Reference (5)).

Most effluent from the chemical precipitation train will be routed to FTB Pond. Some effluent from the chemical precipitation train will be recycled to the secondary membrane system, as described in Section 4.3.7.4.

Table 4-7 summarizes preliminary design information for the chemical precipitation systems. Additional physical expansion of chemical precipitation equipment is not anticipated, provided the equipment can be operated at sufficiently high loading rates (i.e., 40% higher than the design basis for the first build-out).

Table 4-7 Mine Water Chemical Precipitation System Preliminary Design

Parameter	Value
Peak Capacity, Mine Year 10(1)	819 gpm
Number of Treatment Trains	2
Rapid Mix Tank Peak Hydraulic Residence Time	5 minutes minimum
Reactor Hydraulic Residence Time (HDS and Sulfate Precipitation)	40 minutes minimum
Sludge Recycle Rate to Reactor	25% maximum
Reactor Solids Content	5% maximum
P90 Annual Average Clarifier Overflow Rate (HDS and Sulfate Precipitation)	500 gpd/sf
Peak Clarifier Overflow Rate (HDS and Sulfate Precipitation)	750 gpd/sf
P90 Annual Average Clarifier Overflow Rate (Calcite Clarifier)	750 gpd/sf
Peak Clarifier Overflow Rate (Calcite Clarifier)	1,000 gpd/sf
CO_2 Carrier Water Recirculation Flow Rate (Calcite Clarifier)	50% of forward flow maximum

(1) Source: GoldPHREEQC Mine Water Treatment Train Model Simulations, 2015

4.3.6.3 Sludge Pumping and Pressing

The chemical precipitation processes will produce solid residuals in the form of sludges, including a metal/iron sludge, gypsum sludge, and calcite sludge. These sludges will be conveyed within the WWTS by means of sludge pumps and piping. In the case of the high density sludge (HDS) and sulfate precipitation processes, some fraction of the sludge collected in the clarifiers will be recycled to the precipitation reactors to maintain the necessary solids content in the reactors. Any excess sludge will be pumped to sludge storage tanks.

Sludge piping and pumping will be designed to meet applicable MPCA guidelines as listed in the *Settling Review Checklist* (MPCA, 2001). Blended sludge accumulated in the sludge storage tanks will be dewatered using a plate-and-frame filter press. Dewatered sludge will be transferred from the filter press into trailers for hauling to the HRF or to a permitted solid waste facility. Filtrate will be routed to the Waste Pumping Station for treatment in the mine water chemical precipitation treatment train (Section 4.4.3).

Sludge dewatering facilities will be designed to meet applicable MPCA guidelines as listed in the *Mechanical Dewatering Facilities Review Checklist* (MPCA 2001) and *Pressure Filtration Review Checklist* (MPCA 2001).

Sludge pumping, storage, and filter press equipment will be sized to accommodate the anticipated sludge generation rates as summarized in Table 4-8 and Table 4-9.

Table 4-8 Mine Water Chemical Precipitation Treatment Train Estimated Dry Sludge Quantity Summary

Sludge	Amount @ P90 Annual Average Flow, Mine Year 1	Amount @ P90 Annual Average Flow, Mine Year 5	Amount @ P90 Annual Average Flow, Mine Year 10
HDS Metals, tons/d	18	22	47
Gypsum, tons/d	10	22	37
Calcite, tons/d	7	12	19
Total, tons/d	35	56	103

Source: GoldPHREEQC Mine Water Treatment Model Simulations, 2015

Table 4-9 Mine Water Chemical Precipitation Treatment Train Sludge Handling Preliminary Design through Mine Year 10

Parameter	Value
Clarifier Underflow Solids Content (HDS Sludge)	25%
Clarifier Underflow Solids Content (Sulfate Sludge)	10%
Clarifier Underflow Solids Content (Calcite Sludge)	10%
Dedicated Sludge Storage Capacity	1 day total sludge production
In-Clarifier or Auxiliary Sludge Storage Capacity	1 day total sludge production
Filter Press Cycle Time	Sufficient to press 1 day of sludge production in one 8-hour shift

4.3.7 Mine Water Filtration Train

The primary membrane separation system will remove metals and sulfate from low-concentration mine water. Mine water will pass from the LCEQ Basins at the headworks (Section 4.3.7.1), through greensand filtration (Section 4.3.7.2), to the primary membrane system (Section 4.3.7.3). Primary membrane concentrate as well as some chemical precipitation effluent will be further concentrated using the secondary membrane system (Section 4.3.7.4).

Most membrane permeate from the mine water filtration train will routed to the FTB Pond. Some permeate will be reused within the mine water treatment trains at the WWTS, for purposes such as feed water for the recarbonation system, feed water for the lime slurry system, and water for general cleanup/equipment washing. Concentrate from the primary membrane system, containing rejected metals and sulfate, will be routed to the secondary membrane system and then to the chemical precipitation train for treatment.

4.3.7.1 Headworks

The headworks consist of the LCEQ Basins and lift stations at the Mine Site.

Low Concentration Equalization Basins

LCEQ Basin 1 and LCEQ Basin 2 at the Mine Site will be used to equalize the flow of low-concentration mine water to the WWTS at the Plant Site. Two basins are included in the design, because this provides the flexibility to segregate runoff from the Category 1 Stockpile Groundwater Containment System flows and route it to either of the two mine water treatment trains, depending on its quality during mining operations. LCEQ Basin 2 is sized to equalize the maximum daily flow rate from the Category 1 Stockpile Groundwater Containment System. The combined capacity of LCEQ Basin 1 and Basin 2 is sized to contain the one-month spring snowmelt event in Mine Year 10 (Section 4.1 of Attachment C).

The LCEQ Basins, like the HCEQ Basin, will have a densely-compacted embankment consisting of Common Fill 1, which will have a maximum 6-inch diameter rock size and be free of organic material. Above the embankment will be a geocomposite liner consisting of a geosynthetic clay liner (GCL) overlain by a 60-mil HDPE liner that will extend continuously beneath the CPS and the LCEQ basins. The liner system will be overlain with a 1-foot protective sand layer and 1-foot layer of MnDOT Class V riprap on the side slopes. The LCEQ Basins will have three vertical feet of freeboard above the design volume shown in Table 4-10. Table 4-10 summarizes the preliminary design information for the LCEQ Basins.

Table 4-10 Low Concentration Equalization Basins Preliminary Design

Parameter	Value
Volume, total, Equalization Basin 1 and Equalization Basin 2	107 acre-feet
Total Spring Snowmelt Flow Rate (day 1-3), Mine Year 10	6,225 gpm
Total Spring Snowmelt Flow Rate (day 4-30), Mine Year 10	3,050 gpm
Mean Summer Average Flow Rate (day 30+), Mine Year 10	2,233 gpm
Minimum Required Pumping Rate to Prevent Overfilling, Mine Year 10	2,561 gpm
Equalization Basin 2 Volume	26 acre-feet
Maximum Daily Flow, Category 1 Stockpile Groundwater Containment System	5,785 gpm for 24 hours Total volume = 26 acre-feet

Source: Attachment C

Lift Station

During normal operation, it is anticipated that mine water stored in LCEQ Basins 1 and 2 will be pumped to the WWTS filtration treatment train via the same lift station. This lift station will be housed within the CPS at the Mine Site and will be capable of meeting the minimum pumping requirements to prevent the basin from overfilling during spring snowmelt event with one pump out of service.

4.3.7.2 Greensand Filtration

As described in Section 3.3.5, "greensand filter" is a term that refers to a media filter with an oxidation process. The specific media that will be used for the filter, which could be greensand or other media with an oxidative coating, will be determined during final design based on site-specific information. Effluent from the GSF will be routed to the primary membrane separation system.

Backwash from the GSF, which will contain iron, manganese, and metals removed from the mine water, will be separated via gravity in the backwash tank, with the solids being pumped to the first unit of the chemical precipitation train for collection in the clarifiers. Decanted supernatant will be pumped to the greensand filter feed tank at the head of the mine water filtration train.

Table 4-11 summarizes greensand filter preliminary design information for each build-out. Initial sizing was based on the years requiring maximum membrane train capacity for each build-outs.

Table 4-11 Mine Water Membrane Treatment Train Greensand Filter Preliminary Design

Parameter	Value
Feed Capacity, Mine Year 1$^{(1)}$	1,476 gpm
Feed Capacity, Mine Year 5$^{(1)}$	1,866 gpm
Feed Capacity, Mine Year 7-8$^{(1)}$	2,214 gpm
Feed Capacity, Mine Year 9-20$^{(1)}$	2,798 gpm
Loading Rate	3.5 gpm/ft^2 to 4.9 gpm/ft^2
Sodium Permanganate Dose	1.65 mg/L
Backwash Volume (each cycle)	12-15 gpm/ft^2
Backwash Cycle Time	15-25 minutes
Maximum Differential Pressure	7 psi

(1) Source: GoldPHREEQC Mine Water Treatment Train Model Simulations, July 2015

4.3.7.3 Primary Membrane Separation System

The primary membrane separation system will be equipped with a high-pressure pump that will push the water across the NF membranes. The mine water primary membrane separation system will use a conventional, spiral wound membrane configuration, with multiple membranes operating in a series and parallel configuration to provide the needed capacity. This system is designed to operate on a continuous basis while isolated elements are removed from the process for periodic cleaning or maintenance.

Based on the results of pilot-testing (Attachment B and Attachment E), the following membranes have been demonstrated to be effective with site-specific mine water:

- GE HL4040FM NF as reported in the Waste Water Treatment Facility Pilot-Testing Program (Attachment E)
- Dow NF-270 NF as reported in the Waste Water Treatment Facility Pilot-Testing Program (Attachment E)

The membranes that will be used in the primary membrane separation system will be selected during the final design process based on ability to remove the constituents of interest for this Project and to meet the effluent requirements established in the NPDES/SDS Permit.

Permeate from the primary membrane system will be routed to the blended permeate tank. Concentrate will be routed to the secondary membrane system.

The NF membranes will require periodic cleaning to remove accumulated foulants and maintain flux. The chemicals used for cleaning may include either high pH or low pH solutions. These CIP wastes will be routed to the FTB Pond.

Table 4-12 summarizes primary membrane system preliminary design information for each build-out. Initial sizing was based on the Mine Years requiring maximum membrane train capacity during each build-out period.

Table 4-12 Mine Water Primary NF Membrane Preliminary Design

Parameter	Value
Feed Capacity, Mine Year 1-4(1)	1,440 gpm
Feed Capacity, Mine Year 5-6(1)	1,820 gpm
Feed Capacity, Mine Year 7-8(1)	2,160 gpm
Feed Capacity, Mine Year 9-20(1)	2,730 gpm
Recovery	80%
Flux	16 gfd
Sodium Bisulfite Dose	1 ppm
Pre-treatment	Antiscalant, Sodium bisulfite

(1) Source: GoldPHREEQC Mine Water Treatment Train Model Simulations, July 2015

4.3.7.4 Secondary Membrane System

Similar to the secondary membrane system for the tailings basin seepage treatment train (Section 3.3.7), the secondary membrane system at the mine water membrane treatment train will consist of a manufactured stack of flat-sheet NF membranes using a VSEP to reduce precipitation on the membrane surfaces. The secondary membranes will operate in a batch-mode with a declining flux rate to produce the secondary membrane concentrate and the secondary membrane permeate. The NF-270 membrane, manufactured by Dow, was shown to be effective at treating site-specific water, as described in Attachment E. The specific membrane manufacturer and type will be determined during final design.

The secondary membrane system will receive feed from primary membrane system concentrate and chemical precipitation system effluent, with proportions of these flows routed to secondary membranes dependent on seasonal flows and treatment required to meet treatment targets on a 12-month rolling average basis. During peak flow periods, the available secondary membrane capacity will be used to reduce the hydraulic load on the chemical precipitation train by treating the primary NF concentrate stream and as much chemical precipitation effluent as required to meet treatment targets on a 12-month rolling average basis. As described in the modeling construct and adaptive management, during lower flow periods, primary membrane concentrate can be routed directly to chemical precipitation to sustain minimum hydraulic load on the chemical precipitation equipment. Secondary membrane capacity not needed to process the primary membrane concentrate stream will be used to re-treat the chemical precipitation effluent, with concentrate being routed back to chemical precipitation for further sulfate removal.

The secondary membrane units will be fed in a batch mode using dedicated feed tanks. Carbon dioxide will be applied to the secondary membrane feed tank to adjust pH in the range of 6.0 to 6.5 to maintain flux throughout the batch process. Concentrate from the secondary membranes will be pumped to the flow control structure at the head of the chemical precipitation train. Permeate from the secondary membrane will be blended with the primary membrane permeate and the chemical precipitation effluent and routed to the FTB Pond.

The secondary membrane system will require periodic cleaning and maintenance. Waste cleaning solution is not anticipated to contain target constituents for removal by the chemical precipitation system, and will be routed to the FTB Pond.

Table 4-13 summarizes the secondary membrane system preliminary design information for Mine Years 1, 5, and 10.

Table 4-13 Mine Water Secondary Membrane Preliminary Design

Parameter	Value
Feed Capacity, Mine Year 1(1)	309 gpm
Feed Capacity, Mine Year 5(1)	635 gpm
Feed Capacity, Mine Year 10(1)	833 gpm
Flux	65 gfd
Filtrate Recovery Rate	80%
Cleaning Waste Generation Rate	5% of feed
Pre-Treatment	Antiscalant, Sodium bisulfite, Carbon dioxide to pH<6.0
Batch Volume	20,000 gallons
Redundancy and Down Time Factor	50%

(1) Source: GoldPHREEQC Mine Water Treatment Train Model Simulations, July 2015

4.3.8 Treated Mine Water Handling

Treated mine water handling equipment will consist of an effluent blend tank, which will receive and blend the effluent from the chemical precipitation train with the permeate from the primary and secondary membrane treatment systems. The discharge works will include a lift station to pump treated mine water to the FTB Pond.

4.3.9 Construction Mine Water Basin

Construction mine water will be generated during the construction of the waste rock stockpiles and other mining features. During the initial construction phase of the Mine Site, this includes construction dewatering of saturated mineral overburden, which may contain dissolved metals and other constituents at concentrations that do not meet construction stormwater requirements. Water sent to the Construction Mine Water Basin will not be treated at the WWTS. The Construction Mine Water Basin will store construction mine water and runoff from the OSLA and will act as an equalization and settling basin. Construction mine water will be routed directly to the Construction Mine Water Basin through the CPS. In the CPS, an option to add chemical coagulant to enhance flocculation and settling of dissolved solids in the construction mine water will be included. Construction mine water and OSLA runoff will be pumped from the Construction Mine Water Basin through the Construction Mine Water Pipeline to the FTB.

4.4 Mine Water Managment

This section describes key aspects of operations related to the mine water management, including operation and inspection of the Equalization Basin Area and the MPP and management of treated mine water and byproducts.

4.4.1 Equalization Basin Area and Mine to Plant Pipelines

The Equalization Basin Area is located at the Mine Site, south of Dunka Road. The equalization basins and the Construction Mine Water Basin will serve to decrease the variability of mine water influent streams in terms of flowrate and water quality. The pumping rate from the HCEQ and LCEQ Basins to the WWTS mine water treatment trains and the Construction Mine Water Basin to the FTB will vary depending upon the volume of water in the basins. When the basins are nearly full, pumping out of the basins will be at a faster rate, and when they are nearly empty, pumping out of the basins will be at a slower rate. The WWTS operators will be responsible for managing the operation of these basins including initial filling, emergency procedures, and responding to warning systems. Each of the basins will have a water level control system to automatically shut off flow to them before they reach full capacity. In addition, a high-water-level alarm will alert the operators so that overfilling does not occur. The control room at the WWTS will have instrumentation to monitor the water level of each of the basins, and the Equalization Basin Area will be visually inspected at least once per shift.

The WWTS operators will also monitor the sediment level in the basins and arrange for dredging and disposal of sediment, if needed. The Equalization Basin Area embankments will be inspected on a monthly basis to look for signs of deterioration and perform maintenance and repairs, as needed.

Monitoring of the MPP will occur by routine visual inspections and with flow meters, as a form of leak detection. Visual inspections of the MPP alignment will be completed on a regular basis for early identification of any potential leaks. Final design and construction may affect specific details of the monitoring and inspection plan. Once final design and construction of the MPP is completed, PolyMet will include its monitoring and inspection protocols in a spill response plan. Currently, PolyMet anticipates the following elements will be included in its plan: Visual inspections of the MPP will be completed daily at each manhole location, which will include a walk-around inspection. Additionally, monthly visual inspections will occur along the entire MPP alignment (berms, in most cases). Each pipeline of the MPP contains in-line flow meters at both the origin and terminus, which will be monitored in the control room at the WWTS. Having the flow meters on each end of each pipe will allow for continuous monitoring of flow differentials; if a differential suggests that a leak might have occurred, an alarm will sound and the pumps will automatically stop (Section 4.1.3 of Reference (1)) (further details on flow differentials to be determined during final engineering design). Additional procedures for response to potential leaks will be developed based on the final design and construction of the MPP and included in the spill response plan.

4.4.2 Treated Mine Water

Effluent from the mine water chemical precipitation train will be conveyed to the Chemical Precipitation Effluent Tank, and effluent from the mine water filtration treatment train will be routed to the Mine Water Blended Permeate Tank. These waters will be combined in the Effluent Blend Tank and will be routed to the FTB Pond.

4.4.3 Mine Water Treatment Trains Byproduct Streams

The mine water treatment trains will produce byproduct streams as a result of filter and membrane cleaning. Media and membrane filtration systems will be designed with redundant units such that maximum flow rates can be treated with some units can be taken offline for cleaning or maintenance. Cleaning or backwashing of filtration units will be conducted on a rolling basis, with a fraction of units offline for cleaning at any given time. The details and fate of these streams is outlined in Table 4-14.

Table 4-14 Mine Water Treatment Trains Byproduct Streams Description and Fate

Stream	Treatment Process	Parameters	Mine Year 1 P90 Average Production(1)	Mine Year 5 P90 Average Production(1)	Year 10 P90 Average Production(1)	Reports to	Fate
Clean-in-Place Membrane Waste	Primary Membranes	MC1, MC4, trace Fe and Mg	94,000 gal/year	212,000 gal/year	294,000 gal/year	Flotation Tailings Basin	Tailings Basin Solids (Fe) sludge (Mg)
	Secondary Membranes	NLR 404, NLR 505, Na, trace other salts	12,000 gal/day	26,000 gal/day	35,000 gal/day	Flotation Tailings Basin	Primary NF permeate (Na)
Greensand Filter Backwash	Greensand Filter	COD, Fe, Ca, Mg, Mn, Si, Na	18,000 gal/day	40,000 gal/day	56,000 gal/day	Chemical Precipitation Train	HDS Metals Sludge

Source: GoldPHREEQC Mine Water Treatment Train Model Simulations, July 2015

(1) Exact cleaning volumes may be changed in final design or plant startup

5.0 Chemical Handling and System Controls

This section describes chemical handling and system controls for the WWTS.

5.1.1 Chemical Use in the Tailings Basin Seepage Train

Chemicals used in large quantities at the tailings basin seepage treatment train include carbon dioxide (for membrane feed pH adjustment), granular calcite (for effluent stabilization), and sodium permanganate for operation of the greensand filter. Proprietary chemicals such as antiscalants and CIP chemicals will also be used, with feed rates determined during final design. Table 5-1 outlines estimated chemical use and the ultimate fate of the chemicals that will be added at the tailings basin seepage treatment train.

Table 5-1 Tailings Basin Seepage Treatment Train - Chemical Use and Fate

Chemical	Use	Treatment Process	Build-out 1 Max Year Usage Rate (Mine Year 7 P90 Average)[1]	Build-out 2 Max Year Usage Rate (Mine Year 10 P90 Average)[1]	Dose Source	Reports to	Fate
Anionic Polymer (Standby)	Iron Settling Enhancement	Pre-Treatment Basin	72 lbs/day	140 lbs/day	Engineering Practice	Pre-Treatment Basin	Settled with Iron Particles
Sodium Permanganate	Filter Pretreatment	Greensand Filter	230 lbs/day	200 lbs/day	Appendix D Pilot	Flotation Tailings Basin	Permanganate Reduced to Mn(II)
Carbon Dioxide	pH Adjustment	Secondary Membranes	10 tons/day	20 tons/day	Model	N/A	Neutralized
Granular Calcite	Effluent Stabilization	Limestone Contactor	2,000 lbs/day	2,000 lbs/day	Model	WWTS Discharge	Dissolved
GE Hypersperse MDC150	Membrane Antiscalant	Primary Membranes	65 lbs/day	120 lbs/day	Pilot	WWTS Chemical Sludge	No Reaction
NLR 759	Phosphonic Acid Antiscalant	Secondary Membranes	3 gal/day	6 gal/day	Vendor (NLR)	WWTS HDS Sludge	No Reaction
Sodium Bisulfite	Oxidant-Quenching Membrane Pretreatment	Primary Membranes	39 lbs/day	55 lbs/day	Vendor (GE)	WWTS Sulfate Sludge	Sulfite oxidized to sulfate
	Oxidant-Quenching Membrane Pretreatment	Secondary Membranes	7 lbs/day	12 lbs/day	Vendor (GE)	WWTS Sulfate Sludge	Sulfite oxidized to sulfate
MC1	Citric Acid Membrane Cleaner	Primary Membranes	8,000 lbs/year	15,000 lbs/year	Vendor (GE)	Flotation Tailings Basin	Neutralization, adsorption, and degradation in tailings basin solids
MC4	Alkaline Surfactant Membrane Cleaner	Primary Membranes	8,000 lbs/year	15,000 lbs/year	Vendor (GE)	Flotation Tailings Basin	Neutralization, adsorption, and degradation in tailings basin solids

Chemical	Use	Treatment Process	Build-out 1 Max Year Usage Rate (Mine Year 7 P90 Average)(1)	Build-out 2 Max Year Usage Rate (Mine Year 10 P90 Average)(1)	Dose Source	Reports to	Fate
NLR 404	Organic Acid Membrane Cleaner	Secondary Membranes	11 gal/day	21 gal/day	Vendor (NLR)	Flotation Tailings Basin	Neutralization, adsorption, and degradation in tailings basin solids
NLR 505	Alkaline Surfactant Membrane Cleaner	Secondary Membranes	11 gal/day	21 gal/day	Vendor (NLR)	Flotation Tailings Basin	Neutralization, adsorption, and degradation in tailings basin solids

Source: GoldPHREEQC Tailings Basin Seepage Treatment Model Simulations, July 2015

(1) Exact chemicals and usage rates may be adjusted during final design or plant startup. Listed chemicals represent examples for the specific chemical use.

5.1.2 Chemical Use in the Mine Water Treatment Trains

Chemicals used in large quantities in the mine water treatment trains include carbon dioxide, lime, and sodium permanganate. Usage rates listed reflect the modeled P90 annual average use rates for the maximum use year of the first two build-outs (Mine Year 2 and Mine Year 6) plus modeled P90 annual average use rates for Mine Year 10. Proprietary chemicals such as antiscalants, scavengers, and CIP chemicals will also be used, with feed rates determined during final design. Large Table 5 outlines chemical use and ultimate fate of the chemicals that will be added in the WWTS mine water treatment trains.

5.1.3 Chemical Handling at the WWTS

Carbon dioxide will be stored outside the WWTS in a compressed liquid tank, and will be vaporized and delivered to the points of use within the WWTS as a gas.

Granular calcite will be delivered to the WWTS in 2,000 lb super sacks. A forklift will be used to load the super sacks on interior racks until needed. An overhead crane and trolley will be used to transport the sacks to the LBC tanks for filling as needed.

Sodium permanganate, in a concentrated solution, will be stored in a bulk tank, and will be filled directly by delivery truck via a connection through an exterior wall of the building. Sodium permanganate will be injected into the greensand filter feed pipe via a metering pump and tubing.

The lime storage and delivery system will be sized with the capacity to store 30 days usage of quick lime at the P90 annual average usage rate on-site. The system design will also include the flexibility to operate with hydrated lime, in which case the capacity is 7 days of storage on-site, due to the lower density of hydrated lime.

Table 5-2 summarizes the preliminary design for required chemical feed capacities and storage for the WWTS.

Table 5-2 WWTS Design Information for Chemical Handling Equipment

Chemical	Parameter	P90 Average Build-out 1 (Mine Year 1)	P90 Average Build-out 2 (Mine Year 5 for mine water trains, Mine Year 7 for seepage train)	P90 Average Build-out 3 (Mine Year 10)
Sodium Permanganate	Capacity at P90 Annual Average Flow Rate	73 lbs/day	263 lbs/day	253 lbs/day
	On-site supply @ 30 days storage, P90 Annual Average rate	2,200 lbs	7,900 lbs	7,600 lbs
Carbon Dioxide(1)	Carbon Dioxide – Capacity at P90 Annual Average Flow Rate	15 tons/day	18 tons/day	31 tons/day
	On-site supply @ 30 days storage P90 Annual Average rate	450 tons	540 tons	930 tons
Sodium Bisulfite	Capacity at P90 Annual Average Flow Rate	44 lbs/day	65 lbs/day	97 lbs/day
	On-site supply @ 30 days storage P90 Annual Average rate	1,300 lbs	1,950 lbs	2,900 lbs
Calcite	Capacity at P90 Annual Average Flow Rate	900 lbs/day	2,000 lbs/day	2,000 lbs/day
	On-site supply @ 30 days storage P90 Annual Average rate	14 tons	30 tons	30 tons
Hydrated Lime(1)	Capacity at P90 Annual Average Flow Rate	11 tons/day	27 tons/day	41 tons/day
	Required Storage (7 days)	80 tons	190 tons	290 tons

Chemical	Parameter	P90 Average Build-out 1 (Mine Year 1)	P90 Average Build-out 2 (Mine Year 5 for mine water trains, Mine Year 7 for seepage train)	P90 Average Build-out 3 (Mine Year 10)
Hydrochloric Acid (Standby)(2)	Max Allowable Use at P90 Annual Average Flow Rate	less than 1,600 lbs/day	less than 3,200 lbs/day	less than 5,000 lbs/day
	On-site supply @ 30 days storage P90 Annual Average rate	less than 24 tons	less than 48 tons	less than 75 tons
Ferric Sulfate (Standby) (3)	Capacity at P90 Annual Average Flow Rate	less than 2,900 lbs/day	less than 4,500 lbs/day	less than 6,400 lbs/day
	Storage @ 7 Days Supply	less than 10 tons	less than 16 tons	less than 23 tons
Scavenger (Standby) (4)	Capacity at P90 Annual Average Flow Rate	less than 6 lbs/day	less than 9 lbs/day	less than 14 lbs/day
	Storage @ 7 Days Supply	less than 45 lbs	less than 65 lbs	less than 100 lbs
Polymer Flocculant Aid (Standby) (5)	Capacity at P90 Annual Average Flow Rate	less than 6 lbs/day	less than 10 lbs/day	less than 14 lbs/day
	Storage @ 7 Days Supply	Less than 45 lbs	Less than 70 lbs	less than 100 lbs

Source: GoldPHREEQC Mine Water Treatment Train Model Simulations and GoldPHREEQC Tailings Basin Seepage Treatment Train Model Simulations, July 2015

(1) It is anticipated that additional lime and carbon dioxide feed capacity will be required by Mine Year 5.
(2) Hydrochloric acid maximum use determined based on maximum dose before exceeding treated mine water chloride treatment target.
(3) Ferric sulfate maximum dose determined based on dose required to achieve 1% iron in HDS clarifier, higher ferric sulfate doses may be required in scenarios with lower influent concentrations.
(4) Scavenger maximum dose based on vendor-recommended dose of 2 ppm in HDS.
(5) Polymer maximum dose based on vendor-recommended dose of 2 ppm in HDS.

5.1.4 WWTS Controls

Local system controls will be provided with each treatment process. A main WWTS control panel that integrates local controls will be located within the WWTS building. The WWTS control panel will also communicate with the overall Project control system. The Project control philosophy and the preliminary layout of the Project control systems will be completed during final design prior to construction.

6.0 WWTS Relocations

In early 2017, PolyMet proposed modifications to the WWTS for the purpose of combining the Mine Site Waste Water Treatment Facility (WWTF) and the Plant Site Waste Water Treatment Plant (WWTP) into one building at the Plant Site, shown on Large Figure 1. These changes have already been incorporated into this updated version of the Design and Operations Report and are described in detail in a technical memo titled *Proposed Waste Water Treatment System (WWTS) Relocations* (Attachment M). The larger building will house treatment equipment for both the tailings basin seepage train (formerly the Plant Site WWTP) and the mine water treatment trains (formerly the Mine Site WWTF), but each system will operate separately, as before.

This change also involved relocating the Mine Site equalization basins and Construction Mine Water Basin to a new location south of Dunka Road as shown on Large Figure 1. The West and East Equalization Basins were renamed to reflect the quality of mine water stored in each basin, as the High Concentration Equalization (HCEQ) and Low Concentration (LCEQ) Equalization Basin. Mine water will be transported to the Plant Site for treatment in the WWTS in three separate Mine to Plant Pipelines, which replace the former Treated Water Pipeline. In addition, the previous Splitter Building, which routed mine water to the equalization basins and Central Pumping Station, which routed treated mine water through the Treated Water Pipeline, were combined into one Central Pumping Station (CPS), which routes mine water to and from the equalization basins, and includes pumps to convey mine water from the HCEQ Basin and LCEQ Basins to the Plant Site for treatment at the WWTS. The former Central Pumping Station Pond does not exist in the current plan.

Items that remain the same through these relocations include:

- the anticipated flows and water quality of treated discharge to the environment
- the anticipated flows and water quality of flows routed to the FTB Pond
- size and capacity of equalization basins
- required treatment equipment units and capacity
- FTB Pond management and anticipated water quality and levels

Revision History

Date	Version	Description
July 2016	1	Initial release
October 2017	2	Changes to incorporate the WWTS relocations

References

1. **Minnesota Department of Natural Resources, U.S. Army Corps of Engineers and U.S. Forest Service.** Final Environmental Impact Statement: NorthMet Mining Project and Land Exchange. November 2015.

2. **Poly Met Mining Inc.** NorthMet Project Water Modeling Data Package Volume 2 - Plant Site (v11). March 2015.

3. —. NorthMet Project Water Modeling Data Package Volume 1 - Mine Site (v14). February 2015.

4. **Poly Met Mining, Inc.** NorthMet Project Water Management Plan - Plant (v6). August 2017.

5. **Minnesota Pollution Control Agency.** Settling Review Checklist-Water/Wastewater/#5.73. May 2001.

Large Tables

Large Table 1 RO Mass-based Rejections used in Tailings Basin Seepage Treatment Train Process Model

Parameter	Manufacturer-Projected Rejections (GE)(1)						Pilot-Test Rejection, Average (2)	Estimated Rejections for Modeling Tailings Basin Seepage Treatment Train RO(4)					
	Mine Year 1	Mine Year 7	Mine Year 8	Mine Year 10	Mine Year 15	Mine Year 20		Mine Year 1	Mine Year 7	Mine Year 8	Mine Year 10	Mine Year 15	Mine Year 20
Ag	98.93%	99.61%	98.19%	98.39%	98.68%	98.52%		98.9%	99.6%	98.2%	98.4%	98.7%	98.5%
Al	99.19%	99.12%	99.07%	98.44%	99.12%	98.86%		99.2%	99.1%	99.1%	98.4%	99.1%	98.9%
Alk	98.72%	97.77%	97.60%	97.87%	92.75%	90.85%	97.7%	98.7%	97.8%	97.6%	97.9%	92.8%	90.9%
As	97.50%	99.24%	98.25%	98.67%	98.50%	98.50%	85.7%	97.5%	99.2%	98.2%	98.7%	98.5%	98.5%
B	61.41%	61.45%	50.07%	54.49%	56.90%	54.90%		61.4%	61.4%	50.1%	54.5%	56.9%	54.9%
Ba	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	99.8%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Be	99.34%	99.63%	99.04%	98.45%	99.17%	98.90%		99.3%	99.6%	99.0%	98.5%	99.2%	98.9%
Ca	99.19%	99.64%	99.07%	98.44%	99.13%	98.85%	99.4%	99.2%	99.6%	99.1%	98.4%	99.1%	98.9%
Cd	99.10%	99.85%	99.05%	98.43%	99.13%	98.86%		99.1%	99.9%	99.1%	98.4%	99.1%	98.9%
Cl	99.04%	98.35%	98.10%	98.43%	98.66%	98.43%	99.1%	99.0%	98.3%	98.1%	98.4%	98.7%	98.4%
Co	99.15%	99.88%	99.10%	98.46%	99.13%	98.85%	99.9%	99.2%	99.9%	99.1%	98.5%	99.1%	98.9%
Cr	99.20%	99.88%	99.08%	98.43%	99.10%	98.82%		99.2%	99.9%	99.1%	98.4%	99.1%	98.8%
Cu(3)	not given	not given	not given	not given	not given	not given	99.8%	99.0%	99.1%	98.6%	98.7%	98.8%	98.7%
F	98.95%	98.10%	98.01%	98.31%	100.00%	100.00%	98.2%	98.9%	98.1%	98.0%	98.3%	100.0%	100.0%
Fe	100.00%	100.00%	100.00%	100.00%	98.66%	97.84%		100.0%	100.0%	100.0%	100.0%	98.7%	97.8%
K	98.95%	99.38%	98.17%	98.40%	98.65%	98.42%	94.2%	99.0%	99.4%	98.2%	98.4%	98.7%	98.4%
Mg	99.35%	99.57%	99.06%	99.16%	99.30%	99.21%	99.6%	99.4%	99.6%	99.1%	99.2%	99.3%	99.2%
Mn	100.00%	100.00%	100.00%	100.00%	98.68%	98.55%		100.0%	100.0%	100.0%	100.0%	98.7%	98.5%
Na	98.98%	99.29%	98.27%	98.41%	98.66%	98.40%	97.6%	99.0%	99.1%	98.6%	98.7%	98.8%	98.7%
Ni	99.20%	99.95%	99.07%	98.44%	99.13%	98.85%	99.9%	99.2%	99.9%	99.1%	98.4%	99.1%	98.9%
Pb	99.06%	99.91%	99.08%	98.44%	99.13%	98.85%	99.9%	99.1%	99.9%	99.1%	98.4%	99.1%	98.9%
Sb	99.18%	99.89%	99.07%	98.44%	99.12%	98.86%		99.2%	99.9%	99.1%	98.4%	99.1%	98.9%
Se	99.49%	99.84%	99.06%	99.17%	99.29%	99.21%	97.0%	99.5%	99.8%	99.1%	99.2%	99.3%	99.2%
SiO_2	99.37%	99.37%	98.89%	99.04%	99.15%	99.07%	99.4%	99.4%	99.4%	98.9%	99.0%	99.2%	99.1%
SO_4	99.45%	99.06%	99.06%	99.18%	99.29%	99.22%	99.8%	99.5%	99.3%	99.3%	99.4%	99.4%	99.4%
Tl	99.20%	99.47%	98.93%	98.41%	99.18%	98.72%		99.2%	99.5%	98.9%	98.4%	99.2%	98.7%
V	99.19%	99.46%	99.07%	98.44%	99.25%	98.90%		99.2%	99.5%	99.1%	98.4%	99.3%	98.9%
Zn	99.08%	99.79%	99.08%	98.44%	99.13%	98.85%	99.7%	99.1%	99.8%	99.1%	98.4%	99.1%	98.9%

(1) Based on GE projections for AG8040F400 membranes (same expected performance as AG90 membranes according to GE). Rejections for copper were not provided by GE and are based solely on pilot-test results.

(2) Pilot-testing results from Attachment B testing of GE AG90 membranes. Parameters that were below detection limit in pilot RO effluent were not included, as rejection could not accurately be estimated.

(3) Copper rejections not supplied by manufacturer and not measured in SD003 pilot. Copper rejection in models was conservatively assumed to be equal to sodium rejection.

Large Table 2 NF Mass-based Rejections used in Tailings Basin Seepage Treatment Train Process Model

	Manufacturer-Projected Rejections (GE)(1)						Pilot-Test Rejection, Average(2)	Estimated Rejections for Modeling Tailings Basin Seepage Treatment Train NF(4)					
Parameter	Mine Year 1	Mine Year 7	Mine Year 8	Mine Year 10	Mine Year 15	Mine Year 20		Mine Year 1	Mine Year 7	Mine Year 8	Mine Year 10	Mine Year 15	Mine Year 20
Ag	59.03%	46.05%	54.03%	37.77%	30.59%	28.18%	--	66.24%	53.52%	60.23%	43.31%	35.23%	32.02%
Al	91.32%	93.50%	93.52%	89.69%	90.86%	90.10%	--	93.42%	95.07%	95.08%	92.19%	93.06%	92.51%
Alk	50.81%	44.06%	44.66%	35.29%	42.29%	41.46%	48.80%	48.80%	48.80%	48.80%	46.55%	48.80%	47.08%
As	97.34%	98.38%	98.13%	98.58%	98.40%	98.40%	99.40%	98.37%	98.89%	98.76%	98.99%	98.90%	98.90%
B	20.72%	20.80%	20.97%	18.44%	19.09%	17.54%	--	20.72%	20.80%	20.97%	18.44%	19.09%	17.54%
Ba	62.68%	100.00%	100.00%	68.19%	67.98%	59.23%	93.50%	81.59%	93.50%	93.50%	80.85%	80.74%	86.56%
Be	91.51%	93.54%	93.47%	89.69%	90.95%	90.16%	--	93.46%	95.11%	95.05%	92.22%	93.08%	92.51%
Ca	61.55%	93.65%	93.65%	71.42%	86.18%	82.25%	92.60%	80.70%	92.60%	92.60%	85.16%	91.00%	89.48%
Cd	91.06%	93.49%	93.52%	89.72%	90.91%	90.10%	--	93.29%	95.04%	95.07%	92.21%	93.09%	92.51%
Cl	86.03%	32.47%	32.67%	61.63%	58.16%	64.22%	9.40%	9.40%	9.40%	9.40%	9.40%	9.40%	9.40%
Co	90.97%	93.40%	93.54%	89.74%	90.87%	90.11%	99.90%	96.79%	97.48%	97.50%	96.07%	96.48%	96.21%
Cr	91.36%	93.53%	93.53%	89.69%	90.83%	90.08%	--	93.44%	95.09%	95.08%	92.18%	93.02%	92.51%
Cu(3)	not given	not given	not given	not given	not given	not given	93.80%	93.80%	93.80%	93.80%	93.80%	93.80%	93.80%
F	82.95%	32.21%	32.51%	29.18%	32.64%	41.44%	--	86.87%	37.08%	37.47%	32.78%	32.64%	41.44%
Fe	61.72%	90.45%	89.12%	71.90%	68.57%	69.21%	--	80.86%	95.22%	94.56%	71.90%	75.00%	75.37%
K	58.58%	53.87%	54.47%	46.75%	31.23%	28.53%	59.00%	59.00%	59.00%	59.00%	56.60%	47.50%	45.70%
Mg	91.33%	93.52%	93.53%	89.70%	90.88%	90.09%	94.80%	94.11%	94.80%	94.80%	93.50%	93.94%	93.65%
Mn	79.59%	94.07%	94.14%	67.86%	69.06%	68.97%	97.80%	88.69%	95.94%	95.97%	86.04%	86.48%	86.75%
Na	58.65%	57.61%	54.14%	37.72%	30.73%	28.46%	57.60%	57.60%	57.60%	57.60%	50.50%	46.46%	44.90%
Ni	91.32%	93.52%	93.53%	89.69%	90.87%	90.11%	99.80%	96.60%	97.44%	97.44%	95.99%	96.43%	96.16%
Pb	91.28%	93.49%	93.50%	89.69%	90.88%	90.11%	99.40%	96.35%	97.23%	97.24%	95.79%	96.24%	95.96%
Sb	91.39%	93.52%	93.53%	89.70%	90.88%	90.13%	--	93.44%	95.08%	95.09%	92.19%	93.08%	92.53%
Se	93.01%	93.57%	93.57%	89.85%	91.02%	90.21%	99.20%	96.92%	97.17%	97.17%	95.75%	96.21%	95.91%
SiO2	20.12%	20.07%	20.07%	20.04%	20.04%	20.04%	24.10%	22.12%	22.11%	22.11%	22.09%	22.09%	22.09%
SO4	92.96%	93.57%	93.58%	89.88%	91.02%	90.21%	99.00%	96.83%	97.07%	97.07%	95.66%	96.11%	95.81%
Tl	91.47%	93.59%	93.56%	89.85%	90.87%	89.98%	--	93.46%	95.10%	95.07%	92.26%	93.04%	92.48%
V	91.34%	93.52%	93.52%	89.70%	90.84%	90.25%	--	93.43%	95.08%	95.08%	92.20%	93.03%	92.59%
Zn	91.21%	93.56%	93.52%	89.66%	90.89%	90.09%	98.40%	95.86%	96.75%	96.74%	95.29%	95.74%	95.45%

(1) Based on GE projections for Muni-NF-400 membranes (same expected performance as HL4040FM membranes according to GE).

(2) Pilot-testing results from Attachment E testing of GE HL4040FM membranes.

(3) Copper rejections not supplied by manufacturer and not measured in SD003 pilot. Copper rejection in models was assumed to be equal to copper rejections observed in pilot.

Large Table 3 Mine Water Influent from Low Concentration EQ Basin- Water Quality Used in Mine Water Treatment Trains Process Model (P90 Flows and Loads)

Parameter	Units	Mine Year 1	Mine Year 2	Mine Year 3	Mine Year 4	Mine Year 5	Mine Year 6	Mine Year 7	Mine Year 8	Mine Year 9	Mine Year 10
Annual average flow	gpm	483	671	784	916	1090	1324	1362	1327	1511	1755
Peak Flow	gpm	678	863	1047	1232	1416	1645	1874	2103	2332	2561
Summer flow	gpm	678	982	1134	1230	1438	1684	1760	1734	1982	2233
Winter flow	gpm	102	351	396	425	506	768	809	778	821	1096
pH	std units	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Silver	µg/L	0.12	0.18	0.19	0.19	0.19	0.19	0.19	0.19	0.19	0.19
Aluminum	µg/L	1.43	1.67	1.67	1.70	1.67	1.69	1.70	1.70	1.69	1.67
Alkalinity(1)	mg/Las HCO_3	666.00	947.40	981.60	1,118.40	1,387.80	1,062.00	1,040.40	892.80	753.00	738.00
Arsenic	µg/L	56.93	77.85	79.78	80.13	77.92	68.55	69.10	69.38	62.74	54.96
Boron	µg/L	78.10	90.67	91.53	91.00	88.79	86.23	85.18	85.30	80.89	76.75
Barium	µg/L	33.57	27.14	26.35	26.27	26.90	28.38	27.61	27.24	28.26	29.56
Beryllium	µg/L	0.34	0.40	0.40	0.40	0.40	0.39	0.39	0.39	0.39	0.39
Inorganic Carbon(1)	mg/L as HCO_3-	694.20	986.40	1,146.00	1,304.40	1,621.20	1,241.40	1,215.60	1,045.20	881.40	865.80
Calcium	mg/L	201.17	268.04	287.97	307.00	299.99	272.17	281.24	275.73	248.30	223.24
Cadmium	µg/L	7.25	8.86	8.23	7.89	4.74	5.93	6.04	5.66	5.49	4.94
Chloride	mg/L	144.50	76.61	76.86	57.90	55.99	49.52	31.52	40.01	33.66	24.79
Cobalt	µg/L	343.93	331.84	342.48	319.54	271.17	230.97	231.28	227.08	212.28	185.75
Chromium	µg/L	5.42	5.03	4.97	5.15	4.98	4.54	4.62	4.53	4.12	3.68
Copper	µg/L	2,415.65	2,740.53	2,412.83	2,344.48	**1,410.00**	1,906.78	1,808.83	1,783.98	1,722.73	1,528.78
Fluoride	mg/L	**1.44**	1.23	1.18	1.24	1.05	0.95	0.99	0.85	0.77	0.70
Iron	µg/L	157.06	184.52	186.36	185.87	184.25	187.18	185.49	185.13	186.07	189.57
Potassium	mg/L	25.25	25.13	27.16	26.70	25.03	22.88	23.67	23.21	21.25	18.89
Magnesium	mg/L	72.34	96.06	107.73	129.63	127.79	121.64	122.55	120.38	106.64	95.80
Manganese	µg/L	483.78	491.44	496.67	463.71	430.25	401.70	395.78	392.64	372.16	350.95
Sodium	mg/L	85.06	93.65	94.37	105.20	105.79	101.28	99.56	99.10	91.94	83.44
Nickel	µg/L	3,755.30	3,691.19	4,059.77	4,044.73	3,595.77	3,215.86	3,388.31	3,324.34	3,058.27	2,618.19
Lead	µg/L	2.16	3.96	4.80	6.18	7.04	5.41	6.39	6.14	6.43	7.14
Antimony	µg/L	38.44	38.34	39.87	40.29	38.15	34.50	35.44	35.10	31.23	26.88
Silicon(2)	mg/L	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00
Selenium	µg/L	5.94	8.47	12.85	9.78	11.04	8.35	9.06	8.83	9.71	7.22
Sulfate	mg/L	309.58	473.04	546.33	627.36	**409.00**	549.62	612.32	612.48	655.34	553.17
Thallium	µg/L	0.13	0.19	0.18	0.18	0.19	0.19	0.18	0.18	0.18	0.18
Vanadium	µg/L	8.43	10.00	9.94	9.91	9.93	9.95	9.92	9.90	9.84	9.81
Zinc	µg/L	632.97	876.11	787.79	727.85	**460.00**	659.12	613.11	596.87	559.91	518.93

Source: GoldSIM Mine Site Modeling Simulations, December 2014

(1) pH set to 7.5, then influent was charge-balanced using alkalinity and inorganic carbon on PHREEQC.

(2) Silicon set to 54 mg/L in absence of modeling data.

(3) Bolded values indicate P90 concentrations were based on mass loading estimates based concentration estimates from the FEIS GoldSIM model instead of Mine Year 1 or Mine Year 5 concentration estimates from the FEIS GoldSIM model. Mass loadings calculations are described in Attachment C.

Large Table 4 Mine Water Influent from High Concentration EQ Basin- Water Quality used in Mine Water Treatment Train Process Models (P90 Flows and Loads)

Parameter	Units	Mine Year 1	Mine Year 2	Mine Year 3	Mine Year 4	Mine Year 5	Mine Year 6	Mine Year 7	Mine Year 8	Mine Year 9	Mine Year 10
Annual average flow	gpm	101	100	135	167	168	189	221	210	211	222
Peak Flow	gpm	157	0	0	0	235	0	0	0	0	368
Summer flow	gpm	157	153	210	256	257	292	339	322	323	368
Winter flow	gpm	34	39	40	64	66	65	82	82	79	83
pH	std units	5.1	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Silver	µg/L	14.95	29.07	31.20	32.04	33.87	31.94	29.37	34.18	39.10	42.98
Aluminum	mg/L	133.84	193.63	202.63	211.39	213.26	197.14	191.16	250.98	317.76	372.77
Alkalinity(1)	mg/L as HCO3-	22.80	11.20	10.57	11.13	15.68	9.47	9.40	12.08	15.08	17.51
Arsenic	µg/L	303.97	388.89	397.24	409.16	409.32	382.52	343.96	341.68	339.13	337.07
Boron	µg/L	371.71	665.87	707.96	721.90	739.17	699.91	629.73	647.60	671.16	680.86
Barium	µg/L	137.75	194.35	194.39	205.26	209.32	193.84	170.06	168.55	166.18	165.42
Beryllium	µg/L	22.76	34.39	35.90	37.57	37.59	34.44	30.67	32.99	34.75	35.95
Inorganic Carbon(1	mg/L as HCO3-	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01
Calcium(1)	mg/L	380.11	1,368.73	1,582.36	1,436.87	380.24	1,662.52	1,531.06	1,603.20	1,599.59	1,557.91
Cadmium	µg/L	56.32	78.33	83.24	86.49	87.59	82.18	76.23	89.07	105.51	119.83
Chloride	mg/L	208.22	156.22	127.24	78.62	50.44	70.62	37.80	53.21	53.07	46.55
Cobalt	µg/L	3,252.45	6,384.56	6,829.94	7,067.26	7,342.38	6,894.55	6,997.14	9,429.70	11,792.92	14,483.50
Chromium	µg/L	9.50	18.32	20.84	20.42	23.07	23.45	22.81	25.07	26.37	26.69
Copper	mg/L	8.58	10.47	10.49	10.92	10.99	11.25	19.51	36.68	50.04	61.22
Fluoride	mg/L	2.19	2.22	2.03	2.11	2.02	1.95	2.01	1.87	1.76	1.79
Iron	mg/L	190.28	443.28	488.40	504.68	539.42	534.14	461.76	493.37	511.70	526.03
Potassium	mg/L	31.71	46.33	46.89	46.64	46.81	47.70	48.02	45.76	43.30	41.83
Magnesium	mg/L	182.44	475.57	562.70	585.56	**362.00**	652.04	641.33	759.06	851.70	915.39
Manganese	mg/L	5.12	15.74	18.40	17.97	**10.40**	23.09	24.09	31.49	37.06	41.91
Sodium	mg/L	72.28	201.94	232.18	231.49	234.10	243.22	249.14	236.80	228.41	221.37
Nickel	mg/L	12.08	29.41	32.42	31.15	34.44	34.62	50.50	105.08	166.19	223.41
Lead	µg/L	106.82	134.49	139.23	145.90	146.03	134.34	129.83	176.13	220.87	260.00
Antimony	µg/L	225.99	575.53	672.24	662.54	**422.00**	776.16	799.23	1,058.15	1,260.98	1,456.03
Silicon(2)	mg/L	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00	54.00
Selenium	µg/L	36.89	111.84	123.81	120.36	135.00	135.96	131.75	137.74	142.27	144.00
Sulfate	mg/L	2,614.11	7,292.81	8,380.38	8,262.91	**4,980.00**	9,084.46	8,671.93	9,760.02	10,616.58	11,210.08
Thallium	µg/L	0.54	1.28	1.58	1.52	1.82	1.90	2.38	4.11	5.98	7.54
Vanadium	µg/L	45.13	56.24	57.69	59.77	59.81	55.53	50.13	55.04	59.67	63.16
Zinc	mg/L	6.48	8.71	8.98	9.37	9.41	8.70	8.11	9.59	12.34	13.94

Source: GoldSIM Mine Site Modeling Simulations, December 2014

(1) Inorganic carbon set to 1 mg/L and pH set to 5, then influent was charge-balanced using alkalinity and calcium on PHREEQC.

(2) Silicon set to 54 mg/L in absence of modeling data.

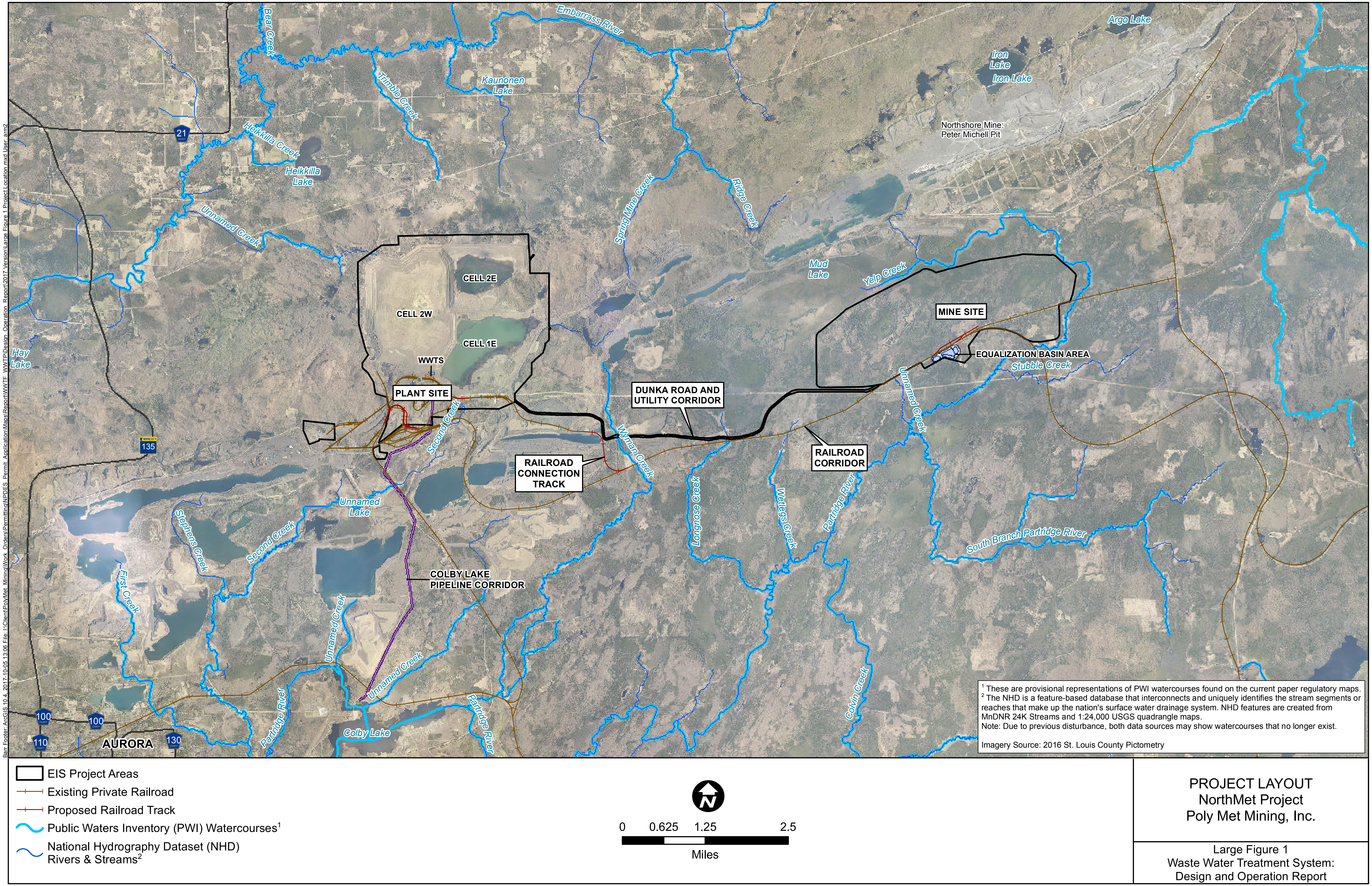
(3) Bolded values indicate P90 concentrations were based on mass loading estimates based concentration estimates from the FEIS GoldSIM model instead of Mine Year 1 or Mine Year 5 concentration estimates from the FEIS GoldSIM model. Mass loadings calculations are described in Attachment C.

Large Table 5 Mine Water Treatment Trains - Chemical Use and Fate

Chemical	Use	Treatment Process	Mine Year 1 P90 Average Usage Rate(1)	Mine Year 5 P90 Average Usage Rate(1)	Mine Year 10 P90 Average Usage Rate(1)	Dose Source	Reports to	Fate
Sodium Permanganate	Filter Pretreatment	Greensand Filter	15 lbs/day	33 lbs/day	53 lbs/day	WWTF Pilot-Test 1,	Flotation Tailings Basin	Permanganate Reduced to Mn(IV)
Carbon Dioxide	pH Adjustment	Re-carbonation	5 tons/day	8 tons/day	11 tons/day	Model	N/A	Neutralized
Hydrated Lime	pH Adjustment	HDS Metals Removal	5 tons/day	15 tons/day	26 tons/day	Model	Calcium to HDS Sludge	Carbonate Neutralized
	pH Adjustment	Sulfate Removal	6 tons/day	12 tons/day	15 tons/day	Model	Calcium to Sulfate Sludge	Carbonate Neutralized
GE Hypersperse MDC150	Membrane Antiscalant	Primary Membranes	12 lbs/day	28 lbs/day	45 lbs/day	WWTP Pilot, Vendor (GE)	Chemical Precipitation Sludge	No Reaction
NLR 759	Phosphonic Acid Antiscalant	Secondary Membranes	4 gal/day	7 gal/day	11 gal/day	Vendor (NLR)	HDS Sludge	No Reaction
Sodium Bisulfite	Oxidant-Quenching Membrane Pretreatment	Primary Membranes	6 lbs/day	13 lbs/day	21 lbs/day	Vendor (GE)	Sulfate Sludge	Sulfite oxidized to sulfate
	Oxidant-Quenching Membrane Pretreatment	Secondary Membranes	3 lbs/day	6 lbs/day	9 lbs/day	Vendor (GE)	Sulfate Sludge	Sulfite oxidized to sulfate
Hydrochloric Acid (Standby)	pH Adjustment	Sulfate Removal	less than 1,600 lbs/day	less than 3,200 lbs/day	less than 5,000 lbs/day	Max before exceed Cl limit	N/A	Neutralized
	pH Adjustment	Secondary Membranes				Max before exceed Cl limit	N/A	Neutralized
Ferric Sulfate (Standby)	Iron Supplement	HDS Metals Removal	less than 2,900 lbs/day	less than 4,500 lbs/day	less than 6,400 lbs/day	0.1% Iron in HDS	HDS Sludge	Iron Precipitate
MetClear MR2405 (Standby)	Metals Polishing Scavenger	HDS Metals Removal	less than 6 lbs/day	less than 9 lbs/day	less than 14 lbs/day	Vendor	HDS Sludge	No Reaction
Anionic Polymer (Standby)	Flocculant Aid	HDS Metals Removal	less than 6 lbs/day	less than 10 lbs/day	less than 14 lbs/day	Vendor	HDS Sludge	No Reaction
MC1	Citric Acid Membrane Cleaner	Primary Membranes	1,600 lbs/year	3,500 lbs/year	5,600 lbs/year	Vendor (GE)	Flotation Tailings Basin	Neutralization, adsorption, and degradation in tailings basin solids
MC4	Alkaline Surfactant Membrane Cleaner	Primary Membranes	1,600 lbs/year	3,500 lbs/year	5,600 lbs/year	Vendor (GE)	Flotation Tailings Basin	Neutralization, adsorption, and degradation in tailings basin solids
NLR 404	Organic Acid Membrane Cleaner	Secondary Membranes	9,000 gal/yr	18,000 gal/yr	27,000 gal/yr	Vendor (NLR)	Flotation Tailings Basin	Neutralization, adsorption, and degradation in tailings basin solids
NLR 505	Alkaline Surfactant Membrane Cleaner	Secondary Membranes	9,000 gal/yr	18,000 gal/yr	27,000 gal/yr	Vendor (NLR)	Flotation Tailings Basin	Neutralization, adsorption, and degradation in tailings basin solids

(1) Exact chemicals and usage rates may be adjusted during final design or plant startup. Listed chemicals represent examples for the specific chemical use.

Large Figures



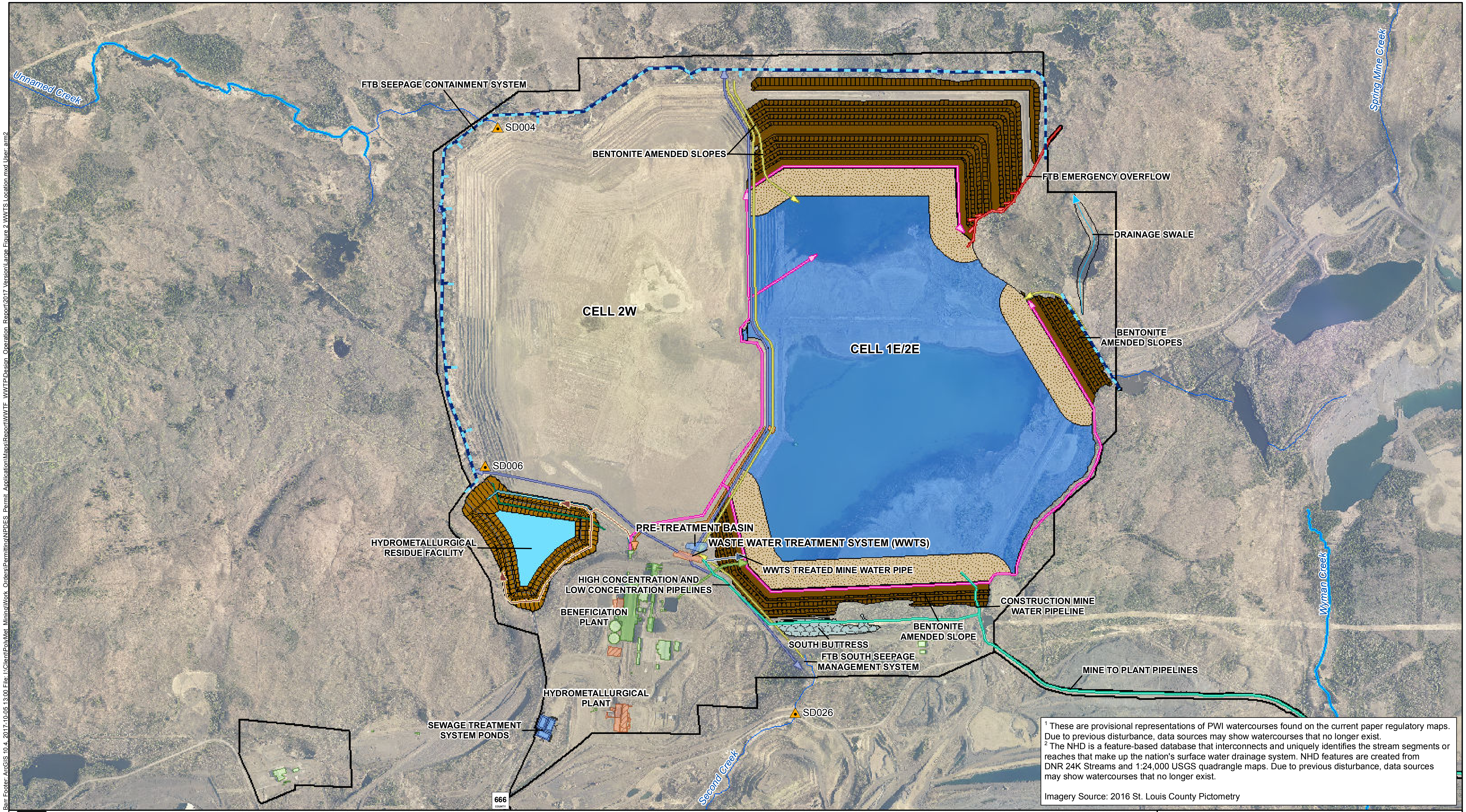
[1] These are provisional representations of PWI watercourses found on the current paper regulatory maps.
[2] The NHD is a feature-based database that interconnects and uniquely identifies the stream segments or reaches that make up the nation's surface water drainage system. NHD features are created from MnDNR 24K Streams and 1:24,000 USGS quadrangle maps.
Note: Due to previous disturbance, both data sources may show watercourses that no longer exist.

Imagery Source: 2016 St. Louis County Pictometry

PROJECT LAYOUT
NorthMet Project
Poly Met Mining, Inc.

Large Figure 1
Waste Water Treatment System:
Design and Operation Report

Barr Footer: ArcGIS 10.4, 2017-10-05 13:06 File: I:\Client\PolyMet_Mining\Work_Orders\Permitting\NPDES_Permit_Application\Maps\Reports\WWTF_WWTP\Design_Operation_Report\2017 Version\Large Figure 1 Project Location.mxd User: arm2



[1] These are provisional representations of PWI watercourses found on the current paper regulatory maps. Due to previous disturbance, data sources may show watercourses that no longer exist.

[2] The NHD is a feature-based database that interconnects and uniquely identifies the stream segments or reaches that make up the nation's surface water drainage system. NHD features are created from DNR 24K Streams and 1:24,000 USGS quadrangle maps. Due to previous disturbance, data sources may show watercourses that no longer exist.

Imagery Source: 2016 St. Louis County Pictometry

☐ EIS Project Areas

▲ Existing NPDES Discharge Stations

FTB Seepage Containment System

Mine to Plant Pipelines

FTB Water Return Pipe

FTB Tailings Discharge Pipe

Tailings Basin Seepage Water Pipe

Plant Reservoir Overflow

Treated Water Pipe

Treated Mine Water Pipe

FTB Seepage Collection Drain (under HRF)

Return Water Pipe

Residue Discharge Pipe

Mine Year 20 Footprints

- Dam
- Beach
- Pond
- South Buttress
- HRF Pond
- HRF Dam

Public Waters Inventory (PWI) Watercourses[1]

National Hydrography Dataset (NHD) Rivers & Streams[2]

Drainage Flow Direction (The drainage swale drains stormwater away from the toe of the dam.)

N

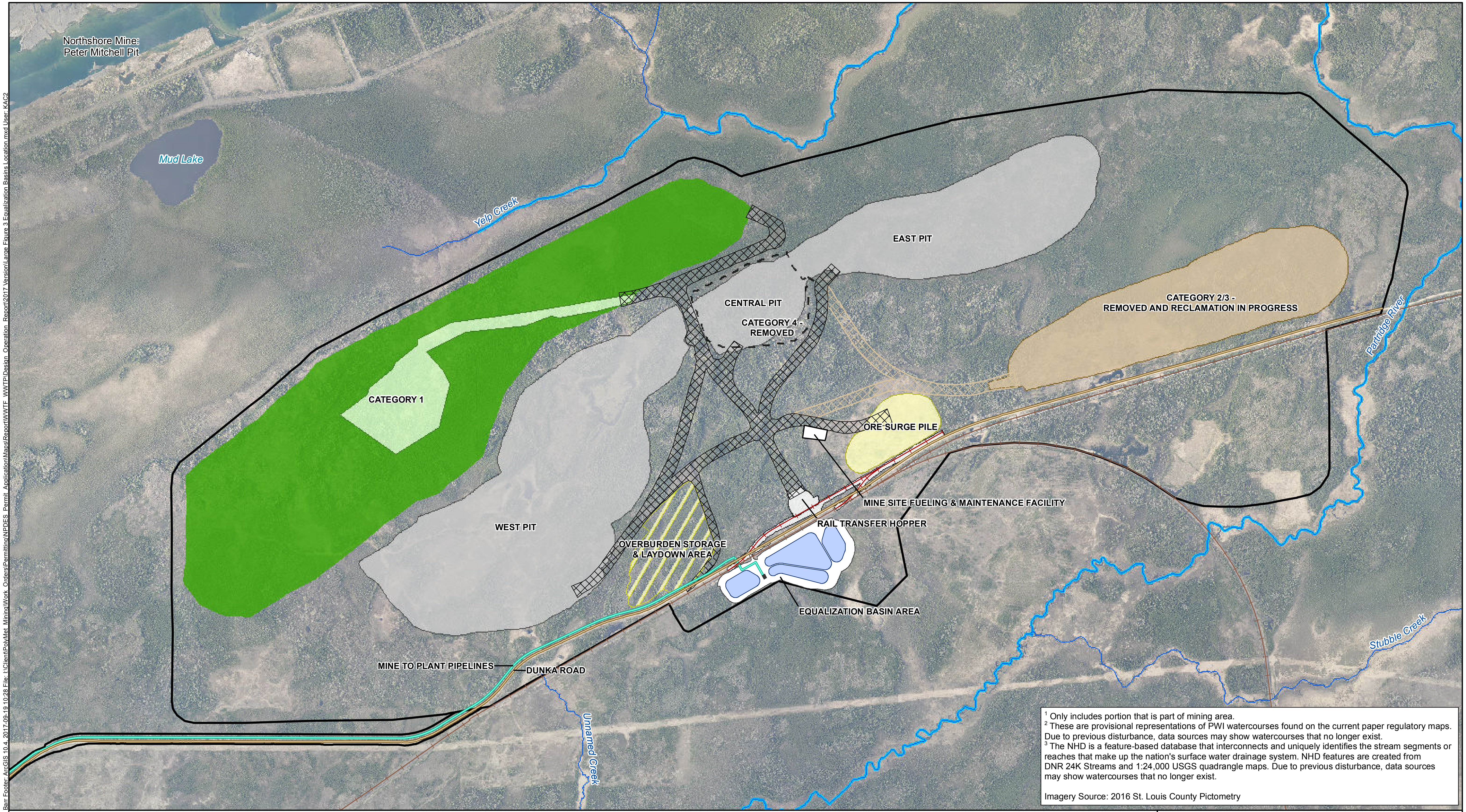
0 1,000 2,000 4,000

Feet

WWTS LOCATION
NorthMet Project
Poly Met Mining, Inc.

Large Figure 2
Waste Water Treatment System:
Design and Operation Report

Barr Footer: ArcGIS 10.4, 2017-10-05 13:00 File: I:\Client\PolyMet Mining\Work Orders\Permitting\NPDES Permit Application\Maps\Report\WWTF WWTP\Design Operation Report\2017 Version\Large Figure 2 WWTS Location.mxd User: arm2



[1] Only includes portion that is part of mining area.

[2] These are provisional representations of PWI watercourses found on the current paper regulatory maps. Due to previous disturbance, data sources may show watercourses that no longer exist.

[3] The NHD is a feature-based database that interconnects and uniquely identifies the stream segments or reaches that make up the nation's surface water drainage system. NHD features are created from DNR 24K Streams and 1:24,000 USGS quadrangle maps. Due to previous disturbance, data sources may show watercourses that no longer exist.

Imagery Source: 2016 St. Louis County Pictometry

- ▭ EIS Project Areas
- ─ Dunka Road[1]
- Mine Year 20 Footprints
- ⬜ Mine Pits
- 🟩 Open Stockpile
- 🟩 Covered Stockpile
- ⬚ Removed Stockpile
- 🟨 Active Stockpile
- ▨ Storage & Laydown Area
- 🟫 Removed and Reclaimed Stockpiles
- ┼ Existing Private Railroad
- ┼ Proposed Railroad Track
- ～ Public Waters Inventory (PWI) Watercourses[2]
- ～ National Hydrography Dataset (NHD) Rivers & Streams[3]

N

0 750 1,500 3,000

Feet

EQUALIZATION BASINS LOCATION

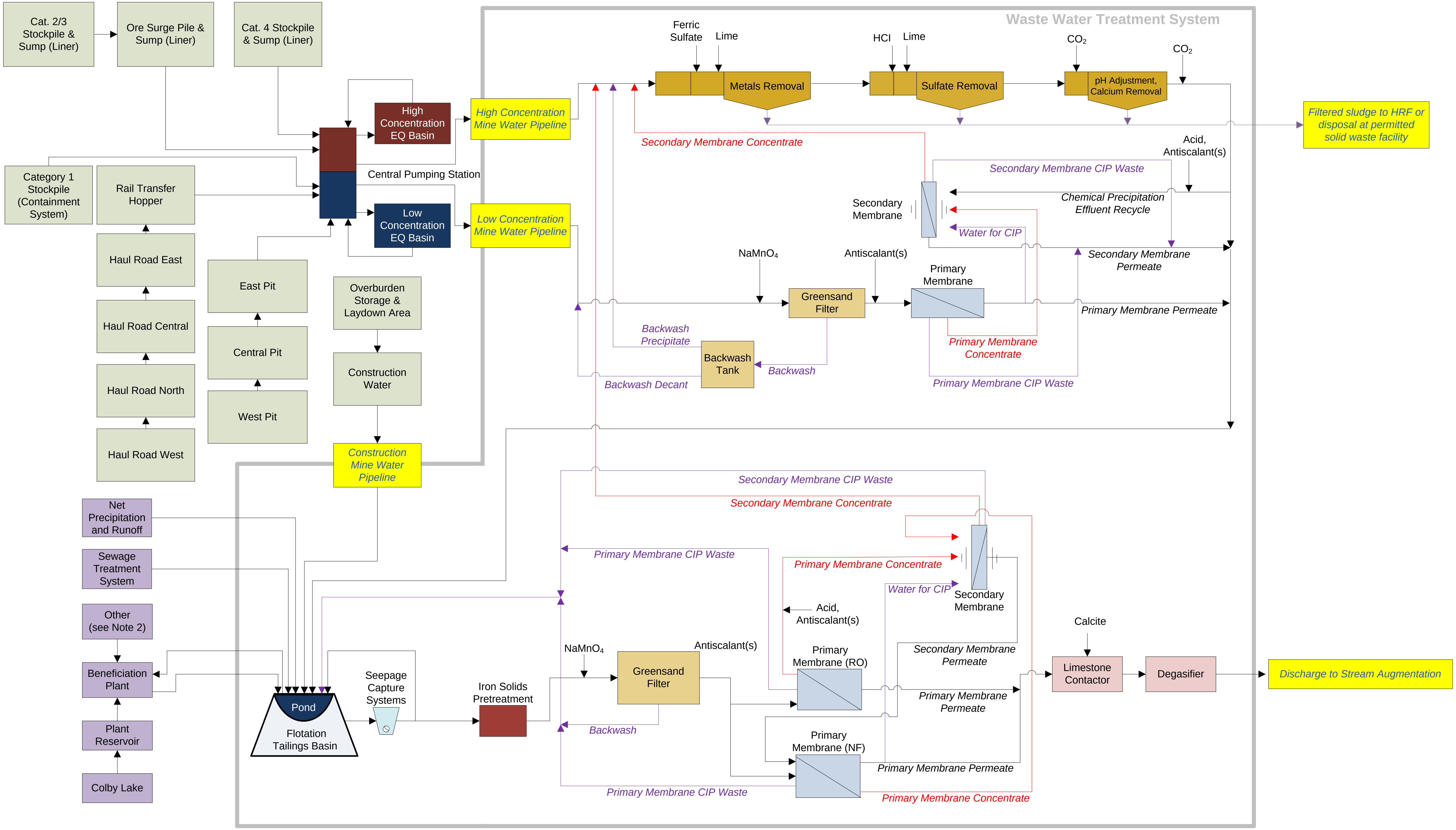
NorthMet Project

Poly Met Mining, Inc.

Large Figure 3

Waste Water Treatment System:

Design and Operation Report



Notes:

(1) This figure shows the Waste Water Treatment System configuration at the beginning of operations.

(2) Other inflows to the Beneficiation Plant include water in the raw ore, reagents, and gland seals of slurry pumps.

Large Figure 4
Water Treatment
Overall Flow Sheet – Operations
NorthMet Project
Poly Met Mining, Inc.
Hoyt Lakes, MN

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10/4/2017

Attachments

Attachment A

Waste Water Flow and Load Design Basis Report – Tailings Basin Seepage Treatment Train

Waste Water Flow and Load Design Basis Report

Waste Water Treatment System - Tailings Basin Seepage Inputs

NorthMet Project

Prepared for
Poly Met Mining, Inc.

October 2017

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Waste Water Flow and Load Design Basis Report
Waste Water Treatment System - Tailings Basin Seepage Inputs
NorthMet Project

October 2017

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Certifications

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota, specifically Waste Water Flow and Load Design Basis Report, Waste Water Treatment System - Tailings Basin Seepage Inputs, NorthMet Project.

10/12/2017

Don E. Richard, P.E.
PE #: 21193

Date

1.0 Introduction

This Waste Water Flow and Load Design Basis Report provides a summary of the procedures that have been used to evaluate the available information and establish the waste water flows and loads that will be used to complete the design of the tailings basin seepage treatment train at the Waste Water Treatment System (WWTS) for the 20-year operational life of the NorthMet Project (Project). This portion of the Project is referred to as the operations phase.

The flow and load information presented in this report has been obtained from the results of the GoldSim model simulations for the Plant Site water quality and quantity estimates in support of the Final Environmental Impact Statement (FEIS, Reference (1)) prepared for Poly Met Mining, Inc. This information is presented in the Water Modeling Data Package – Volume 2, Plant Site (Reference (2)). However, additional simulations have been completed to better optimize the potential for water storage during the operations phase, as described further in the following sections.

This report is organized into three sections, including this introduction. The following sections include:

- Section 2 contains a description of the tailings basin seepage water quantity inputs to the WWTS and the development of the flow design basis for the tailings basin seepage treatment train at the WWTS.
- Section 3 presents a statistical evaluation of the water quality obtained from GoldSim model simulation results as a basis for establishing the design loads for the tailings basin seepage treatment train at the WWTS.

2.0 Description of Tailings Basin Seepage Quantity Inputs and Flow Design Basis

The Flotation Tailings Basin (FTB) is the primary reservoir for the management of water at the Plant Site for the Project. Primary water inputs to the FTB include return water from the beneficiation process, treated mine water from the WWTS, construction mine water and Overburden Storage and Laydown Area (OSLA) water from the Mine Site, precipitation and runoff collected within the Tailings Basin, and make-up water from Colby Lake, if necessary. Water in the FTB is managed within a reservoir (pond) with some of the water being lost to the pore spaces of tailings material. Water within the saturated portion of the Tailings Basin eventually flows to the perimeter where it will be collected as seepage by the FTB seepage capture systems. A portion of the tailings basin seepage collected by the FTB seepage capture systems will be returned to the FTB Pond for re-use. However, to maintain safe water elevations within the FTB Pond and to maintain the hydrologic conditions in the streams surrounding the Tailings Basin, a portion of the tailings basin water will need to be treated and discharged. A more detailed description of the water balance for the Tailings Basin is provided in the Reference (2).

2.1 Water Quantity Projections

Table 2-1 summarizes the estimated quantity of tailings basin seepage that will need to be treated at the WWTS over the 20-year operational life of the Project. These estimates are based on the Plant Site GoldSim modeling completed for the FEIS (Reference (2). Actual flow rates are expected to fluctuate annually and seasonally. The storage component of the model allowed for additional water to be stored in the FTB Pond for the purposes of WWTS design. For the first seven years, tailings are not deposited in a portion of the FTB referred to as Cell 1E, thus, the water levels in this portion of the FTB was allowed to rise and fall, within acceptable elevations for dam stability. This resulted in a slight reduction in the overall tailings basin seepage flow to the WWTS and significantly reduced maximum flow rates. Using this volume to account for storage, the maximum treatment rate needed for the first seven years of operation was reduced to 2,000 gpm as shown in Figure 1. Because this flow rate is also close to the minimum value needed to maintain the hydrologic conditions in the receiving streams, the tailings basin seepage treatment train at the WWTS is expected to operate at a relatively constant flow rate for the first seven years of the Project.

Beginning in Mine Year 8, Cells 1E and 2E of the FTB will be merged into a single pond. Allowing the elevation of this expanded pond to fluctuate within a slightly higher upward tolerance than used in Reference (2), but still within acceptable ranges for dam stability and for the reduction of fugitive emissions from the beaches, the maximum required treatment rate for the remaining portion of operations (Mine Year 8 through 20) was set at 4,000 gpm (Figure 1).

Even with the reduced flow rates used in the model run that accounted for storage, the upper operating range for the tailings basin seepage routed to the WWTS is still conservative because the modeling does not account for potentially lowering of the FTB Pond below a target elevation and it does not account for additional storage volume created within the basin based on earthmoving operations related to dam construction during the first seven years of operation. Although accounting for these additional factors could reduce the maximum operating flow for design, the additional treatment capacity at the design rates of 2,000 and 4,000 gpm respectively provide the ability to manage short-term influxes associated with normal storm events.

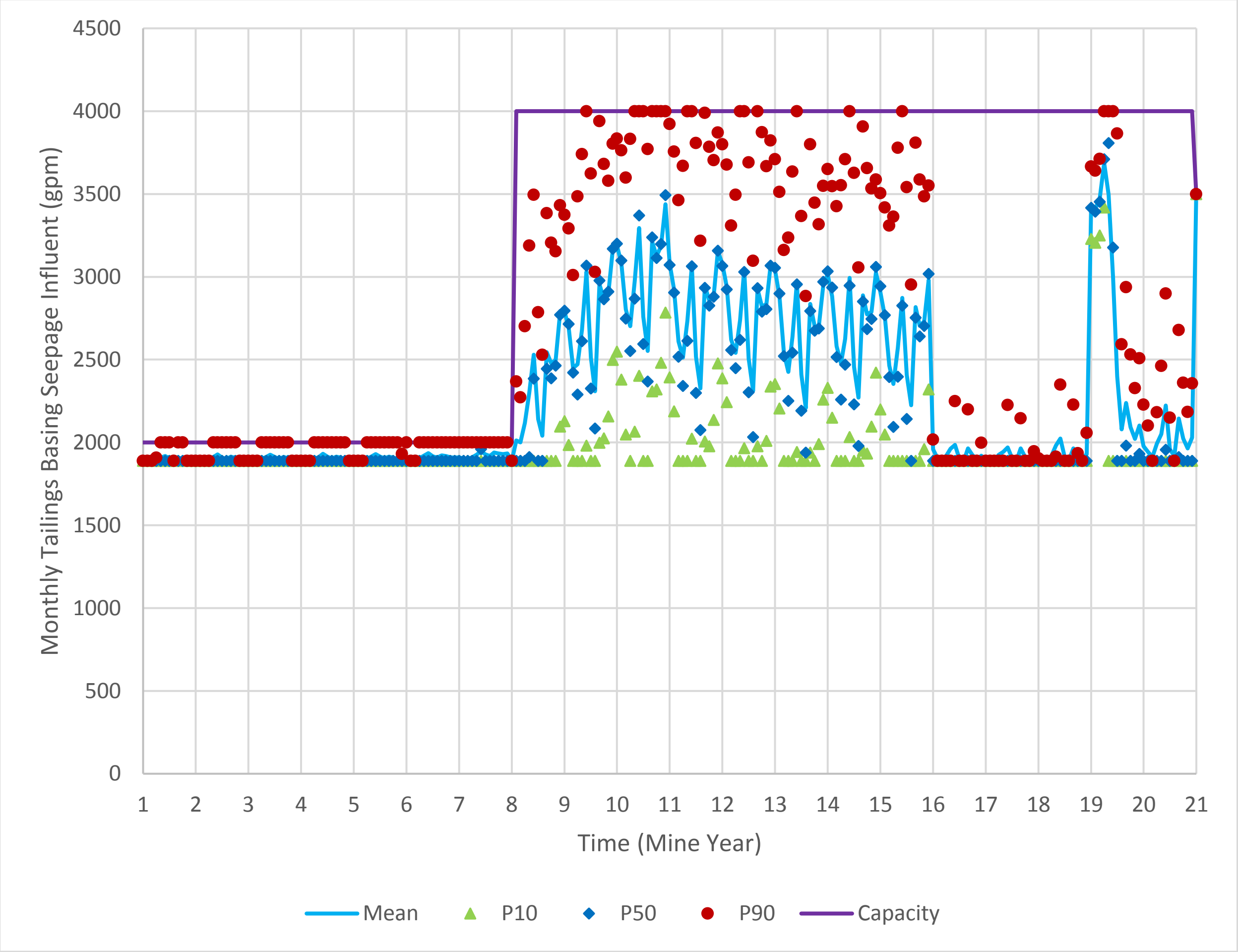
As shown in Table 2-1, the P90 annual average flow rate is similar to the mean monthly maximum flow through Mine Year 20. Figure 1 is a graph of the mean, 90th, and 10th percentile monthly flow rates over the operations phase. The information shown on Figure 1 indicates that the P90 monthly average tailings basin seepage flow to the WWTS peaks in Mine Year 10. The P90 monthly flow is relatively constant over the middle years of the Plant Site operation with an estimated value of 4,000 gpm from Mine Year 9 to Mine Year 15.

Table 2-1 Flows to the Tailings Basin Seepage Treatment Train at the WWTS

Mine Year	Tailings Basin Seepage to WWTS (gpm)			
	Annual Average		Monthly Maximum	
	Mean	P90	Mean	P90 (1)
1	1,900	1,937	1,918	2,000
5	1,906	1,967	1,929	2,000
10	3,026	3,900	3,437	4,000
14	2,731	3,605	3,025	4,000
15	2,649	3,525	2,980	4,000
20	2,011	2,282	2,223	2,900

Source: GoldSim Plant Site Model Simulations, January 2015 (Reference (2))

(1) Monthly maximum P90 influent to the tailings basin seepage treatment train at the WWTS is limited to the treatment train capacity. Excess tailings basin seepage is routed to the FTB Pond.



Source: GoldSIM Plant Site Model Simulations, January 2015

Figure 1 **Tailings Basin Seepage Influent Flow Statistics over the Operations Phase**

2.2 Tailings Basin Seepage Flow Design Basis

Based on the range of potential flows presented in Table 2-1 and Figure 1, the ultimate design capacity of the tailings basin seepage treatment train at the WWTS will be 4,000 gpm during operations. This capacity will be needed no later than Mine Year 8. The initial capacity required for the tailings basin seepage treatment train is 2,000 gpm. This value provides capacity to treat the average annual flow and the P90 monthly flows for the first seven years of operation.

3.0 Water Quality Design Basis

This section summarizes the statistical evaluation of GoldSim modeling results for the Plant Site to determine the design loads for the tailings basin seepage treatment train at the WWTS. Establishment of the basis for the tailings basin seepage water quality to the WWTS will allow the development of process models that can be used to determine treatment units, power requirements, chemical usage rates, and other design parameters.

3.1 Statistical Evaluation of GoldSim Water Quality Estimates

Within the GoldSim model, water collected from different locations along the FTB seepage capture systems that will be delivered to the WWTS was prioritized based on the estimated quality of the tailings basin seepage at each location. The locations that were modeled to have the highest concentrations of solutes were assumed to be routed to the WWTS first. Tailings basin seepage from those locations along the FTB seepage capture systems that were modeled to have lower concentrations of solutes were either returned to the FTB Pond, if possible, or added to the WWTS tailings basin seepage treatment train as needed to maintain a safe and effective water balance within the FTB.

3.1.1 Tailings Basin Seepage Influent Chemistry Data

Large Table 1 summarizes the estimated water quality of tailings basin seepage that will need to be treated at the WWTS over the 20-year operational life of the Project. These estimates are based on the Plant Site GoldSim modeling completed for the FEIS (Reference (2)).

The water quality estimates represented by the GoldSim realizations are not charge-balanced solutions, and did not include silicon, a constituent known to accompany calcium in the water and of importance to the design of the water treatment processes. Mine Year 1 silicon concentrations were estimated using feed water quality data from the Plant Site Wastewater Treatment Plant Pilot-Testing Report (Attachment B of the Waste Water Treatment System: Design and Operations Report), as water quality in Mine Year 1 is anticipated to be similar to current water quality in the seepage from the existing LTV Steel Mining Company tailings basin. As water quality in the tailings basin seepage is anticipated to change over time, future silicon concentrations were estimated using a molar ratio of 1.4:1 Si:Ca, in accordance with the stoichiometry of the weathering reaction that generates those constituents from rocks similar to those that will be mined for the Project, with the maximum concentration of silica capped at 34.8 mg/L. Then, a pH of 7.5 was assumed based on the projected neutral pH condition of the water, and the charge was balanced in PHREEQC using bicarbonate.

Next, the following factors were considered in the development of the water quality design basis:

- Some constituents may have concentrations that are positively correlated to flow rate. For these constituents, the upper distributions of flow and concentration are expected to be concurrent.

- Some constituents may have concentrations that are independent of flow rate (i.e., solubility-limited at the source). For these constituents and sources, the upper distributions of flow and concentration could be concurrent.
- Some constituents may have concentrations that are negatively correlated to flow rate. For such constituents and sources, assuming that the upper end of the concentration distribution is concurrent with the upper end of the flow distribution will be overly-conservative from a mass loading standpoint.

Thus, a key step in development of the water quality design basis was identifying those constituents and sources whose concentrations appear to be positively or negatively correlated with flow rate. A principal component analysis (PCA) was completed to identify these potential correlations, as described further below.

3.1.2 Principal Component Analysis Methods

Each of the 100 realizations generated by GoldSim for each month of the years modeled included a flow and corresponding concentrations for all parameters. The 1,200 realizations for Mine Years 1, 7, 8, 10, 14, and 20 were used for the PCA. PCA is a multivariate statistical method that allows rapid, graphical examination of the result sets for potential correlations between all parameters (Reference (3)). The PCA method also produces correlation coefficients for pairs of parameters.

In the PCA figures, the GoldSim output parameters are each depicted as individual vectors. Those vectors pointing in the same direction contribute to variability in a similar manner, and those constituents therefore correlate positively to one another. Vectors pointing in opposite directions (i.e., at 180 degrees) generally correlate negatively to one another, while vectors pointing orthogonally to one another (i.e., at 90 degrees) generally do not correlate to one another. Because these figures are two-dimensional representations of multi-dimensional relationships, both the direction of the vectors and the relative length of the vectors are important in interpreting a potential correlation. Longer vectors generally suggest that the constituent vector is more closely aligned to the plane through the PCA represented on the figure. Thus, longer vectors in the same direction (or opposite directions) suggest greater significance for the correlation inferred by the two vectors in the plane that is represented, while vectors appearing as very short lines are projecting in a direction that is not aligned with the plot and may suggest that the variability of the constituent is not well-described by the plot.

3.1.3 Principal Component Analysis Results and Discussion

The graphical results of the PCA for all parameters and for each of these years are shown on Figure 2 through Figure 7. A general interpretation of the graphical presentation of these results is included for each graph.

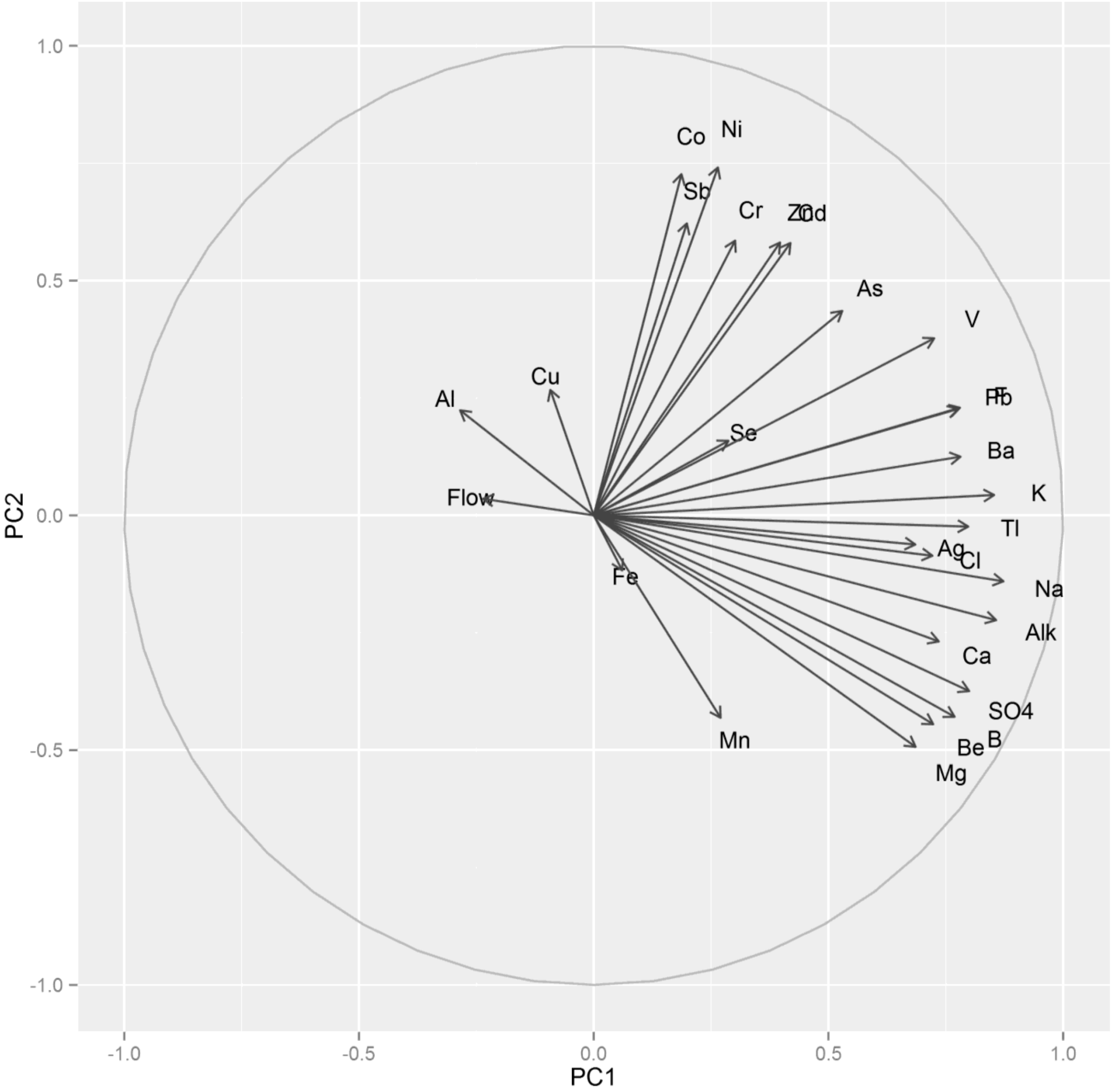


Figure 2 Principal Component Plot – Tailings Basin Seepage Influent to WWTS, Mine Year 1

The direction of the flow vector in Figure 2, which represents the tailings basin seepage data for Mine Year 1, is different than most other constituents. In addition, the length of the flow vector is shorter than the vector for the other constituents in this view of the PCA analysis. These two factors suggest that the variability of the flow data does not correlate with the variability of the other constituents in the tailings basin seepage in Mine Year 1.

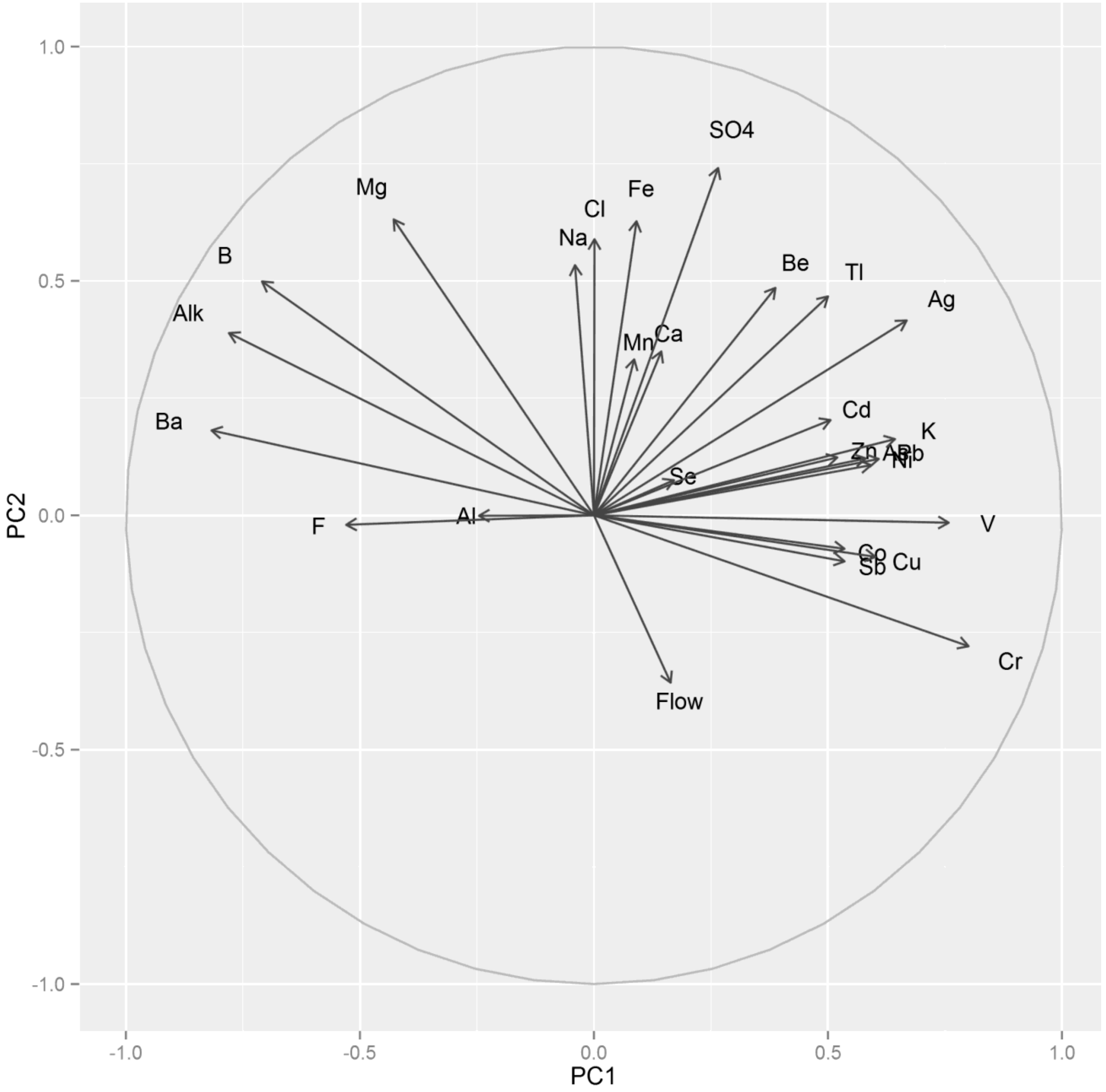


Figure 3 **Principal Component Plot – Tailings Basin Seepage Influent to WWTS, Mine Year 7**

As shown in Figure 3, Mine Year 7 shows similar behavior to Mine Year 1, in that the observed, direction of the flow vector, is again different than most other constituents. These observations again suggest that the variability of the flow data may not correlate with the variability of the other constituents in the tailings basin seepage in Mine Year 7.

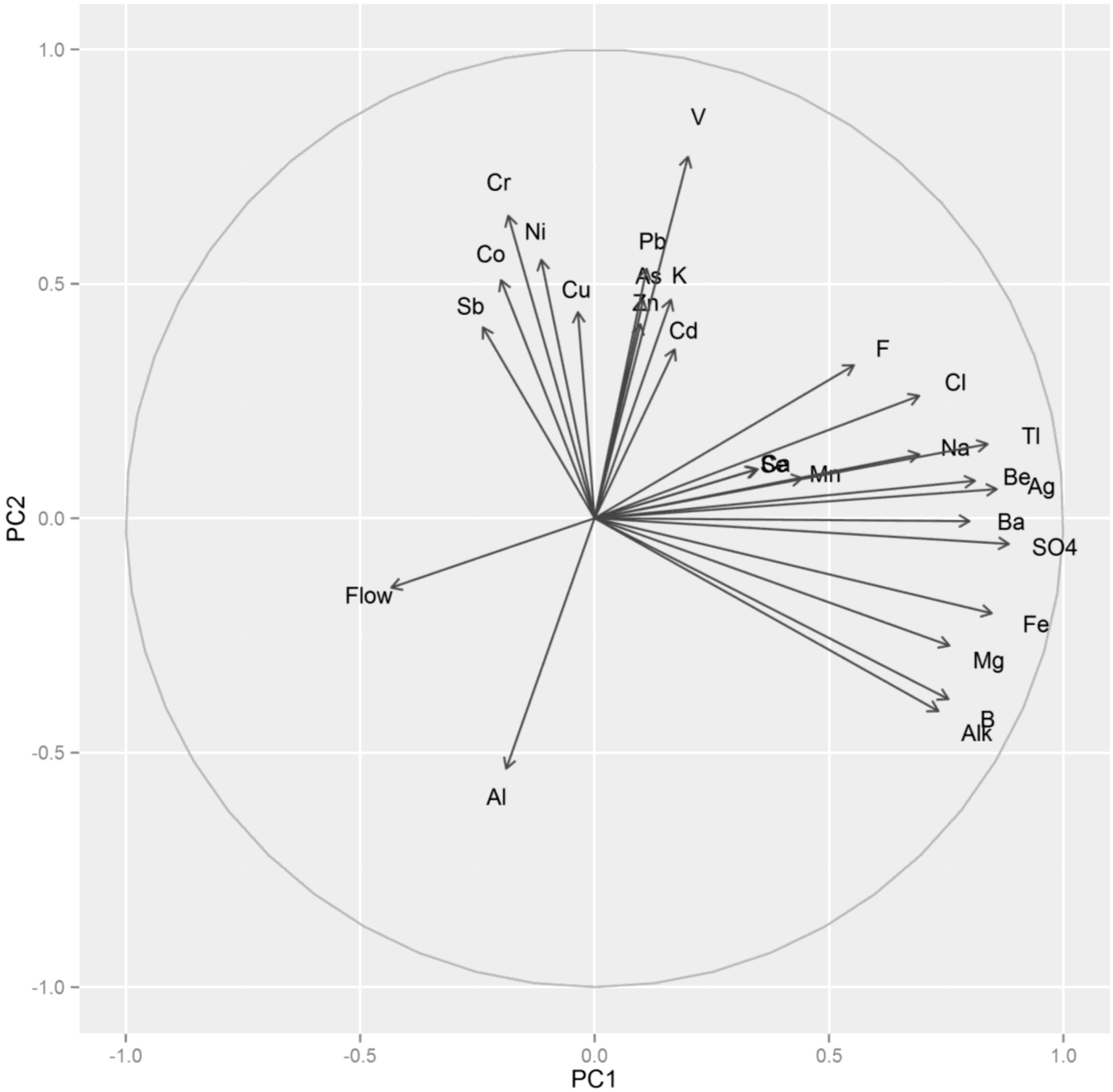


Figure 4 Principal Component Plot – Tailings Basin Seepage Influent to WWTS, Mine Year 8

Figure 4 provides a view of the tailings basin seepage data for Mine Year 8. In this figure, the flow vector is opposed to most of the other constituents and the relative length of the vector compared to the vectors for other constituents may suggest a negative correlation with some constituents including fluoride, chloride, thallium, sodium, beryllium, silver, barium, sulfate and potentially iron. No constituents appear to be positively correlated with flow.

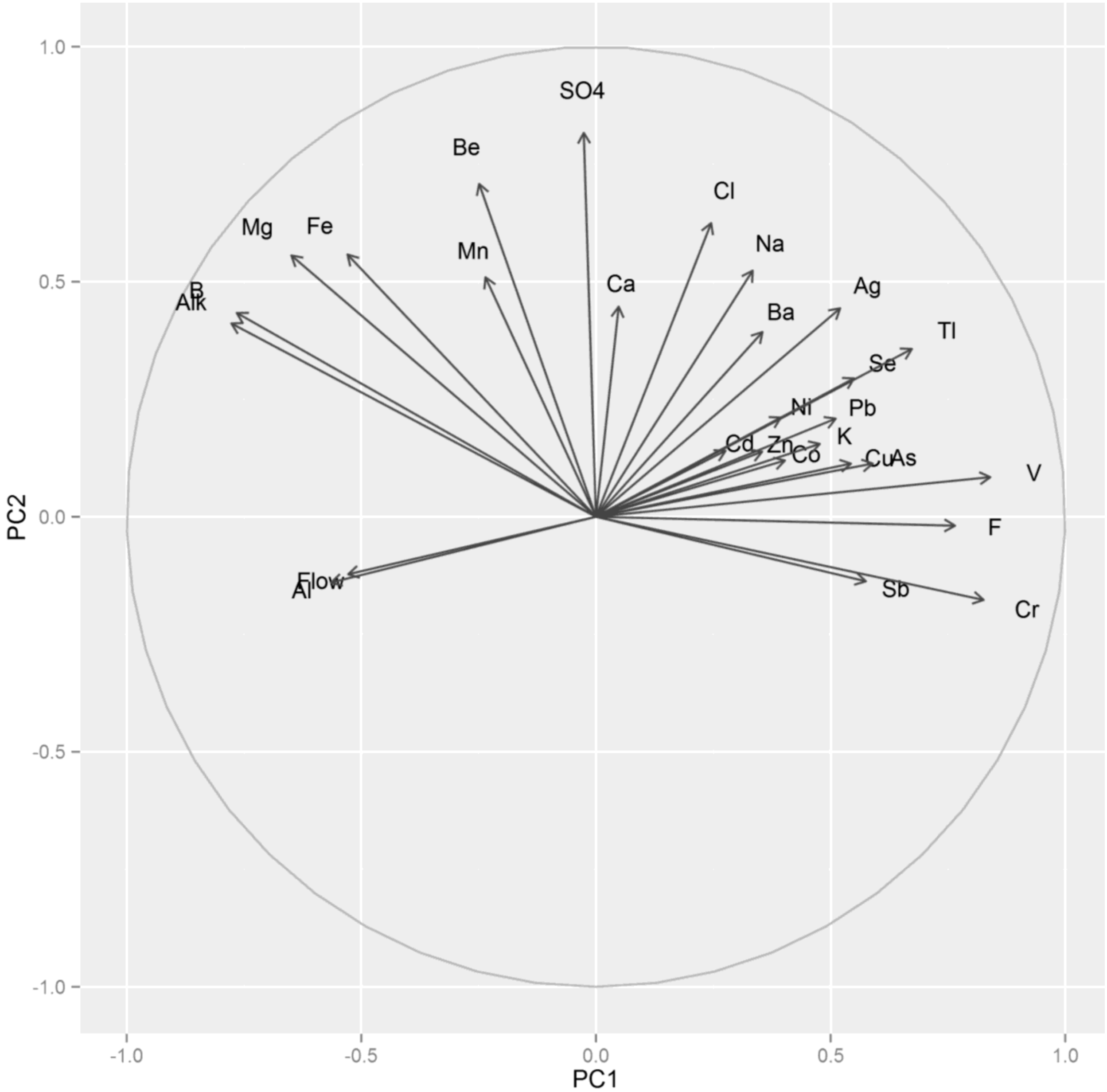


Figure 5 **Principal Component Plot – Tailings Basin Seepage Influent to WWTS, Mine Year 10**

Based on Figure 5, the flow vector for Mine Year 10 shows a potentially positive correlation with aluminum because both vectors are in the same direction and approximately the same length. Several parameters also show a potential negative correlation to flow, including fluoride, thallium, vanadium, chromium, and silver.

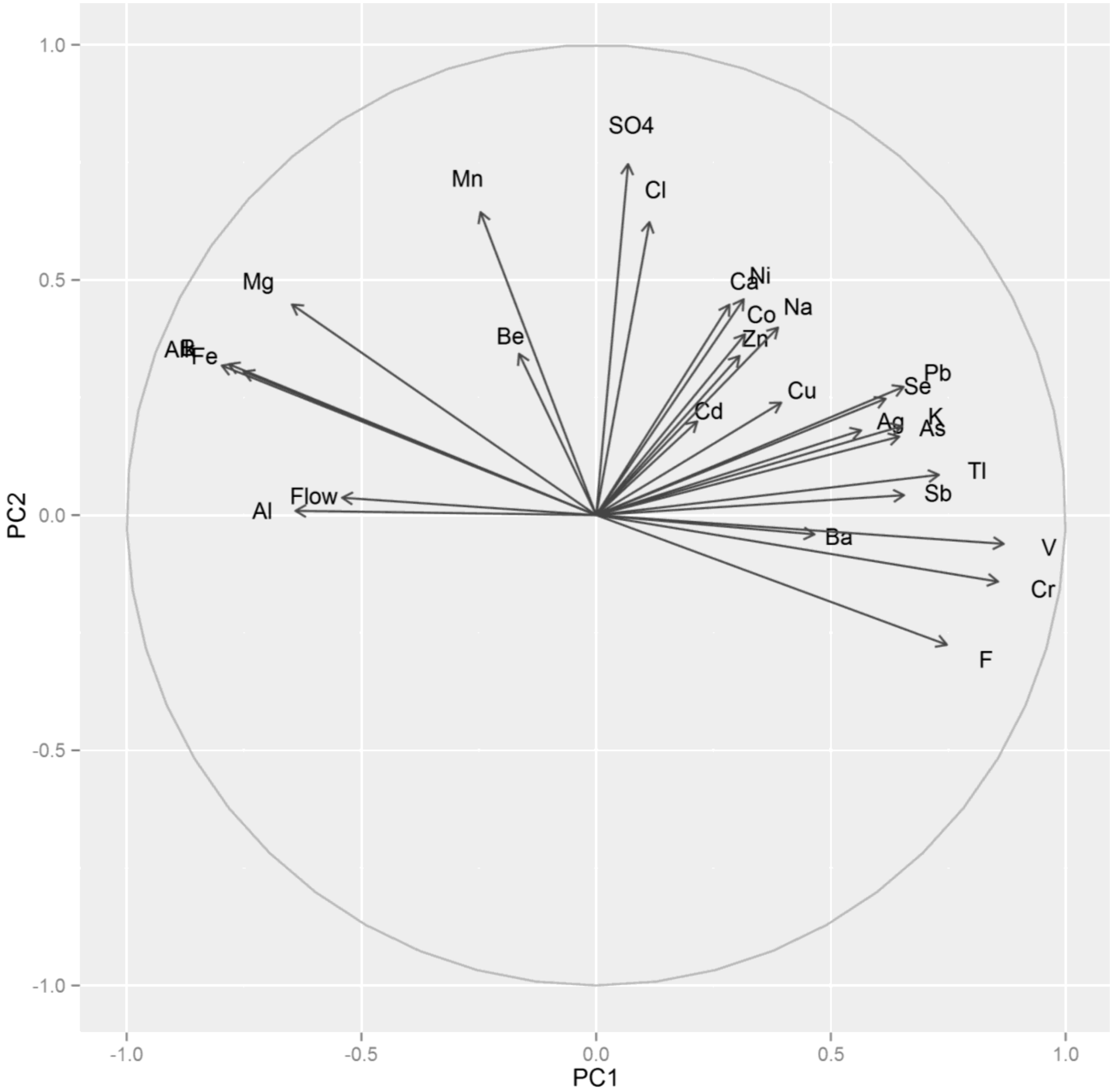


Figure 6 **Principal Component Plot – Tailings Basin Seepage Influent to WWTS, Mine Year 14**

Based on Figure 6, the flow vector for Mine Year 14 again shows a potentially positive correlation with aluminum and a potential negative correlation with fluoride, chromium, thallium, and vanadium.

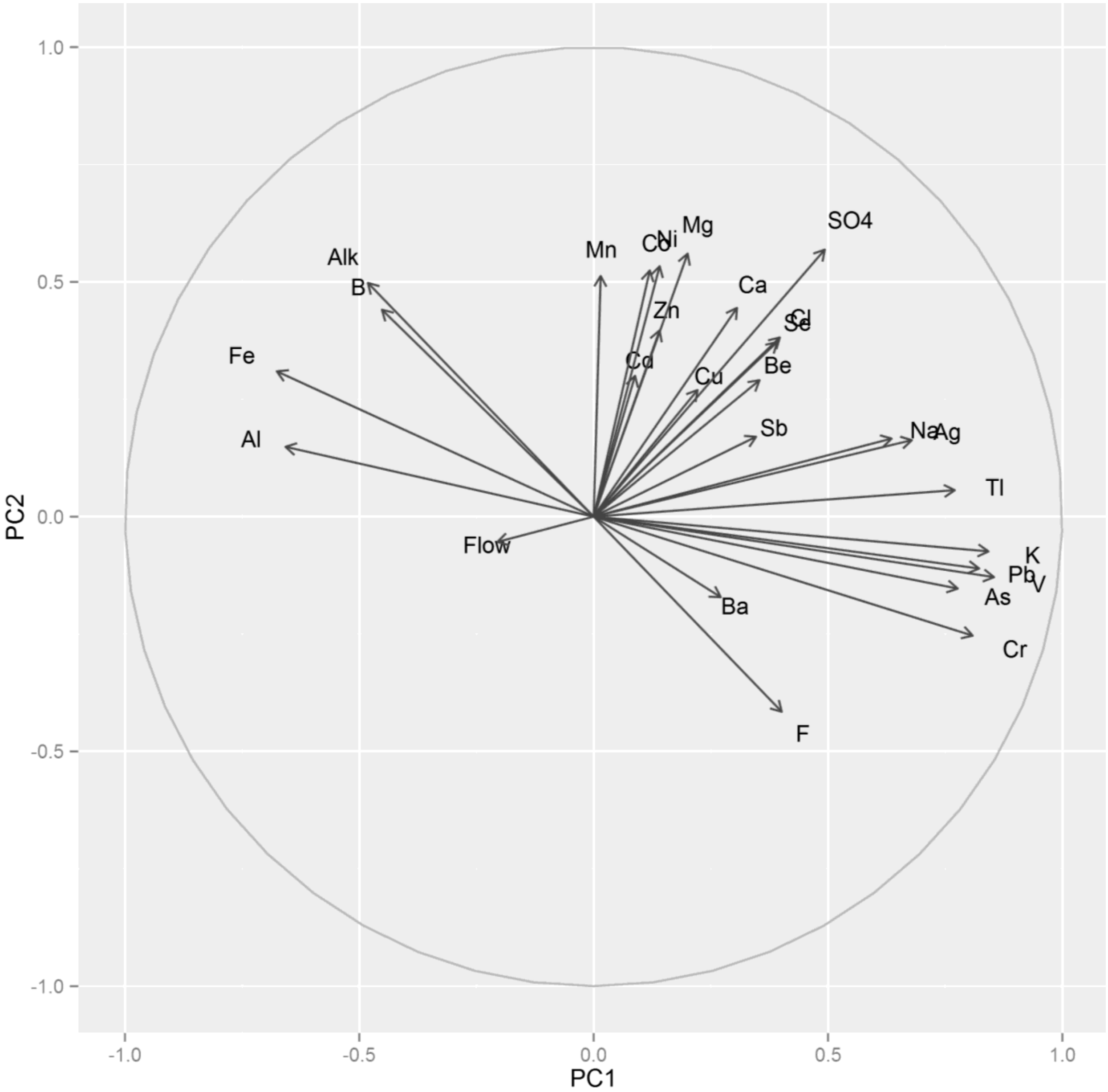


Figure 7 **Principal Component Plot – Tailings Basin Seepage Influent to WWTS, Mine Year 20**

The relatively short flow vector in Figure 7, which provides a graphical representation of the data for Mine Year 20, suggests that none of the other constituents are correlated with flow at the end of the operations phase of the Project.

Correlation coefficients were calculated between flow and each individual constituent within the tailings basin seepage for each Mine Year. A summary of these coefficients is provided in Table 3-1. While these values provide a relative degree of correlation, they can be used on a comparative basis to assess which constituents are more closely associated with the variability in the flow data. For this relative evaluation, a strong correlation was defined as 25% of the variation in a parameter being related to variations in flow (a correlation coefficient of 0.50 or higher). These values are shown in bold red type in Table 3-1. A medium correlation is defined as 10% of the variation in a parameter being related to variations in flow (a correlation coefficient of 0.32 or higher). These values are shown in bold type in Table 3-1.

Table 3-1 Correlation Coefficients Between Flow and Constituent Concentrations

Constituent	Mine Year 1	Mine Year 7	Mine Year 8	Mine Year 10	Mine Year 14	Mine Year 20
Ag	-0.14	-0.01	**-0.52**	**-0.54**	**-0.45**	-0.17
Al	0.17	0.09	0.19	**0.33**	**0.36**	0.11
Alk	-0.25	-0.29	-0.20	**0.47**	**0.51**	0.17
As	-0.17	0.14	-0.11	**-0.34**	**-0.48**	-0.14
B	-0.20	-0.31	-0.21	**0.46**	**0.50**	0.13
Ba	-0.26	-0.27	**-0.54**	**-0.39**	**-0.36**	0.02
Be	-0.18	-0.11	-0.31	0.07	-0.03	-0.06
Ca	-0.16	-0.07	-0.12	-0.02	-0.13	-0.16
Cd	-0.04	-0.06	-0.14	-0.14	-0.05	-0.07
Cl	-0.17	-0.30	-0.26	-0.15	-0.05	-0.03
Co	0.05	0.10	0.11	-0.13	-0.06	-0.04
Cr	0.00	0.25	-0.07	**-0.49**	**-0.54**	-0.13
Cu	0.02	0.14	0.00	**-0.33**	-0.17	0.06
F	-0.26	-0.18	**-0.54**	**-0.61**	**-0.50**	-0.08
Fe	0.10	-0.13	**-0.44**	0.13	**0.46**	0.15
K	-0.23	0.10	-0.13	-0.21	**-0.39**	-0.13
Mg	-0.17	-0.28	-0.23	**0.37**	**0.39**	-0.12
Mn	0.00	-0.06	-0.12	0.20	0.19	0.02
Na	-0.27	-0.25	**-0.37**	**-0.34**	-0.31	-0.22
Ni	0.01	0.03	0.06	-0.09	-0.03	-0.03
Pb	-0.26	0.07	-0.10	-0.22	**-0.42**	-0.14
Sb	-0.06	0.20	0.05	-0.26	**-0.37**	-0.15
Se	0.03	-0.01	-0.20	**-0.34**	**-0.41**	-0.19
SO_4	-0.22	-0.16	**-0.48**	-0.22	-0.08	-0.21
Tl	-0.27	-0.12	**-0.51**	**-0.56**	**-0.50**	-0.18
V	-0.21	0.07	-0.20	**-0.49**	**-0.59**	-0.19
Zn	-0.09	-0.04	-0.09	-0.16	-0.11	-0.05

Red = correlation coefficient = 0.5 or higher, representing a strong correlation
Bold = correlation coefficient = 0.32 or higher, representing a medium correlation

Based on the coefficients summarized in Table 3-1, the correlations between flow and all other constituent concentrations are relatively minor in Mine Years 1, 7 and 20. This result is consistent with the graphical presentations for Mine Years 1, 7, and 20, which did not suggest any potential correlation between flow and other constituents. Correlation coefficients in Mine Years 8, 10, and 14 indicate more significant positive and negative correlations between flow and some constituents. In comparison to the graphical presentations provided in for these years, the interpretations of the figures provide good agreement for a positive correlation between flow and aluminum in Mine Years 10 and 14. Relatively positive correlations suggested from the values in Table 3-1 for flow with alkalinity, boron, magnesium, and iron (Mine Year 14 only) were not as clearly deduced from the figures. Similarly, for the constituents that were negatively correlated with flow – including fluoride, thallium, vanadium, and chromium – the constituent vectors in the figures for Mine Years 8, 10, and 14 agree with the correlations listed in Table 3-1. While the correlation coefficients for several additional constituents listed in Table 3-1 suggest a potential negative correlation with flow – including arsenic, silver, barium, and selenium in at least two of the three Mine Years – the negative correlation between flow and these constituents is not as apparent on the figures.

3.1.4 Conclusions from PCA Analysis

The PCA of the tailings basin seepage flow and constituent concentration data revealed the following:

- No parameters were consistently correlated with flow – positively or negatively – throughout the design life of the WWTS.
- In Mine Years 1, 7, and 20, no strong positive or negative correlation was identified between flow and any other constituent using either the graphical representations in Figure 2, Figure 3, and Figure 7, or the correlation coefficients summarized in Table 3-1. The lack of a correlation at these times in the Project may be the result of the low variation in flow for those years.
- A medium negative correlation between flow and sulfate was observed in Mine Year 8. No other year shows a significant correlation between flow and sulfate.
- Flow may have a relatively positive correlation with aluminum, alkalinity, and boron and a relatively negative correlation with fluoride, vanadium, thallium, chromium, selenium, arsenic, and barium during the middle of the operations phase – primarily between Mine Year 10 and Mine Year 14.

3.2 Tailings Basin Seepage Treatment Train Water Quality Design Basis

The first step in developing a water quality design basis is to sort constituents into one of two categories based on the PCA results:

- Constituents positively correlated with flow or independent of flow
- Constituents negatively correlated with flow.

The second step in developing a water quality design basis is to assign an appropriately conservative concentration to each constituent.

- For constituents positively correlated with flow, or independent of flow, there is likelihood that a high concentration will occur at a high flow rate. Therefore, the P90 annual average concentration will be selected as the design basis for these constituents.
- For those constituents correlated negatively with flow, it is unlikely that a high concentration will occur at a high flow rate. Therefore, using the P90 annual average concentrations in conjunction with the P90 flow may result in an overly-conservative mass loading to the tailings basin seepage treatment train at the WWTS. For these constituents, computing the P90 annual average mass load and dividing by the P90 annual average flow should produce a more realistic concentration (between the mean and P90 concentrations) that could be expected at the P90 flow rate. In reality, for negatively correlated constituents, as flow rate decreases from the design capacity the concentration will be expected to increase. If this occurred, then the membrane system operation could be modified to lower the membrane recovery. This will maintain the target effluent concentrations in the permeate while minimizing the change in concentrate flow.

When the methodology described above was applied to the estimated tailings basin seepage quality, it returned computed concentrations that fell below the mean annual average values. The reason for this outcome is believed to be the tightness of the distributions for these parameters. Given the tightness of these distributions, it was decided to select the P90 annual average concentrations for all parameters as a conservative basis for design. A summary of the resulting design basis after balancing charge using alkalinity is provided in Table 3-2.

Table 3-2 Concentration Design Basis for the Tailings Basin Seepage Treatment Train at the WWTS

Parameter	Units	Mine Year 1[(1)]	Mine Year 5	Mine Year 10	Mine Year 15	Mine Year 20
pH	std units	7.5	7.5	7.5	7.5	7.5
Silver	µg /L	0.09	0.3	0.3	0.2	0.2
Aluminum	µg /L	11.4	12.7	11.4	10.0	11.4
Alkalinity	mg/L as HCO3-	347.7	131.1	153.3	454.6	762.0
Arsenic	µg /L	3.7	14.1	18.3	24.2	45.7
Boron	µg /L	245.9	276.4	245.1	216.8	229.0
Barium	µg /L	171.7	48.5	33.7	26.5	26.3
Beryllium	µg /L	0.16	0.4	0.5	0.4	0.5
Inorganic Carbon[(2)]	mg/L as HCO3-	342.0	135.5	159.1	476.2	798.6
Calcium	mg/L	37.6	87.1	88.6	90.3	168.8
Cadmium	µg /L	0.10	0.8	1.0	1.3	2.4
Choride	mg/L	18.8	24.2	25.0	24.5	24.4

Parameter	Units	Mine Year 1(1)	Mine Year 5	Mine Year 10	Mine Year 15	Mine Year 20
Cobalt	µg /L	2.09	21.0	22.3	24.4	40.7
Chromium	µg /L	0.45	3.6	4.9	6.0	7.1
Copper	µg /L	8.10	232.3	327.1	395.1	534.1
Fluoride	mg/L	3.89	2.1	1.8	1.4	1.2
Iron	µg /L	1229.0	8375.6	7353.2	2847.0	2357.7
Potassium	mg/L	7.64	15.3	17.6	21.0	31.1
Magensium	mg/L	63.9	102.0	95.5	87.0	99.4
Manganese	µg /L	300.0	899.9	910.4	829.8	898.2
Sodium	mg/L	59.0	73.0	71.9	69.0	77.7
Nickel	µg /L	11.6	256.1	283.4	343.8	563.7
Lead	µg /L	1.10	12.1	20.1	31.7	53.9
Antimony	µg /L	0.44	6.0	6.6	8.0	12.9
Silicon(3)	mg/L	34.8	34.8	34.8	34.8	34.8
Selenium	µg /L	0.50	1.7	1.9	2.0	3.5
Sulfate	mg/L	168.0	650.5	610.3	336.3	358.2
Thallium	µg /L	0.15	0.2	0.2	0.2	0.2
Vanadium	µg /L	3.86	6.1	7.2	8.0	9.2
Zinc	µg /L	10.5	49.9	65.4	86.6	163.3

(1) Mine Year 1 water quality based on SD004 seep water quality from pilot-test.

(2) Modified in PHREEQC to close charge balance at pH 7.5

(3) Silicon based on Ca:Si ratio of 1.4:1, capped at 34.8 mg/L as described in Section 3.1.1.

4.0 References

1. **Minnesota Department of Natural Resources, U.S. Army Corps of Engineers and U.S. Forest Service.** Final Environmental Impact Statement: NorthMet Mining Project and Land Exchange. November 2015.

2. **Poly Met Mining Inc.** NorthMet Project Water Modeling Data Package Volume 2 - Plant Site (v11). March 2015.

3. **Jolliffe, I. T.** *Principal Component Analysis.* Second. New York : Springer-Verlag New York, Inc., 2002.

Large Tables

Large Table 1 Summary Statistics for Tailings Basin Seepage Water Quality During Operations

Mine Year	Ag (Silver), µg/L		Al (Aluminum), µg/L		Alk (Alkalinity), µg/L as HCO3$^-$		As (Arsenic), µg/L		B (Boron), µg/L		Ba (Barium), µg/L		Be (Beryllium), µg/L		Ca (Calcium), µg/L		Cd (Cadmium), µg/L	
	Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages	
	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90
1	0.11	0.11	12.20	13.77	244,860.00	248,219.17	4.10	4.29	270.90	276.16	178.51	180.53	0.23	0.24	37,872.83	39,133.67	0.12	0.13
7	0.30	0.30	10.94	12.70	1357,75.00	142,411.67	11.29	14.14	263.87	276.44	47.27	48.52	0.42	0.43	75,333.92	87,079.25	0.60	0.79
8	0.29	0.31	9.26	11.36	109,065.25	116,657.50	14.53	18.33	231.73	245.09	32.41	33.66	0.43	0.45	76,715.75	88,591.17	0.70	1.00
10	0.21	0.22	6.91	9.97	84,035.92	101,568.08	18.75	24.22	183.40	216.84	25.57	26.48	0.42	0.43	77,689.33	90,256.83	0.80	1.25
14	0.19	0.21	7.80	11.51	94,122.83	113,639.17	31.45	40.39	198.64	235.06	25.61	26.68	0.45	0.48	112,208.33	136,885.00	1.20	2.01
20	0.18	0.19	3.13	5.11	50,503.58	58,565.67	61.87	67.48	109.79	122.54	19.71	20.66	0.38	0.39	219,258.33	288,530.83	2.09	4.01

Mine Year	Cl (Chloride), µg/L		Co (Cobalt), µg/L		Cr (Chromium), µg/L		Cu (Copper), µg/L		F (Fluoride), µg/L		Fe (Iron), µg/L		K (Potassium), µg/L		Mg (Magnesium), µg/L		Mn (Manganese), µg/L	
	Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages	
	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90
1	20,013.42	20,564.00	2.18	2.95	0.50	0.55	7.40	13.92	3,705.55	37,53.32	2,017.74	2,089.88	8,830.66	9,047.73	66,551.67	68,288.83	249.44	261.28
7	22,634.50	24,154.58	14.41	21.02	3.22	3.59	175.79	232.28	1,968.67	2,074.53	7,970.93	8,375.59	13,952.67	15,259.67	95,482.75	101,970.67	790.81	899.86
8	22,767.33	25,035.17	15.43	22.30	4.43	4.92	245.00	327.10	1,641.36	1,784.36	6,776.63	7,353.21	15,565.33	17,646.58	89,203.25	95,523.00	773.84	910.36
10	21,789.50	24,461.25	15.92	24.42	5.26	6.03	289.50	395.12	1,230.75	1,403.08	2,525.17	2,847.03	17,984.17	21,033.92	76,842.58	86,979.83	669.68	829.76
14	21,898.50	24,712.58	21.48	34.39	6.06	7.02	378.82	524.41	1,024.90	1,191.74	1,837.92	2,413.78	24,779.75	29,519.67	86,454.08	98,295.92	722.28	907.29
20	26,694.58	30,590.58	41.79	75.93	7.12	7.57	445.85	602.25	1,251.52	1,366.11	306.46	547.02	36,697.00	38,671.00	86,059.50	98,522.92	604.28	814.20

Mine Year	Na (Sodium), µg/L		Ni (Nickel), µg/L		Pb (Lead), µg/L		Sb (Antimony), µg/L		Se (Selenium), µg/L		SO4 (Sulfate), µg/L		Tl (Thallium), µg/L		V (Vanadium), µg/L		Zn (Zinc), µg/L	
	Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages		Annual Averages	
	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90	Mean	P90
1	63,813.42	64,867.92	9.86	16.66	1.18	1.19	0.53	0.82	0.54	0.54	20,2345.83	206,110.00	0.15	0.15	3.96	4.06	10.73	11.23
7	66,859.08	72,977.00	168.48	256.11	9.34	12.05	4.40	6.00	1.58	1.69	61,9452.50	650,474.17	0.22	0.22	5.52	6.12	39.87	49.92
8	65,389.83	71,874.08	188.16	283.40	15.14	20.07	5.18	6.62	1.74	1.89	56,1475.00	610,264.17	0.21	0.22	6.42	7.19	49.51	65.43
10	63,336.50	69,049.25	223.40	343.79	23.24	31.67	6.45	8.00	1.68	1.96	31,4378.33	336,300.00	0.16	0.17	7.01	7.97	61.55	86.58
14	68,814.83	75,863.75	298.64	475.91	39.15	51.20	9.28	11.45	2.42	2.89	309,002.50	337,384.17	0.17	0.19	8.03	9.09	95.57	138.55
20	103,526.83	113,369.17	563.80	965.77	62.55	67.77	17.22	20.67	4.98	6.03	383,989.17	431,750.83	0.18	0.18	9.01	9.36	157.73	253.59

Source: GoldSim Plant Site Model Simulations, January 2015 (Reference (2))
All units in µg/L except pH (standard pH units). Based on 100 GoldSim realizations.

Attachment B

Final Pilot-Testing Report – Plant Site Waste Water Treatment Plant Pilot-testing Program

Final Pilot-testing Report

Plant Site Wastewater Treatment Plant Pilot-testing Program

Prepared for
Poly Met Mining Inc.

June 2013

Final Pilot-testing Report

Plant Site Wastewater Treatment Plant Pilot-testing Program

Prepared for
Poly Met Mining Inc.

June 2013

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Final Pilot-testing Report
Plant Site Wastewater Treatment Plant Pilot-testing Program

June 2013

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Executive Summary

Treatment technology evaluations conducted by Poly Met Mining Inc. (PolyMet) and Barr Engineering (Barr) identified reverse osmosis (RO) as an established, commercially available treatment technology for removing sulfate from the Flotation Tailings Basin (FTB) seepage to a concentration of 10 mg/L, if needed to meet discharge requirements for the NorthMet Project (Project). This technology has been selected as the primary unit process for water treatment for the Plant Site Waste Water Treatment Plant (WWTP), along with ancillary unit processes for RO pretreatment (greensand filtration) and concentrate management (a specialty, secondary RO membrane process called vibratory shear enhanced processing, VSEP). The reject concentrate generated from the VSEP unit, which includes concentrate and membrane cleaning wastes, will be conveyed to the Mine Site Wastewater Treatment Facility (WWTF) for treatment in the chemical precipitation system.

PolyMet has completed a pilot and bench testing program for the WWTP that evaluated:

- greensand filtration – for iron, manganese, and total suspended solids removal
- reverse osmosis – for sulfate and dissolved solids removal
- VSEP – for RO concentrate volume reduction
- chemical addition – for permeate stabilization
- chemical precipitation of the reject concentrate – for removal of metals and sulfate

Pilot-testing commenced in May 2012 and was completed in December 2012. The primary objectives of the WWTP pilot-testing program were to collect sufficient information to:

- Confirm that the selected technologies can reliably meet the project water quality objectives
- Support the design of the WWTP
- Refine the capital and operating costs for the proposed system
- Support performance guarantees and system warranties

The pilot-testing program yielded several very important results, including the following for the RO system:

- throughout the testing program, the RO system has consistently produced permeate with sulfate concentrations less than 10 mg/L

- the pretreatment selected for the RO system—greensand filtration and antiscalant addition—were effective in maintaining stable RO performance
- the RO system did not experienced significant fouling or scaling during the testing program
- the RO is being operated at a recovery of 80%, which is within the range initially targeted for the WWTP

A critical component of the WWTP will be the ability to manage the RO concentrate using the VSEP technology. The VSEP pilot-test yielded the following results:

- The VSEP sulfate removal efficiency averaged 99.3%. Under the pilot-test conditions, when the VSEP and RO permeates are blended, the sulfate concentration is less than 10 mg/L.
- The VSEP system has demonstrated recoveries ranging from 80 to 90%, within the Project's objectives.
- No irreversible fouling was observed during the course of testing. Once cleaning optimization was complete, the membrane flux was restored to its original flux after each cleaning.
- No decline in sulfate removal has been observed over time.

The discharge from the future WWTP will be a blend of RO and VSEP permeates. Testing was conducted on methods to adjust the pH and reduce the corrosiveness of the blended permeates. The permeate stabilization bench testing results produced the following conclusions:

- lime addition
    - lime addition was able to adjust the pH and meet most water quality targets, including measures of corrosiveness
    - two important factors were identified in the test that would need to be considered on a full-scale design:
        - Quality of lime used (to reduce turbidity from inert materials and minimize unwanted aluminum in the discharge)
        - Method of lime addition and reaction to minimize residual turbidity
- limestone contactor
    - the limestone contactor was able to adjust the pH and meet all water quality targets, including measures of corrosiveness.

    - additional treatment after limestone contactor was needed to remove remaining carbon dioxide (e.g., air sparging).

Upon completion of the pilot-test, two membrane elements from the pilot unit were removed and sent to a third-party laboratory for autopsy. The purpose of the membrane autopsy was to identify potential problematic foulants remaining on the membrane, and to determine if adjustments to pretreatment or cleaning strategies are necessary for the full-scale system. The membrane autopsy identified the presence of some particulate matter, silica, and calcium carbonate on the membranes. While the accumulation was not severe and did not impact performance, it suggests that for the full-scale system, the pretreatment systems should consider additional or different measures to manage these components. Such measures may include the use of tighter cartridge filters or involve the selection of a different antiscalant or use of a mineral acid to lower the pH of the feed water.

Supplemental testing was conducted at the end of the pilot-test to (1) better quantify the removal of certain metals across the pilot treatment train and (2) to simulate the treatment processes that will be employed at the WWTF using the VSEP concentrate.

The metals removal test yield the following results for the RO and VSEP systems:

- Arsenic is expected to be removed primarily across the greensand filter, rather than the RO unit. Removal of arsenic by the greensand filter of up to 99.68% was observed on the pilot-scale.
- Cobalt, copper, lead, nickel, selenium, and zinc were observed to be well-removed by both the RO and VSEP systems, producing a blended permeate with concentrations below the Class 2B water quality standard.

Chemical precipitation bench testing was performed using VSEP concentrate to test performance of the treatment processes contemplated for the Mine Site WWTF. This is worst-case conditions due to the presence of anti-scalants and high ionic strength. The results of this testing indicated that oxidative pre-treatment of the VSEP concentrate is not likely required, and that performance and behavior of the contemplated treatment processes are similar to what is expected based on preliminary process calculations. The bench testing identified aluminum content of the lime reagent as a design consideration. The bench testing results will be incorporated into future design calculations as appropriate.

The initial design for the WWTP will be based partly on the results of the pilot-testing. Because the WWTP is considered an adaptive engineering control, provisions for expansion of the plant and changes to the operating configuration of process units will be incorporated into the full-scale design to match the results of ongoing water quality monitoring and modeling efforts.

1.0 Introduction

Preliminary water quality modeling of the NorthMet FTB operation suggested that seepage from the facility could potentially impact surface water quality down-stream of the Project. To resolve this issue, an FTB Containment System has been incorporated into the Project. While some or all of the water collected by the Containment System can be returned to the beneficiation process, at times a portion of the water will need to be treated and discharged.

Water quality discharge limits will be determined in permitting and may include a limit as low as 10 mg/L for sulfate. Required treatment will be provided by the new Plant Site Waste Water Treatment Plant (WWTP).

Treatment technology evaluations conducted by PolyMet and Barr identified reverse osmosis (RO) as an established, commercially available treatment technology for removing sulfate to a concentration of 10 mg/L. This technology has been selected as the primary unit process for water treatment at the WWTP, along with ancillary unit processes for RO pretreatment (greensand filtration) and concentrate management (vibratory shear enhanced processing, VSEP). The preliminary process schematic for the WWTP is shown on Figure 1, along with its relationship to the Mine Site Waste Water Treatment Facility (WWTF).

In December 2011, PolyMet initiated a pilot and bench testing program for the WWTP to test each primary unit process for the proposed plant:

- Greensand filtration – iron, manganese, and total suspended solids removal
- Reverse osmosis – sulfate and dissolved solids removal
- VSEP – RO concentrate volume reduction
- Chemical addition – permeate stabilization

Additional testing of chemical precipitation of the reject concentrate for removal of metals and sulfate was also completed in support of the design of the WWTF.

The treatment train, as implemented on the pilot scale, is illustrated on Figure 2. Figure 2 also provides the locations for sample collection during the pilot-testing program and the associated nomenclature used for the pilot program. The testing protocol developed for the program describes the objectives, schedules, and methods to be followed for the testing (Reference (1) and Reference (2)).

Pilot-testing commenced in May 2012 and was completed in December 2012. The purpose of this report is to provide the results obtained during the testing program and to provide an evaluation of technologies and their performance with respect to the Project goals and future estimated water quality.

2.0 Testing Program Structure

2.1 Pilot-test Program Overview

The primary objectives of the WWTP pilot-testing program were to collect sufficient information to:

- Confirm that the selected technologies can reliably meet the Project water quality objectives;
- Support the design of the WWTP;
- Refine the capital and operating costs for the proposed system; and
- Support performance guarantees and system warranties.

In order to meet the pilot-testing objectives, the pilot-testing program was conducted in phases, to provide periods of time for investigation and optimization and time for collection of data to assess the longer term performance of the processes under investigation. Each of the testing phases and its objectives are described in the following sections. The schedule followed for the testing program is illustrated on Figure 3.

2.1.1 Phase 1 – Well Testing

In December 2011 a new well was installed at the northwest corner of the existing LTVSMC tailings basin to provide source water for the pilot-test. Initial testing was conducted on this well to determine its capacity to support pilot-testing operations. Monitoring of the water levels in the pilot-test well and nearby monitoring wells was conducted during the pilot-testing program and ongoing water level data collection continues. The monitoring data was used to assess the aquifer characteristics and what, if any, effects the pilot-test well operation has on nearby wetlands. A summary of the pumping tests conducted to assess the well capacity and the longer-term monitoring data can be found in Appendix A.

2.1.2 Phase 2 – Startup and Commissioning

Phase 2 consisted of the startup and commissioning of the reverse osmosis and greensand filter pilot units. This period provided an opportunity for pilot unit installation and assembly, tuning of control systems, implementation of the data collection procedures, and initiation of operation and the initiation of the process of determining operating conditions. Operator training by the vendor was provided during this phase.

2.1.3 Phase 3 – Membrane Selection, Pretreatment Investigations, and System Optimization

The purpose of Phase 3 was to identify pretreatment requirements and RO operating conditions that optimize the treatment train (balancing capital costs, operating costs, and reliability). During this phase, greensand filter operation as well as the recovery and flux of the RO system were adjusted and monitored to determine an operating approach for use in Phase 4.

2.1.4 Phase 4 – Steady-State Operation

During Phase 4, the treatment train and operating conditions based on the Phase 3 investigations were used. The treatment system was operated, largely unaltered, for the duration of Phase 4 under steady-state conditions. The purposes of this test were to gain longer-term operating data on the proposed system to evaluate system reliability, system performance with respect to water quality targets, life cycle cost, ability to effectively clean the membranes, and to generate permeate and concentrate for use in Phase 5 and 6 testing.

2.1.5 Phase 5 – Concentrate Volume Reduction Investigation

Once steady-state operation of the RO pilot was established, a study of further reduction of the concentrate volume was initiated via routing the RO concentrate through the VSEP system, by New Logic Research. The objective of this investigation was to evaluate the recovery, fluxes, and operational requirements for the VSEP equipment, and to characterize the resulting concentrate and permeate quality.

2.1.6 Phase 6 – Effluent Stabilization Investigation

The future WWTP effluent will be a blend of RO and VSEP permeates. The effluent blend will be void of alkalinity and hardness, making the water corrosive to piping and materials near the outfall. The objectives of the effluent stabilization investigation were to identify a stabilization method (e.g., addition of minerals) that will reduce the corrosiveness of the blended effluent, while maintaining compliance with the effluent water quality targets (Section 3.2).

2.1.7 Phase 7 – Membrane Fouling

After completion of pilot-testing, select membranes were removed from the pilot unit for a membrane autopsy. These membranes were disassembled and samples of the flat sheet membrane will be removed for analysis. The membranes were analyzed to identify potential problematic foulants remaining on the membrane.

2.1.8 Supplemental Testing

Towards the end of the pilot-testing program, additional, related testing was conducted to support the Project. This supplemental testing included

- pilot-scale tests to better quantify the removal of select metals across the greensand filter, RO, and VSEP pilot units
- bench testing of the chemical precipitation processes to be used at the Mine Site

The results of the supplemental tests are also presented in this report.

2.1.9 Testing Facilities

The location of the pilot-test well, SD004 (a seep from the existing LTVSMC tailings basin), and water holding tanks are shown on Figure 4. The well that is supplying water for the pilot-test is a 4-inch-diameter, 71-foot-deep well. Water from this well and from SD004 was pumped into holding tanks at the tailings basin. From these tanks, water was pumped into tanker trucks, which transported the water to the Wayne Transports, Inc. facility in Virginia, MN. The pilot-test facility at Wayne Transports is equipped with city water, hot water, power, internet connectivity, and sanitary sewer service. Drawings of the pilot-test facility layout are provided in Appendix B.

2.1.10 Roles

2.1.10.1 PolyMet

PolyMet was the lead organization in the pilot-testing effort. PolyMet activities included:

- contract development for the pilot-testing equipment, laboratories, and consultants
- management of the pilot-testing, equipment suppliers, laboratories, and consultants
- operation of the pilot units, including regular monitoring, assistance with process troubleshooting, and conducting clean-in-place (CIP) procedures for the pilots when required
- management and disposal of wastes generated during the pilot-testing program

2.1.10.2 Barr Engineering

Barr staff provided the following services:

- development of pilot unit plans, specifications, and testing protocols
- dissemination of water quality data to PolyMet and to the equipment suppliers on a regular basis, as results became available from the laboratories

- coordination of and participation in meetings and conference calls with PolyMet and the equipment suppliers
- execution of bench testing for the effluent stabilization investigations
- technical support for process troubleshooting, data evaluations and interpretation, and performance evaluation
- assistance with the development of the refined construction and O&M costs, based on pilot-testing results

2.1.10.3 Equipment Suppliers

The equipment suppliers for this pilot included:

- GE Water & Process Technologies (GE) – Greensand filter and RO pilot systems
- New Logic Research (NLR) – VSEP pilot unit

Equipment supplier activities included:

- provision of pilot-test equipment in accordance with their contracts
- provision of on-site supervision of installation and startup
- completion of membrane selection and pretreatment investigations
- provision of training such that PolyMet staff has sufficient knowledge to support the pilot-testing program
- participation in conference calls and meetings
- provision of a final report summarizing the pilot-testing results
- provision of equipment capital costs and updated annual O&M costs for supplied equipment to support the development of a refined project cost estimate

2.1.10.4 Laboratories

Analysis of samples collected during the pilot-testing program was provided by the following laboratories:

- Legend Technical Services, Inc. (Legend) provided all analytical services for routine sampling of the RO and VSEP systems.
- Pace provided as-needed analytical services for manganese testing where a very fast turn-around time was required.

- Environmental Toxicity Control (ETC) provided WET testing services for the effluent stabilization test.
- Separation Processes Inc. (SPI) provided testing services for the membrane autopsy.

3.0 Water Quality

3.1 Influent Water Quality

In December 2011 a new pumping well was installed and screened in the aquifer that extends beneath the existing tailings basin. This well was used as the feed water source for the pilot-test. To avoid over-pumping the well, additional water from an existing seep from the tailings basin (at outfall SD004) was blended with the well water to produce feed water for the pilot unit. The water quality from these two sources is presented in Table 1 and Table 2. The approximate locations of the pilot-test well and SD004 are shown on Figure 4. Note that all qualifiers for analytical data summarized in this report in Table 1 through Table 40 are included in Table 41.

Figure 5 shows the concentrations of total dissolved solids, total hardness, and sulfate for SD004 and the pilot-test well since the initiation of pilot-testing. Over the duration of the pilot-test, the influent water quality from SD004 was relatively constant. The well water quality was of similar composition as SD004; however, it was more variable in concentration throughout the testing program. Figure 6 illustrates the influent iron and manganese concentrations for both water sources, and confirms the presence of relatively high concentrations of these constituents in the existing tailings basin drainage.

3.2 Treated Water Quality Targets

The final discharge from the WWTP must meet the applicable water quality discharge limits. The target treated water quality targets are shown in Table 3. The targets in Table 3 are the water quality targets for the blended RO and VSEP permeates, and represent the possible discharge limits as known during the development of the pilot-testing program in late 2011.

4.0 Reverse Osmosis Pilot-test Results

4.1 Pretreatment

The greensand filter pilot unit provided by GE for the pilot-test was a pressure filter (Figure 7). This filter is a 30-inch diameter unit filled with coarse gravel (5 inches), greensand filter media (30 inches), and anthracite (12 inches). The greensand media is silica sand coated with manganese oxide. Technical information on the greensand used during the pilot-test and information on the GE pilot unit systems can be found in Appendix C.

For the pilot-test, the influent was dosed continuously with potassium permanganate in order to (1) oxidize iron and manganese for removal by filtration and (2) regenerate the greensand media.

4.1.1 Filter Loading

Over the duration of the testing program, the influent flow rate ranged from 19 to 22 gpm. The resultant range of hydraulic loading to the filter was 3.5 to 4.9 gpm per square foot (gpm/ft^2) of filter bed area.

4.1.2 Filter Removal Rates

The greensand filter removal rates for total suspended solids, iron, and manganese are presented in Table 4. Overall (including startup and optimization phases of testing), the removal of total suspended solids across the filter averaged >87% (to less than the method reporting limit in the filtrate). During Phase 4, the removal of total suspended solids (TSS) was >90% on average. Iron removal by the filter consistently averaged >99.7%. Table 5 displays the greensand filtrate water quality.

During Phases 3 and early in Phase 4, it was noted that, at times, manganese was breaking through the filter (Table 5). Because of this, during Phase 4 at the end of August 2012, a trial to improve manganese removal was initiated. For this optimization, the permanganate dose was increased every other day, with daily monitoring of filter influent and effluent manganese. In order to protect the membranes from potential damage from excess permanganate (a strong oxidant), sodium bisulfite was dosed immediately ahead of the RO unit. Figure 8 provides an overview of the manganese removal results obtained during this optimization. A final potassium permanganate dose of about 4.5 mg/L was selected as the optimal dose for manganese removal based on the filtrate dissolved manganese concentration. As can be seen in Figure 8, manganese removal was significantly improved from an average of 81% prior to optimization to an average of 97% after optimization. The results suggest that the breakthrough of manganese observed during Phase 3 and 4 was likely due to the incomplete oxidation of dissolved manganese and/or insufficient regeneration of the greensand media at the permanganate doses initially applied during testing.

4.1.3 Residuals

Periodically, accumulated solids must be removed from the filter bed to maintain hydraulic capacity and performance. A filter backwash can be triggered based on filter run time, or more commonly, an increase in pressure drop across the filter. For the pilot unit, pressure drop was used to trigger backwash events. When the pressure drop across the unit reached approximately 10 psi, feed water was pumped up through the filter bed at a rate of 60 to 70 gpm (12 gpm/ft^2) to remove solids from the bed. During Phase 4 operations, the filter backwash frequency was approximately once every two days. Samples of the spent backwash water were collected and analyzed. Greensand filter backwash water quality results are summarized in Table 6. In addition to containing elevated concentrations of TSS, iron, and manganese—the targeted constituents—the spent backwash water also contained elevated concentrations of organic material (as chemical oxygen demand), silica, and a number of other metals such as aluminum, arsenic, barium, cobalt, copper, thallium, and vanadium. The removal of arsenic by the greensand filter was further quantified during supplemental testing (Section 7.0). The adsorption of certain metals to iron oxyhydroxide solids, which accumulated in the greensand filter media during the iron removal process, was further evaluated in chemical precipitation bench testing (Section 8.0).

4.1.4 Discussion

The primary purpose of the greensand filter was to protect the RO membranes by removing particulate matter, iron, and manganese. The filter removed TSS and iron to concentrations below the method reporting limits. Manganese was also significantly reduced, especially after optimization of the potassium permanganate dose during Phase 4. The RO membranes, as is discussed in more detail in Section 4.2, did not exhibit signs of fouling during the 7 month pilot-test. The greensand filter was a simple-to-operate, effective means of pretreatment for the feed water from SD004 and the pilot-test well.

In full-scale application, one of the primary design criteria for greensand filters is the hydraulic loading rate. The loading rate for greensand filters has the potential to affect the manganese removal efficiency, the backwash frequency, and the number of filters required for filtration. For this pilot-test, the hydraulic loading rate was fixed by the pilot unit supplied by GE, and was higher than typical hydraulic loadings for this type of filter (approximately 4.5 compared to 3 gpm/ft^2), particularly given the concentrations of iron and manganese in the influent. However, higher-than-typical loading rates can be acceptable if demonstration testing shows acceptable treatment performance and backwash frequency, which was case during this pilot-testing program. As previously mentioned, an autopsy of the RO membranes is on-going. Information from the autopsy will be used determine if iron, manganese, or other scalants or foulants accumulated at a rate that would be potentially detrimental to the membranes, given the duration of the pilot-test program.

4.2 Reverse Osmosis

The RO pilot unit was provided by GE. A picture of the pilot-test unit employed for the project is shown on Figure 9. Manufacturer's information on the pilot unit can be found in Appendix C. The RO pilot unit provided by GE used 18 4-inch-diameter RO modules housed in six vessels, in a 2-2-1-1 array. The membranes employed were low-pressure RO membranes (GE model AK90-LE).

The greensand filter effluent was treated with 1 ppm sodium bisulfite (to quench any excess permanganate from the filter and prevent membrane oxidation) and 2.2 ppm of Hypersperse MDC150, a scale inhibitor.

The pilot unit was operated continuously for approximately 8 hours per day, typically 5 days per week. At the end of each 8-hour shift, the RO system was flushed with permeate and shut down.

4.2.1 Flux and Recovery

During Phase 3 of the pilot-test, a number of operating conditions were tested to optimize the RO system operation. The primary operating variables adjusted were recovery (the percentage of feed water volume that becomes permeate) and flux (the flow rate through the system per unit of membrane in service). In general, the higher the membrane flux, the lower the membrane area required for a given treatment capacity. However, operation at higher flux rates has the potential to increases the fouling rate of the membranes.

Phase 3 lasted approximately 8 weeks and the conditions tested were as follows:

- Condition 1 – 75% recovery, flux of 14 gfd – 3 weeks
- Condition 2 – 80% recovery, flux of 16 gfd – 3 weeks
- Condition 3 – 80% recovery, flux of 18 gfd – 2 weeks

The RO pilot unit performed well at all conditions tested. Condition 3 was considered a "stress condition" because the flux was at the upper end of what is generally used in the design of RO groundwater treatment systems (Reference (3)). Nevertheless, for the short duration test of this operating condition, no operational problems were encountered. The feed-to-concentrate pressure drop across the RO system was stable at all three conditions and was well below the threshold to initiate membrane cleaning (> 50 psi per stage). Changes in recovery and flux can also impact the salt rejection of the membranes. Over the conditions tested in Phase 3, no unacceptable or significant changes in permeate water quality were observed. For Phase 4, a flux of 16 gfd and recovery of 80% were selected. This combination of operating conditions was determined to provide an acceptable performance and reliability. The small increase in pressure drop at the 18-gfd flux condition further demonstrated the selected flux (16 gfd) is not an operational maximum.

During Phase 4, the RO membrane system operated continuously at a recovery of 80% and a flux of 16 gfd. The feed-to-concentrate pressure drop throughout Phase 4 was approximately 25 to 30 psi with little upward movement. The feed-to-concentrate pressure drop and the feed pressures experienced over the course of pilot-testing are shown on Figure 10 and Figure 11. The absence of any substantial change in feed pressure or feed-to-concentrate pressure drop suggests that very little scaling or fouling of the membranes occurred during the pilot-testing program. A membrane autopsy is currently underway to confirm this observation.

4.2.2 Permeate Water Quality

The RO feed (greensand filter effluent), permeate, and concentrate water quality data collected during Phases 3 and 4 are summarized in Table 5, Table 7, and Table 8, respectively.

4.2.2.1 Removal Rates

Average removal rates were estimated for those parameters with detectable concentrations in the greensand filter effluent (RO feed) and are displayed in Table 9. The average sulfate removal was 99.8% during the pilot-test (see Figure 12 of sulfate removal). The average sulfate concentration in the RO permeate was 0.57 mg/L, and the highest sulfate concentration observed was 0.98 mg/L, well below the 10 mg/L water quality target. During Phase 4, the average salt passage through the membranes was <0.6% with no reported total dissolved solids (TDS, reporting limit of 10 mg/l) in the permeate as reported in the analytical results (see Figure 13).

Many other parameters, particularly the major anions and cations, were reduced by greater than 95%. However, in many instances the upper limit of removals were not determined in the routine testing because (1) the concentrations measured in the permeate were less than the method reporting limit and/or (2) the concentrations in the influent were low and close to the method reporting limit. For several metals, both of these conditions applied. Thus, supplemental testing was conducted to better quantify the removals by the greensand filter and RO systems (see Section 7.0 for methods and results).

For some constituents, removal by RO membranes is highly pH-dependent. Examples of this are ammonia, borate, and arsenite. For these compounds, over a range of pH values, they are present as unionized species. The unionized species are not well-removed by membranes. For this pilot-test, the following observations were noted:

- Ammonia: At pH values below 7, most of the ammonia is present as the ammonium ion and can be removed by the RO process. However, the pH of the feed water to the pilot RO system is approximately 7.5, reducing the amount of ammonia that can be removed. In addition, the concentration of ammonia in the influent was relatively low. The low concentration in the influent limited the estimate of quantifiable removal by the RO system.
- Boron: It is well known that boron removal at pH values below the pKa (pH = 9.2) of boric acid is limited due to the lack of charge on the species. The boron removal during the pilot-testing program, while limited, was sufficient to maintain permeate concentrations below 0.5 mg/L, the Class 4A water quality standard. Specialty membranes or pH adjustment are typically required for greater boron removal.

Arsenic removal is further discussed in Section 6.0.

4.2.2.2 Comparison to Equipment Supplier Model

The suppliers of RO membranes commonly use models in their system design and to estimate the permeate water quality. Each supplier typically has developed their own models for their membranes, and each supplier has significant operating data collected over the years for validation of the model output. The model water quality input and output is generally limited to the major anions and cations, pH, boron, and certain constituents of concern with respect to membrane fouling or scaling (e.g., aluminum, barium, silica, strontium). Because equipment supplier models will likely be used during the full-scale system design, a comparison of their output and measured water quality data was made. Table 10 compares the model results with measured permeate water quality for 3 days throughout Phase 4, and Figure 14 graphically displays the comparison for sulfate. For each of these days, the system was operated at 80% recovery and 16 gfd. The water temperatures ranged from 12 to 16°C and the membrane age used in the model was one year. As can be seen from the figure and table, the equipment supplier model reasonably estimates the order of magnitude of the measured result. For sulfate, the model results are within 20% of the measured results.

4.2.3 Cleaning Requirements

Inorganic and organic scale and foulants build up on RO membranes over time and reduce performance. Membranes are chemically cleaned-in-place (CIP) to remove the foulants and restore performance. CIPs are triggered either when the system pressure drop reaches a predetermined value or increases by a certain percentage, if salt passage increases beyond a certain percentage, or on a regular time interval, if other parameters have not triggered a CIP. GE generally recommends that membranes be cleaned every 3-4 months (of continuous operation) if a CIP has not been initiated for other reasons.

Significant increases in pressure drop from the RO feed to the concentrate were not seen in any phase of the pilot-testing. A CIP was conducted on July 30, 2012 to test the cleaning procedures recommended by GE. A low pH cleaner (citric acid) and a proprietary high pH cleaner from GE were used to clean the membranes during the CIP. The cleaning solutions were recirculated through the membranes in a two-step cleaning process and samples of the spent cleaning wastes were collected for analysis (Table 11).

The analytical results from the chemical cleaning wastes can provide insight into the fouling or scaling constituents on the membranes and which cleaner removes them. The following were elevated following treatment of each cleaner:

- low pH cleaner – chemical oxygen demand (COD, from the cleaner), TDS, aluminum, barium, calcium, iron, magnesium, manganese, sodium, vanadium, and zinc
- high pH cleaner – Sodium and COD (both from cleaner) and magnesium

In the low pH cleaning solution waste, iron and manganese were the metals present in the highest concentrations. This finding was one of the reasons for conducting the greensand filter optimization study described in Section 4.1.2.

4.2.4 Membrane Autopsy

Upon completion of the pilot-test activities, two membrane elements (the lead element from the first stage, and the tail element from the last stage) were removed from the pilot unit and sent to a third party laboratory for a membrane autopsy. The laboratory report is presented in Appendix D. The autopsy provided the following observations:

- Silica and some particulate matter were observed on the feed side of the lead element. This is likely from silts and clays present in the feed water. The accumulation was slight and performance was not negatively impacted. Use of a tighter cartridge filters upstream of the full-scale RO skids may mitigate this accumulation.
- Calcium carbonate scaling was observed on the concentrate side of the tail element. While the scaling was not severe and did not impact membrane pressures observed during the pilot, the presence of the scalant does warrant consideration of adjustments to the pretreatment used in the full-scale system. Such adjustments could include selection of a different antiscalant or the addition of a mineral acid to lower the pH of the RO feed to reduce the potential for calcium carbonate formation.
- In both membrane elements, creases were observed in the flat sheets. It is hypothesized that these creases are the result of the element manufacturing process (when the flat sheets are rolled). During the autopsy, the salt passage across sections of the sheet that contained was compared to that where no creases were present. Increased salt passage did occur across the sections containing a crease. While the overall sulfate removal performance of the membranes supplied reliably met the project requirements during the test, the potential impacts of this phenomenon on membrane life are unknown. PolyMet is reviewing this issue with GE and will consider whether additional quality control requirements may be necessary during the procurement of the membranes for the full-scale plant.

4.2.5 Discussion

The selection of RO for treatment of water at the tailings basin was driven primarily by its potential to produce treated water containing less than 10 mg/L of sulfate. Throughout Phases 3 and 4, the RO membranes produced a permeate water quality that consistently met that that and other treated water quality targets (Table 3). As discussed in Section 4.2.2.1, the average sulfate concentration observed in the RO permeate was 0.57 mg/L (0.98 mg/L being the highest concentration observed), which is an average sulfate removal efficiency of 99.8% across the membranes. It is expected that sulfate removal may change over time as the membranes age, but it is also expected that, even with some degradation of performance, water quality targets are likely to be met.

Throughout the duration of the pilot-testing program, no significant operational or maintenance problems were encountered. Based on influent water chemistry and RO treatment modeling conducted by GE, the recovery selected for the RO pilot unit was primarily a function of the solubility limits of calcium carbonate and silica, which become saturated or supersaturated at the membrane surface during treatment. During the pilot-test, a scale inhibitor (a phosphonic acid salt solution) was used to manage the formation of scale and silica on the membranes. The membrane system did not experience a significant increase in pressure drop from the RO feed to the concentrate. This stability indicates that scaling and fouling were not significant during the pilot-test and that the pretreatment systems in place were effective, however some calcium carbonate was observed during the membrane autopsy. Selection of the antiscalant for the full-scale plant will be made in consultation with the membrane supplier, based on the future water chemistry and operational performance of the system.

The feed pressures observed during the pilot were stable and were lower than many brackish water RO applications, averaging 123 psi. The low feed pressures translate to lower operational (energy) costs for pumping into the system.

5.0 VSEP Pilot-test Results

The VSEP pilot unit was provided by New Logic Research. A picture of the pilot-test unit that was used in the pilot-testing program is shown on Figure 15. Manufacturer's information on the pilot unit can be found in Appendix E. The unit can be operated in batch mode or single-pass (continuous) mode, and both operating modes were tested during the Phase 5 pilot-testing activities. For the pilot-test, RO membranes (ESPA series by Hydranautics) were used.

As discussed in Section 2.0, one of the main objectives for the VSEP system was to reduce the volume of the RO concentrate. By minimizing the concentrate volume, the sulfate concentration is increased, ideally to such a degree that sulfate mass can be removed by chemical precipitation at the WWTF (as depicted in Figure 1).

5.1 Pretreatment and Optimization

During the initial phase of testing for the VSEP unit, a number of methods for optimizing performance of the system were investigated:

- operational mode selection—batch versus single-pass operation—to maximize system recovery
- antiscalant dose selection to maximize system recovery
- acidification of the VSEP feed water to maximize system recovery
- cleaning chemical selection and cleaning procedure refinements to maximize the restoration of membrane flux

The preliminary investigations related to each of these are described in the sections that follow.

5.1.1 Operational Mode

The initial startup and optimization of the VSEP unit was led by the New Logic Research field engineer with assistance provided by PolyMet staff. New Logic Research operated the unit in both batch and single-pass mode and determined that greater flux stability could be achieved by operating the unit in batch mode. In batch mode, the VSEP system uses a constant cross flow along with vibration to reduce fouling and polarization at the membrane surface. For the batch process, a fixed volume of concentrate from the GE RO system is fed to the VSEP system. The concentrate from the VSEP unit is returned to the VSEP feed tank and the VSEP permeate is discharged (as illustrated on Figure 2). As a result, the concentration of total dissolved solids in the feed tank increases over the duration of batch processing. This process continues until the target recovery has been achieved or until the flow through the membrane falls below a predetermined threshold. The flow through the system decreases as the osmotic pressure increases and scalants and foulants accumulate on the membrane. When the terminal flow is reached, the membranes must be cleaned. It is possible to process more than one batch of concentrate before a cleaning is required.

5.1.2 Chemical Pretreatment

During New Logic Research's initial startup and optimization of the VSEP pilot unit, RO concentrate was initially processed without the use of any chemical additives. Without chemical addition, the recovery achieved by the VSEP pilot unit was only 10%. A single antiscalant (NRL 759) was added to the batch feed tank and the performance of the unit was re-evaluated. When NRL 759 was dosed at 10 ppm, the VSEP recovery improved to 65%. Higher doses of the antiscalant did not result in noticeable improvement.

Additional improvement in recovery was achieved by lowering the pH of the VSEP feed to approximately 6 to 6.5. At this pH range, the scaling potential of calcium carbonate is reduced. Using acid addition, the recovery across the VSEP unit was improved to 80 to 90%. Figure 16 illustrates the results of the initial pretreatment investigations. The membrane flux was sustained over the batch most effectively using a combination of antiscalant and pH adjustment.

After the initial optimization was completed, a second phase of optimization was conducted in which the following aspects of VSEP operation were investigated:

- Use of hydrochloric or sulfuric acid
- Timing of acid addition for pretreatment

    - A single acid addition event at the beginning of a batch
    - Adjustment of pH at the beginning of the batch, and again once a recovery of 50-65% was reached
    - Adjustment of pH during the batch only when the recovery reached 50-65%.

- Degree of pH adjustment necessary (pH 6.0 versus 6.5)

5.1.2.1 Acid Type

Over the duration of the VSEP pilot-test, two types of acid were used for pH adjustment (pretreatment): 31.7% hydrochloric (muriatic) acid and 40% sulfuric acid. Hydrochloric acid is an effective means of pH adjustment, but within the wastewater management plans for the Project, chloride has the potential to accumulate within the system until reclamation. Sulfuric acid contributes sulfate to the system; however, this mass can be removed by the gypsum precipitation process at the WWTF. Figure 17 provides examples of two batches in which the VSEP feed water was pretreated with sulfuric and hydrochloric acids. The feed water was adjusted to pH 6 at the beginning of the batch and again midway through processing. As can be seen in the figure, the acids are similarly effective in maintaining the membrane flux throughout the batch. With respect to VSEP permeate water quality, when hydrochloric acid was used, the average sulfate concentration in the VSEP permeate was 12 mg/L and, under similar operating conditions (80-85% recovery and pH 6), when sulfuric acid was used, the average VSEP permeate sulfate concentration was 19 mg/L.

5.1.2.2 pH Adjustment Method

The initial optimization of the VSEP pilot unit demonstrated that pH adjustment of the feed water improved recovery. The method for pH adjustment was further refined in subsequent investigations. Figure 18 shows some of the results of the pH adjustment trials in which acid was added to the feed tank:

- Only once a recovery of 50 to 65% had been reached
- At the beginning of the batch, and again when a recovery of 50 to 65% was reached to maintain a pH of approximately 6 in the feed tank
- At the beginning of the batch only

As Figure 18 illustrates, all three approaches were able to achieve 80% recovery, however, the flux was more stable throughout the batch and higher at the end of the batch for Batches 16 and 20, which used pH adjustment initially. During Batch 20 pH was also adjusted again at a recovery of 60%. Throughout the numerous batches processed, the approach of adjusting pH initially consistently resulted in a more stable flux throughout the batch and a higher terminal flux at the end of the batch. Adjusting the pH again later in the batch did not provide significantly different or better results than a single, initial pH adjustment. Maintaining a higher flux rate over more of the batch, as is achieved by adjusting the pH at the beginning of the batch, results in less membrane area required (i.e., less capital cost) to treat the same volume.

5.1.2.3 Degree of pH Adjustment

The amount of acid used per 1,000-L batch typically ranged from 1,500-2,500 mL (of 40% sulfuric acid). For a full-scale system, the cost of chemicals for the system operation must be balanced with the capital costs of the VSEP membranes (membrane area required based on flux). For this reason, several runs were completed to compare the performance of the system at pH 6 versus pH 6.5. Some of these runs are presented in Figure 19. For these runs, the pH was only adjusted at the beginning of the batch. While the trends in flux over the batch were similar at pH 6 and 6.5, the flux for pH 6.5 was generally lower than that achieved for pH 6. The pretreatment acid dose was approximately 30% lower to achieve a pH of 6.5 compared to that needed to achieve pH 6. In addition to lower chemical consumption, operation at pH 6.5 requires less acid, which results in less sulfate in the feed water and less sulfate in the VSEP permeate. The capital and operational trade-offs resulting from the degree of acid adjustment will need to be considered during detailed engineering.

5.1.3 Recovery

In general, higher recovery results in less final VSEP concentrate volume, which has the advantages of (1) minimizing the volume of VSEP concentrate that must be conveyed or otherwise managed on full-scale and (2) maximizing the sulfate concentration in the VSEP concentrate that will be treated at the WWTF by chemical precipitation under the wastewater management approach outlined in Figure 1. A range of recoveries were tested during the pilot-test, based on the results of the pretreatment investigations. Figure 20 shows the results from batches ranging from 80 to 90% recovery. The batches in the figure were pretreated with 10 ppm NLR 759 and sulfuric acid. The pH was adjusted to pH 6 at the beginning of each batch and again at approximately 60% recovery. The system flux was stable at all recoveries tested, however at 90% recovery, a noticeable decline in flux was observed and the membranes required more chemical cleaning after every batch to restore the system flux.

5.1.4 Cleaning

The VSEP membranes must be cleaned on a regular basis. As part of the optimization investigations, several different cleaning strategies were evaluated. Typically for membranes, including standard RO membranes, a two-step cleaning procedure is employed: an acid clean and a basic clean. The acid clean removes scale and foulants such as carbonate minerals and some metals. The basic cleaning step removes organic materials, silica, and biofilms. For the VSEP, three types of cleanings were tested:

- Hot water flush – no chemicals
- Acid clean – using a proprietary cleaning solution from New Logic Research, NLR 404
- Basic clean – using a proprietary cleaning solution from New Logic Research, NLR 505

When only antiscalant was used for chemical pretreatment, the membrane flux was shown to be restored most effectively by NLR 404, suggesting that acid-soluble minerals were limiting the recovery of the membrane. When both antiscalant and acid were used for pretreatment of the batch feed solution, NLR 505 was most effective in restoring membrane flux, suggesting that different components, possibly organic compounds or silica, were limiting recovery under those operating conditions.

Samples of spent cleaning solutions were collected and analyzed during pilot-testing. Table 12 summarizes the resulting analytical data for two cleanings with NRL 505 and one hot water flush using RO permeate. For all cleanings, the spent cleaning solution contained elevated concentrations of chemical oxygen demand (COD). NRL 505 is an organic surfactant and expected to exhibit some COD, however elevated COD was also observed in the hot water flush waste. This indicates some possible accumulation of some organic material on the membranes. Additionally, barium was also elevated in the hot water flush waste, indicating potential accumulation of barium sulfate on the membranes.

Three critical observations can be made about the VSEP membrane cleaning process:

- The cleanings were able to consistently restore the membrane permeability to the original (new membrane) flux (70 gfd). This suggests that irreversible fouling, which reduces membrane life, did not occur.
- Cleaning temperature is an important variable for effective cleanings. New Logic Research recommended that the chemical cleaning solutions be 50°C for the cleaning process. During piloting, cleanings at that temperature and at colder temperatures were tested. Cleanings at 50°C were much more effective at restoring membrane flux.
- Pretreatment with acid and antiscalant may reduce the cleaning frequency required. When this pretreatment is applied, hot water flushes without cleaning chemicals between batches were sometimes sufficient to restore the flux.

5.2 Removal Rates

A summary of the VSEP permeate water quality is presented in Table 13. A preliminary estimate of average removal rates is shown in Table 14 and Table 15 (concentration and mass-based, respectively). Removal rates were estimated for those parameters with detectable concentrations in the RO concentrate (VSEP feed). Many parameters are reduced on average by greater than 90%. Similar to the primary RO unit, in many instances the upper limit of removals were not determined in the routine testing because (1) the concentrations measured in the permeate were less than the method reporting limit and/or (2) the concentrations in the influent were low and close to the method reporting limit. For several metals, both of these conditions applied and supplemental testing was conducted to better quantify the removals by the VSEP system (see Section 6.0 for methods and results).

For some constituents, their removal by RO membranes is highly pH-dependent. Examples of this are ammonia, borate, and arsenite. For these compounds, over a range of pH values, they are present as unionized species. The unionized species are not well-removed by membranes. For this pilot-test, the following observations were noted:

- Ammonia: At pH values below 7, most of the ammonia is present as the ammonium ion and can be removed by the RO process. However, the pH of the feed water to the pilot RO system is approximately 7.5, reducing the amount of ammonia that can be removed. In addition, the concentration of ammonia in the influent was relatively low. The low concentration in the influent limited the estimate of quantifiable removal by the RO system.
- Boron: It is well known that boron removal at pH values below the pKa of boric acid is limited due to the lack of charge on the species. The boron removal during the pilot-testing program, while limited, was sufficient to maintain permeate concentrations below 0.5 mg/L, the Class 4A water quality standard. Specialty membranes or pH adjustment are typically required for greater boron removal.

With the exception of sulfate and boron, the VSEP permeate met the treatment targets listed in Table 3. However, as shown on Figure 1, at the full-scale WWTP, the VSEP permeate will be blended with the RO permeate prior to discharge. With blending, the pilot permeates would have a combined sulfate concentration of approximately 4 mg/L, based on 80% recovery across the primary RO system, 85% recovery across the VSEP, a primary RO permeate sulfate concentration of 1 mg/L and an overall average VSEP permeate sulfate concentration of 16 mg/L. Similarly with boron, when the VSEP permeate is blended with the RO permeate, the combined boron concentration of approximately 0.2 to 0.3 mg/L, which is less than the target water quality goal of 0.5 mg/L.

The VSEP concentrate quality was analyzed during the pilot-test and those results are presented in Table 16.

5.3 Discussion

The VSEP system performed reliably throughout the test, both with respect to water quality produced and operation and maintenance. As illustrated on Figure 1, the Project will have two wastewater treatment plants. The VSEP concentrate from the WWTP will be transported to the WWTF for treatment in the chemical precipitation process. For the WWTP, the two technical objectives for the VSEP units are:

- produce permeate that, when blended with the primary RO system's permeate, meets the water quality targets, including the anticipated 10 mg/L sulfate limit; and
- reduce the volume of the RO concentrate sufficiently such that the concentration of sulfate in the VSEP concentrate is high enough to allow removal by gypsum precipitation at the WWTF

Achievement of the second objective is supported by operating at higher VSEP recovery rates However, with the batch VSEP process, as recovery is increased, the sulfate concentration in the VSEP permeate increases because of the increasing sulfate concentration in the feed tank. Thus, the two objectives must be balanced. If operation at higher recoveries is necessary and the VSEP permeate quality degrades, it is possible to treat all or part of the VSEP permeate through the primary RO system to remove additional sulfate before discharge.

6.0 Effluent Stabilization Bench Test Results

6.1 Overview

Because RO removes dissolved constituents from water, the permeate is virtually void of minerals including low amounts of calcium and alkalinity. Additionally, RO permeate often contains elevated concentrations of dissolved carbon dioxide. The carbon dioxide is formed from the reaction of antiscalant chemicals, which are added to RO feed water to prevent calcium carbonate scaling on the membranes, with bicarbonate alkalinity already present in the feed water. The resulting permeate, with low buffering capacity and low pH, is corrosive. Prior to discharge, RO permeate must be stabilized to meet the discharge water quality targets (Table 3).

An effluent stabilization bench testing experiment was designed and executed with two main objectives: (1) identify a stabilization method (e.g., addition of minerals) that will reduce the corrosiveness of the blended RO and VSEP permeates and maintain compliance with the effluent water quality targets in Table 3, and (2) produce a non-toxic effluent. For the purposes of the bench test, “non-toxic” was defined as water that was neither acutely or chronically toxic to *C. dubia*. The measure of chronic toxicity used for this evaluation was the estimated IC25 value. Two known treatment technologies were tested to meet the above objectives:

- Hydrated lime ($Ca(OH)_2$) and carbon dioxide (CO_2) addition
- Limestone bed contactors (LBC)

The permeate used for testing was a blend of RO and VSEP permeate generated by the RO and VSEP pilot unit, blended at a 5:1 ratio (representing recoveries of 80% for the RO unit and 80% for the VSEP unit). The stabilization bench testing was conducted at Barr’s wastewater laboratory.

In addition to the final water quality targets for the stabilized water shown in Table 3, the following additional targets to measure the corrosiveness and toxicity of the blended effluent were used in this evaluation:

- Langelier Saturation Index (LSI) ≥ 0
- Calcium carbonate saturation index (SI) > 0
- 7-day chronic WET test young reproduction $\geq$ 75% young reproduction of the laboratory control water sample
- $6.5 < pH < 8.5$

LSI and SI are both indices used to measure the scaling potential of calcium carbonate. Positive values for both indices indicate scale forming water versus corrosive negative values. The treatment targets for the stabilization tests were to obtain slightly positive values for each measure.

6.2 Lime Addition Bench Test

The lime and carbon dioxide stabilization process was first modeled using PHREEQC, an aquatic equilibrium model by the United States Geological Survey (USGS). The simulation was used to estimate the lime and carbon dioxide dosages that would be required to achieve the target SI, and the resulting final pH. Table 17 displays the modeling results of the estimated optimal lime dose.

An experimental protocol was then developed using the PHREEQC model dose as a guide. The protocol included the addition of lime to the blended effluent to increase the total hardness concentration of the blended permeates, followed by addition of carbon dioxide to achieve the target SI value. The lime dose would raise the SI value of the blended effluent above the target (0.1) and the carbon dioxide would reduce it to the target value. This approach results in water with minimal carbon dioxide fugacity, which lends stability to the effluent pH and provides stable water for WET testing.

Based on the modeling results shown in Table 17, a range of hydrated lime doses were added to the blended permeates and then the water was titrated down to a pH of approximately 7.3 using carbon dioxide during the bench tests.

6.2.1 Experimental Setup

The lime addition tests were conducted in a 4-L Erlenmeyer flask. A range of hydrated lime doses (Table 18) were added to 3-L aliquots of the blended effluent and were mixed vigorously on a stir plate. The samples were then titrated to a pH of 7.3 using a 5%:95% carbon dioxide and nitrogen gas mix. Final titrated blend samples were submitted to external laboratories for analytical and WET testing.

The hydrated lime used in the bench testing experiments was 94.3% $Ca(OH)_2$.

6.2.2 Results

6.2.2.1 Stabilized Water Chemistry

Table 18 presents a summary of the stabilization bench test results. Doses 4, 5, and 6 all met the calcium carbonate scaling potential water quality targets described in Section 6.1. Dosages 1, 2, and 3 did not have enough hardness and alkalinity to result in a positive LSI or SI value, indicating the final samples were still corrosive. When the results shown in Table 18 are compared to the targeted treated water quality targets presented in Table 3, the following observations can be made:

- turbidity - dosages 4, 5, and 6 exceed the turbidity goal
- TSS – doses 4 and 6 exceed the total suspended solids goal
- aluminum – doses 3, 4, 5, and 6 exceed the aluminum goal
- total hardness – dose 6 exceeds the total hardness goal

The water quality targets not achieved were likely affected by the grade of hydrated lime, lime contact time, and dosing methods. Excess turbidity and TSS likely, in part, resulted from the experimental setup and can be mitigated. Section 6.2.3 contains additional discussion of these issues.

6.2.2.2 Whole Effluent Toxicity

The WET laboratory reports are presented in Appendix F. Based on the results from the bench testing, Dose 4 would likely produce the most stable blended effluent for the system. The LSI and SI values indicate the water would not be corrosive and the WET testing suggests the stabilized blended effluent would pass meet the WET (IC25) requirements.

Figure 21 displays the mean number of young produced per female for each dose compared to 75% of the control. Note that the raw, unstabilized water achieved a mean young production that was 53% of the control (i.e., an observable toxic effect). Doses 2-6 produced effluent that achieved a mean number of young produced per female of at least 75% of the control, suggesting that the stabilization approach reduced toxicity as intended despite the introduction of aluminum as described in the previous section. Dose 4 resulted in a mean young production higher than the control.

6.2.3 Implementation Considerations

Dose 4 was identified as the best dose for the blend of permeate tested. However, chemical dosing methods would have to be designed to avoid exceeding the treated water quality targets in Table 3.

Residual turbidity is a known operational challenge of using a lime addition to stabilize RO effluent (Reference (4)). As listed above in Section 6.2.2.1, lime doses 4 through 6 all exceeded the effluent turbidity limit. If lime addition is the chosen method of RO and VSEP effluent stabilization, effluent turbidity could be managed using the following techniques:

- High quality lime – Using high quality lime reduces the amount of inert material present to contribute to TSS and turbidity. For project implementation, the lime product used should be greater than 94% hydrated lime (purity used for bench testing) if available. High quality lime also has a high specific surface area which helps to maximize reactivity and minimize grit (Reference (5)).

- Liquid lime dosing – Dosing the lime as a liquid slurry rather than a solid provides minimal turbidity increases as less inert materials are present in liquid lime, and it avoids maintenance issues associated with dry lime (Reference (6)).
- Lime contact chamber – Contact chambers provide the necessary turbulent mixing time for the lime to fully dissolve into the blended effluent. The mixing or contact time is a key design parameter and is typically between 5-10 minutes (Reference (4)).

When the lime is initially dosed to the blended effluent, some of the dissolved carbon dioxide reacts with the lime and calcium carbonate precipitates and turns the mixture cloudy. As additional mixing time is allowed in the lime contact chamber, the remaining carbon dioxide reacts dissolving the newly formed calcium carbonate and reducing the turbidity again.

Along with turbidity, all treated water quality targets listed in Table 3 will need to be achieved in the final stabilized blended effluent. The aluminum measured in the stabilized water from the bench tests originated from the hydrated lime product. Using the measured aluminum and calcium concentrations it is estimated that the lime product used contained approximately 0.23% aluminum by weight. In order to achieve the 125 µg/L effluent aluminum concentration (Table 18), using Dose 4 the lime product would have to contain less than 961 mg aluminum/kg hydrated lime product (0.0961% aluminum). Below is a list of the closest lime suppliers to the future WWTP site and the standard aluminum concentration in their lime product:

- Graymont – hydrated lime product contains 0.2-0.4% aluminum oxide or 1,059-2,118 mg aluminum/kg hydrated lime product
- Carmeuse Lime & Stone – hydrated lime products contained on average 0.182% aluminum oxide in 2,012 or 963 mg aluminum/kg hydrated lime product
- Linwood Mining & Minerals – does not test for aluminum separately

The above concentrations indicate that identifying a supplier that can provide a lime product consistently with less than 961 mg aluminum/kg hydrated lime within a reasonable shipping distance will be an important consideration for this stabilization option.

6.3 Limestone Bed Contactor Bench Test

The limestone bed contactor (LBC) system is a semi-passive stabilization option that passes the blended effluent through a crushed limestone bed. As the blended effluent contacts the limestone media, it dissolves the limestone ($CaCO_3$) increasing both the hardness and alkalinity of the blended effluent. The rate of limestone dissolution is an important design parameter for an LBC system. Three different hydraulic loading rates were tested on three identical LBCs to identify the rate that would result in adequate introduction of hardness and alkalinity to the blended permeate.

As the effluent from the LBC columns was anticipated to still have a low LSI, due primarily to remaining dissolved carbon dioxide, air stripping and caustic addition were tested for final pH adjustment.

The objectives of this bench test were as follows:

- identify the maximum hydraulic loading rate that would achieve the treated water quality targets outlined in Section 6.1
- identify the best post-LBC treatment to achieve the treated water quality targets outlined in Section 6.1

6.3.1 Experimental Setup

The LBCs were constructed as 6-feet long, 2-inch diameter upflow columns (Figure 22). The tests were conducted using two types of limestone media:

- ¾-inch crushed landscaping limestone
- Columbia River Carbonates' Puri-Cal RO product with a particle size range of 2-3.4 mm (a product information sheet is provided in Appendix G)

Before both tests were conducted, the media was washed to remove fines. Also for both tests, the blended effluent was pumped at three different hydraulic loading rates through three identical upflow LBCs using a peristaltic pump.

The test program is illustrated in Figure 23. The first 2-L of effluent from each LBC was discarded and the next 6-L of sample from each LBC was collected for analysis. 2-L of the collected sample was sparged with compressed air, 2-L was dosed with caustic soda, and the final 2-L was left unamended. All samples were submitted for analytical and WET testing. Turbidity values were measured upon collection using a field turbidimeter.

6.3.2 Results

6.3.2.1 Stabilized Water Chemistry

The ¾-inch media resulted in an insufficient amount of alkalinity and hardness in the LBC effluent. The Puri-Cal RO product has a higher specific surface area and allowed for more $CaCO_3$ dissolution. Table 19 presents a summary of the results from the testing using the Puri-Cal RO product.

When Table 19 is compared with the targeted treated discharge water quality targets in Table 3, the following observations can be made:

- turbidity – Only the caustic dosed Rate 3 sample exceeded the goal
- total suspended solids – Only the caustic dosed, Rate 3 sample exceeded the goal
- metals – None of the samples exceeded any listed targets
- total hardness – None of the samples exceeded the target

Samples collected from the ¾-inch limestone testing were subjected to low-level mercury analysis. None of the samples had a detectable amount of mercury present, and therefore mercury was not tested for in the second round of LBC testing.

6.3.2.2 Whole Effluent Toxicity

The WET test results for limestone stabilization can be found in Appendix F. Figure 24 displays the mean number of young produced per female for the LBC treatments, compared to 75% of the control sample's reproduction. As shown in the figure, the unstabilized permeate would not likely pass the IC25 criterion. The Rate 1 no treatment and sparged samples and the Rate 2 sparged samples produced effluent that achieved a mean number of young produced per female of at least 75% of the control.

6.3.3 Implementation Considerations

The LBC bench test results suggest that a limestone bed hydraulic loading rate (HLR) of 2.4 gpm/sf using the Puri-Cal RO product, followed by air sparging is able to produce a stabilized effluent that meets the treatment targets. However, in addition to HLR, there are other factors that will need to be considered for full-scale stabilization, such as residence time and bed depth.

For upflow contactors, HLRs ranging from 1.0-17.2 gpm/sf are typical (Reference (7)). The HLR is related to the flow rate of the LBC system required for a given reactor diameter. The highest HLR that achieves the treated water quality targets minimizes the number of LBCs required to stabilize the blended effluent flow. However, HLRs that are too high can cause media blowouts causing turbidity and TSS.

The residence time of the system is related to the dissolution rate of the limestone. Typical empty bed contact times (EBCT) range from 3.6 to 30 minutes for LBC systems (Reference (7)). Required residence times are related to the limestone media size. Larger diameter media has lower specific surface area which requires longer residence times to allow for adequate dissolution of the media.

After the residence time and the HLR are defined, the volume and therefore the bed depth of the LBC can be calculated. The calculated bed depth represents the minimum depth of media required to meet the treatment targets that must always be maintained.

As mentioned above, LBC systems are semi-passive. The limestone will need to be replaced periodically as it dissolves. If the blended permeate is applied at 2.4 gpm/sf to the LBCs and the system is operated 24 hours/day, then 3.38 pounds of limestone per day per square feet of LBC will need to be replaced. How often media is replenished to the LBCs or the available equipment sizes will determine the additional bed height above the minimum that will be added.

Sparge systems are added as a post treatment following the LBCs to strip any excess dissolved carbon dioxide remaining in the effluent. The dissolved carbon dioxide will likely off gas at the discharge point if not removed at the treatment site. Off gassing will cause a pH increase which is known to contribute to failed WET tests. Stripping the carbon dioxide before it reaches the final discharge point will produce a more pH stable water.

Upflow contactors were constructed for this bench test and are the most common LBC, but downflow contactors are also used. Upflow reactors typically result in a lower effluent turbidity and do not require backwashing, but an internal top screen does need to be used to prevent calcite from blowing out of the reactor. Downflow reactors provide calcite dissolution and sediment filtration. Disadvantages of downflow configurations include required backwashing, high turbidity waste streams, increased risk of TSS in the treated effluent from fines breakthrough, and higher capital and operational and maintenance costs (Reference (7)).

The upflow configuration was selected for this application because of the typically lower turbidity effluent and no backwashing requirement.

6.4 Discussion

The results of effluent stabilization bench testing indicated that WWTP effluent can be effectively stabilized via either lime/carbon dioxide treatment or LCB/air sparging. The results also showed that both methods are capable of reducing whole effluent toxicity of the WWTP effluent. Both methods have implementation considerations that must be evaluated further during design.

7.0 Metals Seeding and Arsenic Removal Tests

7.1 Overview

During the development of the SDEIS, the Minnesota Pollution Control Agency (MPCA) and Minnesota Department of Natural Resources (MDNR) inquired about the removal of certain metals across the RO system. These metals included: aluminum (Al), antimony (Sb), arsenic (As), boron (B), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), lead (Pb), mercury (Hg), nickel (Ni), selenium (Se), thallium (Tl), and zinc (Zn). Although these metals were not the primary focus of the pilot-test program, for some of these metals, sufficient data were collected during the routine pilot-testing program (see Table 9, Table 14, and Table 15) to evaluate removal efficiencies. As can be seen in the tables, for several metals, the removal rates are indicated as "greater than" a numerical value. This was primarily due to the very low influent concentrations of the metals. The calculation of the removal rates was limited by this and the method reporting limits in the RO permeate.

A further evaluation of metal removal efficiencies was completed by obtaining additional information via three methods:

- For those metals for which soluble salts could be readily obtained and safely handled, metals were added to the pilot-plant influent to experimentally determine the removal efficiencies across the RO and VSEP systems, and in the case of arsenic, also across the greensand filter.
- For those metals that could not be safely handled at the pilot-plant site or for which soluble salts were not available, a review of the scientific literature was conducted to summarize removal rates that have been observed by researchers in other applications.
- The RO membrane supplier, GE, was asked for additional data to support the observed removal rates for these metals across the membrane being used for this pilot-testing project.

The section summarizes the metals removal data and information that has been collected during the pilot-test, from the literature, and from the RO membrane supplier. The RO and VSEP processes will also be used for treatment of the West Pit lake overflow during long-term closure at the WWTF. The future water quality of the West Pit Lake overflow is generally similar in composition to the water that has been tested during piloting with the inclusion of the metals testing described in this section. For this reason, the performance of the treatment processes for treatment of the West Pit lake overflow during long-term closure is expected to be similar.

7.2 Methodology

7.2.1 Metals Seeding Test

For several metals that were not present in the influent in sufficient concentrations to determine the removal efficiencies, a test was conducted in which solutions of metals salts were added to the pilot-plant influent. The objective of this experiment was to better quantify the removal rates of As, Co, Cu, Ni, Pb, Se, and Zn across the RO and VSEP pilot-systems. These metals were added downstream of the greensand filter. The dosing and sampling locations are shown in Figure 25. Samples from the treatment train were collected during this test and analyzed for the metals under investigation. Because of the limited solubilities of some of the metals salts, three separate stock solutions were prepared and tested separately. These solutions were prepared as shown in Table 20, Table 21, and Table 22. The target doses correspond to the highest projected 90th percentile annual average concentration in the influent to the WWTP for any year, from the GoldSim water quality model for the Project for the first 20 years of operation. The metal salts selected for this experiment for As, Co, Pb, and Se were their reduced forms (i.e., As(III), Co(II), Pb(II), Se(IV)). Typically, the more oxidized species (arsenate versus arsenite or selenate versus selenite, for example) are larger and/or more ionized than the reduced forms and therefore are expected to have greater removal efficiency across the membranes. Thus, using the reduced forms of these constituents was expected to provide a conservative (i.e., worst case) estimate of removal.

Twenty gallons of each stock solution was made using RO permeate and reagent salts purchased from Fisher Scientific. The 20-gallon volume of metal stock solution provided approximately 15 hours of runtime of the RO unit for each of the three solutions.

The rejection of constituents by RO membranes can be influenced by a number of factors, including water temperature, water composition (other bulk ions), membrane age, membrane system recovery, the membrane system flux, and the membrane material. For this test, the operating conditions used were the same as used during the longer-term testing (Phases 4 and 5):

- RO system
    - recovery: 80%
    - flux: 16 gfd
    - membrane: GE AK-90 LE
    - antiscalant: GE Hypersperse MDC150 at 2.2 ppm

- VSEP system
  - recovery: 85%
  - flux: varies as the batch is processed
  - membrane: Hydranautics ESPA
  - antiscalant: NLR759 at 10 ppm
  - pH adjustment: feed adjusted to approximately 6.5 at the beginning of the batch using sulfuric acid

7.2.2 Arsenic Removal Test

A common method to remove arsenic from drinking water is greensand filtration. In the WWTP, if greensand filtration is employed as pretreatment to the RO system, it would be expected to remove the majority of the arsenic from the influent, rather than the RO system. For this reason, a separate 1-day experiment was conducted to determine the arsenic removal across the greensand filter. The experimental setup is illustrated in Figure 26. For this experiment, sodium arsenite was added to the pilot-plant feed tanks to a target concentration of 100 µg/L. The potassium permanganate dose at the greensand filter was 4 mg/L, the same dose that has been used since the oxidant dose optimization study conducted in August 2012. The arsenic concentrations in the feed tank effluent, greensand filter effluent, RO permeate, and RO concentrate were monitored during the test. The greensand filter was backwashed prior to the test to remove iron and other accumulated total suspended solids.

7.3 Results

7.3.1 Metals Seeding Test

Table 23 presents a summary of the analytical data collected during the metals seeding test for the RO and VSEP pilot-units. Calculated removal rates are presented in Table 24 (RO) and Table 25 (VSEP).

7.3.1.1 GE RO Pilot-Unit

As can be seen in Table 24, the metals seeding test allowed the determination of more precise removal efficiencies for As, Co, Cu, and Ni for the GE RO pilot-unit as compared to the previous pilot-testing run. Co, Cu, and Ni were well-removed by the RO pilot-unit, with removal rates in excess of 99.75%.

The average arsenic removal across the RO membrane system was 82.13% and was 66.67% across the VSEP pilot-unit. Arsenic was added to the influent as sodium arsenite, which is mostly present as the unionized species H_3AsO_3 at the neutral pH of the influent and is therefore less well-rejected by the RO membrane. Higher removal rates would be expected at higher pH values (i.e., greater than the pKa values for H_3AsO_3) and for arsenate, which is charged at the circum-neutral pH of the influent. Removal of arsenate by the RO membrane is reported to be greater than 98% (Reference (8)). Removal of arsenic was further evaluated in the arsenic removal test.

For Pb, Se, and Zn, the added metals were removed by the RO pilot-unit to below their respective method reporting limits in the RO permeate. The resulting removal rates in Table 24 are therefore minimum removal rates under the conditions tested.

7.3.1.2 VSEP Pilot-Unit

In general, the VSEP removal rates were similar to the RO pilot-unit rates and quantifiable removal rates were able to be determined for all seeded species. Concentrations of each metal were higher in the VSEP permeate than in the RO permeate due to higher influent concentrations in the VSEP feed.

For the WWTP, blending of the RO and VSEP permeates prior to discharge is being considered in the design process. Using the measured permeate concentrations for the metals added, and the systems' recovery rates, the blended permeate metals concentrations were estimated. This information is shown in Table 26. As can be seen, all of the parameters in the blended permeate would have concentrations below the Class 2B water quality standard.

7.3.2 Arsenic Removal Test

Table 27 summarizes the analytical data collected during the arsenic removal test. During this test, the oxidation of arsenite to arsenate by potassium permanganate and its subsequent removal across the greensand filter and the RO pilot-unit were evaluated. Three sets of grab samples were collected at the locations shown in Figure 26 during the 1-day test run. The feed tank As concentrations were observed to increase throughout the run. This likely reflects physical limitations to feed tank mixing at the pilot-test site. The concentrations, however, spanned the target influent concentration of 100 µg/L. The calculated removal rates are presented in Table 28. Arsenic was very well-removed by the greensand filter – producing filter effluent with arsenic concentrations that were well below the Class 2B water quality standard for all three sampling events.

7.3.3 Literature Review and Vendor Information

As indicated in the preceding sections, it was not possible to determine the removal efficiencies for some metals due to either low solubility of their available salts, or safety considerations at the pilot-plant site. For those metals that could not be tested, a review of the scientific literature was conducted. The sections below summarize the information obtained from GE and from the literature. A summary is also provided in Table 29.

7.3.3.1 Aluminum

RO is not typically employed for the removal of aluminum in water due to its potential to foul the membranes, and the resulting negative impacts on recovery and flux. Aluminum in feed water to a RO membrane can form colloidal aluminum oxides. Colloidal aluminum-silicates will also form if silicon is present above 10 mg/L and the pH is near 6.5 (Reference (9)). Gabelich et al. (Reference (10)) found that reducing the influent total aluminum to less than 50 μg/L significantly reduced membrane fouling and improved membrane performance. Operating at influent pH values less than five can reduce membrane fouling by reducing aluminum hydroxide formation (Reference (8)).

Removal of aluminum in tap water by RO to below the method detection limit has been documented (Reference (11)); however, the study makes no mention of fouling, long-term treatability or feasibility especially on the industrial scale. Published rejection rates for aluminum in RO membranes in peer-reviewed literature were otherwise limited. An RO vendor website (Pure Water Products) suggested that aluminum rejection rates of 99% are possible at the commercial scale. It is likely that due to aluminum’s relatively low solubility, it would primarily be removed upstream of the RO membrane through colloidal precipitation and filtration. Consequently, the RO system would likely receive very little dissolved aluminum.

7.3.3.2 Antimony

Antimony has been reported to be removed by RO membranes at efficiencies ranging from 99 to 99.2% at the bench scale (Reference (12); Reference (13)). The rejection of antimony was reportedly not affected by solution pH or the valence state of the antimony (+3 or +5), (Reference (14)). A personal communication with Paul DiLallo of GE suggested (Reference (8)) that antimony will be removed similarly to calcium (99.3% rejection during pilot-testing).

7.3.3.3 Cadmium

Cadmium rejection has been reported to be 99 to 99.4% at the bench scale and full scale, respectively (Reference (15), Reference (16)). A personal communication with Paul DiLallo of GE suggested (Reference (8)) that cadmium will be removed similarly to calcium (99.3% rejection during pilot-testing).

7.3.3.4 Chromium

Chromium rejection by RO membranes is reportedly high, at 98 to 99.5%, across a wide range of membranes at the pilot- and bench-scale (Reference (16), Reference (17)). A full scale tannery wastewater plant treating high concentrations of influent hexavalent chromium (500-3,000 mg/L) and NaCl (30,000 to 50,000 mg/L) was able to achieve maximum chromium rejection of approximately 80% (Reference (18)). Only one paper specifically tested rejection of chromium in both its +3 and +6 state (Reference (16)). The author did not report a significant difference in rejection between chromium in the +3 and +6 state. A personal communication with Paul DiLallo of GE suggested (Reference (8)) that chromium will be removed similarly to calcium (99.3% rejection during pilot-testing).

7.3.3.5 Mercury

Mercury removal by RO membranes is highly dependent on the type of membrane used. Mercury rejections ranging from 22 to 99.9% have been reported. The chemical state of the mercury is also an important factor in mercury removal. Urgun-Demirtas et al. (Reference (19)), found that mercury in the colloidal or particulate form was easily removed but that free mercury was removed at a lesser rate. Rejection values for organic mercury by RO membranes could not be found in the peer-reviewed literature, but one RO membrane vendor (DuPont) and the University of Nevada – Cooperative Extension claim that methyl mercury cannot be removed across a RO membrane.

Paul Dilallo of GE indicated in a personal communication (Reference (8)) that the rejection for mercury is estimated to be approximately 70%.

7.3.3.6 Thallium

A rejection value for thallium across a reverse osmosis membrane was only found in one published source: a 1983 review paper in the journal Desalination (Reference (20)) that categorized a list of metals including thallium as having rejection rates between 90 and 100%.

Paul Dilallo of GE who supplied the membranes used for pilot-testing indicated (Reference (8)) that thallium should have a similar rejection to calcium (average of 99.3% during pilot-testing).

It is also possible that some thallium will be removed prior to the RO unit (in pretreatment) due to its relatively low solubility.

7.4 Discussion

For the metals of interest to the MPCA and MDNR for the Project, removal from the WWTP influent by the proposed treatment train has been evaluated using pilot-testing, a review of the scientific literature, and by inquiry to the membrane supplier. The following conclusions can be made:

- Arsenic is expected to be removed primarily across the greensand filter, rather than the RO unit. Removal of As by the greensand filter of up to 99.68% was observed on the pilot-scale.
- Boron removal by RO membranes is highly dependent on the influent pH. It is well known that boron removal at pH values below the pKa of boric acid is limited due to the lack of charge on the species. The boron removal during the pilot-testing program, while limited, has been sufficient to maintain permeate concentrations below 0.5 mg/L, the Class 4A water quality standard. Boron concentrations are estimated by the GoldSim model to decrease over time from their current value, so future concentrations experienced by the full-scale WWTP will be less than that experienced by the pilot-units.
- Cobalt, copper, lead, nickel, selenium, and zinc were observed to be well-removed by the membrane systems, producing a blended permeate with concentrations below the Class 2B water quality standard.
- Cadmium and chromium are likely to be well-removed by the membranes, similar to the other heavy metals tested (copper, cobalt, lead, and zinc).
- Aluminum is a known foulant for RO membranes, especially at concentrations greater than 50 µg/L. If necessary, aluminum removal is likely to be via pretreatment in order to preserve membrane performance, rather than be removed by the RO membranes themselves.
- Limited information is available on the removal of thallium by RO membranes, but the reported rejection is in the range of 90 to 100%. Like lead, thallium is sparingly soluble under most conditions. Additional removal of both lead and thallium by RO pretreatment is possible, depending on the water chemistry conditions. Thallium concentrations in the influent to the WWTP are estimated by the GoldSim model to be below the Class 2B water quality standard.
- The scientific literature suggests that antimony will be removed by the RO membranes at rates of greater than 99%. Antimony is also sparingly soluble and additional removal may occur in pretreatment, prior to the RO system.

Mercury removal by RO is highly variable and dependent upon its speciation and the membrane selection. For these reasons, its removal is difficult to quantify. However, mercury concentrations in the WWTP influent during operations were not estimated by the GoldSim model.

8.0 Chemical Precipitation Bench Test Results

This section summarizes the objectives, methodology, and results for the bench testing performed using samples of VSEP concentrate.

8.1 Objectives

The objectives of the VSEP concentrate chemical precipitation bench test were to:

- determine if oxidative pre-treatment is necessary to free metals from anti-scalants prior to treatment via chemical precipitation
- for the high density sludge (HDS) metals process:
  - evaluate the degree of metals adsorption by iron oxyhydroxide sludge at various pH setpoints, sludge concentrations
  - evaluate the effect of two reaction times on the degree of metals adsorption by iron oxyhydroxide sludge
  - evaluate the required overflow rate/settling time for HDS solids
- for the sulfate (gypsum) precipitation process:
  - evaluate the degree of sulfate precipitation achieved by lime treatment/gypsum solids contact
  - evaluate the effect of two reaction times on the degree of sulfate removal
  - evaluate the effect of gypsum solids concentration on the degree of sulfate precipitation
  - evaluate the required overflow rate (settling time) for gypsum solids

8.2 Oxidative Pre-Treatment

8.2.1 Protocol

An initial screening test was conducted to evaluate whether or not oxidative pre-treatment is necessary to destroy antiscalants prior to chemical precipitation. An aliquot of VSEP concentrate was oxidized using potassium permanganate, added drop-wise while mixing, watching for the pink color to dissipate between drops. At the point where the pink color persisted, permanganate addition was ceased and the pre-treated water (along with an un-oxidized control) was subjected to the tests summarized in Table 30, at a 60 minute reaction time.

The water resulting from the screening tests was analyzed for the following parameters to determine if pre-treatment may be necessary for effective removal of metals and sulfate via chemical precipitation:

- metals HDS screening – Dissolved As, Sb, Be, B, Cr, Co, Cu, Fe, Pb, Mn, Ni, Se, Zn
- sulfate precipitation screening – Dissolved calcium, aluminum, dissolved sulfate

8.2.2 Results

The results of the oxidative pre-treatment screening test are in Table 31. The following conclusions can be drawn from the results:

- oxidative pre-treatment generally did not improve the removal of sulfate of metals relative to the un-oxidized control
- concentrations of dissolved metals in the untreated VSEP concentrate were generally low

Based on these results, it was decided to proceed with the other precipitation tests without the use of oxidative pre-treatment, and to increase the concentrations of metals in the VSEP concentrate by spiking with metals salt solutions.

8.3 Chemical Precipitation Testing

8.3.1 Protocol

8.3.1.1 Metals Spiking

As described in the previous section, the results of the oxidative pretreatment screening indicated that concentrations of several target metals were lower than anticipated future levels in the VSEP concentrate. It was therefore decided to spike the VSEP concentrate with higher concentrations of metals.

The elements cobalt, copper, nickel, arsenic, selenium, zinc and lead were chosen to be spiked into the untreated VSEP concentrate that represent the 90th percentile annual average concentrations anticipated in the VSEP concentrate for the design year at the Mine Site (Table 32).

Because of safety and disposal concerns associated with the creation of the stock solutions necessary to add these chemicals at the appropriate dose, the stock solutions that had already been prepared for the metals seeding test were used to add these metals to the water. The metals stock solution #1 has five metals at the concentrations indicated in Table 33. As a result of using this stock solution, it was not possible to exactly achieve the 90th percentile design year concentration for each individual metal. As such, it was decided to add a volume of stock solution to ensure that all 90th percentile concentrations were met or exceeded for: cobalt, copper, nickel, arsenic and zinc. The 90th percentile concentrations for selenium and lead were met exactly because those metals had been prepared as separate individual stock concentrations.

It should also be noted that, in the case of arsenic and selenium, the reduced species of these constituents were added. In the case of arsenic, the reduced species adsorbs less strongly to iron oxyhydroxides. In the case of selenium, the reduced species adsorbs more strongly.

8.3.1.2 HDS Metals Jar Tests

The HDS sludge was prepared by adding lime to 35% ferrous chloride solution until a pH of 7.5 was achieved. Air was then bubbled through the solution to oxidize the iron until all of the solution was a dark rusty red color. The solution was then centrifuged to separate the iron solids from the water, and washed three times with deionized (DI) water to remove excess chloride. The final solids content of the resulting ferric hydroxide sludge was measured at 26% (± 1%) by oven drying at 105°C.

The HDS Metals test was conducted in a series of jars. Each batch consisted of four jars filled with 1 liter of metal-spiked VSEP reject and dosed with the appropriate amount of iron oxyhydroxide sludge to achieve the desired solids content. The pH was adjusted using sulfuric acid or sodium hydroxide (as appropriate) to meet the target pH values specified in Table 33.

The jars were mixed using a Phipps and Bird jar tester. For each batch, samples were collected from each of the four jars after 30 and 60 minutes of mixing. The samples were then filtered through a 0.45 µm filter, and submitted to Legend for dissolved metals analysis. This sampling approach was intended to provide data regarding the degree to which dissolved metals adsorbed to the sludge at two different reaction times. The target analytes for dissolved and total metals analysis are provided in Table 34.

The residual water volume from the three iron solids contents at each pH was combined for use in subsequent settling tests. The residual water was diluted to 2L of volume with DI water and the anionic polymer flocculant Nalclear 7768 was added at 100 mg/g-iron solids to aid in settling. A settling test was performed using 2-L B-KER^2 jars, collecting settled water via the side sample port at 2, 4, and 6 minutes and analyzing for the total metals listed in Table 34. The intent of this approach was to evaluate the sensitivity of metals removal to settling time of the sludge. To that end, iron, along with cobalt and arsenic (the two most sensitive metals from a water quality target standpoint) were selected for total metals analysis in the settled water.

8.3.1.3 Sulfate Precipitation Jar Test

Gypsum sludge was prepared by reacting sodium sulfate and calcium chloride together to form gypsum precipitate. The precipitated gypsum was separated from the water via filtration and washed with a solution of calcium hydroxide (pH 12) to remove excess sodium, chloride, and sulfate. The solids content was determined by drying in an oven at 105°C.

This test was conducted in batches consisting of two 2-L jars filled with VSEP concentrate. The appropriate amount of gypsum solids were added to the jars, and the pH was adjusted to the desired set-point using lime slurry. The gypsum doses and target pHs used are shown in Table 35.

Samples were collected from each jar after 30 and 60 minutes of mixing, filtered via a 0.45-micron filter, and submitted to Legend for dissolved sulfate, calcium, and aluminum analysis. The intent of this approach was to evaluate the effect of time and solids content on the amount of sulfate precipitation as gypsum, as well as the contribution of added lime to the aluminum concentration of the water.

The remaining sample aliquots were allowed to settle, sampled via the side port at 2, 4, and 6 minutes and submitted to Legend for total sulfate, calcium, aluminum, and alkalinity. The intent of this approach was to evaluate the effect of settling time on the removal of precipitated gypsum and aluminum.

8.3.2 Results

8.3.2.1 High Density Sludge (HDS) Metals

Results for the HDS Metals test are in Table 36. It can be seen that removal of metals was generally good. Figure 27 through Figure 35 show the effect of time, pH, and solids content on the removal of each individual metal.

The reported analytical results suggest that the optimal concentration of iron oxyhydroxide sludge was between 0.5% and 1.5% at pH ranges greater than 8 for most metals. Selenium and chromium adsorption were less complete at higher pH values.

There was generally little difference in metals adsorption between the 30 and 60 minute reaction times. Selenium adsorption was marginally more complete at 60 minutes than at 30 minutes.

Results from the HDS sludge settling test are in Table 37, and are illustrated in Figure 36 to Figure 39. It can be seen that settling was more rapid at higher pH values. This likely was a function of not having optimized the anionic flocculant dose at each pH set-point. Had the flocculant dose been better optimized, performance likely would have been better at lower pH values. Notably, both the 4 and 6-minute settling times at the pH 10 set-point yielded cobalt and arsenic concentrations at or below the water quality targets for the WWTF. These settling times correspond with overflow rates of approximately 750 and 500 gpd/sf, respectively.

8.3.2.2 Gypsum Precipitation

Results for the gypsum precipitation test are in Table 38. It can be seen from the table that addition of 1% gypsum solids to the reaction improved sulfate removal over the 0.1% solids concentration. However, the treatment receiving 10% gypsum solids exhibited a higher concentration of sulfate than either of the lower solids concentrations. Likewise, an increase in the amount of dissolved aluminum was also observed with increasing solids concentrations. Lime is known to contain aluminum impurities, and was applied to increase the solution pH, as well as in the preparation of the gypsum solids. The gypsum solids were prepared from sodium sulfate, a soluble salt. Although the gypsum solids were washed, it is possible that they retained a high enough concentration of sulfate in the pore water to bias the results in the 10% solids sample.

Settling data for the 0.1% and 1% gypsum solids treatments is in Table 39. It can be seen from the table that the 1% solids treatment settled more rapidly than the 0.1% treatment, and approached the dissolved sulfate concentration at the 4-minute settling time. The 6 minute settling time exhibited a higher concentration of sulfate relative to 4 minutes. This is believed to be an artifact, possibly due to disturbance of the beaker during sampling.

8.4 Discussion

While future work will incorporate the results of the bench testing into the process design calculations for the Mine Site in more detail, the overall findings of the bench test comport well with the anticipated operating conditions and performance for the WWTF.

- Preliminary process modeling conducted to-date suggests optimal pH between 9 and 10 for metals removal via the HDS process. This range is supported by the bench testing data.
- Preliminary process modeling suggests an iron oxyhydroxide sludge concentration of approximately 1% in the HDS reactors for adequate removal of target metals. This is value is supported by the bench testing results.

- The observed bench testing results for sulfate precipitation are within the range suggested by preliminary process modeling.
- Preliminary process calculations assumed a reaction time of 60 minutes for both metals and sulfate removal processes. This time scale appears to be sufficient based on the bench testing results, and some reactions may achieve completion more rapidly than currently assumed.
- Preliminary process calculations assumed an overflow rate of 500 gpd/sf, which is supported by the bench test results.

Overall, the effects of antiscalants and high ionic strength of the VSEP concentrate were insufficient to inhibit removal of metals or sulfate beyond what is already anticipated in the preliminary process calculations. This is a significant finding, as the VSEP concentrate represents a worst-case scenario for these effects.

Some additional consideration of the contribution of lime to effluent aluminum concentrations in the chemical precipitation effluent is anticipated based on the results of this testing. It may be possible to optimize operation of the recarbonation process, which follows the gypsum precipitation process, to enhance removal of residual aluminum from the effluent.

9.0 Applicability to Future Conditions

A central goal of pilot-testing program was to verify that the core treatment technology selected for the WWTP – reverse osmosis – could reliably meet the water quality objectives for the Project, particularly for sulfate. Of equal importance to the feasibility of implementing RO for the Project was demonstration that the RO concentrate could be successfully managed. Both objectives were met during the pilot-testing program. It is understood that the quality of the influent to the WWTP may change over time, and that this may result in modifications to the WWTP around the core treatment technology, and hence the WWTP is considered an adaptive mitigation tool for the Project.

Table 40 provides a comparison of the pilot plant influent water quality with the Mine Year 20 Plant Site and Mine Year 75 Mine Site influent water quality estimates from the GoldSim project models. Particularly when the metals seeding tests are considered, the pilot-testing program included similar water qualities to what is estimated the full-scale treatment plants may experience in the future. In the event that influent concentrations exceed those estimated by GoldSim or if removal rates for metals or other constituents are less than observed on the pilot-scale or in the literature, several treatment systems modifications are possible to improve performance. Potential modifications could include:

- **Pretreatment modifications:** Pretreatment modifications may include changes to the methods used to protect the RO membranes from scaling and fouling or to otherwise optimize the performance of the RO system. The greensand filter used for the pilot-test performed well, but in the future, other options that could be considered include:

    - Additional iron removal prior to the greensand filter to reduce iron loading to the filter
    - Modifications to the antiscalant selection and/or dose
    - Softening or acid addition to reduce the scaling potential of the influent
    - Addition of chemical scavengers to improve metals removal

- **Post-treatment modifications:** The RO or VSEP permeates, if necessary, could undergo further treatment to improve water quality prior to discharge. Post-treatment modifications that could be considered include:

    - Additional treatment of the VSEP permeate through the primary RO system
    - Addition of polishing treatment units for removal of trace metals (e.g., ion exchange).

- **Treatment modifications:** Modifications to the core treatment technologies to improve treated water quality could include modifications to the membrane selection.

10.0 Summary and Conclusions

PolyMet has completed an extensive 7-month pilot-testing program in support of the proposed design for the WWTP. The pilot-testing program tested all of the major treatment components proposed for the WWTP: media (greensand) filtration, reverse osmosis, concentrate management, and effluent stabilization. Of central importance, it was demonstrated that reverse osmosis is a reliable and technically feasible treatment technology to meet the Project water quality objectives. Additionally, the RO concentrate can be successfully managed using volume reduction (VSEP) and chemical precipitation technologies.

The pilot-testing program yielded several very important results, including the following for the RO system:

- throughout the testing program, the RO system has consistently produced permeate with sulfate concentrations less than 10 mg/L
- the pretreatment selected for the RO system—greensand filtration and antiscalant addition—were effective in maintaining stable RO performance
- the RO system did not experienced significant fouling or scaling during the testing program
- the RO was operated at a recovery of 80%, which is within the range initially targeted for the WWTP

The VSEP pilot-test yielded the following results:

- The VSEP sulfate removal efficiency averaged 99.3%. Under the pilot-test conditions, when the VSEP and RO permeates are blended, the sulfate concentration is less than 10 mg/L.
- The VSEP system demonstrated recoveries ranging from 80 to 90%, within the Project objectives.
- No irreversible fouling was observed during the course of testing. Once cleaning optimization was complete, the membrane flux was restored to its original flux after each cleaning.
- No decline in sulfate removal has been observed over time.

The discharge from the future WWTP will be a blend of RO and VSEP permeates. Testing was conducted on methods to adjust the pH and reduce the corrosiveness of the blended permeates. The permeate stabilization bench testing results produced the following conclusions:

- lime addition
    - lime addition was able to adjust the pH and meet most water quality targets, including measures of corrosiveness
    - two important factors were identified in the test that would need to be considered on a full-scale design
    - quality of lime used (to reduce turbidity from inert materials and minimize unwanted aluminum in the discharge)
        - method of lime addition and reaction to minimize residual turbidity
- limestone contactor
    - the limestone contactor was able to adjust the pH and meet all water quality targets, including measures of corrosiveness.
    - additional treatment after limestone contactor was needed to remove remaining carbon dioxide (e.g., air sparging).

Supplemental testing was conducted at the end of the pilot-test to (1) better quantify the removal of certain metals across the pilot treatment train and (2) to simulate the treatment processes that will be employed at the WWTF using the VSEP concentrate.

The metals removal test yielded the following results for the RO and VSEP systems:

- Arsenic is expected to be removed primarily across the greensand filter, rather than the RO unit. Removal of arsenic by the greensand filter of up to 99.68% was observed on the pilot-scale.
- Cobalt, copper, lead, nickel, selenium, and zinc were observed to be well-removed by both the RO and VSEP systems, producing a blended permeate with concentrations below the Class 2B water quality standard.

Chemical precipitation bench testing was performed using VSEP concentrate to test performance of the treatment processes contemplated for the WWTF under worst-case conditions (i.e., presence of anti-scalants and high ionic strength). The results of this testing indicated that oxidative pre-treatment of the VSEP concentrate is not likely required, and that performance and behavior of the contemplated treatment processes are similar to what is expected based on preliminary process calculations. The bench testing identified aluminum content of the lime reagent as a design consideration. The bench testing results will be incorporated into future design calculations as appropriate.

The initial design for the WWTP will be based on the results of the pilot-testing. Because the WWTP is considered an adaptive engineering control, provisions for expansion of the plant and changes to the operating configuration of process units will be incorporated into the full-scale design to match the results of ongoing water quality monitoring and modeling efforts.

11.0 References

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Tables

Table 1 **SD004 Water Quality**

	Location	**SD004**	**SD004**	**SD004**	**SD004**	**SD004**	**SD004**	**SD004**	**SD004**	**SD004**	**SD004**
	Date	**5/14/2012**	**5/21/2012**	**5/29/2012**	**6/4/2012**	**6/11/2012**	**6/19/2012**	**6/26/2012**	**7/5/2012**	**7/10/2012**	**7/17/2012**
	Sample Type	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**
	Fraction										
General Parameters											
Alkalinity, bicarbonate, as CaCO3	NA	**510 mg/l**	**520 mg/l**	**530 mg/l**	**510 mg/l**	**510 mg/l**	**500 mg/l**	**520 mg/l**	**510 mg/l**	**520 mg/l**	**520 mg/l**
Alkalinity, carbonate, as CaCO3	NA	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	--	--	--	--	--
Alkalinity, total	NA	**510 mg/l**	**520 mg/l**	**530 mg/l**	**510 mg/l**	**510 mg/l**	**500 mg/l**	**520 mg/l**	**510 mg/l**	**520 mg/l**	**520 mg/l**
Carbon, dissolved organic	NA	**2.1 mg/l**	**2.5 mg/l**	**7.9 mg/l**	**3.8 mg/l**	**3.1 mg/l**	**2.1 mg/l**	**2.2 mg/l**	**2.9 mg/l**	**2.1 mg/l**	**2.3 mg/l**
Carbon, total organic	NA	**2.4 mg/l**	**2.3 mg/l**	**14 mg/l**	**2.0 mg/l**	**2.6 mg/l**	**2.3 mg/l**	**2.3 mg/l**	**3.0 mg/l**	**2.3 mg/l**	**2.5 mg/l**
Chloride	NA	**23 mg/l**	**22 mg/l**	**21 mg/l**	**21 mg/l**	**22 mg/l**	**22 mg/l**	**21 mg/l**	**22 mg/l**	**21 mg/l**	**21 mg/l**
Fluoride	NA	**1.7 mg/l**	**1.7 mg/l**	**1.7 mg/l**	**1.7 mg/l**	**1.7 mg/l**	**1.8 mg/l**	**1.8 mg/l**	**1.7 mg/l**	**1.8 mg/l**	**1.8 mg/l**
Nitrogen, ammonia (NH3), as N	NA	< 0.500 mg/l	< 0.500 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	**0.219 mg/l**	< 0.200 mg/l	< 0.200 mg/l
Nitrogen, Nitrate as N	NA	< 1.0 h mg/l	< 0.23 mg/l	< 0.22 mg/l	< 0.22 mg/l	< 0.23 mg/l	< 0.23 mg/l	< 1.0 mg/l	< 0.23 mg/l	< 0.23 mg/l	< 0.23 mg/l
Nitrogen, Nitrite as N	NA	< 0.20 mg/l	< 0.30 mg/l	< 0.30 mg/l	< 0.30 mg/l	< 0.30 mg/l	--	--	--	--	--
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	--	--	--	--	--
pH	NA	**7.9 pH units**	**7.8 pH units**	**7.7 pH units**	**7.8 pH units**	**7.7 pH units**	**7.9 pH units**	**7.9 pH units**	**7.8 pH units**	**7.7 pH units**	**7.6 pH units**
Phosphorus, total	NA	**0.015 mg/l**	**0.013 mg/l**	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l
Silicon dioxide	NA	**22.5 mg/l**	**26.8 mg/l**	**32.1 mg/l**	**38.7 mg/l**	**37.8 mg/l**	**38.7 mg/l**	**37.3 mg/l**	**35.7 mg/l**	**40.4 mg/l**	**36.4 mg/l**
Solids, total dissolved	NA	**1300 mg/l**	**1200 mg/l**	**1400 mg/l**	**1200 mg/l**	**1200 mg/l**	**1100 mg/l**	**1300 mg/l**	**1100 mg/l**	**1100 mg/l**	**1200 mg/l**
Solids, total suspended	NA	**10 mg/l**	**14 mg/l**	**15 mg/l**	**15 mg/l**	**42 mg/l**	**8.0 mg/l**	**22 mg/l**	**110 mg/l**	**9.2 mg/l**	**13 mg/l**
Specific Conductance @ 25oC	NA	**1500 µmhos/cm**	**1600 µmhos/cm**	**1600 µmhos/cm**	**1600 µmhos/cm**	**1600 µmhos/cm**	**1700 µmhos/cm**	**1700 µmhos/cm**	**1600 µmhos/cm**	**1700 µmhos/cm**	**1600 µmhos/cm**
Sulfate	NA	**460 mg/l**	**490 mg/l**	**500 mg/l**	**500 mg/l**	**370 mg/l**	**500 mg/l**	**490 mg/l**	**420 mg/l**	**490 mg/l**	**490 mg/l**
Sulfide	NA	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	--	--	--	--	--
Metals											
Aluminum	Total	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l
Arsenic	Total	**2.7 µg/l**	**3.0 µg/l**	**2.5 µg/l**	**2.1 µg/l**	**4.9 µg/l**	**2.4 µg/l**	**3.0 µg/l**	**20 µg/l**	**3.3 µg/l**	**3.1 µg/l**
Barium	Total	**32 µg/l**	**35 µg/l**	**35 µg/l**	**33 µg/l**	**45 µg/l**	**32 µg/l**	**32 µg/l**	**140 µg/l**	**32 µg/l**	**35 µg/l**
Boron	Total	**0.48 mg/l**	**0.47 mg/l**	**0.49 mg/l**	**0.45 mg/l**	**0.48 mg/l**	**0.47 mg/l**	**0.46 mg/l**	**0.46 mg/l**	**0.49 mg/l**	**0.50 mg/l**
Cadmium	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	--	--	--	--	--
Calcium	Total	**88 mg/l**	**92 mg/l**	**96 mg/l**	**90 mg/l**	**94 mg/l**	**88 mg/l**	**90 mg/l**	**90 mg/l**	**92 mg/l**	**91 mg/l**
Cobalt	Total	**1.0 µg/l**	**1.0 µg/l**	**1.0 µg/l**	**0.81 µg/l**	**1.1 µg/l**	**1.0 µg/l**	**0.84 µg/l**	**1.6 µg/l**	**1.0 µg/l**	**0.97 µg/l**
Copper	Total	**1.8 µg/l**	**3.7 µg/l**	**2.7 µg/l**	< 0.50 µg/l	**2.9 µg/l**	**2.4 µg/l**	**2.3 µg/l**	**2.9 µg/l**	**2.3 µg/l**	**2.9 µg/l**
Iron	Dissolved	**0.070 mg/l**	**8.2 mg/l**	**0.89 mg/l**	**0.66 mg/l**	**0.44 mg/l**	**0.76 mg/l**	**0.64 mg/l**	**0.66 mg/l**	**1.2 mg/l**	**1.3 mg/l**
Iron	Total	**4.4 mg/l**	**7.0 mg/l**	**5.0 mg/l**	**5.3 mg/l**	**12 mg/l**	**3.9 mg/l**	**8.6 mg/l**	**75 mg/l**	**4.8 mg/l**	**6.9 mg/l**
Lead	Total	< 0.20 µg/l	**1.4 µg/l**	**0.42 µg/l**	**0.93 µg/l**	**0.77 µg/l**	**0.32 µg/l**	**0.45 µg/l**	**0.71 µg/l**	**0.41 µg/l**	**0.61 µg/l**
Magnesium	Total	**170 mg/l**	**190 mg/l**	**180 mg/l**	**170 mg/l**	**170 mg/l**	**170 mg/l**	**180 mg/l**	**150 mg/l**	**170 mg/l**	**180 mg/l**
Manganese	Dissolved	**530 µg/l**	**430 µg/l**	**530 µg/l**	**570 µg/l**	**600 µg/l**	**560 µg/l**	**580 µg/l**	**670 µg/l**	**570 µg/l**	**540 µg/l**
Manganese	Total	**570 µg/l**	**590 µg/l**	**570 µg/l**	**570 µg/l**	**640 µg/l**	**640 µg/l**	**560 µg/l**	**900 µg/l**	**570 µg/l**	**540 µg/l**
Mercury	Total	< 0.500 ng/l	< 0.500 ng/l	< 0.500 ng/l	--	--	--	--	--	--	--
Nickel	Total	**3.0 µg/l**	**2.1 µg/l**	**3.2 µg/l**	< 0.50 µg/l	**1.8 µg/l**	**3.0 µg/l**	**2.6 µg/l**	< 0.50 µg/l	**3.5 µg/l**	< 0.50 µg/l
Potassium	Total	**13 mg/l**	**16 mg/l**	**13 mg/l**	**13 mg/l**	**12 mg/l**	**13 mg/l**	**13 mg/l**	**10 mg/l**	**12 mg/l**	**12 mg/l**
Selenium	Total	**1.4 µg/l**	**1.1 µg/l**	**1.6 µg/l**	< 1.0 µg/l	**2.0 µg/l**	**1.5 µg/l**	< 1.0 µg/l	< 1.0 µg/l	**1.1 µg/l**	< 1.0 µg/l
Silicon	Total	**18 mg/l**	**19 mg/l**	**17 mg/l**	**17 mg/l**	**20 mg/l**	**18 mg/l**	**19 mg/l**	**30 mg/l**	**19 mg/l**	**20 mg/l**
Sodium	Total	**89 mg/l**	**99 mg/l**	**89 mg/l**	**88 mg/l**	**84 mg/l**	**85 mg/l**	**84 mg/l**	**71 mg/l**	**85 mg/l**	**83 mg/l**
Strontium	Total	**540 µg/l**	**570 µg/l**	**570 µg/l**	**550 µg/l**	**550 µg/l**	**630 µg/l**	**590 µg/l**	**620 µg/l**	**570 µg/l**	**580 µg/l**
Thallium	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	--	--	--	--	--
Vanadium	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	**0.50 µg/l**	< 0.50 µg/l	< 0.50 µg/l
Zinc	Total	< 5.0 µg/l	< 5.0 µg/l	**6.4 µg/l**	< 5.0 µg/l	**5.7 µg/l**	< 5.0 µg/l	**5.4 µg/l**	**8.9 µg/l**	**5.5 µg/l**	**5.2 µg/l**

	Location	**SD004**	**SD004**	**SD004**	**SD004**	**SD004**	**SD004**	**SD004**	**SD004**	**SD004**	**SD004**
	Date	**7/24/2012**	**8/7/2012**	**8/14/2012**	**8/21/2012**	**8/28/2012**	**9/4/2012**	**9/11/2012**	**9/18/2012**	**9/25/2012**	**10/2/2012**
	Sample Type	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**
	Fraction										
General Parameters											
Alkalinity, bicarbonate, as CaCO3	NA	**540 mg/l**	**480 mg/l**	**570 mg/l**	**550 mg/l**	**600 mg/l**	**590 mg/l**	**600 mg/l**	**600 mg/l**	**600 mg/l**	**590 mg/l**
Alkalinity, carbonate, as CaCO3	NA	--	--	--	--	--	--	--	--	--	--
Alkalinity, total	NA	**540 mg/l**	**480 mg/l**	**570 mg/l**	**550 mg/l**	**600 mg/l**	**590 mg/l**	**600 mg/l**	**600 mg/l**	**600 mg/l**	**590 mg/l**
Carbon, dissolved organic	NA	**1.7 mg/l**	**2.6 mg/l**	**1.7 mg/l**	**2.1 mg/l**	**1.7 mg/l**	**2.3 mg/l**	**2.3 mg/l**	**2.0 mg/l**	**2.0 mg/l**	**2.6 mg/l**
Carbon, total organic	NA	**1.8 mg/l**	**3.1 mg/l**	**1.8 mg/l**	**2.0 mg/l**	**1.8 mg/l**	**1.9 mg/l**	**2.2 mg/l**	**2.2 mg/l**	**2.2 mg/l**	**2.1 mg/l**
Chloride	NA	**22 mg/l**	**24 mg/l**	**21 mg/l**	**21 mg/l**	**20 mg/l**	**20 mg/l**	**21 mg/l**	**21 mg/l**	**20 mg/l**	**20 mg/l**
Fluoride	NA	**1.8 mg/l**	**1.5 mg/l**	**1.7 mg/l**	**1.8 mg/l**	**1.7 mg/l**	**1.7 mg/l**	**1.6 mg/l**	**1.7 mg/l**	**1.6 mg/l**	**1.7 mg/l**
Nitrogen, ammonia (NH3), as N	NA	< 0.200 mg/l	**0.201 mg/l**	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l
Nitrogen, Nitrate as N	NA	< 0.23 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Nitrogen, Nitrite as N	NA	--	--	--	--	--	--	--	--	--	--
Orthophosphate, as PO4	NA	--	--	--	--	--	--	--	--	--	--
pH	NA	**8.1 pH units**	**7.9 pH units**	**7.9 pH units**	**8.0 pH units**	**8.0 pH units**	**7.9 pH units**	**7.8 pH units**	**7.9 pH units**	**7.7 pH units**	**8.0 pH units**
Phosphorus, total	NA	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l
Silicon dioxide	NA	**37.7 mg/l**	**34.7 mg/l**	**52.1 mg/l**	**37.8 mg/l**	**38.4 mg/l**	**38.4 mg/l**	**42.6 mg/l**	**41.5 mg/l**	**40.1 mg/l**	**40.2 mg/l**
Solids, total dissolved	NA	**1300 mg/l**	**1200 mg/l**	**1300 mg/l**	**1400 mg/l**	**1300 mg/l**	**1400 mg/l**	**1400 mg/l**	**1300 mg/l**	**1400 mg/l**	**1400 mg/l**
Solids, total suspended	NA	**12 mg/l**	**24 mg/l**	**17 mg/l**	**14 mg/l**	**14 mg/l**	**17 mg/l**	**14 mg/l**	**12 mg/l**	**14 mg/l**	**20 mg/l**
Specific Conductance @ 25oC	NA	**1700 µmhos/cm**	**1600 µmhos/cm**	**1900 µmhos/cm**	**1900 µmhos/cm**	**1800 µmhos/cm**	**1900 µmhos/cm**	**1800 µmhos/cm**	**1700 µmhos/cm**	**1900 µmhos/cm**	**1900 µmhos/cm**
Sulfate	NA	**490 mg/l**	**400 mg/l**	**530 mg/l**	**550 mg/l**	**520 mg/l**	**520 mg/l**	**530 mg/l**	**530 mg/l**	**520 mg/l**	**620 mg/l**
Sulfide	NA	--	--	--	--	--	--	--	--	--	--
Metals											
Aluminum	Total	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l
Arsenic	Total	**2.6 µg/l**	**2.9 µg/l**	**2.7 µg/l**	**2.5 µg/l**	**2.5 µg/l**	**2.7 µg/l**	**2.4 µg/l**	**2.6 µg/l**	**2.4 µg/l**	**2.7 µg/l**
Barium	Total	**32 µg/l**	**59 µg/l**	**36 µg/l**	**34 µg/l**	**32 µg/l**	**33 µg/l**	**30 µg/l**	**33 µg/l**	**31 µg/l**	**35 µg/l**
Boron	Total	**0.50 mg/l**	**0.45 mg/l**	**0.46 mg/l**	**0.51 mg/l**	**0.54 mg/l**	**0.48 mg/l**	**0.51 mg/l**	**0.50 mg/l**	**0.52 mg/l**	**0.53 mg/l**
Cadmium	Total	--	--	--	--	--	--	--	--	--	--
Calcium	Total	**92 mg/l**	**91 mg/l**	**100 mg/l**	**99 mg/l**	**98 mg/l**	**95 mg/l**	**97 mg/l**	**96 mg/l**	**96 mg/l**	**91 mg/l**
Cobalt	Total	**0.94 µg/l**	**0.79 µg/l**	**0.87 µg/l**	**0.95 µg/l**	**0.92 µg/l**	**0.88 µg/l**	**0.97 µg/l**	**0.91 µg/l**	**0.95 µg/l**	**0.97 µg/l**
Copper	Total	**3.8 µg/l**	**2.6 µg/l**	**7.2 µg/l**	**2.6 µg/l**	**2.6 µg/l**	**3.5 µg/l**	**2.8 µg/l**	**2.2 µg/l**	**2.5 µg/l**	**2.1 µg/l**
Iron	Dissolved	**1.0 mg/l**	**0.98 mg/l**	**0.45 mg/l**	**0.57 mg/l**	**0.44 mg/l**	**0.42 mg/l**	**0.49 mg/l**	**0.61 mg/l**	**1.2 mg/l**	**0.60 mg/l**
Iron	Total	**4.1 mg/l**	**7.9 mg/l**	**5.3 mg/l**	**4.8 mg/l**	**5.9 mg/l**	**5.9 mg/l**	**5.7 mg/l**	**5.0 mg/l**	**4.5 mg/l**	**6.5 mg/l**
Lead	Total	**1.8 µg/l**	**0.59 µg/l**	**6.3 µg/l**	**0.35 µg/l**	**0.34 µg/l**	**0.49 µg/l**	**0.63 µg/l**	< 0.20 µg/l	< 0.20 µg/l	**0.20 µg/l**
Magnesium	Total	**180 mg/l**	**160 mg/l**	**200 mg/l**	**200 mg/l**	**200 mg/l**	**190 mg/l**	**200 mg/l**	**200 mg/l**	**200 mg/l**	**190 mg/l**
Manganese	Dissolved	**550 µg/l**	**900 µg/l**	**590 µg/l**	**610 µg/l**	**610 µg/l**	**650 µg/l**	**620 µg/l**	**620 µg/l**	**640 µg/l**	**640 µg/l**
Manganese	Total	**570 µg/l**	**920 µg/l**	**610 µg/l**	**630 µg/l**	**610 µg/l**	**610 µg/l**	**630 µg/l**	**650 µg/l**	**630 µg/l**	**640 µg/l**
Mercury	Total	--	--	--	--	--	--	--	--	--	--
Nickel	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	**0.67 µg/l**	**1.1 µg/l**	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Potassium	Total	**14 mg/l**	**11 mg/l**	**15 mg/l**	**15 mg/l**	**13 mg/l**	**14 mg/l**	**14 mg/l**	**13 mg/l**	**13 mg/l**	**12 mg/l**
Selenium	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Silicon	Total	**19 mg/l**	**20 mg/l**	**20 mg/l**	**19 mg/l**	**20 mg/l**	**19 mg/l**	**20 mg/l**	**19 mg/l**	**20 mg/l**	**19 mg/l**
Sodium	Total	**88 mg/l**	**74 mg/l**	**96 mg/l**	**95 mg/l**	**85 mg/l**	**89 mg/l**	**88 mg/l**	**84 mg/l**	**84 mg/l**	**77 mg/l**
Strontium	Total	**600 µg/l**	**520 µg/l**	**660 µg/l**	**610 µg/l**	**600 µg/l**	**640 µg/l**	**630 µg/l**	**660 µg/l**	**660 µg/l**	**640 µg/l**
Thallium	Total	--	--	--	--	--	--	--	--	--	--
Vanadium	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Zinc	Total	**5.2 µg/l**	< 5.0 µg/l	**11 µg/l**	**5.9 µg/l**	**5.6 µg/l**	**5.9 µg/l**	**6.3 µg/l**	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l

Location		**SD004**	**SD004**
Date		**10/16/2012**	**10/30/2012**
Sample Type		**N**	**N**
	Fraction		
General Parameters			
Alkalinity, bicarbonate, as CaCO3	NA	**580 mg/l**	**590 mg/l**
Alkalinity, carbonate, as CaCO3	NA	--	--
Alkalinity, total	NA	--	--
Carbon, dissolved organic	NA	--	--
Carbon, total organic	NA	**1.8 mg/l**	**1.42 mg/l**
Chloride	NA	**20 mg/l**	**21 mg/l**
Fluoride	NA	**1.7 mg/l**	**1.6 mg/l**
Nitrogen, ammonia (NH3), as N	NA	< 0.500 mg/l	< 0.500 mg/l
Nitrogen, Nitrate as N	NA	--	--
Nitrogen, Nitrite as N	NA	--	--
Orthophosphate, as PO4	NA	--	--
pH	NA	**8.0 pH units**	**7.8 pH units**
Phosphorus, total	NA	**0.233 mg/l**	< 0.100 mg/l
Silicon dioxide	NA	**39.4 mg/l**	**37.3 mg/l**
Solids, total dissolved	NA	**1500 mg/l**	**1500 mg/l**
Solids, total suspended	NA	**12 mg/l**	**25 mg/l**
Specific Conductance @ 25oC	NA	**1800 µmhos/cm**	**1800 µmhos/cm**
Sulfate	NA	**520 mg/l**	**530 mg/l**
Sulfide	NA	--	--
Metals			
Aluminum	Total	--	--
Arsenic	Total	**2.6 µg/l**	**2.6 µg/l**
Barium	Total	**35 µg/l**	**34 µg/l**
Boron	Total	**0.51 mg/l**	**0.51 mg/l**
Cadmium	Total	--	--
Calcium	Total	**98 mg/l**	**97 mg/l**
Cobalt	Total	**0.90 µg/l**	**0.91 µg/l**
Copper	Total	**2.7 µg/l**	**1.8 µg/l**
Iron	Dissolved	**0.81 mg/l**	**1.1 mg/l**
Iron	Total	**5.4 mg/l**	**4.7 mg/l**
Lead	Total	**21 µg/l**	< 0.20 µg/l
Magnesium	Total	**200 mg/l**	**190 mg/l**
Manganese	Dissolved	**590 µg/l**	**590 µg/l**
Manganese	Total	**620 µg/l**	**610 µg/l**
Mercury	Total	--	--
Nickel	Total	< 0.50 µg/l	**0.68 µg/l**
Potassium	Total	**13 mg/l**	**11 mg/l**
Selenium	Total	< 1.0 µg/l	< 1.0 µg/l
Silicon	Total	**18 mg/l**	**19 mg/l**
Sodium	Total	**83 mg/l**	**82 mg/l**
Strontium	Total	**650 µg/l**	**630 µg/l**
Thallium	Total	--	--
Vanadium	Total	< 0.50 µg/l	< 0.50 µg/l
Zinc	Total	**25 µg/l**	< 5.0 µg/l

Table 2 **Pilot-test Well Water Quality**

	Location	**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**
	Date	**5/14/2012**	**5/21/2012**	**5/29/2012**	**6/4/2012**	**6/11/2012**	**6/19/2012**	**6/26/2012**	**7/5/2012**	**7/10/2012**	**7/17/2012**
	Sample Type	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**
	Fraction										
General Parameters											
Alkalinity, bicarbonate, as CaCO3	NA	**530 mg/l**	**540 mg/l**	**550 mg/l**	**530 mg/l**	**540 mg/l**	**530 mg/l**	**580 mg/l**	**510 mg/l**	**360 mg/l**	**390 mg/l**
Alkalinity, carbonate, as CaCO3	NA	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	--	--	--	--	--
Alkalinity, total	NA	**530 mg/l**	**540 mg/l**	**550 mg/l**	**530 mg/l**	**540 mg/l**	**530 mg/l**	**580 mg/l**	**510 mg/l**	**360 mg/l**	**390 mg/l**
Carbon, dissolved organic	NA	**2.6 mg/l**	**2.1 mg/l**	**8.1 mg/l**	**2.4 mg/l**	**3.0 mg/l**	**2.9 mg/l**	**3.1 mg/l**	**3.1 mg/l**	**7.3 mg/l**	**7.3 mg/l**
Carbon, total organic	NA	**2.3 mg/l**	**2.4 mg/l**	**13 mg/l**	**3.8 mg/l**	**6.5 mg/l**	**3.3 mg/l**	**6.2 mg/l**	**3.6 mg/l**	**8.1 mg/l**	**7.3 mg/l**
Chloride	NA	**22 mg/l**	**22 mg/l**	**22 mg/l**	**22 mg/l**	**21 mg/l**	**22 mg/l**	**21 mg/l**	**21 mg/l**	**31 mg/l**	**27 mg/l**
Fluoride	NA	**1.6 mg/l**	**1.6 mg/l**	**1.6 mg/l**	**1.7 mg/l**	**1.6 mg/l**	**1.5 mg/l**	**1.8 mg/l**	**1.6 mg/l**	**0.92 mg/l**	**1.1 mg/l**
Nitrogen, ammonia (NH3), as N	NA	< 0.500 mg/l	**0.889 mg/l**	< 0.200 mg/l	< 0.200 mg/l	**0.243 mg/l**	< 0.200 mg/l	< 0.200 mg/l	**0.649 mg/l**	**0.462 mg/l**	**0.508 mg/l**
Nitrogen, Nitrate as N	NA	< 1.0 h mg/l	< 0.23 mg/l	< 0.22 mg/l	< 0.22 mg/l	< 0.23 mg/l	< 0.23 mg/l	< 1.0 mg/l	< 0.23 mg/l	< 0.23 mg/l	< 0.23 mg/l
Nitrogen, Nitrite as N	NA	< 1.0 h mg/l	< 0.30 mg/l	< 0.30 mg/l	< 0.30 mg/l	< 0.30 mg/l	--	--	--	--	--
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	--	--	--	--	--
pH	NA	**7.5 pH units**	**7.8 pH units**	**7.3 pH units**	**7.4 pH units**	**7.4 pH units**	**7.5 pH units**	**7.6 pH units**	**7.4 pH units**	**7.2 pH units**	**7.6 pH units**
Phosphorus, total	NA	**0.043 mg/l**	**0.053 mg/l**	**0.312 mg/l**	**0.156 mg/l**	**0.671 mg/l**	< 0.100 mg/l	**0.288 mg/l**	**0.202 mg/l**	< 0.100 mg/l	< 0.100 mg/l
Silicon dioxide	NA	**25.0 mg/l**	**31.3 mg/l**	**33.6 mg/l**	**32.1 mg/l**	**33.0 mg/l**	**38.8 mg/l**	**34.0 mg/l**	**36.4 mg/l**	**37.3 mg/l**	**34.1 mg/l**
Solids, total dissolved	NA	**1200 mg/l**	**1200 mg/l**	**1200 mg/l**	**1200 mg/l**	**1200 mg/l**	**1000 mg/l**	**1300 mg/l**	**1100 mg/l**	**460 mg/l**	**640 mg/l**
Solids, total suspended	NA	**20 mg/l**	**17 mg/l**	**96 mg/l**	**45 mg/l**	**150 mg/l**	**38 mg/l**	**210 mg/l**	**48 mg/l**	**42 mg/l**	**39 mg/l**
Specific Conductance @ 25oC	NA	**1600 µmhos/cm**	**1600 µmhos/cm**	**1500 µmhos/cm**	**1600 µmhos/cm**	**1600 µmhos/cm**	**1600 µmhos/cm**	**1700 µmhos/cm**	**1600 µmhos/cm**	**890 µmhos/cm**	**1000 µmhos/cm**
Sulfate	NA	**430 mg/l**	**450 mg/l**	**440 mg/l**	**460 mg/l**	**350 mg/l**	**430 mg/l**	**470 mg/l**	**450 mg/l**	**100 mg/l**	**160 mg/l**
Sulfide	NA	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	--	--	--	--	--
Metals											
Aluminum	Total	< 10 µg/l	< 10 µg/l	**15 µg/l**	**11 µg/l**	**21 µg/l**	**22 µg/l**	**16 µg/l**	< 10 µg/l	< 10 µg/l	< 10 µg/l
Arsenic	Total	**5.4 µg/l**	**4.6 µg/l**	**11 µg/l**	**6.6 µg/l**	**14 µg/l**	**4.9 µg/l**	**8.6 µg/l**	**4.7 µg/l**	**5.8 µg/l**	**4.8 µg/l**
Barium	Total	**74 µg/l**	**75 µg/l**	**150 µg/l**	**120 µg/l**	**200 µg/l**	**94 µg/l**	**170 µg/l**	**150 µg/l**	**110 µg/l**	**120 µg/l**
Boron	Total	**0.47 mg/l**	**0.48 mg/l**	**0.49 mg/l**	**0.46 mg/l**	**0.50 mg/l**	**0.47 mg/l**	**0.47 mg/l**	**0.47 mg/l**	**0.28 mg/l**	**0.32 mg/l**
Cadmium	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	--	--	--	--	--
Calcium	Total	**77 mg/l**	**86 mg/l**	**86 mg/l**	**83 mg/l**	**91 mg/l**	**85 mg/l**	**88 mg/l**	**93 mg/l**	**68 mg/l**	**73 mg/l**
Cobalt	Total	**0.62 µg/l**	**0.59 µg/l**	**0.72 µg/l**	**0.52 µg/l**	**0.86 µg/l**	**0.70 µg/l**	**0.71 µg/l**	**0.60 µg/l**	**0.54 µg/l**	**0.52 µg/l**
Copper	Total	**3.1 µg/l**	**2.6 µg/l**	**4.3 µg/l**	**0.85 µg/l**	**40 µg/l**	**3.0 µg/l**	**10 µg/l**	**28 µg/l**	**3.5 µg/l**	**2.4 µg/l**
Iron	Dissolved	**5.3 mg/l**	**0.68 mg/l**	**9.5 mg/l**	**8.5 mg/l**	**7.3 mg/l**	**11 mg/l**	**9.6 mg/l**	**14 mg/l**	**15 mg/l**	**16 mg/l**
Iron	Total	**8.8 mg/l**	**11 mg/l**	**34 mg/l**	**27 mg/l**	**56 mg/l**	**14 mg/l**	**39 mg/l**	**19 mg/l**	**17 mg/l**	**17 mg/l**
Lead	Total	**0.54 µg/l**	**0.23 µg/l**	**0.32 µg/l**	**0.32 µg/l**	**6.8 µg/l**	**0.25 µg/l**	**3.0 µg/l**	**4.4 µg/l**	**1.1 µg/l**	**0.65 µg/l**
Magnesium	Total	**170 mg/l**	**190 mg/l**	**170 mg/l**	**170 mg/l**	**170 mg/l**	**180 mg/l**	**180 mg/l**	**160 mg/l**	**75 mg/l**	**86 mg/l**
Manganese	Dissolved	**570 µg/l**	**540 µg/l**	**480 µg/l**	**700 µg/l**	**930 µg/l**	**680 µg/l**	**920 µg/l**	**1100 µg/l**	**1400 µg/l**	**1400 µg/l**
Manganese	Total	**370 µg/l**	**490 µg/l**	**590 µg/l**	**600 µg/l**	**760 µg/l**	**770 µg/l**	**770 µg/l**	**1100 µg/l**	**1300 µg/l**	**1400 µg/l**
Mercury	Total	< 0.500 ng/l	< 0.500 ng/l	< 0.500 ng/l	--	--	--	--	--	--	--
Nickel	Total	**2.4 µg/l**	**2.2 µg/l**	**2.8 µg/l**	< 0.50 µg/l	**2.9 µg/l**	**2.7 µg/l**	**2.6 µg/l**	< 0.50 µg/l	**2.0 µg/l**	< 0.50 µg/l
Potassium	Total	**8.0 mg/l**	**10 mg/l**	**8.0 mg/l**	**8.9 mg/l**	**8.4 mg/l**	**8.6 mg/l**	**9.0 mg/l**	**7.2 mg/l**	**3.8 mg/l**	**4.3 mg/l**
Selenium	Total	**1.3 µg/l**	< 1.0 µg/l	**1.8 µg/l**	< 1.0 µg/l	**2.2 µg/l**	**1.5 µg/l**	< 1.0 µg/l	< 1.0 µg/l	**1.7 µg/l**	< 1.0 µg/l
Silicon	Total	**17 mg/l**	**19 mg/l**	**18 mg/l**	**18 mg/l**	**22 mg/l**	**19 mg/l**	**21 mg/l**	**18 mg/l**	**19 mg/l**	**19 mg/l**
Sodium	Total	**81 mg/l**	**99 mg/l**	**87 mg/l**	**88 mg/l**	**86 mg/l**	**80 mg/l**	**81 mg/l**	**74 mg/l**	**35 mg/l**	**39 mg/l**
Strontium	Total	**530 µg/l**	**530 µg/l**	**540 µg/l**	**550 µg/l**	**550 µg/l**	**590 µg/l**	**560 µg/l**	**540 µg/l**	**280 µg/l**	**360 µg/l**
Thallium	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	--	--	--	--	--
Vanadium	Total	< 0.50 µg/l	< 0.50 µg/l	**2.0 µg/l**	**1.2 µg/l**	**3.2 µg/l**	**0.52 µg/l**	**1.7 µg/l**	**0.89 µg/l**	**1.7 µg/l**	**1.5 µg/l**
Zinc	Total	**12 µg/l**	**6.7 µg/l**	**9.7 µg/l**	**9.7 µg/l**	**48 µg/l**	**7.2 µg/l**	**21 µg/l**	**26 µg/l**	**9.6 µg/l**	**6.3 µg/l**

Location		**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**	**Well Discharge**
Date		**7/24/2012**	**8/7/2012**	**8/14/2012**	**8/21/2012**	**8/28/2012**	**9/4/2012**	**9/11/2012**	**9/18/2012**	**9/25/2012**	**10/2/2012**
Sample Type		**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**
	Fraction										
General Parameters											
Alkalinity, bicarbonate, as CaCO3	NA	**360 mg/l**	**350 mg/l**	**510 mg/l**	**370 mg/l**	**370 mg/l**	**550 mg/l**	**390 mg/l**	**370 mg/l**	**380 mg/l**	**380 mg/l**
Alkalinity, carbonate, as CaCO3	NA	--	--	--	--	--	--	--	--	--	--
Alkalinity, total	NA	**360 mg/l**	**350 mg/l**	**510 mg/l**	**370 mg/l**	**370 mg/l**	**550 mg/l**	**390 mg/l**	**370 mg/l**	**380 mg/l**	**380 mg/l**
Carbon, dissolved organic	NA	**7.5 mg/l**	**7.2 mg/l**	**4.9 mg/l**	**7.5 mg/l**	**7.8 mg/l**	**2.9 mg/l**	**3.5 mg/l**	**2.8 mg/l**	**7.4 mg/l**	**7.7 mg/l**
Carbon, total organic	NA	**7.5 mg/l**	**8.0 mg/l**	**4.6 mg/l**	**7.5 mg/l**	**7.7 mg/l**	**7.9 mg/l**	**13 mg/l**	**3.7 mg/l**	**12 mg/l**	**7.8 mg/l**
Chloride	NA	**31 mg/l**	**31 mg/l**	**23 mg/l**	**28 mg/l**	**30 mg/l**	**22 mg/l**	**31 mg/l**	**31 mg/l**	**30 mg/l**	**32 mg/l**
Fluoride	NA	**0.96 mg/l**	**0.75 mg/l**	**1.1 mg/l**	**0.81 mg/l**	**0.80 mg/l**	**1.3 mg/l**	**0.83 mg/l**	**0.78 mg/l**	**0.82 mg/l**	**0.77 mg/l**
Nitrogen, ammonia (NH3), as N	NA	**0.438 mg/l**	**0.520 mg/l**	**0.770 mg/l**	**0.529 mg/l**	**0.506 mg/l**	**0.718 mg/l**	**0.301 mg/l**	**0.236 mg/l**	**0.567 mg/l**	**0.512 mg/l**
Nitrogen, Nitrate as N	NA	< 0.23 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Nitrogen, Nitrite as N	NA	--	--	--	--	--	--	--	--	--	--
Orthophosphate, as PO4	NA	--	--	--	--	--	--	--	--	--	--
pH	NA	**7.8 pH units**	**7.7 pH units**	**7.8 pH units**	**7.2 pH units**	**7.6 pH units**	**7.5 pH units**	**7.2 pH units**	**7.3 pH units**	**7.6 pH units**	**7.4 pH units**
Phosphorus, total	NA	< 0.100 mg/l	< 0.100 mg/l	**0.104 mg/l**	< 0.100 mg/l	< 0.100 mg/l	**1.81 mg/l**	**2.44 mg/l**	**0.608 mg/l**	**1.25 mg/l**	< 0.100 mg/l
Silicon dioxide	NA	**36.0 mg/l**	**33.0 mg/l**	**36.0 mg/l**	**34.8 mg/l**	**33.8 mg/l**	**35.0 mg/l**	**35.6 mg/l**	**36.6 mg/l**	**35.4 mg/l**	**35.5 mg/l**
Solids, total dissolved	NA	**590 mg/l**	**580 mg/l**	**1100 mg/l**	**580 mg/l**	**600 mg/l**	**1200 mg/l**	**580 mg/l**	**560 mg/l**	**600 mg/l**	**620 mg/l**
Solids, total suspended	NA	**37 mg/l**	**44 mg/l**	**54 mg/l**	**45 mg/l**	**42 mg/l**	**110 mg/l**	**53 mg/l**	**43 mg/l**	**58 mg/l**	**40 mg/l**
Specific Conductance @ 25oC	NA	**930 µmhos/cm**	**890 µmhos/cm**	**1600 µmhos/cm**	**950 µmhos/cm**	**940 µmhos/cm**	**1600 µmhos/cm**	**980 µmhos/cm**	**910 µmhos/cm**	**960 µmhos/cm**	**970 µmhos/cm**
Sulfate	NA	**92 mg/l**	**93 mg/l**	**390 mg/l**	**96 mg/l**	**99 mg/l**	**410 mg/l**	**110 mg/l**	**110 mg/l**	**110 mg/l**	**110 mg/l**
Sulfide	NA	--	--	--	--	--	--	--	--	--	--
Metals											
Aluminum	Total	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	**11 µg/l**	< 10 µg/l	< 10 µg/l	< 10 µg/l
Arsenic	Total	**4.3 µg/l**	**4.3 µg/l**	**4.9 µg/l**	**4.2 µg/l**	**4.3 µg/l**	**2.8 µg/l**	**18 µg/l**	**8.2 µg/l**	**8.8 µg/l**	**4.1 µg/l**
Barium	Total	**99 µg/l**	**130 µg/l**	**210 µg/l**	**130 µg/l**	**130 µg/l**	**140 µg/l**	**340 µg/l**	**160 µg/l**	**200 µg/l**	**130 µg/l**
Boron	Total	**0.28 mg/l**	**0.27 mg/l**	**0.38 mg/l**	**0.28 mg/l**	**0.29 mg/l**	**0.29 mg/l**	**0.40 mg/l**	**0.48 mg/l**	**0.27 mg/l**	**0.28 mg/l**
Cadmium	Total	--	--	--	--	--	--	--	--	--	--
Calcium	Total	**63 mg/l**	**71 mg/l**	**100 mg/l**	**73 mg/l**	**73 mg/l**	**72 mg/l**	**88 mg/l**	**90 mg/l**	**70 mg/l**	**66 mg/l**
Cobalt	Total	**0.44 µg/l**	**0.45 µg/l**	**0.53 µg/l**	**0.46 µg/l**	**0.45 µg/l**	**0.41 µg/l**	**0.54 µg/l**	**0.46 µg/l**	**0.43 µg/l**	**0.42 µg/l**
Copper	Total	**15 µg/l**	**3.1 µg/l**	**5.1 µg/l**	**1.8 µg/l**	**1.9 µg/l**	**3.0 µg/l**	**1.9 µg/l**	**2.5 µg/l**	**1.4 µg/l**	**46 µg/l**
Iron	Dissolved	**15 mg/l**	**19 mg/l**	**21 mg/l**	**18 mg/l**	**18 mg/l**	**16 mg/l**	**16 mg/l**	**15 mg/l**	**18 mg/l**	**18 mg/l**
Iron	Total	**15 mg/l**	**19 mg/l**	**23 mg/l**	**19 mg/l**	**19 mg/l**	**17 mg/l**	**70 mg/l**	**29 mg/l**	**37 mg/l**	**17 mg/l**
Lead	Total	**2.0 µg/l**	**0.73 µg/l**	**0.76 µg/l**	**0.23 µg/l**	**0.31 µg/l**	**0.65 µg/l**	**0.23 µg/l**	**0.38 µg/l**	< 0.20 µg/l	**18 µg/l**
Magnesium	Total	**76 mg/l**	**71 mg/l**	**160 mg/l**	**73 mg/l**	**73 mg/l**	**74 mg/l**	**150 mg/l**	**180 mg/l**	**71 mg/l**	**68 mg/l**
Manganese	Dissolved	**1300 µg/l**	**1700 µg/l**	**1600 µg/l**	**1800 µg/l**	**1800 µg/l**	**1600 µg/l**	**930 µg/l**	**840 µg/l**	**1700 µg/l**	**1800 µg/l**
Manganese	Total	**1300 µg/l**	**1700 µg/l**	**1800 µg/l**	**1800 µg/l**	**1800 µg/l**	**1500 µg/l**	**1400 µg/l**	**970 µg/l**	**1800 µg/l**	**1900 µg/l**
Mercury	Total	--	--	--	--	--	--	--	--	--	--
Nickel	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	**2.8 µg/l**	**1.5 µg/l**	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Potassium	Total	**4.2 mg/l**	**3.5 mg/l**	**7.6 mg/l**	**3.8 mg/l**	**3.5 mg/l**	**4.1 mg/l**	**7.5 mg/l**	**8.7 mg/l**	**3.3 mg/l**	**3.4 mg/l**
Selenium	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Silicon	Total	**18 mg/l**	**19 mg/l**	**20 mg/l**	**19 mg/l**	**19 mg/l**	**16 mg/l**	**23 mg/l**	**21 mg/l**	**20 mg/l**	**17 mg/l**
Sodium	Total	**33 mg/l**	**32 mg/l**	**67 mg/l**	**34 mg/l**	**32 mg/l**	**34 mg/l**	**60 mg/l**	**69 mg/l**	**31 mg/l**	**30 mg/l**
Strontium	Total	**320 µg/l**	**280 µg/l**	**530 µg/l**	**290 µg/l**	**290 µg/l**	**300 µg/l**	**490 µg/l**	**560 µg/l**	**310 µg/l**	**320 µg/l**
Thallium	Total	--	--	--	--	--	--	--	--	--	--
Vanadium	Total	**1.5 µg/l**	**1.8 µg/l**	**0.94 µg/l**	**1.8 µg/l**	**1.8 µg/l**	**1.1 µg/l**	**7.4 µg/l**	**1.2 µg/l**	**3.5 µg/l**	**1.6 µg/l**
Zinc	Total	**16 µg/l**	**5.6 µg/l**	**7.4 µg/l**	**5.5 µg/l**	< 5.0 µg/l	**6.6 µg/l**	**5.5 µg/l**	**9.4 µg/l**	**10 µg/l**	**45 µg/l**

Location		**Well Discharge**	**Well Discharge**
Date		**10/16/2012**	**10/30/2012**
Sample Type		**N**	**N**
	Fraction		
General Parameters			
Alkalinity, bicarbonate, as CaCO3	NA	**560 mg/l**	**360 mg/l**
Alkalinity, carbonate, as CaCO3	NA	--	--
Alkalinity, total	NA	--	--
Carbon, dissolved organic	NA	--	--
Carbon, total organic	NA	**2.8 mg/l**	**6.74 mg/l**
Chloride	NA	**22 mg/l**	**30 mg/l**
Fluoride	NA	**1.4 mg/l**	**0.68 mg/l**
Nitrogen, ammonia (NH3), as N	NA	< 0.500 mg/l	**0.530 mg/l**
Nitrogen, Nitrate as N	NA	--	--
Nitrogen, Nitrite as N	NA	--	--
Orthophosphate, as PO4	NA	--	--
pH	NA	**7.7 pH units**	**7.2 pH units**
Phosphorus, total	NA	**0.211 mg/l**	**0.345 mg/l**
Silicon dioxide	NA	**37.5 mg/l**	**33.3 mg/l**
Solids, total dissolved	NA	**1200 mg/l**	**590 mg/l**
Solids, total suspended	NA	**71 mg/l**	**12 mg/l**
Specific Conductance @ 25oC	NA	**1600 µmhos/cm**	**960 µmhos/cm**
Sulfate	NA	**380 mg/l**	**120 mg/l**
Sulfide	NA	--	--
Metals			
Aluminum	Total	--	--
Arsenic	Total	**8.0 µg/l**	**3.3 µg/l**
Barium	Total	**140 µg/l**	**120 µg/l**
Boron	Total	**0.46 mg/l**	**0.30 mg/l**
Cadmium	Total	--	--
Calcium	Total	**89 mg/l**	**68 mg/l**
Cobalt	Total	**0.41 µg/l**	**0.36 µg/l**
Copper	Total	**2.0 µg/l**	**2.1 µg/l**
Iron	Dissolved	**10 mg/l**	**12 mg/l**
Iron	Total	**24 mg/l**	**12 mg/l**
Lead	Total	**0.23 µg/l**	**0.27 µg/l**
Magnesium	Total	**180 mg/l**	**79 mg/l**
Manganese	Dissolved	**910 µg/l**	**1500 µg/l**
Manganese	Total	**920 µg/l**	**1600 µg/l**
Mercury	Total	--	--
Nickel	Total	< 0.50 µg/l	< 0.50 µg/l
Potassium	Total	**8.5 mg/l**	**3.7 mg/l**
Selenium	Total	< 1.0 µg/l	< 1.0 µg/l
Silicon	Total	**20 mg/l**	**17 mg/l**
Sodium	Total	**65 mg/l**	**33 mg/l**
Strontium	Total	**510 µg/l**	**310 µg/l**
Thallium	Total	--	--
Vanadium	Total	**0.96 µg/l**	**1.2 µg/l**
Zinc	Total	**7.9 µg/l**	**9.1 µg/l**

Table 3 **Treated Water Quality Targets**

			Potential Maximum Treated Water Concentrations at Discharge Location	
Chemical Name	**Total or Dissolved**	**Units**	**SD-006**	**SD-026**
General Parameters				
Alkalinity, bicarbonate as CaCO3	NA	mg/L	---(1) 250(4)	---(1) 250(4)
Alkalinity, total	NA	mg/L		
Biochemical Oxygen Demand (5-day)	NA	mg/L		
Carbon, dissolved organic	NA	mg/L		
Carbon, total organic	NA	mg/L		
Chemical Oxygen Demand	NA	mg/L		
Chloride	NA	mg/L	230(4)	230(4)
Cyanide	NA	mg/L	0.0052(4)	0.0052(4)
Fluoride	NA	mg/L	2(4)	---(1)
Hardness, total as CaCO3	NA	mg/L	---(1) 250(4)	---(1) 250(4)
Nitrogen, ammonia as N	NA	mg/L	0.04(4)	0.04(4)
Nitrogen, Nitrate	NA	mg/L		
Nitrogen, Nitrite	NA	mg/L		
Phosphate, ortho	NA	mg/L		
Phosphorus, total	NA	mg/L		
Solids, total dissolved	NA	mg/L	700(4)	700(4)
Solids, total suspended	NA	mg/L	20 (30)	30 (60)
Sulfate	NA	mg/L	10(3)	10(3)
Sulfide	NA	mg/L		
pH, standard units	NA	SU	6.5 - 8.5	6.5 - 8.5
Dissolved oxygen	NA	mg/L		
Redox (oxidation potential)	NA	mV		
Salinity (total)	NA	mg/L	---(1)	---(1)
Specific Conductance µmhos@ 25oC	NA	umho/cm	---(1)	1000
Temperature, degrees C	NA	degC	---(1)	
Turbidity	NA	NTU	25	25(4)
Chronic Whole Effluent Toxicity (WET) Test - IC25	NA	%	100	100
Metals				
Aluminum	Total	µg/L	125(4)	125(4)
Antimony	Total	µg/L	31(4)	31(4)
Arsenic	Total	µg/L	53(4)	53(4)
Barium	Total	µg/L		
Beryllium	Total	µg/L		
Boron	Total	µg/L	500(4)	---(1)
Cadmium	Total	µg/L		
Calcium	Total	µg/L		---(1)
Chromium	Total	µg/L	11(5)	11(5)
Cobalt	Total	µg/L	5(4)	---(1)
Copper	Total	µg/L	30(4)	30(4)
Iron	Total	µg/L	1000 (2000)(2)	300(4)
Lead	Total	µg/L	19(4)	19(4)
Magnesium	Total	µg/L		---(1)
Manganese	Total	µg/L		---(1)
Mercury	Total	µg/L	---(1)	---(1)
Molybdenum	Total	µg/L		---(1)
Nickel	Total	µg/L		
Palladium	Total	µg/L		
Platinum	Total	µg/L		
Potassium	Total	µg/L		---(1)
Selenium	Total	µg/L	5(4)	5(4)
Silica	Dissolved	mg/L		
Silica	Total	mg/L		
Silver	Total	µg/L	1(4)	1(4)
Sodium	Total	µg/L		---(1)
Strontium	Total	µg/L		
Thallium	Total	µg/L	0.56(4)	0.56(4)
Titanium	Total	µg/L		
Zinc	Total	µg/L	388(4)	388(4)

(1) Monitor Only specified in the NPDES Permit
(2) Monthly Average (Monthly Maximum) Dissolved as specificed in NPDES permit
(3) Assumed 10 mg/L sulfate standard
(4) Potential Value based on MN WQ Standards
(5) Potential Value based on MN WQ Standards - Value for Cr6+

Table 4 Greensand Filter Removal Rates

		TSS			Total Fe			Total Mn		
	Sample Date	Feed Tank Effluent	GSF Effluent	% Removal	Feed Tank Effluent	GSF Effluent	% Removal	Feed Tank Effluent	GSF Effluent	% Removal
Phase 3 - Optimization	05/10/2012	12	2	>83%	6300	25	>99.6%		1.50	
	05/14/2012	6.8	2	>71%	5100	25	>99.5%		9.10	
	05/21/2012	7.6	2	>74%	5400	25	>99.5%		5.40	
	05/29/2012	12	2	>83%	6400	25	>99.6%		880	
	06/04/2012	12	2	>83%	6800	25	>99.6%		440	
	06/11/2012	22	2	>91%	7900	25	>99.7%		610	
	06/19/2012	22	2	>91%	11000	25	>99.8%	1200	630	47.5%
	06/26/2012	10	2	>80%	4400	25	>99.4%	1200	210	82.5%
Phase 4 - Steady State	07/05/2012	20	2	>90%	6700	25	>99.6%	1100	86	92.2%
	07/10/2012	21	2	>90%	11000	25	>99.8%	1200	380	68.3%
	07/17/2012	42	2	>95%	18000	25	>99.9%	1100	170	84.5%
	07/24/2012	14	2	>86%	8200	25	>99.7%	1100	220	80.0%
	08/07/2012	37	2	>95%	20000	25	>99.9%	1400	89	93.6%
	08/14/2012	36	2	>94%	17000	25	>99.9%	1400	54	96.1%
	08/21/2012	27	2	>93%	12000	25	>99.8%	1500	31	97.9%
	08/28/2012	35	2	>94%	19000	25	>99.9%	1600	51	96.8%
	09/04/2012	14	2	>86%	5500	25	>99.5%	1400	71	94.9%
	09/11/2012	10	2	>80%	5500	25	>99.5%	950	15	98.4%
	09/18/2012	20	2	>90%	8600	59	99.3%	1200	15	98.8%
	09/25/2012	34	2	>94%	16000	25	>99.8%	1400	22	98.4%
	10/02/2012	29	2	>93%	16000	25	>99.8%	1600	24	98.5%
	10/16/2012	20	2	>90%	8500	25	>99.7%	1400	47	96.6%
	10/30/2012	8	2	>75%	4500	25	>99.4%	1300	56	95.7%

Notes:
Where “>” (greater than) is indicated, the filtrate concentration was less than the method reporting limit. Half of the method reporting limit was used to calculate the percent removal in those cases.

Values in red are half the method reporting limit.

Table 5 **Greensand Filter Water Quality**

		Phase 3 - Optimization							
Location		Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent
Date		5/10/2012	5/14/2012	5/21/2012	5/29/2012	6/4/2012	6/11/2012	6/19/2012	6/26/2012
Sample Type		N	N	N	N	N	N	N	N
	Fraction								
General Parameters									
Alkalinity, bicarbonate, as CaCO3	NA	**450 mg/l**	**430 mg/l**	**410 mg/l**	**390 mg/l**	**390 mg/l**	**390 mg/l**	**410 mg/l**	**420 mg/l**
Alkalinity, carbonate, as CaCO3	NA	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	--	--
Alkalinity, total	NA	**450 mg/l**	**430 mg/l**	**410 mg/l**	**390 mg/l**	**390 mg/l**	**390 mg/l**	**410 mg/l**	**420 mg/l**
Carbon, dissolved organic	NA	**3.3 mg/l**	**3.1 mg/l**	**4.1 mg/l**	**7.3 mg/l**	**4.8 mg/l**	**4.9 mg/l**	**4.6 mg/l**	**4.4 mg/l**
Carbon, total organic	NA	**3.1 mg/l**	**3.3 mg/l**	**3.8 mg/l**	**9.4 mg/l**	**4.6 mg/l**	**4.9 mg/l**	**4.2 mg/l**	**4.3 mg/l**
Chloride	NA	**23 mg/l**	**24 mg/l**	**25 mg/l**	**26 mg/l**	**27 mg/l**	**28 mg/l**	**28 mg/l**	**26 mg/l**
Fluoride	NA	**1.3 mg/l**	**1.4 mg/l**	**1.3 mg/l**	**1.1 mg/l**	**1.0 mg/l**	**1.0 mg/l**	**1.2 mg/l**	**1.3 mg/l**
Nitrogen, ammonia (NH3), as N	NA	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	**0.262 mg/l**	**0.234 mg/l**	**0.313 mg/l**	**0.317 mg/l**	**0.284 mg/l**
Nitrogen, Nitrate as N	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.045 * mg/l	< 0.23 mg/l	< 1.0 mg/l
Nitrogen, Nitrite as N	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.061 mg/l	< 0.061 mg/l	< 0.061 mg/l	< 0.061 mg/l	--	--
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	--	--
pH	NA	**7.8 pH units**	**7.9 pH units**	**7.7 pH units**	**7.6 pH units**	**7.6 pH units**	**7.7 pH units**	**7.7 pH units**	**7.5 pH units**
Phosphorus, total	NA	**0.010 mg/l**	**0.010 mg/l**	< 0.010 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l
Silicon dioxide	NA	**20.0 mg/l**	**25.0 mg/l**	**32.7 mg/l**	**32.5 mg/l**	**45.3 * mg/l**	**36.8 mg/l**	**36.9 mg/l**	**37.3 mg/l**
Solids, total dissolved	NA	**980 mg/l**	**910 mg/l**	**830 mg/l**	**860 mg/l**	**730 mg/l**	**690 mg/l**	**710 mg/l**	**910 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25oC	NA	**1200 µmhos/cm**	**1500 µmhos/cm**	**1200 µmhos/cm**	**1100 µmhos/cm**	**990 µmhos/cm**	**1100 µmhos/cm**	**1200 µmhos/cm**	**1200 µmhos/cm**
Sulfate	NA	**290 mg/l**	**330 mg/l**	**280 mg/l**	**230 mg/l**	**180 mg/l**	**180 mg/l**	**230 mg/l**	**290 mg/l**
Sulfide	NA	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	--	--
Metals									
Aluminum	Total	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l
Arsenic	Total	**1.1 µg/l**	< 1.0 µg/l	**1.0 µg/l**	**1.1 µg/l**	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Barium	Total	**11 µg/l**	**9.0 µg/l**	**28 µg/l**	**37 µg/l**	**44 µg/l**	**51 µg/l**	**55 µg/l**	**51 µg/l**
Boron	Total	**0.41 mg/l**	**0.41 mg/l**	**0.38 mg/l**	**0.35 mg/l**	**0.32 mg/l**	**0.33 mg/l**	**0.33 mg/l**	**0.36 mg/l**
Cadmium	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	--	--
Calcium	Total	**68 mg/l**	**69 mg/l**	**74 mg/l**	**72 mg/l**	**70 mg/l**	**75 mg/l**	**72 mg/l**	**78 mg/l**
Cobalt	Total	< 0.20 µg/l	**0.20 µg/l**	< 0.20 µg/l	**0.24 µg/l**	< 0.20 µg/l	**0.26 µg/l**	**0.21 µg/l**	< 0.20 µg/l
Copper	Total	**2.0 µg/l**	**2.8 µg/l**	**2.0 µg/l**	**2.6 µg/l**	< 0.50 µg/l	**2.6 µg/l**	**2.1 µg/l**	**2.3 µg/l**
Iron	Dissolved	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Lead	Total	< 0.20 µg/l	**1.1 µg/l**	**0.42 µg/l**	< 0.20 µg/l	< 0.20 µg/l	**0.56 µg/l**	**0.33 µg/l**	**0.57 µg/l**
Magnesium	Total	**130 mg/l**	**130 mg/l**	**120 mg/l**	**99 mg/l**	**87 mg/l**	**89 mg/l**	**100 mg/l**	**120 mg/l**
Manganese	Dissolved	**1.1 µg/l**	**0.95 µg/l**	**0.95 µg/l**	**900 µg/l**	**440 µg/l**	**620 µg/l**	**560 µg/l**	**200 µg/l**
Manganese	Total	**1.5 µg/l**	**9.1 µg/l**	**5.4 µg/l**	**880 µg/l**	**440 µg/l**	**610 µg/l**	**630 µg/l**	**210 µg/l**
Nickel	Total	**2.6 µg/l**	**2.9 µg/l**	**2.2 µg/l**	**2.7 µg/l**	< 0.50 µg/l	**0.70 µg/l**	**2.5 µg/l**	**2.5 µg/l**
Potassium	Total	**8.0 mg/l**	**8.9 mg/l**	**7.9 * mg/l**	**6.0 mg/l**	**6.0 mg/l**	**5.8 mg/l**	**6.4 mg/l**	**7.6 mg/l**
Selenium	Total	**2.2 µg/l**	**1.9 µg/l**	**1.7 µg/l**	**2.0 µg/l**	< 1.0 µg/l	**2.2 µg/l**	**1.9 µg/l**	< 1.0 µg/l
Silicon	Total	**17 mg/l**	**17 mg/l**	**17 mg/l**	**16 mg/l**	**16 mg/l**	**18 mg/l**	**16 mg/l**	**17 mg/l**
Sodium	Total	**63 mg/l**	**64 mg/l**	**62 mg/l**	**51 mg/l**	**45 mg/l**	**46 mg/l**	**49 mg/l**	**56 mg/l**
Strontium	Total	**400 µg/l**	**410 µg/l**	**420 µg/l**	**360 µg/l**	**330 µg/l**	**330 µg/l**	**420 µg/l**	**460 µg/l**
Thallium	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	--	--
Vanadium	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Zinc	Total	< 5.0 µg/l	**5.2 µg/l**	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	**5.8 µg/l**	< 5.0 µg/l	**5.8 µg/l**

Location		Phase 4 - Longer-Term Operation														
Location		Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent	Pretreated Effluent
Date		7/5/2012	7/10/2012	7/17/2012	7/24/2012	8/7/2012	8/14/2012	8/21/2012	8/28/2012	9/4/2012	9/11/2012	9/18/2012	9/25/2012	10/2/2012	10/16/2012	10/30/2012
Sample Type		N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
	Fraction															
General Parameters																
Alkalinity, bicarbonate, as CaCO3	NA	**420 mg/l**	**420 mg/l**	**430 mg/l**	**450 mg/l**	**410 mg/l**	**410 mg/l**	**410 mg/l**	**410 mg/l**	**410 mg/l**	**550 mg/l**	**490 mg/l**	**440 mg/l**	**410 mg/l**	**470 mg/l**	**440 mg/l**
Alkalinity, carbonate, as CaCO3	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Alkalinity, total	NA	**420 mg/l**	**420 mg/l**	**430 mg/l**	**450 mg/l**	**410 mg/l**	**410 mg/l**	**410 mg/l**	**410 mg/l**	**410 mg/l**	**550 mg/l**	**490 mg/l**	**440 mg/l**	**410 mg/l**	--	--
Carbon, dissolved organic	NA	**4.6 mg/l**	**4.8 mg/l**	**4.6 mg/l**	**4.0 mg/l**	**5.0 mg/l**	**5.0 mg/l**	**5.1 mg/l**	**5.5 mg/l**	**5.7 mg/l**	**3.4 mg/l**	**3.8 mg/l**	**4.7 mg/l**	**5.2 mg/l**	--	--
Carbon, total organic	NA	**4.2 mg/l**	**4.8 mg/l**	**4.4 mg/l**	**4.1 mg/l**	**4.8 mg/l**	**5.2 mg/l**	**4.8 mg/l**	**5.0 mg/l**	**5.2 mg/l**	**3.0 mg/l**	**3.8 mg/l**	**4.5 mg/l**	**5.3 mg/l**	--	--
Chloride	NA	**27 mg/l**	**27 mg/l**	**26 mg/l**	**26 mg/l**	**28 mg/l**	**29 mg/l**	**28 mg/l**	**28 mg/l**	**28 mg/l**	**22 mg/l**	**25 mg/l**	**27 mg/l**	**29 mg/l**	**26 mg/l**	**27 mg/l**
Fluoride	NA	**1.3 mg/l**	**1.2 mg/l**	**1.2 mg/l**	**1.3 mg/l**	**1.0 mg/l**	**0.87 mg/l**	**0.99 mg/l**	**0.91 mg/l**	**0.92 mg/l**	**1.5 mg/l**	**1.2 mg/l**	**1.2 mg/l**	**0.93 mg/l**	**1.2 mg/l**	**1.2 mg/l**
Nitrogen, ammonia (NH3), as N	NA	**0.326 mg/l**	**0.287 mg/l**	**0.300 mg/l**	**0.320 mg/l**	**0.352 mg/l**	**0.433 mg/l**	**0.404 mg/l**	**0.409 mg/l**	**0.370 mg/l**	**0.219 mg/l**	**0.331 mg/l**	**0.334 mg/l**	**0.390 mg/l**	< 0.500 mg/l	< 0.500 mg/l
Nitrogen, Nitrate as N	NA	< 0.23 mg/l	< 0.23 mg/l	< 0.23 mg/l	< 0.23 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	--	--
Nitrogen, Nitrite as N	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Orthophosphate, as PO4	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
pH	NA	**7.6 pH units**	**7.6 pH units**	**7.7 pH units**	**7.8 pH units**	**8.1 pH units**	**7.7 pH units**	**8.0 pH units**	**7.8 pH units**	**7.8 pH units**	**7.8 pH units**	**7.9 pH units**	**7.8 pH units**	**7.7 pH units**	**7.9 pH units**	**7.5 pH units**
Phosphorus, total	NA	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l
Silicon dioxide	NA	**36.2 mg/l**	**37.5 mg/l**	**35.8 mg/l**	**35.8 mg/l**	**34.4 mg/l**	**32.0 mg/l**	**35.4 mg/l**	**32.0 mg/l**	**34.5 mg/l**	**39.9 mg/l**	**38.1 mg/l**	**36.7 mg/l**	**38.0 mg/l**	**37.0 mg/l**	**35.2 mg/l**
Solids, total dissolved	NA	**790 mg/l**	**680 mg/l**	**840 mg/l**	**940 mg/l**	**770 mg/l**	**710 mg/l**	**730 mg/l**	**720 mg/l**	**690 mg/l**	**1300 mg/l**	**950 mg/l**	**1000 mg/l**	**710 mg/l**	**920 mg/l**	**900 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25oC	NA	**1200 µmhos/cm**	**1200 µmhos/cm**	**1300 µmhos/cm**	**1300 µmhos/cm**	**1100 µmhos/cm**	**1100 µmhos/cm**	**1200 µmhos/cm**	**1100 µmhos/cm**	**1100 µmhos/cm**	**1600 µmhos/cm**	**1300 µmhos/cm**	**1200 µmhos/cm**	**1100 µmhos/cm**	**1400 µmhos/cm**	**1300 µmhos/cm**
Sulfate	NA	**220 mg/l**	**240 mg/l**	**260 mg/l**	**300 mg/l**	**200 mg/l**	**150 mg/l**	**210 mg/l**	**160 mg/l**	**180 mg/l**	**450 mg/l**	**340 mg/l**	**240 mg/l**	**190 mg/l**	**270 mg/l**	**280 mg/l**
Sulfide	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Metals																
Aluminum	Total	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	--	--
Arsenic	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Barium	Total	**46 µg/l**	**48 µg/l**	**54 µg/l**	**48 µg/l**	**48 µg/l**	**52 µg/l**	**51 µg/l**	**54 µg/l**	**45 µg/l**	**41 µg/l**	**39 µg/l**	**34 µg/l**	**40 µg/l**	**55 µg/l**	**35 µg/l**
Boron	Total	**0.36 mg/l**	**0.34 mg/l**	**0.38 mg/l**	**0.38 mg/l**	**0.33 mg/l**	**0.30 mg/l**	**0.33 mg/l**	**0.33 mg/l**	**0.30 mg/l**	**0.45 mg/l**	**0.40 mg/l**	**0.35 mg/l**	**0.33 mg/l**	**0.37 mg/l**	**0.36 mg/l**
Cadmium	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Calcium	Total	**75 mg/l**	**75 mg/l**	**78 mg/l**	**80 mg/l**	**76 mg/l**	**76 mg/l**	**77 mg/l**	**75 mg/l**	**75 mg/l**	**90 mg/l**	**86 mg/l**	**78 mg/l**	**71 mg/l**	**80 mg/l**	**78 mg/l**
Cobalt	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l
Copper	Total	**2.1 µg/l**	**2.8 µg/l**	**3.1 µg/l**	**2.5 µg/l**	**2.1 µg/l**	**2.5 µg/l**	**1.7 µg/l**	**1.8 µg/l**	**2.0 µg/l**	**2.1 µg/l**	**1.8 µg/l**	**1.5 µg/l**	**1.5 µg/l**	**1.8 µg/l**	**2.9 µg/l**
Iron	Dissolved	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	--	--
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	**0.059 mg/l**	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Lead	Total	**0.41 µg/l**	**0.51 µg/l**	**0.93 µg/l**	**0.35 µg/l**	**0.34 µg/l**	**0.40 µg/l**	**0.27 µg/l**	< 0.20 µg/l	< 0.20 µg/l	**0.22 µg/l**	**0.21 µg/l**	< 0.20 µg/l	**0.35 µg/l**	**0.44 µg/l**	**0.51 µg/l**
Magnesium	Total	**110 mg/l**	**100 mg/l**	**120 mg/l**	**120 mg/l**	**99 mg/l**	**96 mg/l**	**100 mg/l**	**91 mg/l**	**93 mg/l**	**170 mg/l**	**140 mg/l**	**110 mg/l**	**92 mg/l**	**120 mg/l**	**120 mg/l**
Manganese	Dissolved	**99 µg/l**	**380 µg/l**	**170 µg/l**	**230 µg/l**	**85 µg/l**	**55 µg/l**	**31 µg/l**	**50 µg/l**	**72 µg/l**	**15 µg/l**	**15 µg/l**	**22 µg/l**	**24 µg/l**	--	--
Manganese	Total	**86 µg/l**	**380 µg/l**	**170 µg/l**	**220 µg/l**	**89 µg/l**	**54 µg/l**	**31 µg/l**	**51 µg/l**	**71 µg/l**	**15 µg/l**	**15 µg/l**	**22 µg/l**	**24 µg/l**	**47 µg/l**	**56 µg/l**
Nickel	Total	**0.54 µg/l**	**2.5 µg/l**	**0.80 µg/l**	**0.55 µg/l**	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	**0.56 µg/l**	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	**0.93 µg/l**	**1.0 µg/l**
Potassium	Total	**7.4 mg/l**	**6.7 mg/l**	**7.4 mg/l**	**7.9 mg/l**	**6.1 mg/l**	**6.1 mg/l**	**6.4 mg/l**	**5.4 mg/l**	**6.5 mg/l**	**12 mg/l**	**8.6 mg/l**	**7.2 mg/l**	**5.3 mg/l**	**7.8 mg/l**	**7.0 mg/l**
Selenium	Total	< 1.0 µg/l	**1.6 µg/l**	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Silicon	Total	**17 mg/l**	**17 mg/l**	**17 mg/l**	**17 mg/l**	**18 mg/l**	**18 mg/l**	**17 mg/l**	**17 mg/l**	**16 mg/l**	**18 mg/l**	**17 mg/l**	**18 mg/l**	**17 mg/l**	**16 mg/l**	**17 mg/l**
Sodium	Total	**51 mg/l**	**50 mg/l**	**54 mg/l**	**57 mg/l**	**46 mg/l**	**45 mg/l**	**45 mg/l**	**40 mg/l**	**43 mg/l**	**76 mg/l**	**59 mg/l**	**49 mg/l**	**39 mg/l**	**51 mg/l**	**50 mg/l**
Strontium	Total	**390 µg/l**	**360 µg/l**	**410 µg/l**	**420 µg/l**	**350 µg/l**	**360 µg/l**	**340 µg/l**	**330 µg/l**	**350 µg/l**	**530 µg/l**	**430 µg/l**	**410 µg/l**	**370 µg/l**	**420 µg/l**	**410 µg/l**
Thallium	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Vanadium	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Zinc	Total	< 5.0 µg/l	**5.3 µg/l**	**6.7 µg/l**	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	**23 µg/l**	< 5.0 µg/l	**6.5 µg/l**	**5.6 µg/l**	**5.5 µg/l**

Table 6 **Greensand Filter Backwash Water Quality**

	Location	**Green Sand Filt Back**	**Green Sand Filt Back**	**Green Sand Filt Back**	**Green Sand Filt Back**	**Green Sand Filt Back**	**Green Sand Filt Back**
	Date	**5/14/2012**	**5/29/2012**	**6/26/2012**	**7/10/2012**	**10/8/2012**	**10/15/2012**
	Sample Type	**N**	**N**	**N**	**N**	**N**	**N**
	Fraction						
General Parameters							
Alkalinity, bicarbonate, as CaCO3	NA	**790 mg/l**	**400 mg/l**	**610 mg/l**	**530 mg/l**	**460 mg/l**	**560 mg/l**
Alkalinity, carbonate, as CaCO3	NA	< 20 mg/l	< 20 mg/l	--	--	--	--
Alkalinity, total	NA	**790 mg/l**	**400 mg/l**	**610 mg/l**	**530 mg/l**	--	--
Carbon, total organic	NA	**67 mg/l**	**32 mg/l**	**46 mg/l**	**90 mg/l**	**25 mg/l**	**36 mg/l**
Chemical Oxygen Demand	NA	**820 mg/l**	**68 mg/l**	**210 mg/l**	**650 mg/l**	--	--
Chloride	NA	**24 mg/l**	**27 mg/l**	**25 mg/l**	**27 mg/l**	**29 mg/l**	**28 mg/l**
Fluoride	NA	**1.3 mg/l**	**1.1 mg/l**	**1.3 mg/l**	**1.2 mg/l**	**0.84 mg/l**	**1.1 mg/l**
Nitrogen, ammonia (NH3), as N	NA	**0.788 mg/l**	**0.399 mg/l**	**0.352 mg/l**	**0.494 mg/l**	**0.627 mg/l**	**0.577 mg/l**
Nitrogen, Nitrate as N	NA	< 0.20 mg/l	< 0.22 mg/l	< 1.0 mg/l	< 0.23 mg/l	--	--
Nitrogen, Nitrite as N	NA	< 0.20 mg/l	< 0.30 mg/l	--	--	--	--
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 mg/l	--	--	--	--
pH	NA	**7.6 pH units**	**7.5 pH units**	**7.5 pH units**	**7.4 pH units**	**7.5 pH units**	**7.4 pH units**
Phosphorus, total	NA	**7.61 mg/l**	**1.35 mg/l**	**1.53 mg/l**	**1.64 mg/l**	**0.738 mg/l**	**0.907 mg/l**
Silicon dioxide	NA	--	**30.0 mg/l**	--	--	--	--
Solids, total dissolved	NA	**900 mg/l**	**1900 mg/l**	**880 mg/l**	**600 mg/l**	**750 mg/l**	**990 mg/l**
Solids, total suspended	NA	**3000 mg/l**	**780 mg/l**	**1900 mg/l**	**1400 mg/l**	**600 mg/l**	**1000 mg/l**
Specific Conductance @ 25oC	NA	**1300 µmhos/cm**	**1100 µmhos/cm**	**1300 µmhos/cm**	**1100 µmhos/cm**	**1100 µmhos/cm**	**1500 µmhos/cm**
Sulfate	NA	**300 mg/l**	**220 mg/l**	**280 mg/l**	**260 mg/l**	**180 mg/l**	**240 mg/l**
Sulfide	NA	< 0.12 mg/l	< 0.12 mg/l	--	--	--	--
Metals							
Aluminum	Total	**0.86 mg/l**	**0.20 mg/l**	**0.22 mg/l**	**0.15 mg/l**	--	--
Arsenic	Total	**0.19 mg/l**	**0.081 mg/l**	**0.18 mg/l**	**0.17 mg/l**	**51 µg/l**	**82 µg/l**
Barium	Total	**4.2 mg/l**	**0.81 mg/l**	**2.7 mg/l**	**3.0 mg/l**	--	--
Boron	Total	**0.62 mg/l**	**0.38 mg/l**	**0.46 mg/l**	**0.42 mg/l**	**0.33 mg/l**	**0.42 mg/l**
Cadmium	Total	**0.0041 mg/l**	< 0.0010 mg/l	--	--	--	--
Calcium	Total	**190 mg/l**	**100 mg/l**	**120 mg/l**	**130 mg/l**	**93 mg/l**	**110 mg/l**
Cobalt	Total	**0.044 mg/l**	< 0.0050 mg/l	**0.030 mg/l**	**0.023 mg/l**	**5.9 µg/l**	**12 µg/l**
Copper	Total	**0.28 mg/l**	< 0.020 mg/l	**0.064 mg/l**	**0.11 mg/l**	**13 µg/l**	**57 µg/l**
Iron	Dissolved	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	--
Iron	Total	**650 mg/l**	**310 mg/l**	**370 mg/l**	**640 mg/l**	**230 mg/l**	**320 mg/l**
Lead	Total	< 0.030 mg/l	< 0.0030 mg/l	< 0.0030 mg/l	< 0.0030 mg/l	< 1.0 µg/l	**5.0 µg/l**
Magnesium	Total	**150 mg/l**	**100 mg/l**	**120 mg/l**	**110 mg/l**	**91 mg/l**	**110 mg/l**
Manganese	Dissolved	< 0.020 mg/l	**1.1 mg/l**	**0.21 mg/l**	**0.50 mg/l**	**2100 µg/l**	--
Manganese	Total	**88 mg/l**	**6.5 mg/l**	**110 mg/l**	**82 mg/l**	**36000 µg/l**	**76000 µg/l**
Nickel	Total	< 0.025 mg/l	< 0.0050 mg/l	< 0.0050 mg/l	< 0.0050 mg/l	< 2.5 µg/l	< 2.5 µg/l
Potassium	Total	**10 mg/l**	**6.6 mg/l**	**8.2 mg/l**	**7.6 mg/l**	**5.2 mg/l**	**7.0 mg/l**
Selenium	Total	< 0.020 mg/l	< 0.020 mg/l	< 0.020 mg/l	< 0.020 mg/l	< 5.0 µg/l	< 5.0 µg/l
Silicon	Total	**130 mg/l**	**47 mg/l**	**79 mg/l**	**91 mg/l**	**41 mg/l**	**49 mg/l**
Sodium	Total	**54 mg/l**	**54 mg/l**	**56 mg/l**	**50 mg/l**	**38 mg/l**	**49 mg/l**
Strontium	Total	**2.6 mg/l**	**0.67 mg/l**	**1.0 mg/l**	**1.1 mg/l**	--	--
Thallium	Total	< 0.040 mg/l	< 0.040 mg/l	--	--	--	--
Vanadium	Total	**0.046 mg/l**	**0.024 mg/l**	**0.053 mg/l**	**0.044 mg/l**	**19 µg/l**	**28 µg/l**
Zinc	Total	**0.33 mg/l**	**0.021 mg/l**	**0.030 mg/l**	**0.048 mg/l**	**46 µg/l**	**81 µg/l**

Table 7 **RO Permeate Water Quality**

		Phase 3 - Optimization							
	Location	**RO Permeate**	**RO Permeate**	**RO Permeate**	**RO Permeate**	**RO Permeate**	**RO Permeate**	**RO Permeate**	**RO Permeate**
	Date	**5/10/2012**	**5/14/2012**	**5/21/2012**	**5/29/2012**	**6/4/2012**	**6/11/2012**	**6/19/2012**	**6/26/2012**
	Sample Type	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**
	Fraction								
General Parameters									
Alkalinity, bicarbonate, as CaCO3	NA	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l
Alkalinity, carbonate, as CaCO3	NA	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	--	--
Alkalinity, total	NA	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l
Carbon, total organic	NA	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l
Chloride	NA	**0.24 mg/l**	**0.30 mg/l**	**0.35 mg/l**	**0.29 mg/l**	**0.26 mg/l**	**0.31 mg/l**	**0.34 mg/l**	**0.26 mg/l**
Fluoride	NA	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Nitrogen, ammonia (NH3), as N	NA	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l
Nitrogen, Nitrate as N	NA	< 0.20 mg/l	< 0.20 mg/l	**0.076 mg/l**	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.20 mg/l
Nitrogen, Nitrite as N	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.061 mg/l	< 0.061 mg/l	< 0.061 mg/l	< 0.061 mg/l	--	--
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	--	--
pH	NA	**5.8 pH units**	**5.7 pH units**	**5.7 pH units**	**5.7 pH units**	**5.7 pH units**	**5.8 pH units**	**5.8 pH units**	**5.8 pH units**
Phosphorus, total	NA	< 0.010 mg/l	< 0.010 mg/l	< 0.010 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l
Silicon dioxide	NA	--	--	< 0.500 mg/l	< 0.500 mg/l	--	--	--	--
Solids, total dissolved	NA	**40 mg/l**	**10 mg/l**	< 10 mg/l	< 10 h mg/l	**26 mg/l**	< 10 mg/l	< 10 mg/l	< 10 mg/l
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25oC	NA	**79 µmhos/cm**	**13 µmhos/cm**	**11 µmhos/cm**	**10 µmhos/cm**	**10 µmhos/cm**	**11 µmhos/cm**	< 10 µmhos/cm	**11 µmhos/cm**
Sulfate	NA	**0.74 mg/l**	**0.88 mg/l**	**0.76 mg/l**	**0.49 mg/l**	**0.42 mg/l**	**0.40 mg/l**	**0.43 mg/l**	**0.59 mg/l**
Sulfide	NA	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	--	--
Metals									
Aluminum	Total	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l
Arsenic	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Barium	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l
Boron	Total	**0.20 mg/l**	**0.22 mg/l**	**0.21 mg/l**	**0.19 mg/l**	**0.18 mg/l**	**0.19 mg/l**	**0.18 mg/l**	**0.19 mg/l**
Cadmium	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	--	--
Calcium	Total	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Cobalt	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l
Copper	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Lead	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l
Magnesium	Total	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Manganese	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	**1.1 µg/l**	**0.68 µg/l**	**0.94 µg/l**	**0.56 µg/l**	< 0.50 µg/l
Mercury	Total	< 0.500 ng/l	< 0.500 ng/l	< 0.500 ng/l	< 0.500 ng/l	--	--	--	--
Nickel	Total	< 0.50 µg/l	< 0.50 µg/l	**0.70 µg/l**	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Potassium	Total	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Selenium	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Silicon	Total	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l
Sodium	Total	**1.2 mg/l**	**1.4 mg/l**	**1.7 mg/l**	**1.2 mg/l**	**1.5 mg/l**	**1.6 mg/l**	**1.2 mg/l**	**1.5 mg/l**
Strontium	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Thallium	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	--	--
Vanadium	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Zinc	Total	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l

		Phase 4 - Longer-Term Operation														
Location Date Sample Type		**RO Permeate 7/5/2012 N**	**RO Permeate 7/10/2012 N**	**RO Permeate 7/17/2012 N**	**RO Permeate 7/24/2012 N**	**RO Permeate 8/7/2012 N**	**RO Permeate 8/14/2012 N**	**RO Permeate 8/21/2012 N**	**RO Permeate 8/28/2012 N**	**RO Permeate 9/4/2012 N**	**RO Permeate 9/11/2012 N**	**RO Permeate 9/18/2012 N**	**RO Permeate 9/25/2012 N**	**RO Permeate 10/2/2012 N**	**RO Permeate 10/16/2012 N**	**RO Permeate 10/30/2012 N**
	Fraction															
General Parameters																
Alkalinity, bicarbonate, as CaCO3	NA	< 20 mg/l	__410 ** mg/l__	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l
Alkalinity, carbonate, as CaCO3	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Alkalinity, total	NA	< 20 mg/l	__410 ** mg/l__	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	--	--
Carbon, total organic	NA	< 1.5 mg/l	__4.6 ** mg/l__	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	--	--
Chloride	NA	**0.30 mg/l**	__28 ** mg/l__	**0.29 mg/l**	**0.28 mg/l**	**0.26 mg/l**	**0.27 mg/l**	**0.28 mg/l**	**0.29 mg/l**	**0.33 mg/l**	**0.31 mg/l**	**0.31 mg/l**	**0.31 mg/l**	**0.35 mg/l**	**0.35 mg/l**	**0.31 mg/l**
Fluoride	NA	< 0.050 mg/l	__1.2 ** mg/l__	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Nitrogen, ammonia (NH3), as N	NA	< 0.200 mg/l	__0.292 ** mg/l__	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.500 mg/l	< 0.500 mg/l
Nitrogen, Nitrate as N	NA	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.045 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	--	--
Nitrogen, Nitrite as N	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Orthophosphate, as PO4	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
pH	NA	**5.8 pH units**	__7.6 ** pH units__	**5.5 pH units**	**5.7 pH units**	**5.7 pH units**	**5.8 pH units**	**5.9 pH units**	**5.5 pH units**	**5.5 pH units**	**5.8 pH units**	**5.9 pH units**	**5.8 pH units**	**5.8 pH units**	**6.8 pH units**	**6.3 pH units**
Phosphorus, total	NA	< 0.100 mg/l	**0.115 mg/l**	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	--	--
Silicon dioxide	NA	--	__35.4 ** mg/l__	--	--	--	--	--	--	--	--	--	--	--	--	--
Solids, total dissolved	NA	< 10 mg/l	__630 ** mg/l__	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	--	--
Specific Conductance @ 25oC	NA	**12 µmhos/cm**	__1200 ** µmhos/cm__	**12 µmhos/cm**	**11 µmhos/cm**	**11 µmhos/cm**	**10 µmhos/cm**	< 10 µmhos/cm	**11 µmhos/cm**	**13 µmhos/cm**	**14 µmhos/cm**	**13 µmhos/cm**	**10 µmhos/cm**	**11 µmhos/cm**	**14 µmhos/cm**	**12 µmhos/cm**
Sulfate	NA	**0.56 mg/l**	__250 ** mg/l__	**0.62 mg/l**	**0.57 mg/l**	**0.43 mg/l**	**0.37 mg/l**	**0.38 mg/l**	**0.35 mg/l**	**0.45 mg/l**	**0.98 mg/l**	**0.74 mg/l**	**0.60 mg/l**	**0.44 mg/l**	**0.62 mg/l**	**0.67 mg/l**
Sulfide	NA	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Metals																
Aluminum	Total	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	--	--
Arsenic	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Barium	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	--	--
Boron	Total	**0.22 mg/l**	**0.19 mg/l**	**0.23 mg/l**	**0.23 mg/l**	**0.18 mg/l**	**0.17 mg/l**	**0.18 mg/l**	**0.18 mg/l**	**0.18 mg/l**	**0.28 mg/l**	**0.22 mg/l**	**0.20 mg/l**	**0.18 mg/l**	**0.22 mg/l**	**0.21 mg/l**
Cadmium	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Calcium	Total	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Cobalt	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l
Copper	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	**1.4 µg/l**	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	**1.0 µg/l**	< 0.50 µg/l	**1.0 µg/l**
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Lead	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l
Magnesium	Total	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Manganese	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Mercury	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nickel	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Potassium	Total	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Selenium	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Silicon	Total	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l
Sodium	Total	**1.7 mg/l**	**1.6 mg/l**	**1.7 mg/l**	**1.8 mg/l**	**1.4 mg/l**	**1.2 mg/l**	**1.2 mg/l**	**1.5 mg/l**	**1.8 mg/l**	**1.9 mg/l**	**1.6 mg/l**	**1.4 mg/l**	**1.3 mg/l**	**1.9 mg/l**	**1.7 mg/l**
Strontium	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	--	--
Thallium	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Vanadium	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Zinc	Total	< 5.0 µg/l	**6.8 µg/l**	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l

Table 8 **RO Concentrate Water Quality**

Location		**RO Concentrate**	**RO Concentrate**	**RO Concentrate**	**RO Concentrate**	**RO Concentrate**	**RO Concentrate**	**RO Concentrate**	**RO Concentrate**	**RO Concentrate**	**RO Concentrate**
Date		**5/10/2012**	**5/14/2012**	**5/21/2012**	**5/29/2012**	**6/4/2012**	**6/11/2012**	**6/19/2012**	**6/26/2012**	**7/5/2012**	**7/10/2012**
Sample Type		**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**
	Fraction										
General Parameters											
Alkalinity, bicarbonate, as CaCO3	NA	**1600 mg/l**	**1700 mg/l**	**1600 mg/l**	**1500 mg/l**	**1300 mg/l**	**1300 mg/l**	**1300 mg/l**	**1400 mg/l**	**1300 mg/l**	**1400 mg/l**
Alkalinity, carbonate, as CaCO3	NA	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	--	--	--	--
Alkalinity, total	NA	**1600 mg/l**	**1700 mg/l**	**1600 mg/l**	**1500 mg/l**	**1300 mg/l**	**1300 mg/l**	**1300 mg/l**	**1400 mg/l**	**1300 mg/l**	**1400 mg/l**
Carbon, total organic	NA	**13 mg/l**	**12 mg/l**	**14 mg/l**	**35 mg/l**	**16 mg/l**	**17 mg/l**	**14 mg/l**	**14 mg/l**	**15 mg/l**	**16 mg/l**
Chemical Oxygen Demand	NA	< 50 mg/l	< 50 mg/l	< 50 mg/l	< 50 mg/l	< 50 mg/l	< 50 mg/l	--	--	--	--
Chloride	NA	**100 mg/l**	**96 mg/l**	**100 mg/l**	**110 mg/l**	**95 mg/l**	**98 mg/l**	**88 mg/l**	**83 mg/l**	**89 mg/l**	**89 mg/l**
Fluoride	NA	**5.1 mg/l**	**4.7 mg/l**	**4.7 mg/l**	**4.2 mg/l**	**3.4 mg/l**	**3.3 mg/l**	**3.7 mg/l**	**4.2 mg/l**	**4.1 mg/l**	**3.9 mg/l**
Nitrogen, ammonia (NH3), as N	NA	**0.560 mg/l**	< 0.500 mg/l	**0.773 mg/l**	**0.917 mg/l**	**0.887 mg/l**	**1.10 mg/l**	**0.998 mg/l**	**1.01 mg/l**	**0.971 mg/l**	**0.998 mg/l**
Nitrogen, Nitrate as N	NA	< 1.0 h* mg/l	< 1.0 h mg/l	< 0.23 mg/l	< 0.22 mg/l	< 0.22 mg/l	< 0.23 mg/l	< 0.23 mg/l	< 1.0 mg/l	< 0.23 mg/l	< 0.23 mg/l
Nitrogen, Nitrite as N	NA	< 1.0 h mg/l	< 1.0 h mg/l	< 0.30 mg/l	< 0.30 mg/l	< 0.30 mg/l	< 0.30 mg/l	--	--	--	--
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	--	--	--	--
pH	NA	**8.0 pH units**	**7.9 pH units**	**7.9 pH units**	**7.8 pH units**	**7.7 pH units**	**7.8 pH units**	**7.9 pH units**	**7.8 pH units**	**7.8 pH units**	**7.7 pH units**
Phosphorus, total	NA	**0.032 mg/l**	**0.030 mg/l**	**0.022 mg/l**	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	**0.276 mg/l**	< 0.100 mg/l	< 0.100 mg/l
Silicon dioxide	NA	--	--	**107 mg/l**	**122 mg/l**	--	--	--	--	--	**124 mg/l**
Solids, total dissolved	NA	**3800 mg/l**	**3600 mg/l**	**3200 mg/l**	**6500 mg/l**	**2400 mg/l**	**2300 mg/l**	**2300 mg/l**	**3500 mg/l**	**2700 mg/l**	**2700 mg/l**
Solids, total suspended	NA	**4.0 mg/l**	< 4.0 mg/l	< 4.0 mg/l	**4.8 mg/l**	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	**6.8 mg/l**	**4.4 mg/l**	< 4.0 mg/l
Specific Conductance @ 25oC	NA	**3900 µmhos/cm**	**3700 µmhos/cm**	**3600 µmhos/cm**	**3400 µmhos/cm**	**2800 µmhos/cm**	**2800 µmhos/cm**	**3100 µmhos/cm**	**3500 µmhos/cm**	**3300 µmhos/cm**	**3300 µmhos/cm**
Sulfate	NA	**1200 mg/l**	**1200 mg/l**	**1100 mg/l**	**890 mg/l**	**620 mg/l**	**580 mg/l**	**750 mg/l**	**920 mg/l**	**790 mg/l**	**800 mg/l**
Sulfide	NA	--	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	< 0.12 mg/l	--	--	--	--
Metals											
Aluminum	Total	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l
Arsenic	Total	**3.7 µg/l**	**3.3 µg/l**	**3.2 µg/l**	**4.0 µg/l**	**1.6 µg/l**	**3.0 µg/l**	**2.4 µg/l**	**2.2 µg/l**	**1.8 µg/l**	**2.9 µg/l**
Barium	Total	**42 µg/l**	**35 µg/l**	**100 µg/l**	**150 µg/l**	**150 µg/l**	**170 µg/l**	**180 µg/l**	**190 µg/l**	**150 µg/l**	**160 µg/l**
Boron	Total	**1.0 mg/l**	**0.95 mg/l**	**0.85 mg/l**	**0.84 mg/l**	**0.64 mg/l**	**0.65 mg/l**	**0.68 mg/l**	**0.72 mg/l**	**0.69 mg/l**	**0.72 mg/l**
Cadmium	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	--	--	--	--
Calcium	Total	**270 mg/l**	**270 mg/l**	**280 mg/l**	**280 mg/l**	**230 mg/l**	**250 mg/l**	**230 mg/l**	**250 mg/l**	**240 mg/l**	**250 mg/l**
Cobalt	Total	**0.67 µg/l**	**0.65 µg/l**	**0.51 µg/l**	**0.86 µg/l**	**0.35 µg/l**	**0.80 µg/l**	**0.64 µg/l**	**0.53 µg/l**	**0.40 µg/l**	**0.56 µg/l**
Copper	Total	**6.4 µg/l**	**6.3 µg/l**	**8.3 µg/l**	**9.2 µg/l**	**1.4 µg/l**	**6.4 µg/l**	**5.4 µg/l**	**5.5 µg/l**	**5.4 µg/l**	**6.5 µg/l**
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	**0.14 mg/l**	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Lead	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	**0.20 µg/l**	< 0.20 µg/l	< 0.20 µg/l	**0.26 µg/l**	< 0.20 µg/l
Magnesium	Total	**500 mg/l**	**510 mg/l**	**460 mg/l**	**390 mg/l**	**290 mg/l**	**300 mg/l**	**320 mg/l**	**380 mg/l**	**340 mg/l**	**360 mg/l**
Manganese	Total	**5.5 µg/l**	**6.3 µg/l**	**6.7 µg/l**	**3500 µg/l**	**1700 µg/l**	**2100 µg/l**	**1900 µg/l**	**660 µg/l**	**250 µg/l**	**1200 µg/l**
Nickel	Total	**8.9 µg/l**	**8.2 µg/l**	**4.3 µg/l**	**9.8 µg/l**	**0.50 µg/l**	**2.3 µg/l**	**7.1 µg/l**	**6.7 µg/l**	**0.69 µg/l**	**6.3 µg/l**
Potassium	Total	**35 mg/l**	**38 mg/l**	**34 mg/l**	**27 mg/l**	**21 mg/l**	**21 mg/l**	**23 mg/l**	**27 mg/l**	**25 mg/l**	**24 mg/l**
Selenium	Total	**6.6 µg/l**	**6.5 µg/l**	**4.3 µg/l**	**7.3 µg/l**	**2.4 µg/l**	**7.9 µg/l**	**5.6 µg/l**	**2.5 µg/l**	**2.5 µg/l**	**5.3 µg/l**
Silicon	Total	**67 mg/l**	**65 mg/l**	**66 mg/l**	**60 mg/l**	**53 mg/l**	**59 mg/l**	**52 mg/l**	**56 mg/l**	**58 mg/l**	**58 mg/l**
Sodium	Total	**270 mg/l**	**280 mg/l**	**250 mg/l**	**220 mg/l**	**170 mg/l**	**160 mg/l**	**180 mg/l**	**200 mg/l**	**180 mg/l**	**180 mg/l**
Strontium	Total	**1700 µg/l**	**1600 µg/l**	**1600 µg/l**	**1400 µg/l**	**1200 µg/l**	**1200 µg/l**	**1200 µg/l**	**1400 µg/l**	**1300 µg/l**	**1200 µg/l**
Thallium	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	--	--	--	--
Vanadium	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	**0.59 µg/l**	< 0.50 µg/l	< 0.50 µg/l	**0.61 µg/l**	< 0.50 µg/l	**0.56 µg/l**	**0.62 µg/l**
Zinc	Total	**6.5 µg/l**	**6.2 µg/l**	**6.8 µg/l**	**13 µg/l**	**11 µg/l**	**11 µg/l**	**9.6 µg/l**	**8.3 µg/l**	**5.4 µg/l**	**8.2 µg/l**

Location		RO Concentrate	RO Concentrate	RO Concentrate	RO Concentrate	RO Concentrate	RO Concentrate	RO Concentrate	RO Concentrate	RO Concentrate	RO Concentrate
Date		7/17/2012	7/24/2012	8/7/2012	8/14/2012	8/21/2012	8/28/2012	9/4/2012	9/11/2012	9/18/2012	9/25/2012
Sample Type		N	N	N	N	N	N	N	N	N	N
	Fraction										
General Parameters											
Alkalinity, bicarbonate, as CaCO3	NA	**1400 mg/l**	**1500 mg/l**	**1300 mg/l**	**1300 mg/l**	**1400 mg/l**	**1200 mg/l**	**1400 mg/l**	**1700 mg/l**	**1800 mg/l**	**1500 mg/l**
Alkalinity, carbonate, as CaCO3	NA	--	--	--	--	--	--	--	--	--	--
Alkalinity, total	NA	**1400 mg/l**	**1500 mg/l**	**1300 mg/l**	**1300 mg/l**	**1400 mg/l**	**1200 mg/l**	**1400 mg/l**	**1700 mg/l**	**1800 mg/l**	**1500 mg/l**
Carbon, total organic	NA	**14 mg/l**	**13 mg/l**	**16 mg/l**	**18 mg/l**	**17 mg/l**	**18 mg/l**	**19 mg/l**	**9.3 mg/l**	**14 mg/l**	**16 mg/l**
Chemical Oxygen Demand	NA	--	--	--	--	--	--	--	--	--	--
Chloride	NA	**82 mg/l**	**87 mg/l**	**92 mg/l**	**94 mg/l**	**96 mg/l**	**93 mg/l**	**96 mg/l**	**71 mg/l**	**82 mg/l**	**89 mg/l**
Fluoride	NA	**4.0 mg/l**	**4.0 mg/l**	**3.2 mg/l**	**3.0 mg/l**	**3.3 mg/l**	**2.9 mg/l**	**3.1 mg/l**	**4.3 mg/l**	**3.7 mg/l**	**3.4 mg/l**
Nitrogen, ammonia (NH3), as N	NA	**0.937 mg/l**	**1.01 mg/l**	**1.13 mg/l**	**1.22 mg/l**	**1.35 mg/l**	**1.31 mg/l**	**1.26 mg/l**	**0.672 mg/l**	**1.05 mg/l**	**1.10 mg/l**
Nitrogen, Nitrate as N	NA	< 0.23 mg/l	< 0.23 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Nitrogen, Nitrite as N	NA	--	--	--	--	--	--	--	--	--	--
Orthophosphate, as PO4	NA	--	--	--	--	--	--	--	--	--	--
pH	NA	**7.5 pH units**	**7.8 pH units**	**7.9 pH units**	**7.8 pH units**	**7.8 pH units**	**7.6 pH units**	**7.8 pH units**	**7.8 pH units**	**8.0 pH units**	**7.9 pH units**
Phosphorus, total	NA	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	**0.365 mg/l**	**0.396 mg/l**
Silicon dioxide	NA	--	--	--	--	--	--	--	--	--	--
Solids, total dissolved	NA	**2900 mg/l**	**3100 mg/l**	**2500 mg/l**	**2400 mg/l**	**2700 mg/l**	**2200 mg/l**	**2400 mg/l**	**3900 mg/l**	**4200 mg/l**	**2700 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	**4.0 mg/l**	**4.4 mg/l**	< 4.0 mg/l	< 4.0 mg/l	**4.0 mg/l**
Specific Conductance @ 25oC	NA	**3500 µmhos/cm**	**3700 µmhos/cm**	**3200 µmhos/cm**	**3200 µmhos/cm**	**3400 µmhos/cm**	**3000 µmhos/cm**	**3300 µmhos/cm**	**4400 µmhos/cm**	**3700 µmhos/cm**	**3700 µmhos/cm**
Sulfate	NA	**920 mg/l**	**950 mg/l**	**660 mg/l**	**590 mg/l**	**740 mg/l**	**570 mg/l**	**630 mg/l**	**1400 mg/l**	**1100 mg/l**	**820 mg/l**
Sulfide	NA	--	--	--	--	--	--	--	--	--	--
Metals											
Aluminum	Total	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l
Arsenic	Total	**2.1 µg/l**	**2.3 µg/l**	**1.7 µg/l**	**1.8 µg/l**	**1.6 µg/l**	**1.6 µg/l**	**1.6 µg/l**	**1.5 µg/l**	**1.5 µg/l**	**1.6 µg/l**
Barium	Total	**180 µg/l**	**170 µg/l**	**170 µg/l**	**180 µg/l**	**180 µg/l**	**190 µg/l**	**150 µg/l**	**130 µg/l**	**130 µg/l**	**110 µg/l**
Boron	Total	**0.75 mg/l**	**0.76 mg/l**	**0.72 mg/l**	**0.60 mg/l**	**0.70 mg/l**	**0.67 mg/l**	**0.58 mg/l**	< 1.0 mg/l	**0.79 mg/l**	**0.73 mg/l**
Cadmium	Total	--	--	--	--	--	--	--	--	--	--
Calcium	Total	**260 mg/l**	**270 mg/l**	**260 mg/l**	**240 mg/l**	**270 mg/l**	**250 mg/l**	**250 mg/l**	**300 mg/l**	**280 mg/l**	**260 mg/l**
Cobalt	Total	**0.38 µg/l**	**0.37 µg/l**	**0.34 µg/l**	**0.34 µg/l**	**0.44 µg/l**	**0.36 µg/l**	**0.40 µg/l**	**0.37 µg/l**	**0.43 µg/l**	**0.36 µg/l**
Copper	Total	**5.6 µg/l**	**6.2 µg/l**	**5.2 µg/l**	**4.2 µg/l**	**4.6 µg/l**	**4.4 µg/l**	**5.1 µg/l**	**5.7 µg/l**	**4.9 µg/l**	**3.9 µg/l**
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.50 mg/l	< 0.050 mg/l	< 0.050 mg/l
Lead	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l
Magnesium	Total	**400 mg/l**	**420 mg/l**	**330 mg/l**	**300 mg/l**	**360 mg/l**	**310 mg/l**	**320 mg/l**	**580 mg/l**	**450 mg/l**	**380 mg/l**
Manganese	Total	**450 µg/l**	**420 µg/l**	**270 µg/l**	**220 µg/l**	**100 µg/l**	**170 µg/l**	**240 µg/l**	**42 µg/l**	**45 µg/l**	**62 µg/l**
Nickel	Total	**0.56 µg/l**	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	**1.2 µg/l**	**1.4 µg/l**	< 0.50 µg/l	< 0.50 µg/l
Potassium	Total	**27 mg/l**	**30 mg/l**	**22 mg/l**	**22 mg/l**	**26 mg/l**	**20 mg/l**	**24 mg/l**	**32 mg/l**	**31 mg/l**	**26 mg/l**
Selenium	Total	**2.5 µg/l**	**2.2 µg/l**	**2.0 µg/l**	**2.5 µg/l**	**2.5 µg/l**	**2.5 µg/l**	**2.6 µg/l**	**1.6 µg/l**	**2.0 µg/l**	**2.3 µg/l**
Silicon	Total	**59 mg/l**	**58 mg/l**	**60 mg/l**	**58 mg/l**	**58 mg/l**	**58 mg/l**	**55 mg/l**	**55 mg/l**	**57 mg/l**	**60 mg/l**
Sodium	Total	**190 mg/l**	**210 mg/l**	**160 mg/l**	**150 mg/l**	**180 mg/l**	**150 mg/l**	**160 mg/l**	**220 mg/l**	**200 mg/l**	**180 mg/l**
Strontium	Total	**1500 µg/l**	**1500 µg/l**	**1200 µg/l**	**1200 µg/l**	**1200 µg/l**	**1100 µg/l**	**1100 µg/l**	**1800 µg/l**	**1600 µg/l**	**1400 µg/l**
Thallium	Total	--	--	--	--	--	--	--	--	--	--
Vanadium	Total	< 0.50 µg/l	< 0.50 µg/l	**0.61 µg/l**	**0.52 µg/l**	**0.51 µg/l**	**0.58 µg/l**	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Zinc	Total	**5.9 µg/l**	**6.0 µg/l**	< 5.0 µg/l	**5.2 µg/l**	**5.5 µg/l**	< 5.0 µg/l	**5.2 µg/l**	**7.9 µg/l**	**9.0 µg/l**	**8.5 µg/l**

Location		**RO Concentrate**	**RO Concentrate**	**RO Concentrate**
Date		**10/2/2012**	**10/16/2012**	**10/30/2012**
Sample Type		**N**	**N**	**N**
	Fraction			
General Parameters				
Alkalinity, bicarbonate, as CaCO3	NA	**1400 mg/l**	**1600 mg/l**	**1500 mg/l**
Alkalinity, carbonate, as CaCO3	NA	--	--	--
Alkalinity, total	NA	**1400 mg/l**	--	--
Carbon, total organic	NA	**19 mg/l**	--	--
Chemical Oxygen Demand	NA	--	--	--
Chloride	NA	**96 mg/l**	**90 mg/l**	**89 mg/l**
Fluoride	NA	**3.1 mg/l**	**4.4 mg/l**	**3.6 mg/l**
Nitrogen, ammonia (NH3), as N	NA	**1.24 mg/l**	**1.12 mg/l**	**1.01 mg/l**
Nitrogen, Nitrate as N	NA	< 1.0 mg/l	--	--
Nitrogen, Nitrite as N	NA	--	--	--
Orthophosphate, as PO4	NA	--	--	--
pH	NA	**7.8 pH units**	**8.0 pH units**	**7.9 pH units**
Phosphorus, total	NA	**0.433 mg/l**	--	--
Silicon dioxide	NA	--	--	--
Solids, total dissolved	NA	**2300 mg/l**	**3200 mg/l**	**3200 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	--	--
Specific Conductance @ 25oC	NA	**3300 µmhos/cm**	**3700 µmhos/cm**	**3700 µmhos/cm**
Sulfate	NA	**630 mg/l**	**1100 mg/l**	**960 mg/l**
Sulfide	NA	--	--	--
Metals				
Aluminum	Total	< 10 µg/l	--	--
Arsenic	Total	**1.4 µg/l**	< 5.0 µg/l	**1.4 µg/l**
Barium	Total	**130 µg/l**	**200 µg/l**	**120 µg/l**
Boron	Total	**0.67 mg/l**	**0.74 mg/l**	< 1.0 mg/l
Cadmium	Total	--	--	--
Calcium	Total	**240 mg/l**	**270 mg/l**	**260 mg/l**
Cobalt	Total	**0.44 µg/l**	< 1.0 µg/l	**0.45 µg/l**
Copper	Total	**3.6 µg/l**	**6.4 µg/l**	**5.8 µg/l**
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.50 mg/l
Lead	Total	< 0.20 µg/l	< 1.0 µg/l	< 0.20 µg/l
Magnesium	Total	**300 mg/l**	**420 mg/l**	**420 mg/l**
Manganese	Total	**71 µg/l**	**150 µg/l**	**200 µg/l**
Nickel	Total	< 0.50 µg/l	< 2.5 µg/l	**1.6 µg/l**
Potassium	Total	**18 mg/l**	**28 mg/l**	**23 mg/l**
Selenium	Total	**2.2 µg/l**	< 5.0 µg/l	**2.1 µg/l**
Silicon	Total	**56 mg/l**	**58 mg/l**	**57 mg/l**
Sodium	Total	**130 mg/l**	**180 mg/l**	**160 mg/l**
Strontium	Total	**1200 µg/l**	**1400 µg/l**	**1400 µg/l**
Thallium	Total	--	--	--
Vanadium	Total	**0.52 µg/l**	< 2.5 µg/l	< 0.50 µg/l
Zinc	Total	**10 µg/l**	< 25 µg/l	**8.2 µg/l**

Table 9 **Average RO Removal Rates – No Metals Added**

	Fraction	Percent Reduction
General Parameters		
Alkalinity, bicarbonate, as CaCO3	NA	> 97.7%
Alkalinity, total	NA	> 97.6%
Carbon, total organic	NA	> 82.7%
Chloride	NA	98.9%
Fluoride	NA	> 97.8%
Nitrogen, ammonia (NH3), as N	NA	> 68.6%
Silicon dioxide	NA	> 99.2%
Solids, total dissolved	NA	> 99.1%
Specific Conductance @ 25oC	NA	98.8%
Sulfate	NA	99.8%
Metals		
Arsenic	Total	> 53.0%
Barium	Total	> 99.7%
Boron	Total	43.6%
Calcium	Total	> 99.3%
Cobalt	Total	> 55.6%
Copper	Total	> 83.5%
Lead	Total	> 73.9%
Magnesium	Total	> 99.5%
Manganese	Total	> 98.5%
Nickel	Total	> 75.4%
Potassium	Total	> 92.8%
Selenium	Total	> 73.8%
Silicon	Total	> 99.3%
Sodium	Total	97.0%
Strontium	Total	> 99.9%
Zinc	Total	> 62.1%

- Where “>” (greater than) is indicated, the permeate concentration was often less than the method reporting limit. Half of the method reporting limit was used to calculate the percent removal in those cases.

Table 10 **Comparison of Measured and Modeled RO Permeate Quality**

		7/5/2012		8/7/2012		10/2/2012	
Location		Measured RO Permeate	Modeled Permeate	Measured RO Permeate	Modeled Permeate	Measured RO Permeate	Modeled Permeate
	Fraction						
General Parameters							
Alkalinity, bicarbonate, as CaCO3	NA	< 20 mg/l	13.2 mg/l	< 20 mg/l	11.3 mg/l	< 20 mg/l	9.6 mg/l
Chloride	NA	0.30 mg/l	0.41 mg/l	0.26 mg/l	0.28 mg/l	0.35 mg/l	0.12 mg/l
Fluoride	NA	< 0.050 mg/l	0.03 mg/l	< 0.050 mg/l	0.02 mg/l	< 0.050 mg/l	0.02 mg/l
pH	NA	5.8 pH units	5.97 pH units	5.7 pH units	6.32 pH units	5.8 pH units	5.93 pH units
Solids, total dissolved	NA	< 10 mg/l	16.92 mg/l	< 10 mg/l	14.43 mg/l	< 10 mg/l	12.1 mg/l
Sulfate	NA	0.56	0.60	0.43	0.50	0.44	0.41
Metals							
Boron	Total	0.22 mg/l	0.24 mg/l	0.18 mg/l	0.21 mg/l	0.18 mg/l	0.21 mg/l
Calcium	Total	< 1.0 mg/l	1.28 mg/l	< 1.0 mg/l	1.18 mg/l	< 1.0 mg/l	0.95 mg/l
Magnesium	Total	< 1.0 mg/l	0.76 mg/l	< 1.0 mg/l	0.63 mg/l	< 1.0 mg/l	0.59 mg/l
Potassium	Total	< 1.0 mg/l	0.56 mg/l	< 1.0 mg/l	0.44 mg/l	< 1.0 mg/l	0.32 mg/l
Sodium	Total	1.7 mg/l	1.42 mg/l	1.4 mg/l	1.16 mg/l	1.3 mg/l	0.88 mg/l

Table 11 RO CIP Waste Quality

Location **Date** **Sample Type**		**High pH Cleaning** **7/31/2012** **N**	**Low pH Cleaning** **7/30/2012** **N**
	Fraction		
General Parameters			
Alkalinity, bicarbonate, as CaCO3	NA	**160 mg/l**	< 20 mg/l
Alkalinity, total	NA	**370 mg/l**	< 20 mg/l
Chemical Oxygen Demand	NA	**350 mg/l**	**4100 mg/l**
Chloride	NA	**5.8 mg/l**	**10 mg/l**
Fluoride	NA	**0.17 mg/l**	**1.1 mg/l**
Nitrogen, ammonia (NH3), as N	NA	< 0.200 mg/l	< 0.200 mg/l
Nitrogen, Nitrate as N	NA	< 0.20 * mg/l	< 0.20 h mg/l
pH	NA	**10 pH units**	**3.3 pH units**
Phosphorus, total	NA	**0.490 mg/l**	**0.216 mg/l**
Solids, total dissolved	NA	**790 mg/l**	**5300 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25oC	NA	**1100 µmhos/cm**	**1500 µmhos/cm**
Sulfate	NA	**180 mg/l**	**110 mg/l**
Metals			
Aluminum	Total	**17 µg/l**	**390 µg/l**
Arsenic	Total	**1.7 µg/l**	**16 µg/l**
Barium	Total	**6.9 µg/l**	**1100 µg/l**
Boron	Total	**0.22 mg/l**	**0.32 mg/l**
Calcium	Total	**12 mg/l**	**280 mg/l**
Cobalt	Total	< 0.20 µg/l	**11 µg/l**
Copper	Total	**24 µg/l**	**250 µg/l**
Iron	Total	**0.29 mg/l**	**16 mg/l**
Lead	Total	**0.92 µg/l**	**50 µg/l**
Magnesium	Total	**14 mg/l**	**53 mg/l**
Manganese	Total	**54 µg/l**	**58000 µg/l**
Nickel	Total	**0.58 µg/l**	**25 µg/l**
Potassium	Total	**1.9 mg/l**	**4.0 mg/l**
Selenium	Total	< 1.0 µg/l	< 10 µg/l
Silicon	Total	**6.7 mg/l**	**8.7 mg/l**
Sodium	Total	**260 mg/l**	**21 mg/l**
Strontium	Total	**46 µg/l**	**880 µg/l**
Vanadium	Total	**0.75 µg/l**	**15 µg/l**
Zinc	Total	**9.8 µg/l**	**140 µg/l**

Table 12 VSEP CIP Waste Quality

		NLR 505	**Hot Water Flush**	**NLR 505**
Location		**VSEP CIP**	**VSEP CIP**	**VSEP CIP**
Date		**10/16/2012**	**10/31/2012**	**11/7/2012**
Sample Type		**N**	**N**	**N**
	Fraction			
General Parameters				
Alkalinity, bicarbonate, as CaCO3	NA	**30 mg/l**	**98 mg/l**	**120 mg/l**
Alkalinity, total	NA	**810 mg/l**	**98 mg/l**	**720 mg/l**
Chemical Oxygen Demand	NA	**1800 mg/l**	**1800 mg/l**	**1800 mg/l**
Chloride	NA	< 2.0 mg/l	< 2.0 mg/l	< 2.0 mg/l
Fluoride	NA	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l
Nitrogen, ammonia (NH3), as N	NA	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l
Orthophosphate, as PO4	NA	**6.9 h mg/l**	**3.3 mg/l**	**3.8 mg/l**
pH	NA	**12 pH units**	**7.1 pH units**	**11 pH units**
Phosphorus, total	NA	**351 mg/l**	**324 mg/l**	**274 mg/l**
Solids, total dissolved	NA	**3200 mg/l**	**650 mg/l**	**2700 mg/l**
Solids, total suspended	NA	**4.4 mg/l**	< 4.0 mg/l	**5.6 mg/l**
Specific Conductance @ 25oC	NA	**2800 µmhos/cm**	**570 µmhos/cm**	**2500 µmhos/cm**
Sulfate	NA	**18 mg/l**	**4.5 mg/l**	**18 mg/l**
Metals				
Aluminum	Total	< 50 µg/l	**92 µg/l**	**76 µg/l**
Arsenic	Total	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l
Barium	Total	**2.4 µg/l**	**1000 µg/l**	**60 µg/l**
Boron	Total	< 1.0 mg/l	**0.31 mg/l**	**0.30 mg/l**
Calcium	Total	< 10 mg/l	**1.5 mg/l**	**2.0 mg/l**
Cobalt	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Copper	Total	**220 µg/l**	**220 µg/l**	**250 µg/l**
Iron	Total	< 0.50 mg/l	**0.17 mg/l**	**0.69 mg/l**
Lead	Total	**18 µg/l**	**25 µg/l**	**15 µg/l**
Magnesium	Total	< 10 mg/l	**2.5 mg/l**	**3.1 mg/l**
Manganese	Total	**4.2 µg/l**	**7.8 µg/l**	**20 µg/l**
Nickel	Total	**2.7 µg/l**	< 2.5 µg/l	< 2.5 µg/l
Potassium	Total	**12 mg/l**	**14 mg/l**	**12 mg/l**
Selenium	Total	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l
Silicon	Total	**15 mg/l**	**11 mg/l**	**12 mg/l**
Sodium	Total	**880 mg/l**	**790 mg/l**	**760 mg/l**
Strontium	Total	**6.5 µg/l**	**100 µg/l**	**13 µg/l**
Vanadium	Total	< 2.5 µg/l	< 2.5 µg/l	< 2.5 µg/l
Zinc	Total	**140 µg/l**	**160 µg/l**	**120 µg/l**

Table 13 **VSEP Permeate Water Quality**

	Location	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate
	Date	8/28/2012	9/5/2012	9/11/2012	9/12/2012	9/13/2012	9/14/2012	9/17/2012	9/18/2012	9/19/2012	9/20/2012
	Sample Type	N	N	N	N	N	N	N	N	N	N
	Fraction										
General Parameters											
Alkalinity, bicarbonate, as CaCO3	NA	< 20 mg/l	**22 mg/l**	**24 mg/l**	**62 mg/l**	< 20 mg/l	< 20 mg/l	**20 mg/l**	< 20 mg/l	**21 mg/l**	< 20 mg/l
Alkalinity, total	NA	< 20 mg/l	**22 mg/l**	**24 mg/l**	**62 mg/l**	< 20 mg/l	< 20 mg/l	**20 mg/l**	< 20 mg/l	**21 mg/l**	< 20 mg/l
Carbon, total organic	NA	**2.3 mg/l**	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	**1.6 mg/l**	**1.5 mg/l**
Chloride	NA	**17 mg/l**	**5.6 mg/l**	**4.5 mg/l**	**4.3 mg/l**	**3.7 mg/l**	**3.2 mg/l**	**4.7 mg/l**	**4.0 mg/l**	**11 mg/l**	**33 mg/l**
Fluoride	NA	**0.098 mg/l**	**0.16 mg/l**	**0.11 mg/l**	**0.22 mg/l**	**0.15 mg/l**	**0.16 mg/l**	**0.21 mg/l**	**0.25 mg/l**	**0.18 mg/l**	**0.19 mg/l**
Nitrogen, ammonia (NH3), as N	NA	**0.251 mg/l**	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l
Nitrogen, Nitrate as N	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 h mg/l	< 0.20 h mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 * mg/l	< 0.20 mg/l
pH	NA	**6.9 pH units**	**6.7 pH units**	**5.8 pH units**	**5.7 pH units**	**5.2 pH units**	**5.3 pH units**	**5.4 pH units**	**5.3 pH units**	**5.2 pH units**	**5.2 pH units**
Phosphorus, total	NA	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l
Solids, total dissolved	NA	**140 mg/l**	< 200 mg/l	**64 mg/l**	**120 mg/l**	**83 mg/l**	**52 mg/l**	**70 mg/l**	**62 mg/l**	**100 mg/l**	**120 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25oC	NA	**110 µmhos/cm**	**100 µmhos/cm**	**100 µmhos/cm**	**170 µmhos/cm**	**120 µmhos/cm**	**91 µmhos/cm**	**120 µmhos/cm**	**100 µmhos/cm**	**140 µmhos/cm**	**180 µmhos/cm**
Sulfate	NA	**3.9 mg/l**	**12 mg/l**	**14 mg/l**	**34 mg/l**	**22 mg/l**	**16 mg/l**	**24 mg/l**	**20 mg/l**	**22 mg/l**	**10 mg/l**
Metals											
Aluminum	Total	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l
Arsenic	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Barium	Total	**1.8 µg/l**	**1.4 µg/l**	**1.4 µg/l**	**1.6 µg/l**	**1.3 µg/l**	**0.83 µg/l**	**1.3 µg/l**	**0.98 µg/l**	**1.4 µg/l**	**1.8 µg/l**
Boron	Total	**0.36 mg/l**	**0.40 mg/l**	**0.37 mg/l**	**0.53 mg/l**	**0.36 mg/l**	**0.36 mg/l**	**0.42 mg/l**	**0.41 mg/l**	**0.40 mg/l**	**0.39 mg/l**
Calcium	Total	**2.5 mg/l**	**2.3 mg/l**	**2.5 mg/l**	**3.7 mg/l**	**2.8 mg/l**	**1.8 mg/l**	**2.6 mg/l**	**2.0 mg/l**	**3.1 mg/l**	**4.0 mg/l**
Cobalt	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l
Copper	Total	**0.60 µg/l**	**0.88 µg/l**	**0.97 µg/l**	**1.3 µg/l**	**0.73 µg/l**	**1.0 µg/l**	**0.79 µg/l**	**1.0 µg/l**	**0.83 µg/l**	**1.2 µg/l**
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Lead	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l
Magnesium	Total	**2.7 mg/l**	**3.1 mg/l**	**3.5 mg/l**	**7.5 mg/l**	**4.9 mg/l**	**3.0 mg/l**	**4.1 mg/l**	**3.2 mg/l**	**5.1 mg/l**	**5.8 mg/l**
Manganese	Total	**1.4 µg/l**	**1.3 µg/l**	**21 µg/l**	**1.4 µg/l**	**0.59 µg/l**	< 0.50 µg/l	< 0.50 µg/l	**0.86 µg/l**	**0.66 µg/l**	**0.60 µg/l**
Nickel	Total	< 0.50 µg/l	< 0.50 µg/l	**0.53 µg/l**	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Potassium	Total	**2.2 mg/l**	**1.7 mg/l**	**1.9 mg/l**	**2.8 mg/l**	**2.0 mg/l**	**1.6 mg/l**	**2.0 mg/l**	**1.6 mg/l**	**2.2 mg/l**	**3.1 mg/l**
Selenium	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Silicon	Total	**1.9 mg/l**	**2.1 mg/l**	**2.2 mg/l**	**2.5 mg/l**	**1.7 mg/l**	**1.6 mg/l**	**2.2 mg/l**	**1.9 mg/l**	**1.8 mg/l**	**1.7 mg/l**
Sodium	Total	**13 mg/l**	**13 mg/l**	**12 mg/l**	**19 mg/l**	**12 mg/l**	**10 mg/l**	**13 mg/l**	**11 mg/l**	**15 mg/l**	**19 mg/l**
Strontium	Total	**11 µg/l**	**9.3 µg/l**	**11 µg/l**	**20 µg/l**	**14 µg/l**	**8.6 µg/l**	**12 µg/l**	**10 µg/l**	**16 µg/l**	**19 µg/l**
Vanadium	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Zinc	Total	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l

	Location	**VSEP Permeate**	**VSEP Permeate**	**VSEP Permeate**	**VSEP Permeate**	**VSEP Permeate**	**VSEP Permeate**	**VSEP Permeate**	**VSEP Permeate**	**VSEP Permeate**	**VSEP Permeate**
	Date	**9/24/2012**	**9/25/2012**	**9/26/2012**	**9/27/2012**	**10/1/2012**	**10/2/2012**	**10/3/2012**	**10/4/2012**	**10/8/2012**	**10/9/2012**
	Sample Type	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**
	Fraction										
General Parameters											
Alkalinity, bicarbonate, as CaCO3	NA	**20 mg/l**	< 20 mg/l	< 20 mg/l	**28 mg/l**	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l
Alkalinity, total	NA	**20 mg/l**	< 20 mg/l	< 20 mg/l	**28 mg/l**	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	--	--
Carbon, total organic	NA	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	**1.6 mg/l**	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	--	--
Chloride	NA	**40 mg/l**	**38 mg/l**	**35 mg/l**	**4.4 mg/l**	**3.8 mg/l**	**4.6 mg/l**	**3.8 mg/l**	**5.0 mg/l**	**4.6 mg/l**	**3.8 mg/l**
Fluoride	NA	**0.17 mg/l**	**0.15 mg/l**	**0.14 mg/l**	**0.13 mg/l**	**0.16 mg/l**	**0.18 mg/l**	**0.15 mg/l**	**0.16 mg/l**	**0.15 mg/l**	**0.11 mg/l**
Nitrogen, ammonia (NH3), as N	NA	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l	< 0.200 mg/l
Nitrogen, Nitrate as N	NA	< 0.20 h mg/l	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 h mg/l	< 0.20 h mg/l	< 0.20 mg/l	< 0.20 * mg/l	< 0.20 mg/l	--	--
pH	NA	**6.0 pH units**	**5.6 pH units**	**5.7 pH units**	**5.6 pH units**	**5.8 pH units**	**5.6 pH units**	**5.5 pH units**	**5.5 pH units**	**5.4 pH units**	**5.2 pH units**
Phosphorus, total	NA	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l
Solids, total dissolved	NA	**140 mg/l**	**160 mg/l**	**110 mg/l**	**100 mg/l**	**160 mg/l**	**170 mg/l**	**75 mg/l**	**100 mg/l**	**51 mg/l**	**64 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	--	--
Specific Conductance @ 25oC	NA	**190 µmhos/cm**	**180 µmhos/cm**	**170 µmhos/cm**	**80 µmhos/cm**	**89 µmhos/cm**	**98 µmhos/cm**	**79 µmhos/cm**	**92 µmhos/cm**	**94 µmhos/cm**	**72 µmhos/cm**
Sulfate	NA	**9.9 mg/l**	**7.8 mg/l**	**9.7 mg/l**	**12 mg/l**	**12 mg/l**	**18 mg/l**	**11 mg/l**	**17 mg/l**	**18 mg/l**	**11 mg/l**
Metals											
Aluminum	Total	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	--	--
Arsenic	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Barium	Total	**2.0 µg/l**	**1.5 µg/l**	**1.8 µg/l**	**0.63 µg/l**	**0.69 µg/l**	**1.0 µg/l**	**0.75 µg/l**	**1.2 µg/l**	--	--
Boron	Total	**0.42 mg/l**	**0.44 mg/l**	**0.42 mg/l**	**0.40 mg/l**	**0.37 mg/l**	**0.38 mg/l**	**0.37 mg/l**	**0.38 mg/l**	**0.36 mg/l**	**0.35 mg/l**
Calcium	Total	**4.4 mg/l**	**3.5 mg/l**	**4.0 mg/l**	**1.3 mg/l**	**1.2 mg/l**	**1.9 mg/l**	**1.4 mg/l**	**2.0 mg/l**	**2.3 mg/l**	**1.4 mg/l**
Cobalt	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l
Copper	Total	**1.3 µg/l**	**1.6 µg/l**	**1.4 µg/l**	**1.7 µg/l**	**1.0 µg/l**	**0.69 µg/l**	**0.91 µg/l**	**1.6 µg/l**	**1.9 µg/l**	**0.95 µg/l**
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Lead	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l
Magnesium	Total	**6.2 mg/l**	**4.9 mg/l**	**5.4 mg/l**	**2.0 mg/l**	**1.8 mg/l**	**2.7 mg/l**	**2.0 mg/l**	**2.7 mg/l**	**3.0 mg/l**	**2.0 mg/l**
Manganese	Total	**0.96 µg/l**	**2.1 µg/l**	**1.3 µg/l**	< 0.50 µg/l	**0.53 µg/l**	**1.6 µg/l**	**0.59 µg/l**	**3.1 µg/l**	**5.3 µg/l**	**2.3 µg/l**
Nickel	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Potassium	Total	**3.7 mg/l**	**3.5 mg/l**	**3.3 mg/l**	**1.5 mg/l**	**1.2 mg/l**	**1.5 mg/l**	**1.2 mg/l**	**1.4 mg/l**	**1.4 mg/l**	**1.2 mg/l**
Selenium	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Silicon	Total	**2.0 mg/l**	**1.9 mg/l**	**1.8 mg/l**	**1.6 mg/l**	**1.7 mg/l**	**1.9 mg/l**	**1.8 * mg/l**	**2.2 mg/l**	--	--
Sodium	Total	**21 mg/l**	**22 mg/l**	**19 mg/l**	**10 mg/l**	**9.2 mg/l**	**10 mg/l**	**9.6 mg/l**	**11 mg/l**	**11 mg/l**	**8.9 mg/l**
Strontium	Total	**22 µg/l**	**17 µg/l**	**19 µg/l**	**6.6 µg/l**	**6.5 µg/l**	**9.2 µg/l**	**6.6 µg/l**	**9.9 µg/l**	**9.9 µg/l**	**6.1 µg/l**
Vanadium	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Zinc	Total	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	**6.0 µg/l**	< 5.0 µg/l	< 5.0 µg/l

Location		VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate
Date		**10/10/2012**	**10/11/2012**	**10/15/2012**	**10/16/2012**	**10/17/2012**	**10/18/2012**	**10/23/2012**	**10/31/2012**	**11/7/2012**
Sample Type		**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**
	Fraction									
General Parameters										
Alkalinity, bicarbonate, as CaCO3	NA	< 20 mg/l	< 20 mg/l	**22 mg/l**	**21 mg/l**	**21 mg/l**	< 20 mg/l	**24 mg/l**	**26 mg/l**	**25 mg/l**
Alkalinity, total	NA	--	--	--	--	--	--	--	--	--
Carbon, total organic	NA	--	--	--	--	--	--	--	--	**4.72 mg/l**
Chloride	NA	**2.8 mg/l**	**5.3 mg/l**	**5.5 mg/l**	**5.4 mg/l**	**5.2 mg/l**	**4.9 mg/l**	**4.3 mg/l**	**3.7 mg/l**	**4.3 mg/l**
Fluoride	NA	**0.19 mg/l**	**0.15 mg/l**	**0.21 mg/l**	**0.24 mg/l**	**0.25 mg/l**	**0.20 mg/l**	**0.19 mg/l**	**0.11 mg/l**	**0.094 mg/l**
Nitrogen, ammonia (NH3), as N	NA	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l
Nitrogen, Nitrate as N	NA	--	--	--	--	--	--	--	--	--
pH	NA	**5.2 pH units**	**5.4 pH units**	**5.5 pH units**	**5.7 pH units**	**5.4 pH units**	**5.9 pH units**	**5.7 pH units**	**5.6 pH units**	**5.8 pH units**
Phosphorus, total	NA	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l	< 0.100 mg/l
Solids, total dissolved	NA	**59 mg/l**	**33 mg/l**	**92 mg/l**	**70 mg/l**	**34 mg/l**	**88 mg/l**	**49 mg/l**	**65 mg/l**	**32 mg/l**
Solids, total suspended	NA	--	--	--	--	--	--	--	--	--
Specific Conductance @ 25oC	NA	**63 µmhos/cm**	**96 µmhos/cm**	**110 µmhos/cm**	**120 µmhos/cm**	**120 µmhos/cm**	**130 µmhos/cm**	**99 µmhos/cm**	**93 µmhos/cm**	**87 µmhos/cm**
Sulfate	NA	**7.1 mg/l**	**17 mg/l**	**19 mg/l**	**21 mg/l**	**23 mg/l**	**25 mg/l**	**20 mg/l**	**15 mg/l**	**14 mg/l**
Metals										
Aluminum	Total	--	--	--	--	--	--	--	--	--
Arsenic	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Barium	Total	--	--	--	--	--	--	--	--	--
Boron	Total	**0.34 mg/l**	**0.38 mg/l**	**0.46 mg/l**	**0.47 mg/l**	**0.45 mg/l**	**0.47 mg/l**	**0.46 mg/l**	**0.43 mg/l**	**0.40 mg/l**
Calcium	Total	< 1.0 mg/l	**2.2 mg/l**	**2.0 mg/l**	**2.3 mg/l**	**2.3 mg/l**	**2.5 mg/l**	**2.0 mg/l**	**1.8 mg/l**	**1.8 mg/l**
Cobalt	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l
Copper	Total	**3.1 µg/l**	**1.6 µg/l**	**0.67 µg/l**	< 0.50 µg/l	< 0.50 µg/l	**0.54 µg/l**	**0.75 µg/l**	< 0.50 µg/l	**0.76 µg/l**
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Lead	Total	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l	< 0.20 µg/l
Magnesium	Total	**1.3 mg/l**	**3.0 mg/l**	**3.1 mg/l**	**3.5 mg/l**	**3.8 mg/l**	**4.3 mg/l**	**3.4 mg/l**	**3.2 mg/l**	**3.0 mg/l**
Manganese	Total	**0.93 µg/l**	**2.9 µg/l**	**1.3 µg/l**	**2.8 µg/l**	**1.5 µg/l**	**1.2 µg/l**	**0.90 µg/l**	**0.93 µg/l**	**2.0 µg/l**
Nickel	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Potassium	Total	**1.1 mg/l**	**1.5 mg/l**	**1.8 mg/l**	**2.0 mg/l**	**2.1 mg/l**	**2.2 mg/l**	**1.9 mg/l**	**1.8 mg/l**	**1.9 mg/l**
Selenium	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Silicon	Total	--	--	--	--	--	--	--	--	--
Sodium	Total	**8.8 mg/l**	**11 mg/l**	**14 mg/l**	**15 mg/l**	**15 mg/l**	**15 mg/l**	**14 mg/l**	**13 mg/l**	**12 mg/l**
Strontium	Total	**4.1 µg/l**	**9.6 µg/l**	**9.5 µg/l**	**11 µg/l**	**11 µg/l**	**13 µg/l**	**10 µg/l**	**8.5 µg/l**	**8.5 µg/l**
Vanadium	Total	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l	< 0.50 µg/l
Zinc	Total	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l

Table 14 Average VSEP Removal Rates (Concentration – Based) – No Metals Added

Parameter	Recovery		
	80%	85%	90%
Alkalinity, bicarbonate, as CaCO3	>98.5%	>98.0%	>96.3%
Carbon, total organic	>91.3%	>89.0%	NA
Chloride	96.2%	95.1%	95.0%
Fluoride	95.7%	95.2%	95.6%
Nitrogen, ammonia (NH3), as N	>84.3%	>86.1%	>80.9%
Phosphorus, total	>49.2%	>84.0%	>92.6%
Solids, total dissolved	>92.9%	>96.1%	98.2%
Sulfate	99.2%	99.2%	99.0%
Aluminum	ND	ND	NA
Arsenic	>67.4%	>66.5%	ND
Barium	99.1%	99.1%	NA
Boron	42.2%	39.9%	39.2%
Calcium	>99.3%	99.2%	99.2%
Cobalt	>74.0%	>74.7%	ND
Copper	78.3%	>80.8%	>89.6%
Iron	ND	ND	ND
Lead	ND	ND	ND
Magnesium	99.4%	99.1%	99.1%
Manganese	86.7%	98.7%	99.1%
Nickel	62.1%	>90.8%	>91.1%
Potassium	93.0%	91.8%	92.8%
Selenium	>74.6%	>77.8%	ND
Silicon	96.5%	96.6%	NA
Sodium	93.6%	91.8%	92.1%
Strontium	99.4%	99.2%	99.2%
Vanadium	>56.9%	>51.9%	ND
Zinc	>77.0%	>76.3%	ND

- Where “>” (greater than) is indicated, the permeate concentration was often less than the method reporting limit. Half of the method reporting limit was used to calculate the percent removal in those cases.
- ND = Parameter not detected either VSEP feed or permeate
- NA = Parameter was not analyzed in VSEP permeate

Table 15 **Average VSEP Removal Rates (Mass-Based) – No Metals Added**

Parameter	Recovery		
	80%	85%	90%
Alkalinity, bicarbonate, as CaCO3	>98.8%	>98.3%	>96.6%
Carbon, total organic	>93.0%	>90.6%	NA
Chloride	97.0%	95.8%	95.5%
Fluoride	96.6%	95.9%	96.0%
Nitrogen, ammonia (NH3), as N	>87.5%	>88.2%	>82.8%
Phosphorus, total	>59.4%	>86.4%	>93.3%
Solids, total dissolved	>94.3%	>96.7%	98.4%
Sulfate	99.3%	99.3%	99.1%
Aluminum	ND	ND	NA
Arsenic	>73.9%	>71.5%	ND
Barium	99.3%	99.3%	NA
Boron	53.8%	48.9%	45.3%
Calcium	>99.5%	99.3%	99.3%
Cobalt	>79.2%	>78.5%	ND
Copper	82.7%	>83.7%	>90.7%
Iron	ND	ND	ND
Lead	ND	ND	ND
Magnesium	99.5%	99.3%	99.2%
Manganese	89.3%	98.9%	99.2%
Nickel	69.7%	>92.2%	>92.0%
Potassium	94.4%	93.0%	93.5%
Selenium	>79.7%	>81.1%	ND
Silicon	97.2%	97.1%	ND
Sodium	94.9%	93.0%	92.9%
Strontium	99.5%	99.3%	99.3%
Vanadium	>65.5%	>59.1%	ND
Zinc	>81.6%	>79.9%	ND

- Where ">" (greater than) is indicated, the permeate concentration was often less than the method reporting limit. Half of the method reporting limit was used to calculate the percent removal in those cases.
- ND = Parameter not detected either VSEP feed or permeate
- NA = Parameter was not analyzed in VSEP permeate

Table 16 VSEP Concentrate Water Quality

	Location	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**
	Date	**8/28/2012**	**9/5/2012**	**9/11/2012**	**9/12/2012**	**9/13/2012**	**9/14/2012**	**9/17/2012**	**9/18/2012**	**9/19/2012**	**9/20/2012**
	Sample Type	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**
	Fraction										
General Parameters											
Alkalinity, bicarbonate, as CaCO3	NA	**1000 mg/l**	**2000 mg/l**	**2400 mg/l**	**2400 mg/l**	**1700 mg/l**	**2100 mg/l**	**1200 mg/l**	**1100 mg/l**	**2600 mg/l**	**2500 mg/l**
Alkalinity, total	NA	**1000 mg/l**	**2000 mg/l**	**2400 mg/l**	**2400 mg/l**	**1700 mg/l**	**2100 mg/l**	**1200 mg/l**	**1100 mg/l**	**2600 mg/l**	**2500 mg/l**
Carbon, total organic	NA	**47 mg/l**	**83 mg/l**	**94 mg/l**	**54 mg/l**	**83 mg/l**	--	**80 mg/l**	**70 mg/l**	**70 mg/l**	**58 mg/l**
Chloride	NA	**3100 mg/l**	**530 mg/l**	**300 mg/l**	**290 mg/l**	**340 mg/l**	**390 mg/l**	**430 mg/l**	**420 mg/l**	**1500 mg/l**	**3300 mg/l**
Fluoride	NA	**11 mg/l**	**13 mg/l**	**10 mg/l**	**19 mg/l**	**14 mg/l**	**16 mg/l**	**17 mg/l**	**16 mg/l**	**19 mg/l**	**17 mg/l**
Nitrogen, ammonia (NH3), as N	NA	**4.51 mg/l**	**5.16 mg/l**	**3.29 mg/l**	**2.78 mg/l**	**3.55 mg/l**	**3.07 mg/l**	**4.66 mg/l**	**5.04 mg/l**	**2.05 mg/l**	**1.81 mg/l**
Nitrogen, Nitrate as N	NA	< 2.0 mg/l	< 2.0 mg/l	< 2.0 mg/l	< 2.0 h mg/l	< 2.0 h mg/l	< 2.0 h mg/l	< 2.0 mg/l	< 2.0 mg/l	< 2.0 mg/l	< 2.0 mg/l
pH	NA	**6.8 pH units**	**6.8 pH units**	**6.9 pH units**	**6.8 pH units**	**6.6 pH units**	**6.8 pH units**	**6.4 pH units**	**6.5 pH units**	**6.6 pH units**	**6.7 pH units**
Phosphorus, total	NA	**3.51 mg/l**	**2.34 mg/l**	**0.295 mg/l**	**2.29 mg/l**	**1.41 mg/l**	**1.31 mg/l**	**1.97 * mg/l**	**1.06 mg/l**	**4.89 mg/l**	**3.95 mg/l**
Solids, total dissolved	NA	**23000 mg/l**	**14000 mg/l**	**10000 mg/l**	**20000 mg/l**	**15000 mg/l**	**16000 mg/l**	**19000 mg/l**	**16000 mg/l**	**24000 mg/l**	**24000 mg/l**
Solids, total suspended	NA	**11 mg/l**	**21 mg/l**	**9.2 mg/l**	**16 mg/l**	**15 mg/l**	**18 mg/l**	**14 mg/l**	**20 mg/l**	**84 mg/l**	**66 mg/l**
Specific Conductance @ 25oC	NA	**14000 µmhos/cm**	**12000 e µmhos/cm**	**9900 µmhos/cm**	**15000 µmhos/cm**	**12000 µmhos/cm**	**13000 e µmhos/cm**	**14000 e µmhos/cm**	**13000 e µmhos/cm**	**15000 e µmhos/cm**	**16000 e µmhos/cm**
Sulfate	NA	**2100 mg/l**	**7400 mg/l**	**4000 mg/l**	**9100 mg/l**	**8500 mg/l**	**8900 mg/l**	**11000 mg/l**	**8300 mg/l**	**8800 mg/l**	**4400 mg/l**
Metals											
Aluminum	Total	< 50 µg/l	< 50 µg/l	< 50 µg/l	< 50 µg/l	< 50 µg/l	< 50 µg/l	< 50 µg/l	< 50 µg/l	< 50 µg/l	< 50 µg/l
Arsenic	Total	**6.2 µg/l**	**8.2 µg/l**	**5.6 µg/l**	**6.9 µg/l**	**7.0 µg/l**	**7.4 µg/l**	**8.6 µg/l**	**7.8 µg/l**	**7.8 µg/l**	< 5.0 µg/l
Barium	Total	**810 µg/l**	**280 µg/l**	**330 µg/l**	**400 µg/l**	**250 µg/l**	**520 µg/l**	**380 µg/l**	**420 µg/l**	**510 µg/l**	**560 µg/l**
Boron	Total	**1.4 mg/l**	**1.5 mg/l**	**1.2 mg/l**	**2.0 mg/l**	**2.0 mg/l**	**2.1 mg/l**	**2.1 mg/l**	**2.0 mg/l**	**2.3 mg/l**	**2.0 mg/l**
Cadmium	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Calcium	Total	**1100 mg/l**	**860 mg/l**	**920 mg/l**	**1200 mg/l**	**1000 mg/l**	**1200 mg/l**	**860 mg/l**	**890 mg/l**	**1400 mg/l**	**1200 mg/l**
Cobalt	Total	**2.3 µg/l**	**1.6 µg/l**	**2.2 µg/l**	**1.6 µg/l**	**1.8 µg/l**	**1.9 µg/l**	**1.7 µg/l**	**1.6 µg/l**	**2.7 µg/l**	**2.2 µg/l**
Copper	Total	**26 µg/l**	**270 µg/l**	**350 µg/l**	**240 µg/l**	**200 µg/l**	**230 µg/l**	**230 µg/l**	**320 µg/l**	**380 µg/l**	**790 µg/l**
Iron	Total	< 0.050 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l
Lead	Total	**1.9 µg/l**	< 1.0 µg/l	**2.1 µg/l**	**1.1 µg/l**	**1.5 µg/l**	**2.0 µg/l**	**1.4 µg/l**	< 1.0 µg/l	**2.0 µg/l**	**1.1 µg/l**
Magnesium	Total	**1200 mg/l**	**1500 mg/l**	**1200 mg/l**	**2300 mg/l**	**1800 mg/l**	**1900 mg/l**	**2100 mg/l**	**1900 mg/l**	**2200 mg/l**	**1900 mg/l**
Manganese	Total	**580 µg/l**	**520 µg/l**	**7100 µg/l**	**320 µg/l**	**150 µg/l**	**190 µg/l**	**140 µg/l**	**370 µg/l**	**210 µg/l**	**140 µg/l**
Nickel	Total	< 2.5 µg/l	**17 µg/l**	**37 µg/l**	**13 µg/l**	**17 µg/l**	**5.0 µg/l**	**9.8 µg/l**	**10 µg/l**	**27 µg/l**	**11 µg/l**
Potassium	Total	**90 mg/l**	**92 mg/l**	**77 mg/l**	**140 mg/l**	**100 mg/l**	**120 mg/l**	**130 mg/l**	**110 mg/l**	**130 mg/l**	**110 mg/l**
Selenium	Total	**10 µg/l**	**12 µg/l**	**8.5 µg/l**	**7.5 µg/l**	**9.2 µg/l**	**9.7 µg/l**	**11 µg/l**	**10 µg/l**	**10 µg/l**	**8.1 µg/l**
Silicon	Total	**240 mg/l**	**240 mg/l**	**170 mg/l**	**230 mg/l**	**240 mg/l**	**240 mg/l**	**250 mg/l**	**260 mg/l**	**280 mg/l**	**260 mg/l**
Sodium	Total	**600 mg/l**	**640 mg/l**	**480 mg/l**	**920 mg/l**	**710 mg/l**	**780 mg/l**	**850 mg/l**	**770 mg/l**	**890 mg/l**	**750 mg/l**
Strontium	Total	**5100 µg/l**	**4300 µg/l**	**4200 µg/l**	**6900 µg/l**	**5100 µg/l**	**6000 µg/l**	**5000 µg/l**	**1000 µg/l**	**7400 µg/l**	**6400 µg/l**
Thallium	Total	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l	< 1.0 µg/l
Vanadium	Total	< 2.5 µg/l	**2.8 µg/l**	< 2.5 µg/l	< 2.5 µg/l	< 2.5 µg/l	< 2.5 µg/l	**2.5 µg/l**	< 2.5 µg/l	< 2.5 µg/l	< 2.5 µg/l
Zinc	Total	**75 µg/l**	**250 µg/l**	**110 µg/l**	**71 µg/l**	**110 µg/l**	**87 µg/l**	**77 µg/l**	**79 µg/l**	**110 µg/l**	**88 µg/l**

	Location	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**	**VSEP Concentrate**
	Date	**9/24/2012**	**9/25/2012**	**9/26/2012**	**9/27/2012**	**10/1/2012**	**10/2/2012**	**10/3/2012**	**10/4/2012**	**10/8/2012**
	Sample Type	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**
	Fraction									
General Parameters										
Alkalinity, bicarbonate, as CaCO3	NA	**1900 mg/l**	**1700 mg/l**	**2000 mg/l**	**2100 mg/l**	**1200 mg/l**	**1100 mg/l**	**1500 mg/l**	**1300 mg/l**	**1400 mg/l**
Alkalinity, total	NA	**1900 mg/l**	**1700 mg/l**	**2000 mg/l**	**2100 mg/l**	**1200 mg/l**	**1100 mg/l**	**1500 mg/l**	**1300 mg/l**	--
Carbon, total organic	NA	**58 mg/l**	**48 mg/l**	**69 mg/l**	**96 mg/l**	**100 mg/l**	**110 mg/l**	**99 mg/l**	**120 mg/l**	**100 mg/l**
Chloride	NA	**4800 mg/l**	**4600 mg/l**	**4100 mg/l**	**560 mg/l**	**480 mg/l**	**510 mg/l**	**520 mg/l**	**640 mg/l**	**540 mg/l**
Fluoride	NA	**18 mg/l**	**18 mg/l**	**19 mg/l**	**18 mg/l**	**16 mg/l**	**17 mg/l**	**16 mg/l**	**8.5 mg/l**	**15 mg/l**
Nitrogen, ammonia (NH3), as N	NA	**4.83 mg/l**	**4.88 mg/l**	**3.31 mg/l**	**5.35 * mg/l**	**6.74 mg/l**	**6.89 mg/l**	**6.56 mg/l**	**7.66 mg/l**	**7.12 mg/l**
Nitrogen, Nitrate as N	NA	< 2.0 h mg/l	< 2.0 mg/l	< 2.0 h mg/l	< 2.0 h mg/l	< 2.0 h mg/l	< 2.0 mg/l	< 2.0 mg/l	< 2.0 mg/l	--
pH	NA	**6.7 pH units**	**7.0 pH units**	**6.6 pH units**	**6.8 pH units**	**6.5 pH units**	**6.5 pH units**	**6.7 pH units**	**6.5 pH units**	**6.7 pH units**
Phosphorus, total	NA	**1.86 mg/l**	**3.95 mg/l**	**0.796 mg/l**	**3.93 mg/l**	**2.02 mg/l**	**3.21 mg/l**	**2.03 mg/l**	**3.49 mg/l**	**4.39 mg/l**
Solids, total dissolved	NA	**17000 mg/l**	**16000 mg/l**	**15000 mg/l**	**19000 mg/l**	**17000 mg/l**	**20000 mg/l**	**15000 mg/l**	**15000 mg/l**	**18000 mg/l**
Solids, total suspended	NA	**22 mg/l**	**20 mg/l**	**60 mg/l**	**20 mg/l**	**20 mg/l**	**26 mg/l**	**82 mg/l**	**84 mg/l**	**66 mg/l**
Specific Conductance @ 25oC	NA	**19000 e µmhos/cm**	**20000 e µmhos/cm**	**20000 e µmhos/cm**	**15000 e µmhos/cm**	**14000 e µmhos/cm**	**15000 e µmhos/cm**	**14000 e µmhos/cm**	**15000 e µmhos/cm**	**14000 e µmhos/cm**
Sulfate	NA	**4600 mg/l**	**4800 mg/l**	**6000 mg/l**	**10000 mg/l**	**9600 mg/l**	**11000 mg/l**	**9400 mg/l**	**2300 mg/l**	**9800 mg/l**
Metals										
Aluminum	Total	< 50 µg/l	< 50 µg/l	< 100 µg/l	< 100 µg/l	< 100 µg/l	< 100 µg/l	< 100 µg/l	< 100 µg/l	--
Arsenic	Total	< 5.0 µg/l	< 5.0 µg/l	< 10 µg/l	< 10 µg/l	< 10 µg/l	**10 µg/l**	< 10 µg/l	**10 µg/l**	**8.0 µg/l**
Barium	Total	**360 µg/l**	**370 µg/l**	**680 µg/l**	**650 µg/l**	**250 µg/l**	**430 µg/l**	**430 µg/l**	**450 µg/l**	**270 µg/l**
Boron	Total	**2.0 mg/l**	**2.1 mg/l**	**2.3 mg/l**	**2.3 mg/l**	**2.0 mg/l**	**2.1 mg/l**	**2.1 mg/l**	**2.1 mg/l**	**2.0 mg/l**
Cadmium	Total	< 1.0 µg/l	< 1.0 µg/l	< 2.0 µg/l	< 2.0 µg/l	< 2.0 µg/l	< 2.0 µg/l	< 2.0 µg/l	< 2.0 µg/l	--
Calcium	Total	**1300 mg/l**	**1400 mg/l**	**1500 mg/l**	**1400 mg/l**	**880 mg/l**	**1000 mg/l**	**1200 mg/l**	**1100 mg/l**	**930 mg/l**
Cobalt	Total	**2.5 µg/l**	**2.9 µg/l**	**3.5 µg/l**	**2.5 µg/l**	**2.3 µg/l**	**2.8 µg/l**	**2.6 µg/l**	**2.6 µg/l**	**1.8 µg/l**
Copper	Total	**610 µg/l**	**1200 µg/l**	**730 µg/l**	**220 µg/l**	**180 µg/l**	**160 µg/l**	**120 µg/l**	**150 µg/l**	**110 µg/l**
Iron	Total	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l
Lead	Total	**2.8 µg/l**	**2.6 µg/l**	**3.5 µg/l**	**5.7 µg/l**	**2.6 µg/l**	**3.2 µg/l**	**3.6 µg/l**	**2.7 µg/l**	**1.7 µg/l**
Magnesium	Total	**2000 mg/l**	**2100 mg/l**	**2100 mg/l**	**2000 mg/l**	**1800 mg/l**	**1900 mg/l**	**1800 mg/l**	**1900 mg/l**	**1900 mg/l**
Manganese	Total	**190 µg/l**	**870 µg/l**	**420 µg/l**	**360 µg/l**	**400 µg/l**	**1100 µg/l**	**410 µg/l**	**2000 µg/l**	**3300 µg/l**
Nickel	Total	**8.2 µg/l**	**34 µg/l**	**51 µg/l**	**16 µg/l**	**15 µg/l**	**13 µg/l**	**8.7 µg/l**	**7.7 µg/l**	**8.2 µg/l**
Potassium	Total	**110 mg/l**	**110 mg/l**	**120 mg/l**	**120 mg/l**	**99 mg/l**	**120 mg/l**	**93 mg/l**	**100 mg/l**	**97 mg/l**
Selenium	Total	**7.9 µg/l**	**7.5 µg/l**	< 10 µg/l	**12 µg/l**	**15 µg/l**	**16 µg/l**	**15 µg/l**	**17 µg/l**	**13 µg/l**
Silicon	Total	**290 mg/l**	**280 mg/l**	**320 mg/l**	**320 mg/l**	**300 mg/l**	**320 mg/l**	**290 mg/l**	**340 mg/l**	**320 mg/l**
Sodium	Total	**790 mg/l**	**830 mg/l**	**820 mg/l**	**820 mg/l**	**710 mg/l**	**790 mg/l**	**750 mg/l**	**820 mg/l**	**770 mg/l**
Strontium	Total	**7000 µg/l**	**7400 µg/l**	**8000 µg/l**	**7500 µg/l**	**5200 µg/l**	**5500 µg/l**	**5600 µg/l**	**5500 µg/l**	**4900 µg/l**
Thallium	Total	< 1.0 µg/l	< 1.0 µg/l	< 2.0 µg/l	< 2.0 µg/l	< 2.0 µg/l	< 2.0 µg/l	< 2.0 µg/l	< 2.0 µg/l	--
Vanadium	Total	< 2.5 µg/l	< 2.5 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	< 5.0 µg/l	**3.3 µg/l**
Zinc	Total	**79 µg/l**	**240 µg/l**	**140 µg/l**	**80 µg/l**	**84 µg/l**	**110 µg/l**	**120 µg/l**	**200 µg/l**	**150 µg/l**

	Location	VSEP Concentrate	VSEP Concentrate	VSEP Concentrate	VSEP Concentrate	VSEP Concentrate	VSEP Concentrate	VSEP Concentrate	VSEP Concentrate	VSEP Concentrate	VSEP Concentrate
	Date	**10/9/2012**	**10/10/2012**	**10/11/2012**	**10/15/2012**	**10/16/2012**	**10/17/2012**	**10/18/2012**	**10/23/2012**	**10/31/2012**	**11/7/2012**
	Sample Type	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**	**N**
	Fraction										
General Parameters											
Alkalinity, bicarbonate, as CaCO3	NA	**1800 mg/l**	**1100 mg/l**	**2700 mg/l**	**2300 mg/l**	**2200 mg/l**	**2000 mg/l**	**2300 mg/l**	**3000 mg/l**	**4500 mg/l**	**3500 mg/l**
Alkalinity, total	NA	--	--	--	--	--	--	--	--	--	--
Carbon, total organic	NA	**130 mg/l**	**81 mg/l**	**150 mg/l**	**160 mg/l**	**120 mg/l**	**110 mg/l**	**87 mg/l**	**82 mg/l**	**78.7 mg/l**	--
Chloride	NA	**630 mg/l**	**410 mg/l**	**700 mg/l**	**680 mg/l**	**660 mg/l**	**580 mg/l**	**530 mg/l**	**480 mg/l**	**490 mg/l**	**490 mg/l**
Fluoride	NA	**17 mg/l**	**14 mg/l**	**18 mg/l**	**25 mg/l**	**27 mg/l**	**24 mg/l**	**25 mg/l**	**23 mg/l**	**21 mg/l**	**18 mg/l**
Nitrogen, ammonia (NH3), as N	NA	**7.70 mg/l**	**6.26 mg/l**	**10.3 mg/l**	**8.79 mg/l**	**7.93 mg/l**	**6.51 mg/l**	**5.54 mg/l**	**5.22 mg/l**	**5.46 mg/l**	**5.10 mg/l**
Nitrogen, Nitrate as N	NA	--	--	--	--	--	--	--	--	--	--
pH	NA	**6.9 pH units**	**6.6 pH units**	**7.1 pH units**	**6.8 pH units**	**7.0 pH units**	**6.8 pH units**	**6.8 pH units**	**7.1 pH units**	**7.2 pH units**	**7.5 pH units**
Phosphorus, total	NA	**2.41 mg/l**	**3.68 mg/l**	**6.01 mg/l**	**6.29 * mg/l**	**6.11 mg/l**	**5.52 mg/l**	**5.19 mg/l**	**4.36 mg/l**	**3.73 mg/l**	**4.08 mg/l**
Solids, total dissolved	NA	**22000 mg/l**	**14000 mg/l**	**18000 mg/l**	**14000 mg/l**	**15000 mg/l**	**22000 mg/l**	**25000 mg/l**	**22000 mg/l**	**21000 mg/l**	**18000 mg/l**
Solids, total suspended	NA	**50 mg/l**	**16 mg/l**	**460 mg/l**	**530 mg/l**	**500 mg/l**	**340 mg/l**	**250 mg/l**	**390 mg/l**	**97 mg/l**	**18 mg/l**
Specific Conductance @ 25oC	NA	**15000 e µmhos/cm**	**12000 e µmhos/cm**	**16000 e µmhos/cm**	**18000 e µmhos/cm**	**19000 µmhos/cm**	**18000 e µmhos/cm**	**18000 µmhos/cm**	**16000 e µmhos/cm**	**16000 e µmhos/cm**	**14000 e µmhos/cm**
Sulfate	NA	**11000 mg/l**	**7900 mg/l**	**12000 mg/l**	**14000 mg/l**	**15000 mg/l**	**15000 mg/l**	**15000 mg/l**	**12000 mg/l**	**10000 mg/l**	**8400 mg/l**
Metals											
Aluminum	Total	--	--	--	--	--	--	--	--	--	--
Arsenic	Total	**8.2 µg/l**	**7.0 µg/l**	**11 µg/l**	**13 µg/l**	**12 µg/l**	**10 µg/l**	**9.0 µg/l**	**9.5 µg/l**	**6.8 µg/l**	**7.1 µg/l**
Barium	Total	**300 µg/l**	**600 µg/l**	**500 µg/l**	**570 µg/l**	**360 µg/l**	**420 µg/l**	**480 µg/l**	**490 µg/l**	**610 µg/l**	**510 µg/l**
Boron	Total	**2.2 mg/l**	**1.8 mg/l**	**2.3 mg/l**	**2.6 mg/l**	**2.7 mg/l**	**2.4 mg/l**	**2.6 mg/l**	**2.3 mg/l**	**2.4 mg/l**	**2.2 mg/l**
Cadmium	Total	--	--	--	--	--	--	--	--	--	--
Calcium	Total	**1300 mg/l**	**1100 mg/l**	**1200 mg/l**	**830 mg/l**	**920 mg/l**	**900 mg/l**	**990 mg/l**	**1300 mg/l**	**1400 mg/l**	**1400 mg/l**
Cobalt	Total	**2.4 µg/l**	**1.9 µg/l**	**2.2 µg/l**	**2.6 µg/l**	**2.5 µg/l**	**1.8 µg/l**	**1.7 µg/l**	**1.9 µg/l**	**2.4 µg/l**	**2.1 µg/l**
Copper	Total	**92 µg/l**	**71 µg/l**	**87 µg/l**	**160 µg/l**	**120 µg/l**	**69 µg/l**	**63 µg/l**	**62 µg/l**	**45 µg/l**	**48 µg/l**
Iron	Total	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l
Lead	Total	**5.6 µg/l**	**5.3 µg/l**	**3.9 µg/l**	**2.9 µg/l**	**2.8 µg/l**	**1.6 µg/l**	**1.6 µg/l**	**3.7 µg/l**	**1.7 µg/l**	**2.5 µg/l**
Magnesium	Total	**2000 mg/l**	**1500 mg/l**	**2400 mg/l**	**3000 mg/l**	**3100 mg/l**	**2900 mg/l**	**2900 mg/l**	**2600 mg/l**	**2300 mg/l**	**2000 mg/l**
Manganese	Total	**2300 µg/l**	**630 µg/l**	**3700 µg/l**	**1200 µg/l**	**2200 µg/l**	**1100 µg/l**	**760 µg/l**	**460 µg/l**	**580 µg/l**	**1400 µg/l**
Nickel	Total	**5.0 µg/l**	**3.9 µg/l**	**6.4 µg/l**	**17 µg/l**	**14 µg/l**	**8.6 µg/l**	**8.1 µg/l**	**7.5 µg/l**	**12 µg/l**	**11 µg/l**
Potassium	Total	**110 mg/l**	**81 mg/l**	**130 mg/l**	**170 mg/l**	**190 mg/l**	**170 mg/l**	**170 mg/l**	**150 mg/l**	**140 mg/l**	**130 mg/l**
Selenium	Total	**15 µg/l**	**11 µg/l**	**18 µg/l**	**21 µg/l**	**18 µg/l**	**14 µg/l**	**13 µg/l**	**12 µg/l**	**8.7 µg/l**	**11 µg/l**
Silicon	Total	**360 mg/l**	**250 mg/l**	**420 mg/l**	**380 mg/l**	**410 mg/l**	**360 mg/l**	**330 mg/l**	**290 mg/l**	**280 mg/l**	**260 mg/l**
Sodium	Total	**860 mg/l**	**610 mg/l**	**1000 mg/l**	**1200 mg/l**	**1300 mg/l**	**1200 mg/l**	**1100 mg/l**	**1000 mg/l**	**960 mg/l**	**830 mg/l**
Strontium	Total	**6700 µg/l**	**5200 µg/l**	**13000 µg/l**	**6000 µg/l**	**5900 µg/l**	**6200 µg/l**	**6700 µg/l**	**7700 µg/l**	**7300 µg/l**	**6100 µg/l**
Thallium	Total	--	--	--	--	--	--	--	--	--	--
Vanadium	Total	< 2.5 µg/l	< 2.5 µg/l	**3.7 µg/l**	< 5.0 µg/l	< 5.0 µg/l	< 2.5 µg/l	< 2.5 µg/l	< 2.5 µg/l	< 2.5 µg/l	< 2.5 µg/l
Zinc	Total	**130 µg/l**	**85 µg/l**	**100 µg/l**	**120 µg/l**	**140 µg/l**	**99 µg/l**	**77 µg/l**	**63 µg/l**	**75 µg/l**	**54 µg/l**

Table 17 **Modeled Lime Dose for Effluent Stabilization**

Addition	Chemical	Optimal Dose (mg/L)	Optimal Final pH	$CaCO_3$ SI Final
Lime and CO_2	$Ca(OH)_2$	130	7.3	0.10
	CO_2	77		

Table 18 Summary of Lime Addition Bench Test Results

Parameter	Total or Dissolved	Units	Control	Unstabilized Permeate	Dose 2	Dose 3	Dose 4	Dose 5	Dose 6
Hydrated Lime Dose, as $Ca(OH)_2$	NA	mg/L		0	65	98	130	195	260
Alkalinity, bicarbonate, as CaCO3	NA	mg/L	NA	<20	80	100	130	160	200
Alkalinity, total	NA	mg/L	NA	<20	80	100	130	160	200
Chloride	NA	mg/L	NA	0.83	0.89	0.84	0.78	0.77	0.78
Fluoride	NA	mg/L	NA	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Nitrogen, ammonia (NH3), as N	NA	mg/L	NA	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
pH	NA	SU	NA	6.1	7.4	7.6	7.9	7.8	7.9
Turbidity	NA	NTU	NA	0.0	7.0	11.0	44.9	193.0	253.0
Phosphorus, total	NA	mg/L	NA	<0.10	<0.10	0.11	<0.10	<0.10	<0.10
Silicon dioxide	NA	mg/L	NA	1.0	1.5	1.7	1.8	2.3	2.8
Solids, total dissolved	NA	mg/L	NA	<10	240	280	210	220	230
Solids, total suspended	NA	mg/L	NA	<4.0	4.4	4.4	24.0	10.0	140.0
Sulfate	NA	mg/L	NA	4.0	4.2	4.2	3.7	3.7	3.7
Aluminum	Total	µg/L	NA	<10	120	180	230	390	470
Antimony	Total	µg/L	NA	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic	Total	µg/L	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Boron	Total	mg/L	NA	0.24	0.24	0.24	0.24	0.23	0.24
Cadmium	Total	µg/L	NA	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Calcium	Total	mg/L	NA	<1.0	29	44	57	86	110
Chromium (VI)	Total	mg/L	NA	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Cobalt	Total	µg/L	NA	<0.20	<0.20	<0.20	<0.20	0.23	0.28
Copper	Total	µg/L	NA	0.8	0.9	<0.50	0.79	0.85	1.0
Iron	Total	mg/L	NA	<0.05	0.08	0.12	0.18	0.25	0.32
Lead	Total	µg/L	NA	<0.050	<0.20	<0.20	<0.20	<0.20	<0.20
Manganese	Total	µg/L	NA	<0.5	2.00	2.90	4.0	5.9	7.3
Mercury	Total	ng/L	NA	<0.100	<0.100	0.33	0.134	0.123	0.155
Molybdenum	Total	µg/L	NA	<0.20	<0.20	0.26	0.41	0.31	0.27
Nickel	Total	µg/L	NA	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50
Potassium	Total	mg/L	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Selenium	Total	µg/L	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Silicon	Total	mg/L	NA	0.36	0.62	0.76	0.87	1.1	1.3
Sodium	Total	mg/L	NA	3.3	3.5	3.3	3.1	3.1	3.1
Thallium	Total	µg/L	NA	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Zinc	Total	µg/L	NA	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
WET Test Results									
Survival	NA	%	100	90	100	100	100	100	90
Reproduction	NA	#/female	14.4	7.7	12.2	14	14.6	13.8	10.9
Calculated Indices									
LSI	NA	NA	NA	-4.56	-0.76	-0.29	0.25	0.41	0.72
SI	NA	NA	NA	-4.48	-0.61	-0.16	0.34	0.48	0.76

Table 19 **Summary of Limestone Bed Contactor Bench Test Results**

				Rate 1			Rate 2			Rate 3			Raw
Parameter	**Total or Dissolved**	**Units**	**Comtrol**	**Caustic**	**No Treatment**	**Sparge**	**Caustic**	**No Treatment**	**Sparge**	**Caustic**	**No Treatment**	**Sparge**	**Untreated Permeate**
Hydraulic Loading Rate	NA	gpm/sf	NA	2.4	2.4	2.4	3.6	3.6	3.6	4.8	4.8	4.8	NA
Alkalinity, bicaronate, as CaCO3	NA	mg/l	NA	110	120	110	110	110	100	110	110	92	< 20
pH	NA	pH units	NA	7.8	7.7	7.9	7.8	7.8	7.9	7.9	7.8	7.9	7.7
Phosporus, total	NA	mg/l	NA	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100	< 0.100
Solids, total dissolved	NA	mg/l	NA	69	77	71	85	120	52	58	57	76	< 10
Solids, total suspended	NA	mg/l	NA	< 4.0	< 4.0	< 4.0	< 4.0	< 4.0	7	29	< 5.0	5.6	< 4.0
Sulfate	NA	mg/l	NA	3.1	3.3	3.1	3.1	3.2	3.1	3.1	3.3	3.1	3
Final Turbidity	NA	NTU	NA	5.5	7.2	3.1	4.5	7.3	5.7	53	12.5	10.6	0
Metals													
Aluminum	Total	µg/l	NA	21	13	14	15	13	15	88	20	25	< 10
Antimony	Total	µg/l	NA	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Arsenic	Total	µg/l	NA	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Cadmium	Total	µg/l	NA	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Calcium	Total	mg/l	NA	47	47	45	43	42	43	60	42	42	< 1.0
Chromium, exavalent	NA	mg/l	NA	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020	< 0.020
Cobalt	Total	µg/l	NA	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Copper	Total	µg/l	NA	0.66	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	0.52
Iron	Total	mg/l	NA	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	< 0.050	0.058	< 0.050	< 0.050	< 0.050
Lead	Total	µg/l	NA	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	0.49	< 0.20	0.2	< 0.20
Manganese	Total	µg/l	NA	5.5	3	4.5	4.3	3.1	3.7	12	3.9	4.4	0.95
Molydenum	Total	µg/l	NA	0.38	0.66	0.46	0.39	0.59	0.6	0.41	0.59	0.6	< 0.20
Nickel	Total	µg/l	NA	0.55	0.69	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50	< 0.50
Selenium	Total	µg/l	NA	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Silicon	Total	mg/l	NA	0.49	0.47	0.45	0.46	0.45	0.46	0.71	0.49	0.5	0.44
Tallium	Total	µg/l	NA	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20	< 0.20
Zinc	Total	µg/l	NA	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0	< 5.0
WET Test Results													
Survival	NA	%	100	100	100	100	100	100	100	90	100	100	90
Reproduction	NA	#/female	19.3	13.6	16.5	16.6	12	12.8	14.5	10	12.9	12	11.1
Calculated Indices													
LSI	NA	NA	NA	0.00	0.00	0.10	0.00	0.00	0.10	0.30	0.00	0.00	-3.00
SI	NA	NA	NA	0.1967	0.1333	0.2777	0.1624	0.1533	0.222	0.387	0.1533	0.1704	-2.7851

Table 20 Stock Solution 1 Composition

Stock Solution 1 - Arsenic, cobalt, copper, nickel, and zinc	
Copper sulfate pentahydrate	$CuSO_4$-$5H_2O$
Target influent Cu concentration	700 µg/L
Stock solution Cu concentration	700 mg/L
Stock solution salt concentration	2,750 mg/L
Mass of copper salt required for 20 gal	165.0 g
Cobalt chloride hexahydrate	$CoCl_2$-$6H_2O$
Target influent Co concentration	150 µg/L
Stock solution Co concentration	150 mg/L
Stock solution Co salt concentration	606 mg/L
Mass of cobalt salt required for 20 gal	36.3 g
Nickel chloride hexahydrate	$NiCl_2$-$6H_2O$
Target influent Ni concentration	1300 µg/L
Stock solution Ni concentration	1,300 mg/L
Stock solution salt concentration	5,265 mg/L
Mass of nickel salt required for 20 gal	315.9 g
Sodium arsenite	$NaAsO_2$
Target influent As concentration	100 µg/L
Stock solution As concentration	100 mg/L
Stock solution salt concentration	173 mg/L
Mass of arsenic salt required for 20 gal	10.4 g
Zinc sulfate heptahydrate	$ZnSO_4$-$7H_2O$
Target influent Zn concentration	300 µg/L
Stock solution Zn concentration	300 mg/L
Stock solution salt concentration	1, 319 mg/L
Mass of zinc salt required for 20 gal	79.2 g

Table 21 **Stock Solution 2 Composition**

Stock Solution 2 - Selenium	
Sodium selenite	Na_2SeO_3
Target influent selenium concentration	10 µg/L
Stock solution selenium concentration	10 mg/L
Stock solution salt concentration	22 mg/L
Mass of salt required for 20 gal	1.3 g

Table 22 Stock Solution 3 Composition

Stock Solution 3 - Lead	
Lead nitrate	$Pb(NO_3)_2$
Target influent lead concentration	100 µg/L
Stock solution lead concentration	100 mg/L
Stock solution salt concentration	160 mg/L
Mass of salt required for 20 gal	9.6 g

Table 23 Summary of Metals Seeding Test Results

		Fraction	Alkalinity, total NA	pH NA	Solids, total dissolved NA	Arsenic Total	Cobalt Total	Copper Total	Lead Total	Nickel Total	Selenium Total	Zinc Total
Location	lab_sample_id	Date										
Pretreated Effluent	1205772-01	12/7/12 11:15 AM	480 mg/l	7.7 pH units	960 mg/l	< 1.0 ug/l	< 0.20 ug/l	2.6 ug/l	--	< 2.5 ug/l	--	8.9 ug/l
Pretreated Effluent	1205772-05	12/7/12 11:15 AM	500 mg/l	7.8 pH units	1000 mg/l	< 1.0 ug/l	< 0.20 ug/l	2.2 ug/l	--	0.91 ug/l	--	5.3 ug/l
Pretreated Effluent	1205787-01	12/8/12 10:30 AM	480 mg/l	8.0 pH units	1200 mg/l	< 1.0 ug/l	< 0.20 ug/l	2.8 ug/l	--	0.69 ug/l	--	5.3 ug/l
Pretreated Effluent	1205787-05	12/8/12 10:30 AM	460 mg/l	7.7 pH units	1000 mg/l	< 1.0 ug/l	< 0.20 ug/l	2.1 ug/l	--	1.1 ug/l	--	6.2 ug/l
Pretreated Effluent	1205787-09	12/9/12 10:00 AM	470 mg/l	7.5 pH units	1100 mg/l	< 1.0 ug/l	< 0.20 ug/l	2.5 ug/l	--	0.96 ug/l	--	5.4 ug/l
Pretreated Effluent	1205772-13	12/10/12 9:00 AM	430 mg/l	7.6 pH units	860 mg/l	--	--	--	--	--	< 1.0 ug/l	--
Pretreated Effluent	1205787-15	12/10/12 9:00 AM	440 mg/l	7.4 pH units	970 mg/l	--	--	--	--	--	< 1.0 ug/l	--
Pretreated Effluent	1205786-01	12/11/12 10:00 AM	430 mg/l	7.6 pH units	960 mg/l	--	--	--	--	--	< 1.0 ug/l	--
Pretreated Effluent	1205786-05	12/11/12 10:00 AM	450 mg/l	7.6 pH units	980 mg/l	--	--	--	--	--	< 1.0 ug/l	--
Pretreated Effluent	1205835-01	12/13/12 7:00 AM	450 mg/l	7.8 pH units	1000 mg/l	--	--	--	0.23 ug/l	--	--	--
Pretreated Effluent	1205835-05	12/13/12 7:00 AM	450 mg/l	7.7 pH units	970 mg/l	--	--	--	0.24 ug/l	--	--	--
Pretreated Effluent	1205874-01	12/14/12 10:30 AM	450 mg/l	8.0 pH units	1000 mg/l	--	--	--	0.44 ug/l	--	--	--
Pretreated Effluent	1205874-05	12/14/12 10:30 AM	450 mg/l	7.6 pH units	940 mg/l	--	--	--	0.26 ug/l	--	--	--
RO Feed	1205772-02	12/7/12 11:15 AM	490 mg/l	7.7 pH units	700 mg/l	170 ug/l	210 ug/l	990 ug/l	--	1700 ug/l	--	630 ug/l
RO Feed	1205772-06	12/7/12 11:15 AM	500 mg/l	7.8 pH units	890 mg/l	160 ug/l	200 ug/l	940 ug/l	--	1700 ug/l	--	580 ug/l
RO Feed	1205787-02	12/8/12 10:30 AM	490 mg/l	7.8 pH units	1100 mg/l	200 ug/l	220 ug/l	1200 ug/l	--	1800 ug/l	--	750 ug/l
RO Feed	1205787-06	12/8/12 10:30 AM	460 mg/l	7.8 pH units	1100 mg/l	96 ug/l	160 ug/l	550 ug/l	--	1300 ug/l	--	320 ug/l
RO Feed	1205787-10	12/9/12 10:00 AM	460 mg/l	7.8 pH units	1100 mg/l	100 ug/l	180 ug/l	570 ug/l	--	1400 ug/l	--	360 ug/l
RO Feed	1205772-14	12/10/12 9:00 AM	430 mg/l	7.5 pH units	660 mg/l	--	--	--	--	--	14 ug/l	--
RO Feed	1205787-16	12/10/12 9:00 AM	450 mg/l	7.4 pH units	920 mg/l	--	--	--	--	--	13 ug/l	--
RO Feed	1205786-02	12/11/12 10:00 AM	430 mg/l	7.7 pH units	920 mg/l	--	--	--	--	--	13 ug/l	--
RO Feed	1205786-06	12/11/12 10:00 AM	440 mg/l	7.6 pH units	990 mg/l	--	--	--	--	--	13 ug/l	--
RO Feed	1205835-02	12/13/12 7:00 AM	450 mg/l	8.3 pH units	1100 mg/l	--	--	--	150 ug/l	--	--	--
RO Feed	1205835-06	12/13/12 7:00 AM	460 mg/l	7.8 pH units	1000 mg/l	--	--	--	140 ug/l	--	--	--
RO Feed	1205874-02	12/14/12 10:30 AM	460 mg/l	7.7 pH units	960 mg/l	--	--	--	150 ug/l	--	--	--
RO Feed	1205874-06	12/14/12 10:30 AM	470 mg/l	7.7 pH units	950 mg/l	--	--	--	150 ug/l	--	--	--
RO Permeate	1205772-04	12/7/12 11:15 AM	< 20 mg/l	6.2 pH units	< 10 mg/l	31 ug/l	0.27 ug/l	1.6 ug/l	--	2.1 ug/l	--	< 5.0 ug/l
RO Permeate	1205772-08	12/7/12 11:15 AM	< 20 mg/l	7.1 pH units	< 10 mg/l	28 ug/l	0.27 ug/l	3.1 ug/l	--	2.2 ug/l	--	< 5.0 ug/l
RO Permeate	1205787-04	12/8/12 10:30 AM	< 20 mg/l	7.0 pH units	< 10 mg/l	32 ug/l	0.28 ug/l	2.5 ug/l	--	2.3 ug/l	--	< 5.0 ug/l
RO Permeate	1205787-08	12/8/12 10:30 AM	< 20 mg/l	6.0 pH units	18 mg/l	23 ug/l	0.24 ug/l	1.3 ug/l	--	1.9 ug/l	--	< 5.0 ug/l
RO Permeate	1205787-12	12/9/12 10:00 AM	< 20 mg/l	5.9 pH units	12 mg/l	26 ug/l	0.29 ug/l	2.0 ug/l	--	2.4 ug/l	--	< 5.0 ug/l
RO Permeate	1205772-16	12/10/12 9:00 AM	< 20 mg/l	5.7 pH units	< 10 mg/l	--	--	--	--	--	< 1.0 ug/l	--
RO Permeate	1205787-17	12/10/12 9:00 AM	< 20 mg/l	5.5 pH units	17 mg/l	--	--	--	--	--	< 1.0 ug/l	--
RO Permeate	1205786-04	12/11/12 10:00 AM	< 20 mg/l	5.6 pH units	< 10 mg/l	--	--	--	--	--	< 1.0 ug/l	--
RO Permeate	1205786-08	12/11/12 10:00 AM	< 20 mg/l	5.6 pH units	< 10 mg/l	--	--	--	--	--	< 1.0 ug/l	--
RO Permeate	1205835-04	12/13/12 7:00 AM	< 20 mg/l	6.1 pH units	44 mg/l	--	--	--	< 0.20 ug/l	--	--	--
RO Permeate	1205835-08	12/13/12 7:00 AM	< 20 mg/l	6.5 pH units	33 mg/l	--	--	--	< 0.20 ug/l	--	--	--
RO Permeate	1205874-04	12/14/12 10:30 AM	< 20 mg/l	6.6 pH units	< 10 mg/l	--	--	--	0.27 ug/l	--	--	--
RO Permeate	1205874-08	12/14/12 10:30 AM	< 20 mg/l	6.2 pH units	< 10 mg/l	--	--	--	0.20 ug/l	--	--	--
RO Concentrate	1205787-03	12/8/12 10:30 AM	1700 mg/l	7.8 pH units	3800 mg/l	400 ug/l	620 ug/l	4300 ug/l	--	6300 ug/l	--	2200 ug/l
RO Concentrate	1205787-07	12/8/12 10:30 AM	1600 mg/l	7.8 pH units	3600 mg/l	310 ug/l	540 ug/l	2000 ug/l	--	4800 ug/l	--	1200 ug/l
RO Concentrate	1205787-11	12/9/12 10:00 AM	1600 mg/l	7.7 pH units	3600 mg/l	330 ug/l	590 ug/l	2000 ug/l	--	4800 ug/l	--	1200 ug/l
RO Concentrate	1205772-15	12/10/12 9:00 AM	1500 mg/l	7.8 pH units	2800 mg/l	--	--	--	--	--	66 ug/l	--
RO Concentrate	1205787-18	12/10/12 9:00 AM	1500 mg/l	7.7 pH units	3400 mg/l	--	--	--	--	--	63 ug/l	--
RO Concentrate	1205786-03	12/11/12 10:00 AM	1500 mg/l	7.7 pH units	3400 mg/l	--	--	--	--	--	61 ug/l	--
RO Concentrate	1205786-07	12/11/12 10:00 AM	1500 mg/l	7.8 pH units	3400 mg/l	--	--	--	--	--	61 ug/l	--
RO Concentrate	1205835-03	12/13/12 7:00 AM	1500 mg/l	7.9 pH units	3700 mg/l	--	--	--	530 ug/l	--	--	--
RO Concentrate	1205835-07	12/13/12 7:00 AM	1600 mg/l	7.8 pH units	3500 mg/l	--	--	--	440 ug/l	--	--	--
RO Concentrate	1205874-03	12/14/12 10:30 AM	1600 mg/l	7.8 pH units	3400 mg/l	--	--	--	520 ug/l	--	--	--
RO Concentrate	1205874-07	12/14/12 10:30 AM	1600 mg/l	7.8 pH units	3300 mg/l	--	--	--	530 ug/l	--	--	--
RO Concentrate	1205772-03	12/7/12 11:15 AM	1700 mg/l	7.8 pH units	3800 mg/l	360 ug/l	590 ug/l	3200 ug/l	--	5400 ug/l	--	2000 ug/l
RO Concentrate	1205772-07	12/7/12 11:15 AM	970 mg/l	7.8 pH units	3600 mg/l	340 ug/l	590 ug/l	3100 ug/l	--	5700 ug/l	--	2100 ug/l
VSEP Feed	1205772-09	12/8/12 7:00 AM	850 mg/l	6.4 pH units	4200 mg/l	420 ug/l	660 ug/l	3100 ug/l	--	5400 ug/l	--	2000 ug/l
VSEP Feed	1205772-10	12/9/12 7:00 AM	620 mg/l	6.2 pH units	4500 mg/l	420 ug/l	720 ug/l	2400 ug/l	--	5100 ug/l	--	2200 ug/l
VSEP Feed	1205786-09	12/11/12 12:30 PM	680 mg/l	6.4 pH units	4000 mg/l	--	--	--	--	--	47 ug/l	--
VSEP Feed	1205804-01	12/12/12 7:00 AM	730 mg/l	6.4 pH units	3900 mg/l	--	--	--	--	--	49 ug/l	--
VSEP Feed	1205874-09	12/14/12 7:00 AM	610 mg/l	6.4 pH units	3700 mg/l	--	--	--	460 ug/l	--	--	--
VSEP Feed	1205874-12	12/15/12 7:00 AM	860 mg/l	6.5 pH units	4500 mg/l	--	--	--	570 ug/l	--	--	--
VSEP Permeate	1205772-12	12/8/12 12:30 PM	34 mg/l	5.5 pH units	76 mg/l	160 ug/l	9.4 ug/l	42 ug/l	--	73 ug/l	--	18 ug/l
VSEP Permeate	1205787-14	12/9/12 12:30 PM	26 mg/l	5.3 pH units	130 mg/l	120 ug/l	5.9 ug/l	22 ug/l	--	47 ug/l	--	12 ug/l
VSEP Permeate	1205786-11	12/11/12 12:30 PM	25 mg/l	5.3 pH units	120 mg/l	--	--	--	--	--	1.0 ug/l	--
VSEP Permeate	1205804-03	12/12/12 12:30 PM	22 mg/l	6.3 pH units	120 mg/l	--	--	--	--	--	1.0 ug/l	--
VSEP Permeate	1205874-11	12/14/12 12:00 PM	26 mg/l	5.5 pH units	100 mg/l	--	--	--	3.2 ug/l	--	--	--
VSEP Permeate	1205874-14	12/15/12 12:30 PM	22 mg/l	5.2 pH units	37 mg/l	--	--	--	1.1 ug/l	--	--	--
VSEP Concentrate	1205772-11	12/8/12 12:30 PM	4800 mg/l	7.1 pH units	24000 mg/l	2100 ug/l	4500 ug/l	21000 ug/l	--	36000 ug/l	--	13000 ug/l
VSEP Concentrate	1205787-13	12/9/12 12:30 PM	3300 mg/l	6.9 pH units	24000 mg/l	1100 ug/l	3600 ug/l	13000 ug/l	--	29000 ug/l	--	11000 ug/l
VSEP Concentrate	1205786-10	12/11/12 12:30 PM	2700 mg/l	6.9 pH units	22000 mg/l	--	--	--	--	--	310 ug/l	--
VSEP Concentrate	1205804-02	12/12/12 12:30 PM	2800 mg/l	6.9 pH units	21000 mg/l	--	--	--	--	--	310 ug/l	--
VSEP Concentrate	1205874-10	12/14/12 12:00 PM	3500 mg/l	7.1 pH units	21000 mg/l	--	--	--	3000 ug/l	--	--	--
VSEP Concentrate	1205874-13	12/15/12 12:30 PM	3600 mg/l	7.0 pH units	26000 mg/l	--	--	--	3200 ug/l	--	--	--

Table 24 Metals Seeding Test RO Removal Rates

	Stock Solution 1		**Stock Solution 2**			**Stock Solution 3**				
	12/7/2012		**12/10/2012**	**12/11/2012**		**12/13/2012**		**12/14/2012**		
Parameter	***Sample 1***	***Sample 2***	***Sample 1***	***Sample 2***	***Sample 3***	***Sample 1***	***Sample 2***	***Sample 3***	***Sample 4***	**Average Reduction**
As	81.76%	82.50%								82.13%
Co	99.87%	99.87%								99.87%
Cu	99.84%	99.67%								99.75%
Ni	99.88%	99.87%								99.87%
Pb						>99.93%	>99.93%	99.82%	99.87%	>99.89%
Se			>96.43%	>96.15%	>96.15%					>96.25%
Zn	>99.60%	>99.57%								>99.59%

- Where ">" (greater than) is indicated, the permeate concentration was less than the method reporting limit. Half of the method reporting limit was used to calculate the percent removal in those cases.

Table 25 Metals Seeding Test VSEP Removal Rates (Concentration-Based)

	Stock Solution 1		Stock Solution 2		Stock Solution 3		
	12/8/2012	12/9/2012	12/11/2012	12/12/2012	12/14/2012	12/15/2012	
Parameter	***Batch 1***	***Batch 2***	***Batch 1***	***Batch 2***	***Batch 1***	***Batch 2***	**Average Removal**
As	61.90%	71.43%					66.67%
Co	98.58%	99.18%					98.88%
Cu	98.65%	99.08%					98.86%
Ni	98.65%	99.08%					98.86%
Pb					99.30%	99.81%	99.56%
Se			97.87%	97.96%			97.92%
Zn	98.30%	98.82%					98.56%

Table 26 Metals Seeding Test Estimated Blended Permeate Water Quality

	Average Permeate Concentrations (µg/L)				
Parameter	**RO**	**VSEP**	**Blend**	**Class 2B WQS**	
As	29.5	140	48.9	53	
Co	0.27	7.65	1.6	5	
Cu	2.4	32	7.5	9.8	(assumes total hardness of 100 mg/L as CaCO3)
Ni	2.2	60	12.3	158	(assumes total hardness of 100 mg/L as CaCO3)
Pb	0.2	2.15	0.5	3.2	(assumes total hardness of 100 mg/L as CaCO3)
Se	0.5	1	0.6	5	
Zn	2.5	15	4.7	106	(assumes total hardness of 100 mg/L as CaCO3)

Red values are half the reporting limit.
Blend concentration based on 80% RO recovery and 85% VSEP recovery

Table 27 Summary of Arsenic Removal Test Results

Fraction			Alkalinity, total NA	pH NA	Solids, total dissolved NA	Arsenic Total
Location	**lab_sample_id**	**Date**				
Feed Tank Effluent	1205928-01	12/19/12 7:30 AM	**450 mg/l**	**8.0 pH units**	**910 mg/l**	**64 µg/l**
Feed Tank Effluent	1205928-05	12/19/12 9:00 AM	**450 mg/l**	**7.8 pH units**	**900 mg/l**	**67 µg/l**
Feed Tank Effluent	1205928-09	12/19/12 10:30 AM	**450 mg/l**	**7.6 pH units**	**1100 mg/l**	**370 µg/l**
RO Concentrate	1205928-03	12/19/12 7:30 AM	**1500 mg/l**	**7.7 pH units**	**3000 mg/l**	< 5.0 µg/l
RO Concentrate	1205928-07	12/19/12 9:00 AM	**1500 mg/l**	**7.7 pH units**	**3100 mg/l**	< 5.0 µg/l
RO Concentrate	1205928-11	12/19/12 10:30 AM	**1500 mg/l**	**7.7 pH units**	**3000 mg/l**	< 5.0 µg/l
RO Feed	1205928-02	12/19/12 7:30 AM	**450 mg/l**	**7.7 pH units**	**890 mg/l**	< 1.0 µg/l
RO Feed	1205928-06	12/19/12 9:00 AM	**460 mg/l**	**7.5 pH units**	**890 mg/l**	< 1.0 µg/l
RO Feed	1205928-10	12/19/12 10:30 AM	**450 mg/l**	**7.8 pH units**	**910 mg/l**	**1.2 µg/l**
RO Permeate	1205928-04	12/19/12 7:30 AM	< 20 mg/l	**6.8 pH units**	< 10 mg/l	< 1.0 µg/l
RO Permeate	1205928-08	12/19/12 9:00 AM	< 20 mg/l	**6.8 pH units**	< 10 mg/l	< 1.0 µg/l
RO Permeate	1205928-12	12/19/12 10:30 AM	< 20 mg/l	**6.6 pH units**	< 10 mg/l	< 1.0 µg/l

Table 28 **Greensand Filter Arsenic Removal Rates**

	As Removal
Sampling event 1	> 99.22%
Sampling event 2	> 99.25%
Sampling event 3	99.68%
Average	99.38%

Table 29 Metals Removal Literature Review Summary

Element	Influent	Effluent	Max Rejection	Median rejection	Temp	Membrane	System Recovery	Test Type	Source
Aluminum			99.90%						Pure water Products
Aluminum	80 µg/L	<MDL	>99.9%		Room			Bench	Reference (11)
Antimony	18.2 µg/L		>99%	99%	N/A	TFC RO		Bench Scale	Reference (12)
Antimony	50 mg/L			99.2%	N/A		80%	Bench Scale	Reference (13)
Cadmium	0.23 mg/L		99%		Room	Toray		Pilot	Reference (16)
Cadmium	500 mg/L		99.40%		Room	Polyamide	80%	Full Scale	Reference (15)
Chromium	NA	1.5 mg/L		>99%	20C	Polyamide	50-80%	Pilot	Reference (16)
Chromium (III)	0.29 mg/L	<MDL	>99%	98%	Room	Filmtec	10.40%	Pilot	Reference (16)
Chromium (III)	1.23 mg/L		99%	99%	Room	Hydranautics	10.70%	Pilot	Reference (16)
Chromium (VI)	NA			99.50%	20C	Polyamide	63%	Full Scale	Reference (17)
Chromium (VI)	0.61 mg/L			98%	Room	Toray		Pilot	Reference (16)
Mercury	0.026 mg/l	<MDL	>98%		Room	DuPont	50%	Pilot	Reference (16)
Mercury	0.076 mg/L		22%	16%	Room	Dow	59%	Pilot	Reference (16)
Mercury	6µg/L		99.9%		Room	Polyamide		Bench Scale	Reference (19)
Thallium			90-100%						Reference (20)

Table 30 Oxidation Pretreatment Test Conditions

Batch #	HDS Metals Screening		Sulfate Precipitation Screening	
	Iron Solids, %	pH, std units	Gypsum Solids, %	pH, std units
Pre-Treated Water	1	9	10	12
Untreated Water	1	9	10	12

Table 31 Summary of Oxidation Pretreatment Test Results

Dissolved Constituents, µg/L	VSEP Concentrate	HDS Metals-Treated		Gypsum Precipitation-Treated	
		Oxidative Pre-Treatment	No Oxidative Pre-Treatment	Oxidative Pre-Treatment	No Oxidative Pre-Treatment
Sulfate	9,200,000			1,800,000	2,200,000
Aluminum	<50			<50	<50
Antimony	<1.0				
Arsenic	8	<5.0	<5.0		
Beryllium	<1.0	<1.0	<1.0		
Boron	1.8	<1.0	<1.0		
Chromium	22	8.3	8		
Cobalt	2.7	3.4	2.7		
Copper	260	67	60		
Iron	<0.5	<0.5	<0.5		
Lead	2	<1.0	<1.0		
Manganese	180	<2.5	3		
Nickel	23	15	19		
Selenium	11	7.3	8.3		
Zinc	100	<50	<50		

Table 32 **Comparison of Stock Solutions and Future Mine Site WWTF Influent Concentrations**

Solution		Metal Salt Formula	Stock Concentration (mg/L)	90th Percentile Concentration (mg/L)	Concentration Possible Using Specified Stock Solution (mg/L)	Volume Of Stock Solution to Add
						(ml of stock/Liter of Water)
Solution #1	Cobalt	$CoCl_2*6H_2O$	150	0.47	2.09	13.9
Solution #1	Copper	$CuSO_4*5H_2O$	700	9.76	9.76	13.9
Solution #1	Nickel	$NiCl_2*6H_2O$	1300	6.59	18.12	13.9
Solution #1	Arsenic	$NaAsO_2$	100	0.63	1.39	13.9
Solution #1	Zinc	$ZnSO_4*7H_2O$	300	0.15	0.15	13.9
Solution #2	Selenium	Na_2SeO_3	22	0.06	0.011	0.5
Solution #3	Lead	$Pb(NO_3)_2$	100	0.81	0.81	8.1

Table 33 **HDS Test Conditions**

Batch #	Jar A		Jar B		Jar C		Jar D	
	Ferric Hydroxide Solids, %	pH, std units	Ferric Hydroxide Solids, %	pH, std units	Ferric Hydroxide Solids, %	pH, std units	Ferric Hydroxide Solids, %	pH, std units
1	0.05	7	0.05	8	0.05	9	0.05	10
2	0.5	7	0.5	8	0.5	9	0.5	10
3	1.5	7	1.5	8	1.5	9	1.5	10

Table 34 **HDS Test Analytes**

Dissolved Metals List	As, Sb, Be, B, Cr, Co, Cu, Fe, Pb, Mn, Ni, Se, Zn
Total Metals List	Co, As, Fe

Table 35 **Gypsum Test Conditions**

Batch #	Gypsum Solids, %	pH, std units
1	0.1	12
2	1	12
3	10	12

Table 36 Summary of HDS Bench Test Results

Sample	pH	Rxn Time (min)	Fe Solids (%)	Sb	As	Be	B	Cr	Co	Cu	Fe	Pb	Mn	Ni	Se	Zn
Raw	NA	NA	NA	--	1200	--	1.7	20	1800	7500	0.50	730	170	14000	18	2500
1	7	30	0.05	2.0	610	1.0	--	14	1600	1100	0.25	2.2	160	13000	10.0	510
2	7	30	0.50	2.0	47	1.0	--	11	170	130	0.25	1.1	79	6000	7.1	46
3	7	30	1.50	2.0	14	1.0	--	12	31	110	0.25	1.2	29	1600	5.0	34
4	7	60	0.05	2.0	560	1.0	--	14	1400	830	0.25	2.3	160	13000	9.7	140
5	7	60	0.50	2.0	41	1.0	--	11	100	130	0.25	1.1	54	4700	6.7	37
6	7	60	1.50	2.0	12	1.0	--	12	21	100	0.25	1.1	20	1200	5.0	34
7	8	30	0.05	2.0	770	1.0	--	15	1000	840	0.25	5.2	110	10000	12.0	57
8	8	30	0.50	2.0	53	1.0	--	12	93	120	0.25	1.0	25	3300	8.5	34
9	8	30	1.50	2.0	13	1.0	--	14	20	110	0.25	1.0	15	810	6.4	35
10	8	60	0.05	2.0	630	1.0	--	16	1000	800	0.25	4.2	120	9900	11.0	62
11	8	60	0.50	2.0	37	1.0	--	12	68	110	0.25	1.0	20	2700	6.8	34
12	8	60	1.50	2.0	9	1.0	--	15	12	99	0.25	1.0	9.6	530	5.0	51
13	9	30	0.05	--	440	--	1.1	14	28	94	0.25	1.1	3.8	810	11.0	29
14	9	30	0.50	--	38	--	1.1	20	11	95	0.25	1.0	0.25	350	8.6	33
15	9	30	1.50	--	7	--	0.9	22	3.5	97	0.25	1.0	0.25	56	8.0	34
16	9	60	0.05	--	370	--	1.0	14	22	79	0.25	1.0	0.25	530	9.6	30
17	9	60	0.50	--	24	--	1.1	24	8.5	97	0.25	1.0	0.25	230	9.8	25
18	9	60	1.50	--	6.2	--	0.87	22	3.5	93	0.25	1.0	0.25	46	5.5	42
19	10	30	0.05	--	34	--	0.5	20	7	84	0.25	1.0	0.25	65	11.0	25
20	10	30	0.50	--	16	--	0.5	22	3.7	83	0.25	1.0	0.25	27	8.5	26
21	10	30	1.50	--	7.6	--	1.0	24	3	92	0.25	1.0	0.25	29	7.4	28
22	10	60	0.05	--	17	--	1.0	22	7	80	0.25	1.0	0.25	41	9.1	25
23	10	60	0.50	--	13	--	1.0	25	4.1	79	0.25	1.0	0.25	25	10.0	26
24	10	60	1.50	--	7	--	1.0	24	3	89	0.25	1.0	0.25	28	7.9	30

Results in RED reflect the reporting limit of the instrumentation.
All units are µg/L EXCEPT Fe/B, which are mg/L

🟧 Not requested on CoC or formally cancelled.

Table 37 **Summary of HDS Settling Test Results**

Sample	pH	Settling Time (min)	Total As, µg/L	Total Co, µg/L	Total Fe, µg/L
37	7	2	140	800	1300
38	7	4	61	120	150
39	7	6	30	70	62
40	8	2	82	140	220
41	8	4	27	47	57
42	8	6	20	34	28
43	9	2	41	64	99
44	9	4	16	13	14
45	9	6	14	10	10
46	10	2	26	36	47
47	10	4	9	5.6	6.8
48	10	6	7.7	3.7	2.1

Table 38 **Summary of Gypsum Precipitation Bench Test Results**

Sample	pH	Reaction Time (min)	Solids (%)	Dissolved Al, µg/L	Dissolved Ca, µg/L	Dissolved Alk, mg/L	Dissolved SO4, mg/L
25	12	30	0.10	3900	4900	11000	2100
26	12	30	1.00	5300	9800	16000	1900
27	12	30	10.00	7500	8800	12000	4400
28	12	60	0.10	3600	4700	6300	2100
29	12	60	1.00	5500	9200	8600	1800
30	12	60	10.00	8000	7800	1100	4300

Table 39 **Summary of Gypsum Precipitation Settling Test Results**

Sample	pH	Settling Time, min	Solids (%)	Total Al, µg/L	Total Ca, mg/L	Total SO4, mg/L
31	NA	2	0.10	2600	3200	4200
32	NA	4	0.10	2500	3100	4400
33	NA	6	0.10	2500	3100	3300
34	NA	2	1.00	3800	7200	2800
35	NA	4	1.00	3800	6300	2200
36	NA	6	1.00	3500	6100	3600

Table 40 **Comparison of Pilot Plant Influent and Estimated Future Influent Water Qualities**

	Mine Site WWTF(1)			Plant Site WWTP(2)				Plant Site Pilot-testing Program(3,4,5)						
	Mine Year 75 Annual Average Concentrations (mg/L)			Mine Year 20 Annual Average Concentrations (mg/L)		MineYear 20 Annual Maximum Concentrations (mg/L)		SD004 (mg/L)			Pilot-test Well (mg/L)			Metals Seeding And Arsenic Removal Tests (mg/L)
Parameter	***P10***	***P50***	***P90***	***Mean***	***P90***	***Mean***	***P90***	***Min***	***Max***	***Ave***	***Min***	***Max***	***Ave***	***Ave***
Ag	0.0002	0.0002	0.0002	0.00019	0.0002	0.0002	0.0002	NA	NA	NA	NA	NA	NA	NA
Al	0.0009	0.0014	0.0021	0.0035	0.0044	0.0073	0.012	<0.010	<0.010	<0.010	<0.010	0.022	0.0083	NA
As	0.0092	0.0122	0.0196	0.064	0.069	0.069	0.073	0.002	0.02	0.004	0.0028	0.018	0.007	0.17
B	0.10	0.10	0.10	0.11	0.12	0.12	0.12	0.45	0.54	0.49	0.27	0.50	0.38	NA
Ca	56.3	63.9	80.1	293	376	311	401	88	100	94	63	100	80	NA
Cd	0.0010	0.0015	0.0036	0.0023	0.0039	0.0024	0.0042	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	NA
Cl	10	12	15	35	40	37	42	20	24	21	21	32	26	NA
Co	0.014	0.028	0.061	0.048	0.096	0.051	0.10	0.00079	0.0016	0.00097	0.00036	0.00086	0.00053	0.21
Cr	0.0033	0.0034	0.0037	0.0074	0.0078	0.0078	0.0081	NA	NA	NA	NA	NA	NA	NA
Cu	0.12	0.24	0.65	0.48	0.63	0.49	0.66	<0.0005	0.0072	0.0028	0.00085	0.046	0.0083	0.97
Mg	19.7	21.7	26.7	147	162	152	167	150	200	184	68	190	128	NA
Ni	0.22	0.38	0.67	0.64	1.19	0.68	1.26	<0.0005	0.0035	0.0011	<0.0005	0.0029	0.0011	1.7
Pb	0.0069	0.0086	0.012	0.064	0.069	0.070	0.074	<0.0002	0.021	0.0017	<0.0002	0.018	0.0019	0.15
Sb	0.0085	0.0096	0.0124	0.017	0.019	0.017	0.029	NA	NA	NA	NA	NA	NA	NA
Se	0.0002	0.0025	0.0035	0.0056	0.0072	0.0059	0.0076	<0.001	0.002	0.001	<0.001	0.0022	0.0008	0.013
Tl	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.00021	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	NA
Zn	0.08	0.10	0.22	0.173	0.26	0.18	0.27	<0.005	0.03	0.006	0.0025	0.048	0.013	0.61

(1) Preliminary output, Model Version: AWMP Version 4.0, Run Date: 12/09/12, concentrations are the dissolved fraction
(2) Plant Site GoldSim model output, October 2012
(3) Preliminary data from pilot-test program, 5/2012 through 10/2012; concentrations are total concetrations. Metals seeding and As removal test data were collected 12/2012.
(4) NA = not analyzed
(5) Where analytical results were less than the method reporting limit, half the reporting limit was used to calculate the averages.

Table 41 **Analytical Data Notes and Qualifiers**

Qualifier	Definition
--	Not analyzed/not available.
b	Potential false positive value based on blank data validation procedures.
e	Estimated value, exceeded the instrument calibration range.
h	EPA recommended sample preservation, extraction or analysis holding time was exceeded.
j	Reported value is less than the stated laboratory quantitation limit and is considered an estimated value.
*	Estimated value, QA/QC criteria not met.
**	Unusable value, QA/QC criteria not met.
N	Sample Type: Normal
FD	Sample Type: Field Duplicate

Figures

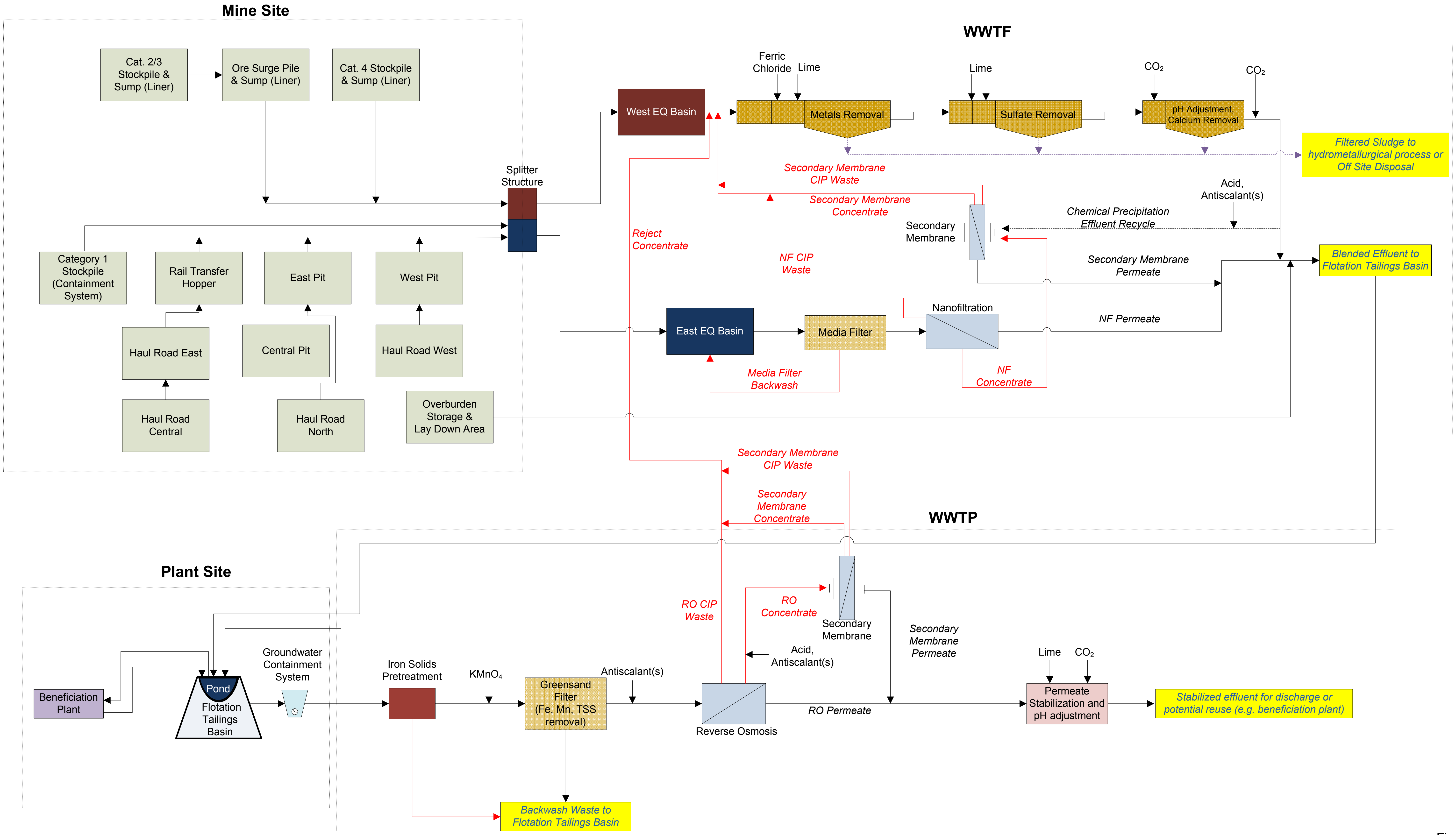
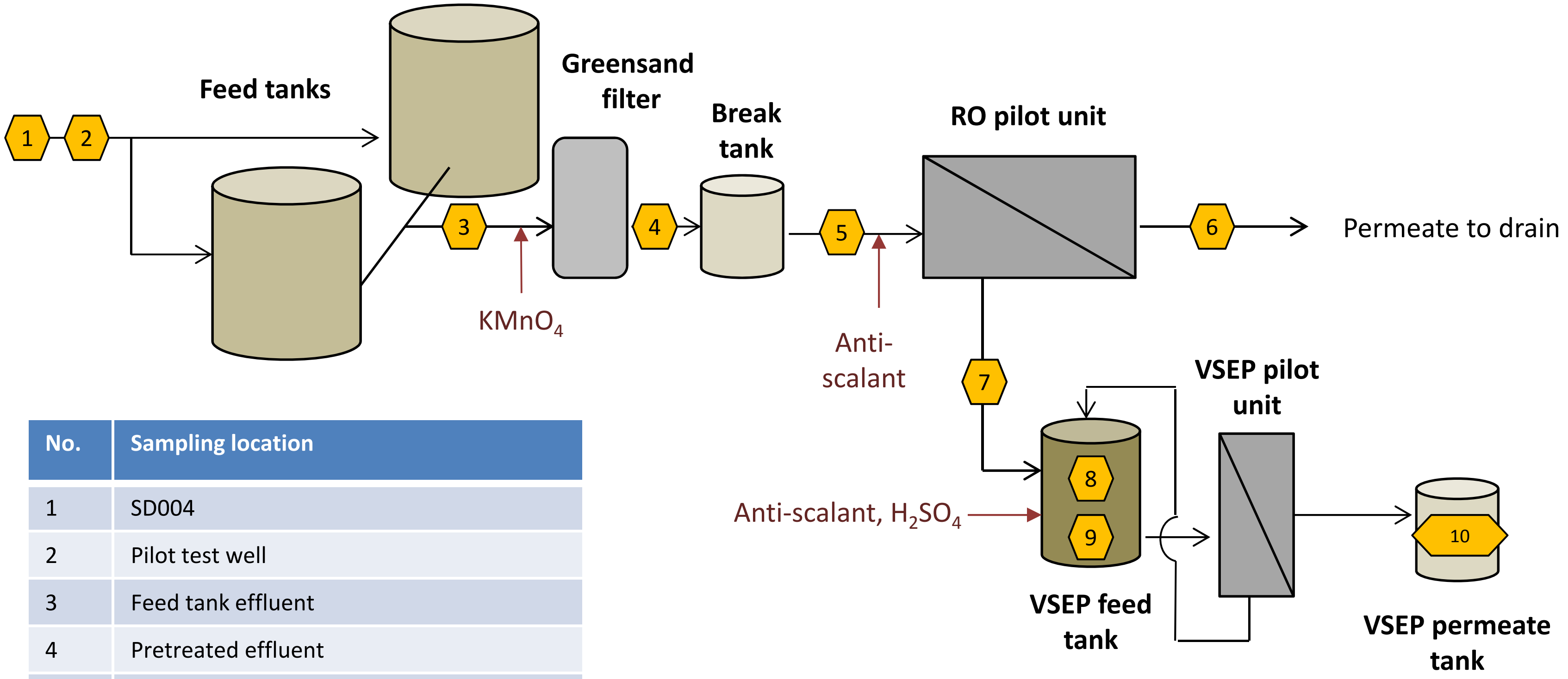


Figure 1
Water Treatment
Overall Flow Sheet-Operations
NorthMet Project
Poly Met Mining, Inc.
Hoyt Lakes, MN

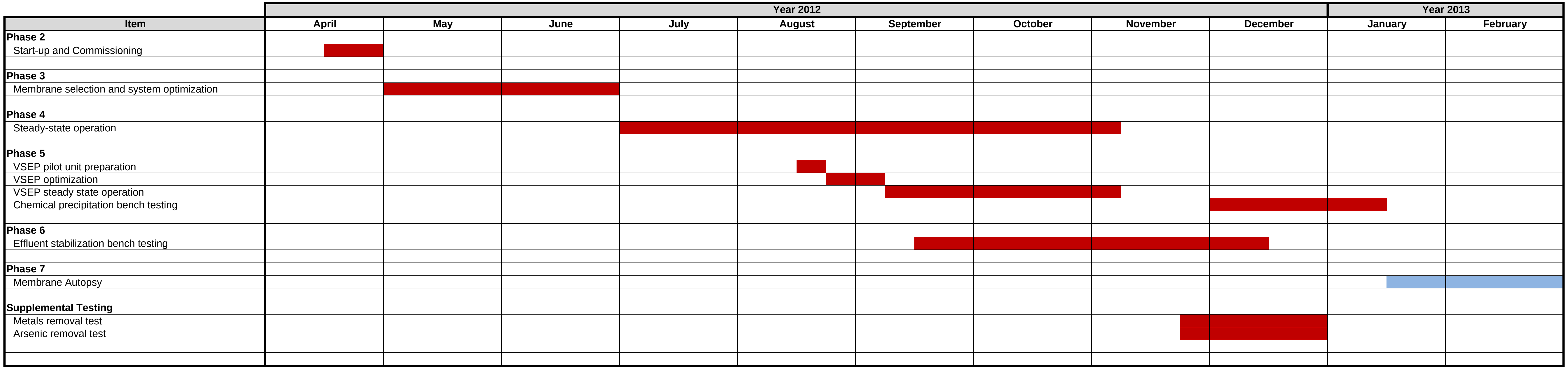
Figure 2. Pilot Testing Program Components and Sampling Locations



No.	Sampling location
1	SD004
2	Pilot test well
3	Feed tank effluent
4	Pretreated effluent
5	RO feed
6	RO permeate
7	RO concentrate
8	VSEP feed (beginning of batch)
9	VSEP concentrate (end of batch)
10	VSEP permeate (end of batch)

\# Sampling location

Figure 3. Testing Schedule



This conceptual milestone schedule is subject to modification depending on the results of the pilot-scale testing.

Notes:

🟥 Tasks completed as of report's cover date

🟦 Tasks to-be completed as of report's cover date

● Existing Surface Discharges

● Existing Groundwater Wells

▲ Pilot Test Well

Figure 4
SITE LAYOUT
NorthMet Project
Poly Met Mining, Inc.
Hoyt Lakes, MN

Figure 5. Influent Dissolved Solids, Total Hardness, and Sulfate Concentrations

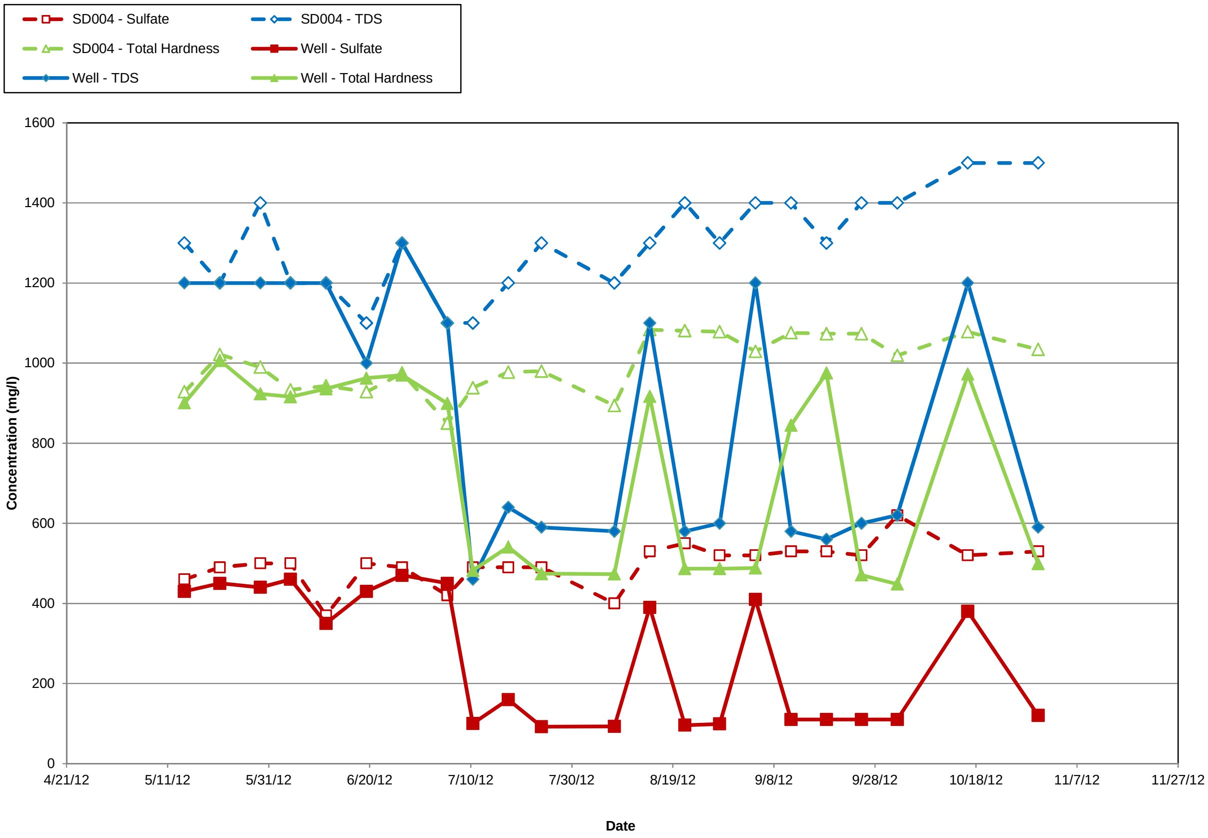


Figure 6. Influent Iron and Manganese Concentrations

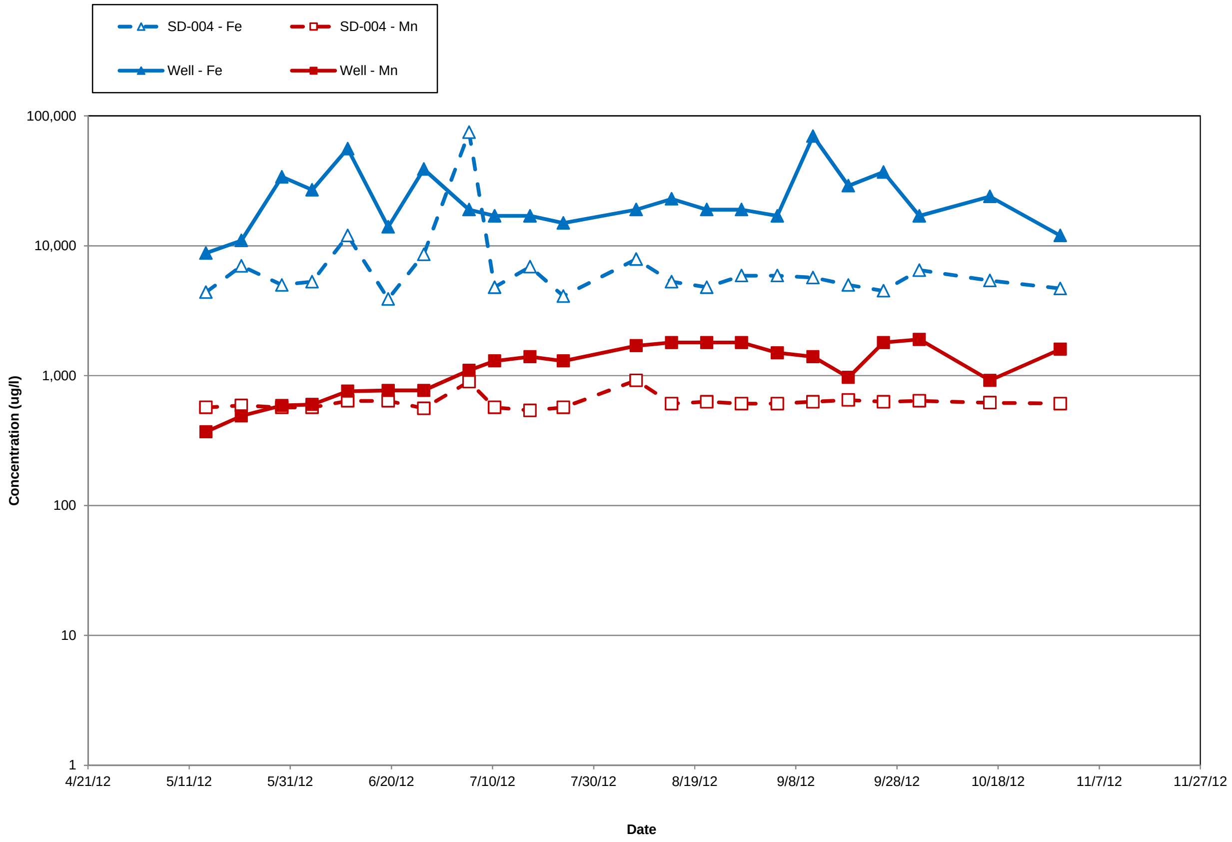


Figure 7. Greensand Filter Pilot Unit

Figure 8. Permanganate Dose Optimization

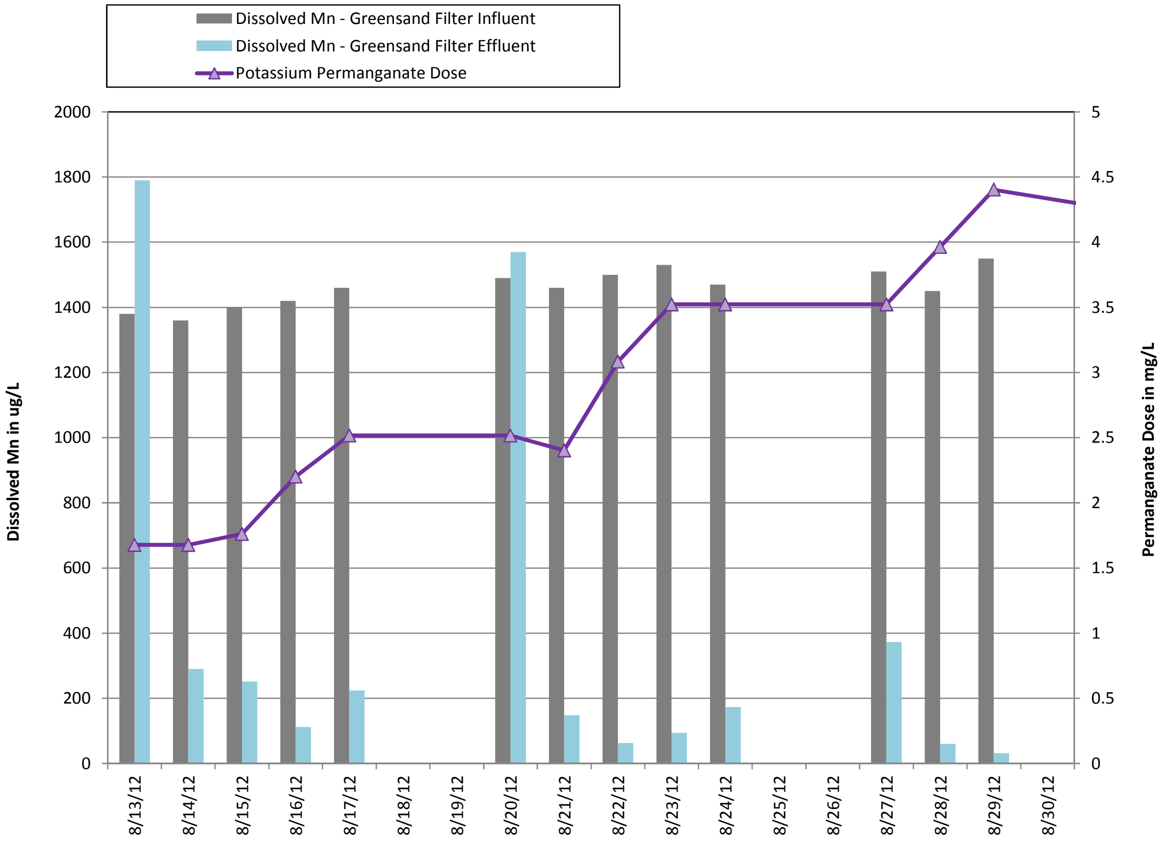


Figure 9. RO Pilot Unit

Figure 10. RO Feed-to-Concentrate Pressure Drop

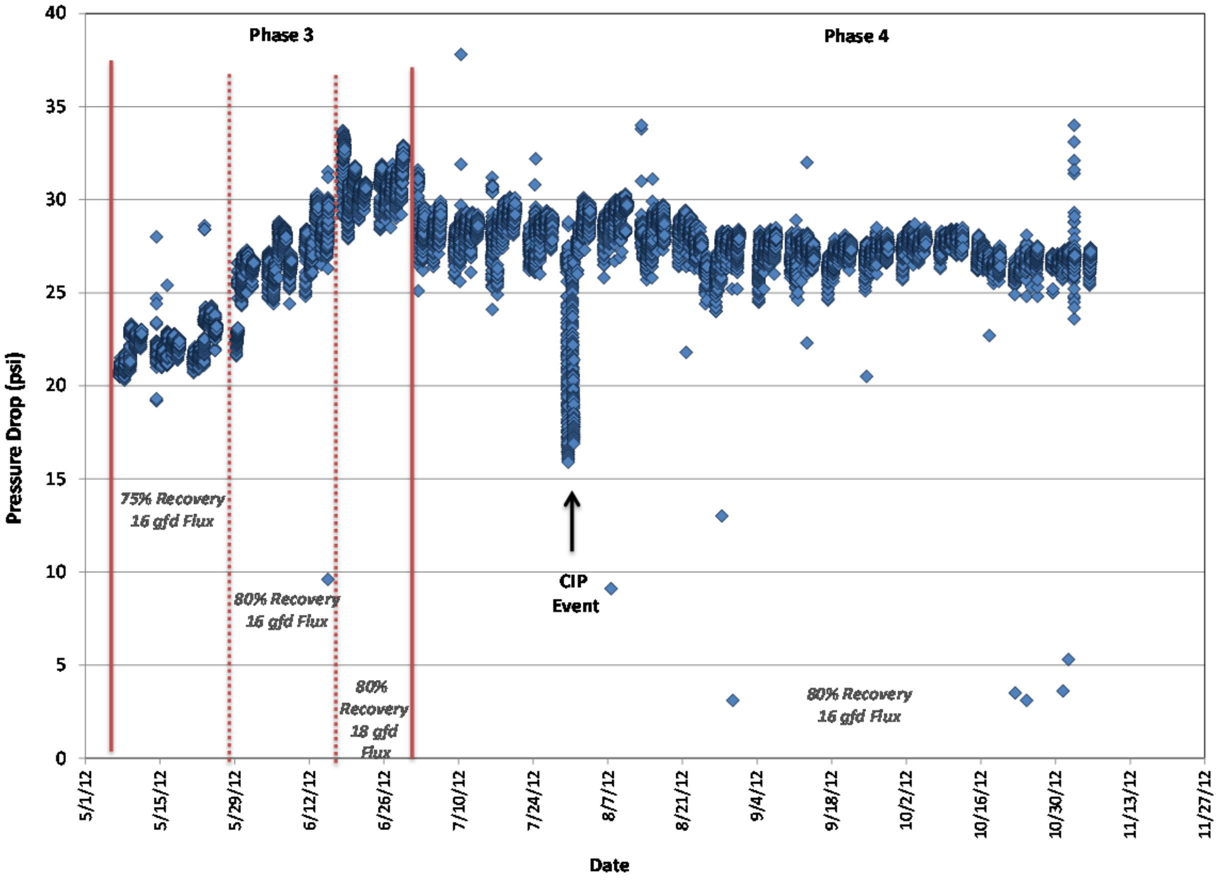


Figure 11. RO Feed Pressure

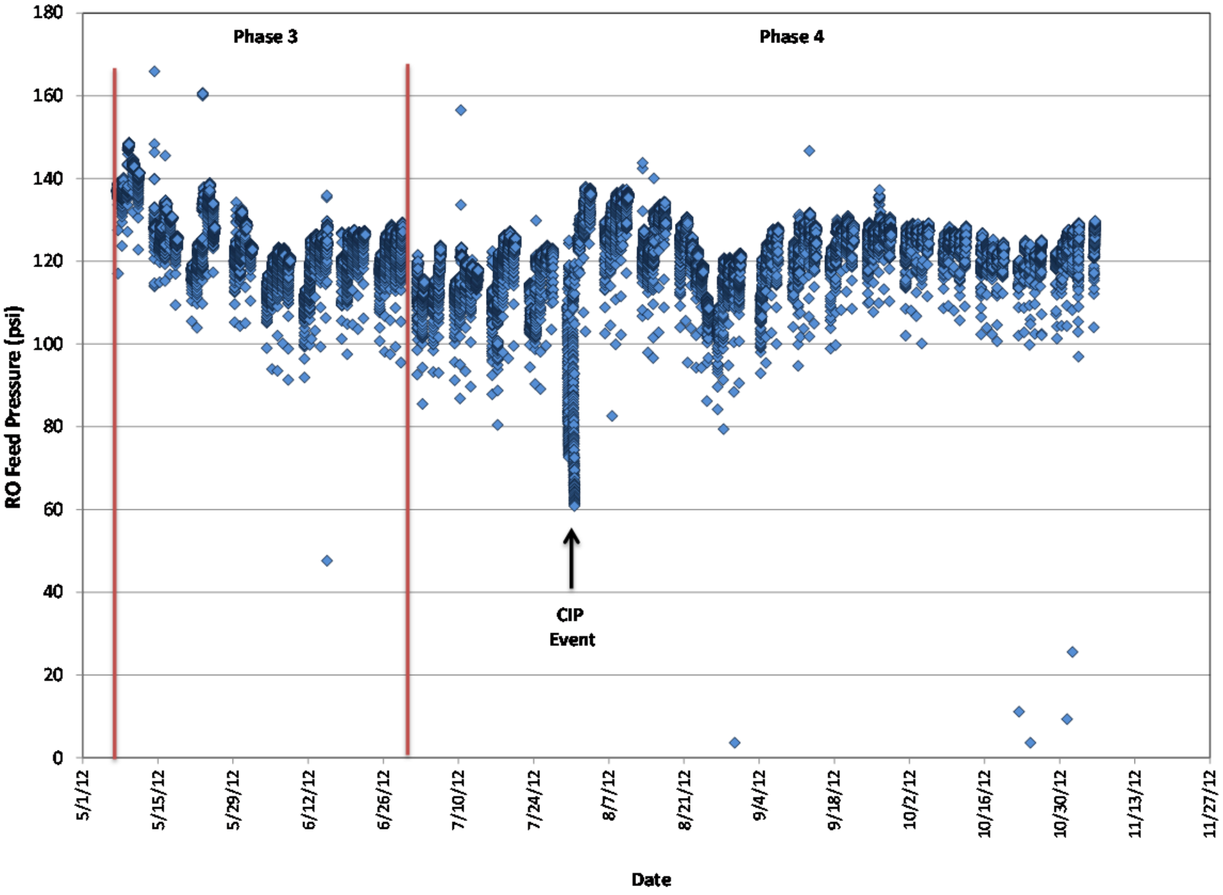


Figure 12. Sulfate Removal by the RO Process

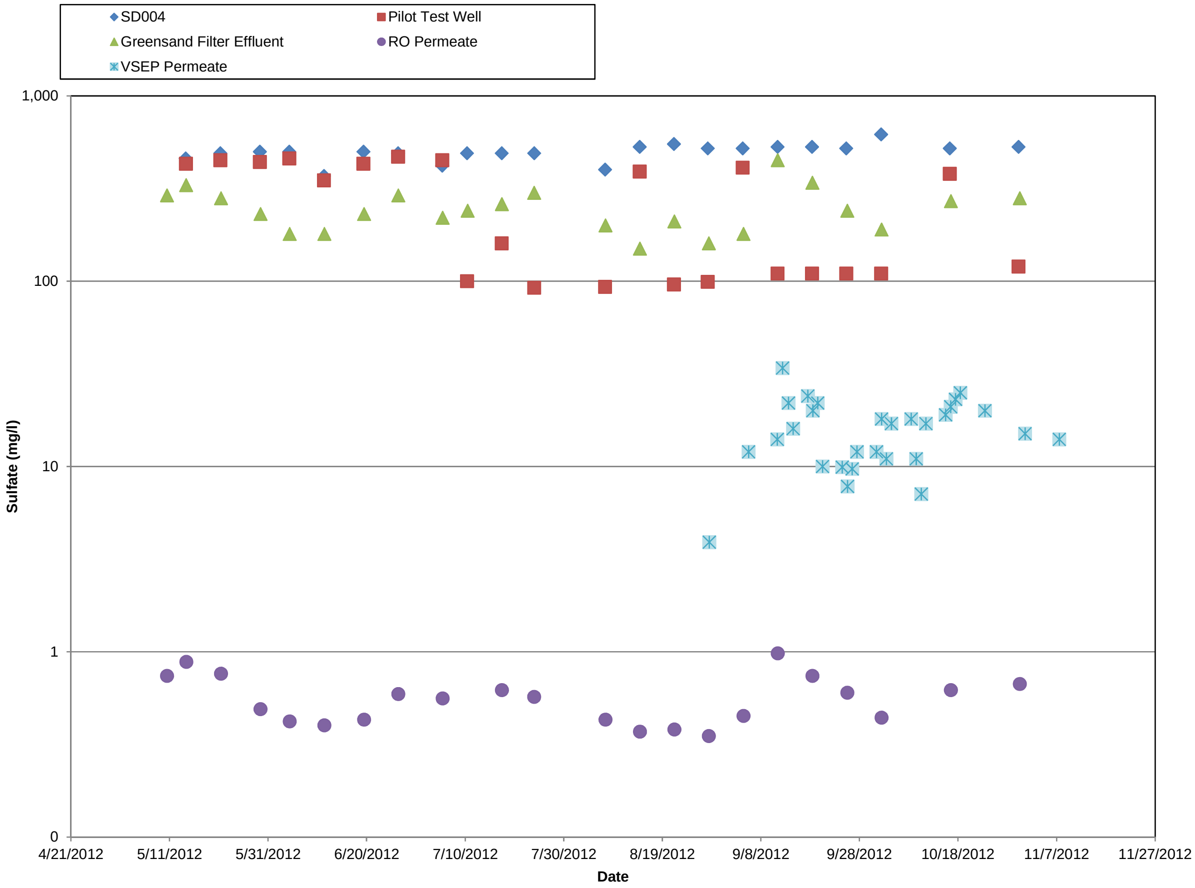


Figure 13. Total Dissolved Solids by the RO Process

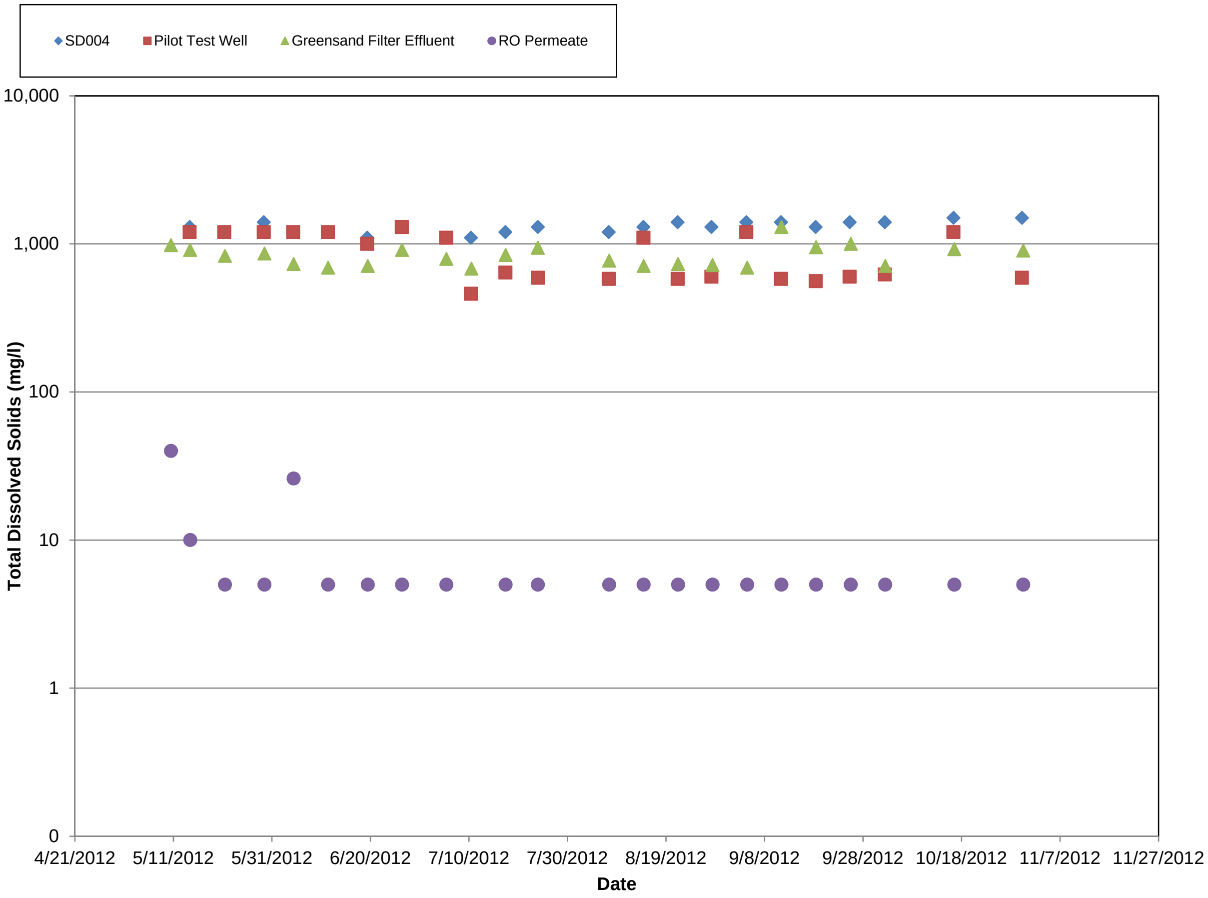


Figure 14. Comparison of Measured and Modeled RO Permeate Sulfate Concentrations

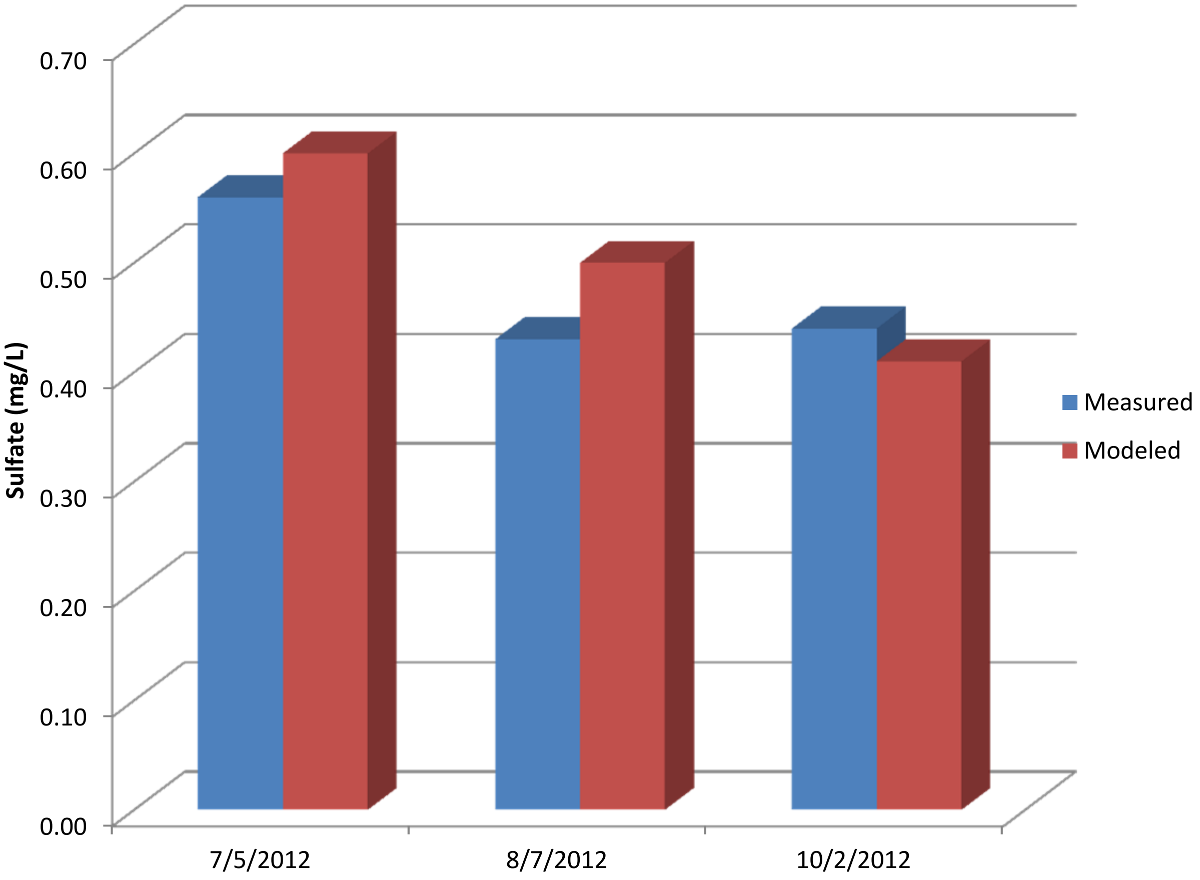


Figure 15. VSEP Pilot Unit

Figure 16. Initial VSEP Pretreatment Optimization

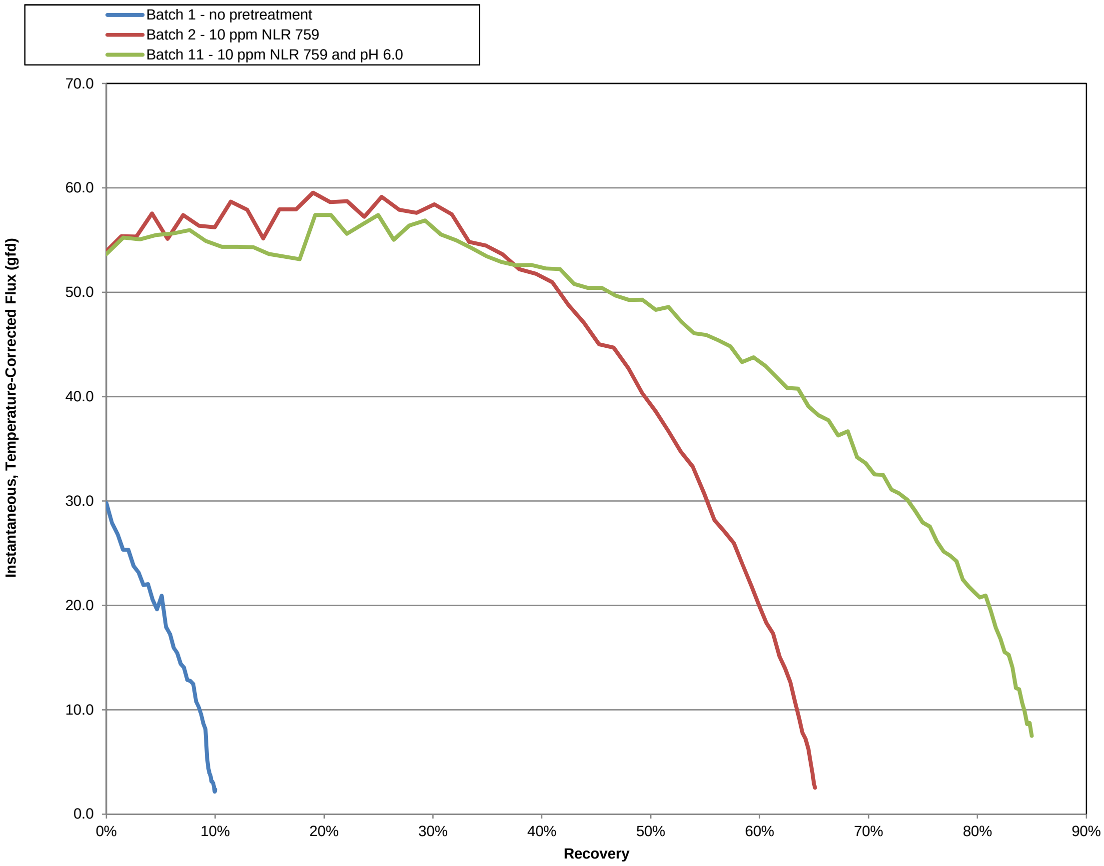


Figure 17. VSEP Operation with Hydrochloric and Sulfuric Acids

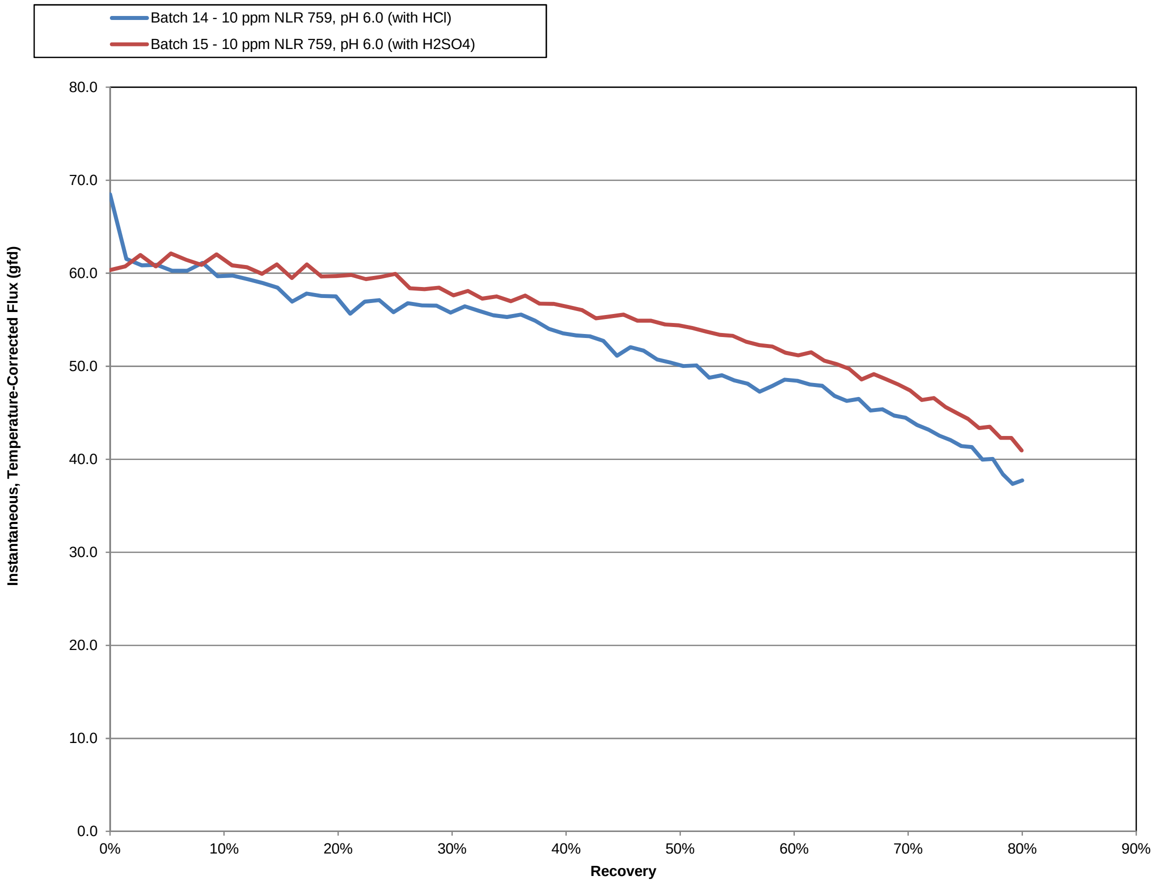


Figure 18. Comparison of the Effects of pH Adjustment Timing on VSEP Flux and Recovery

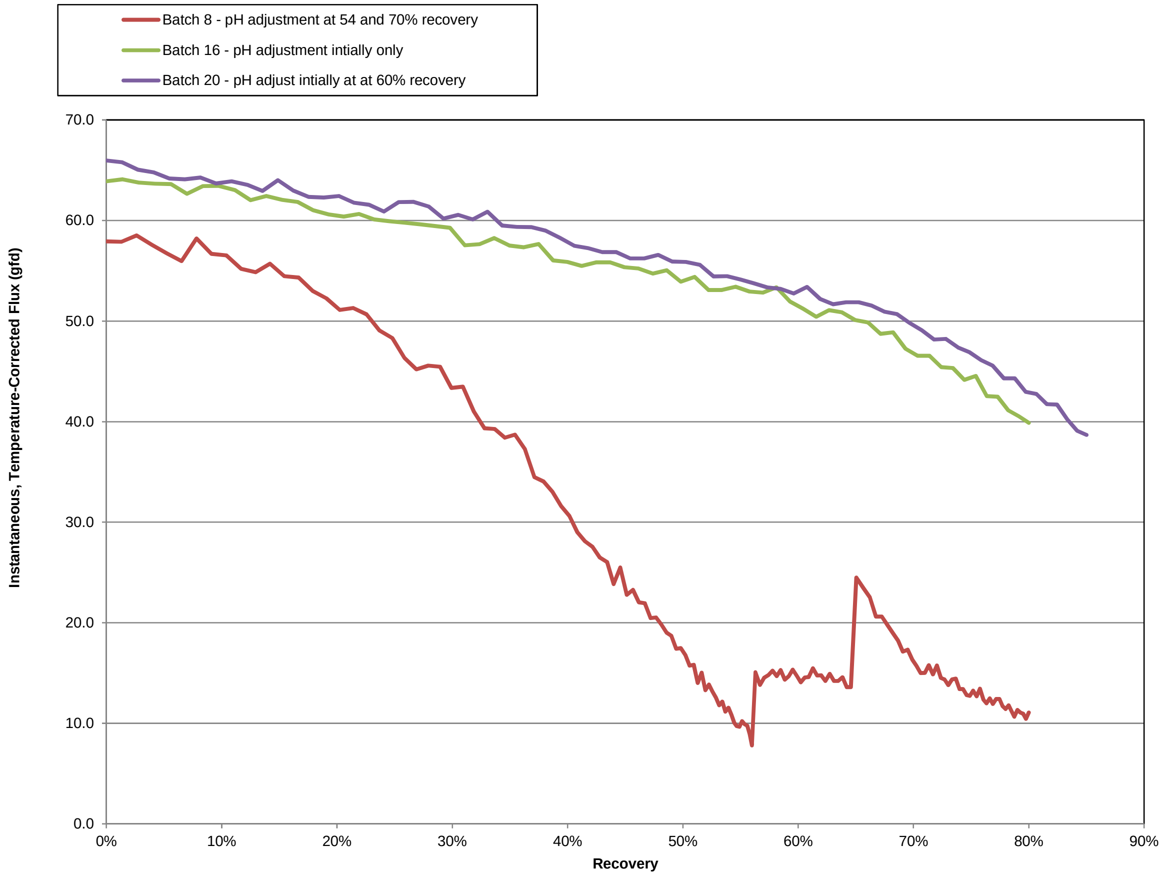


Figure 19. Effect of Degree of pH Adjustment on VSEP Flux and Recovery

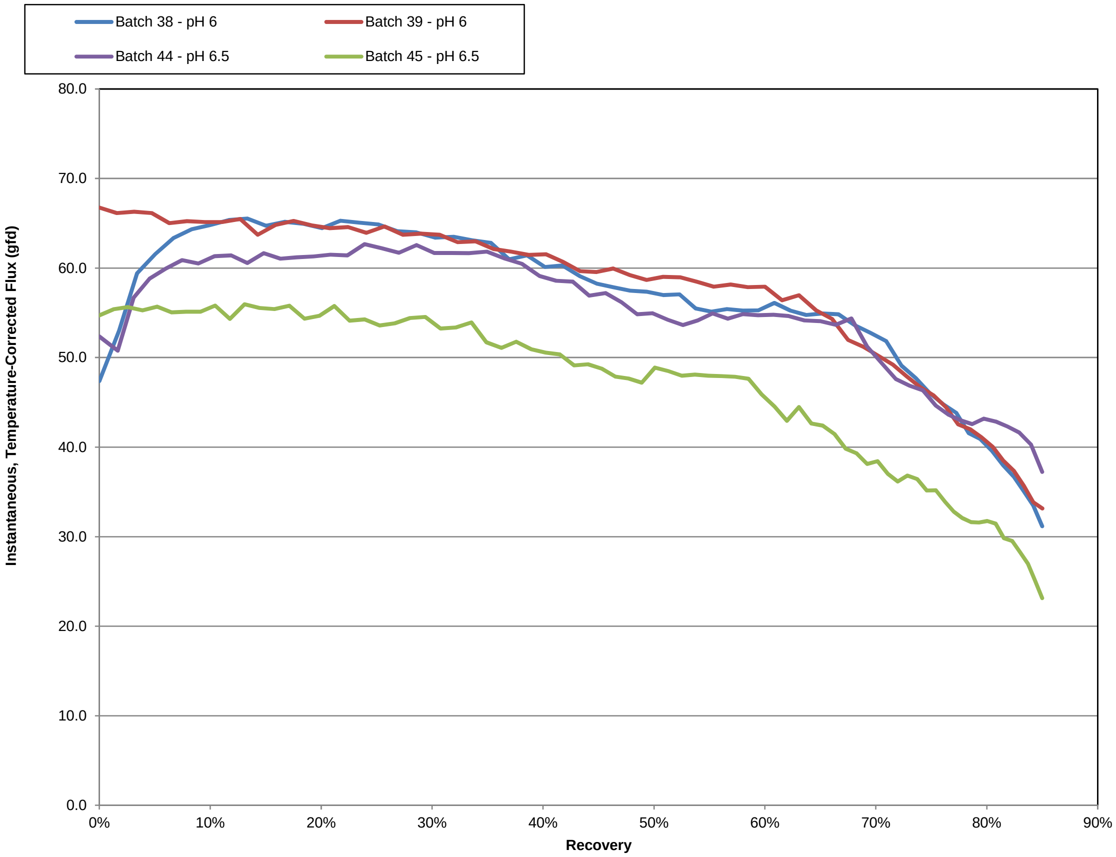


Figure 20. VSEP Recovery Optimization

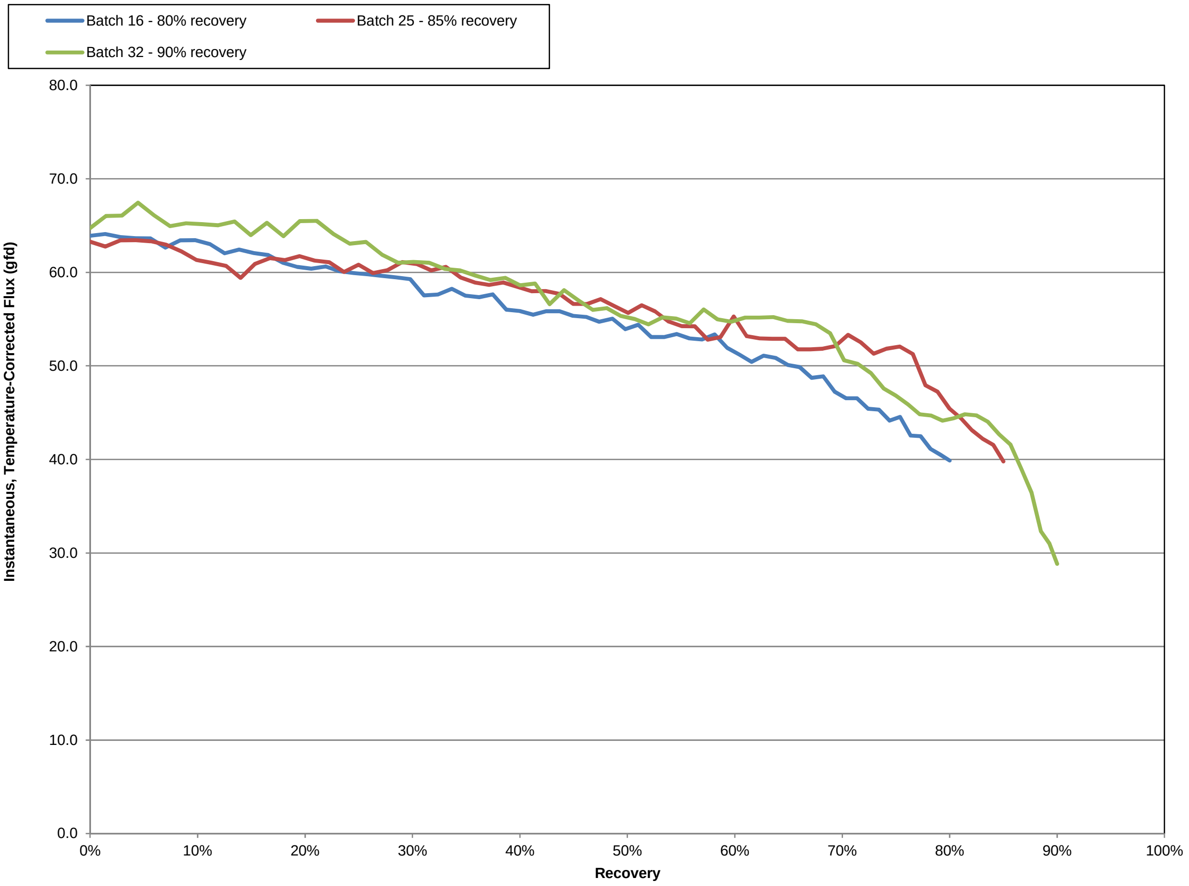


Figure 21. Lime Addition WET Test Results

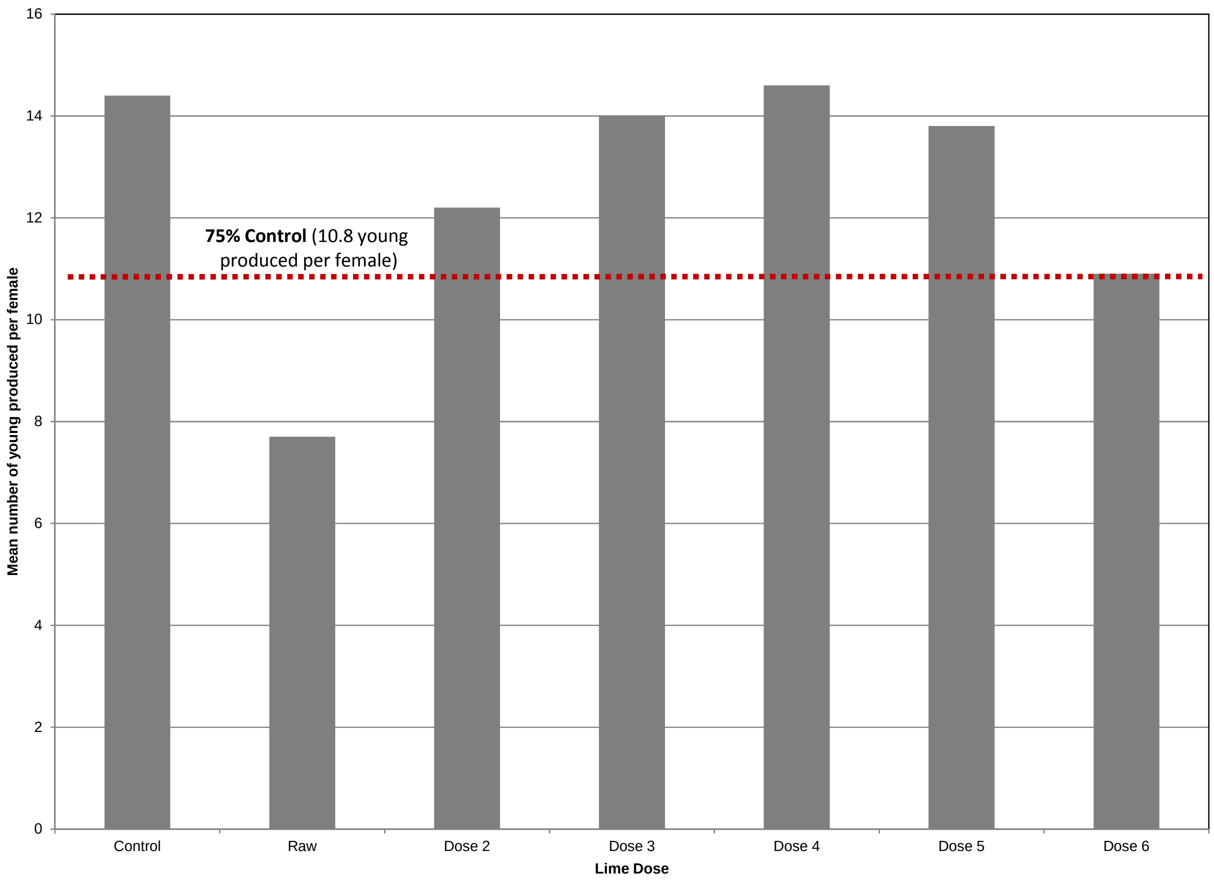


Figure 22. Limestone Bed Contactor Columns

Upflow columns

Puri-Cal RO media

Figure 23. Limestone Bed Contactor Tests

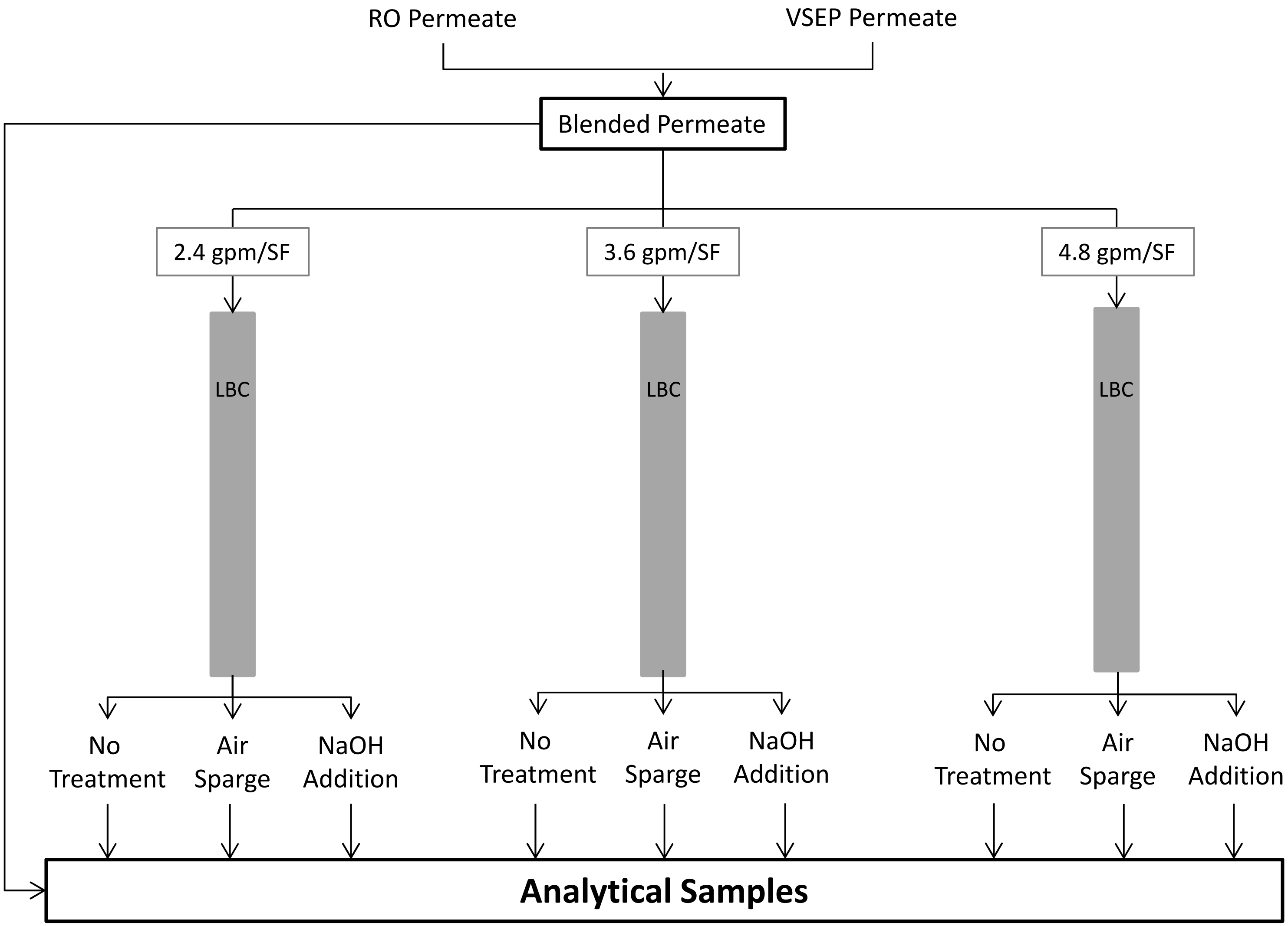


Figure 24. Limestone Bed Contactor WET Test Results

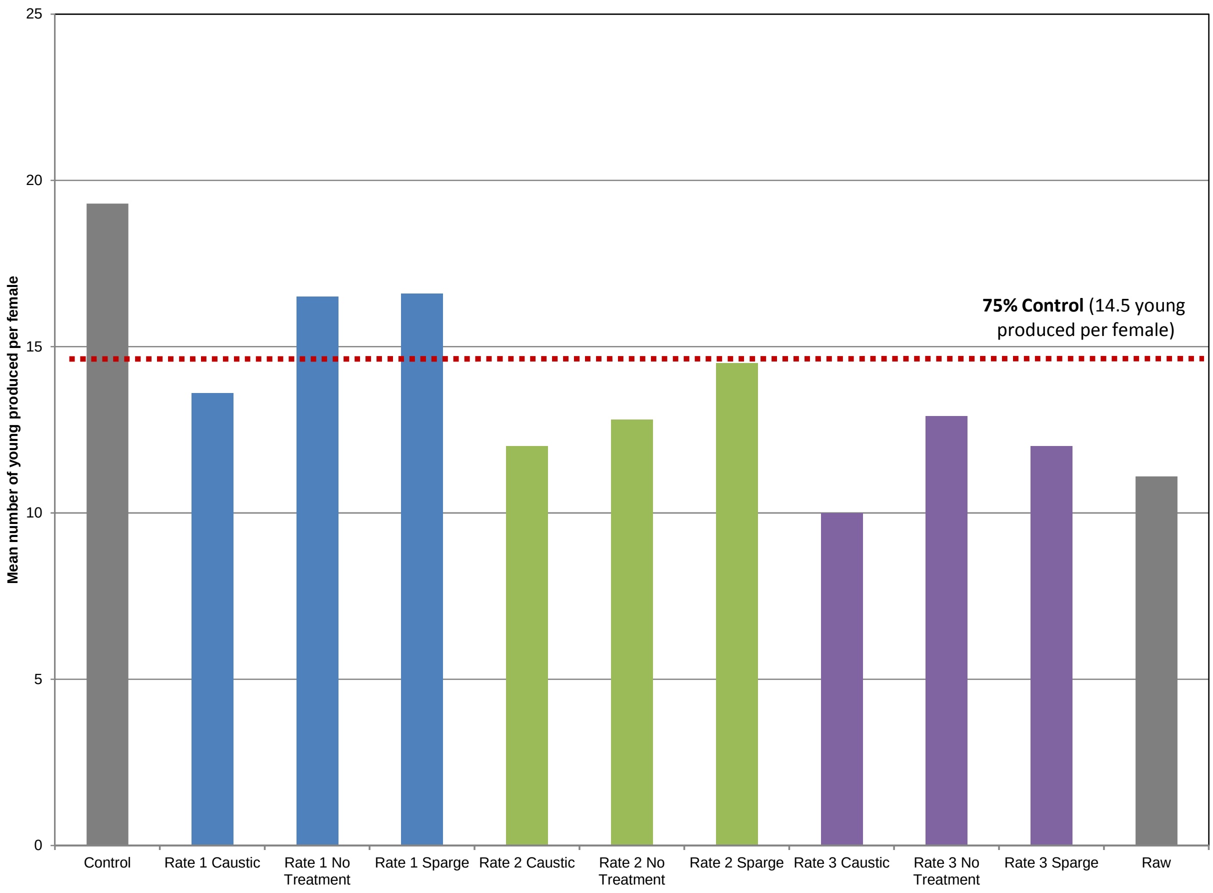
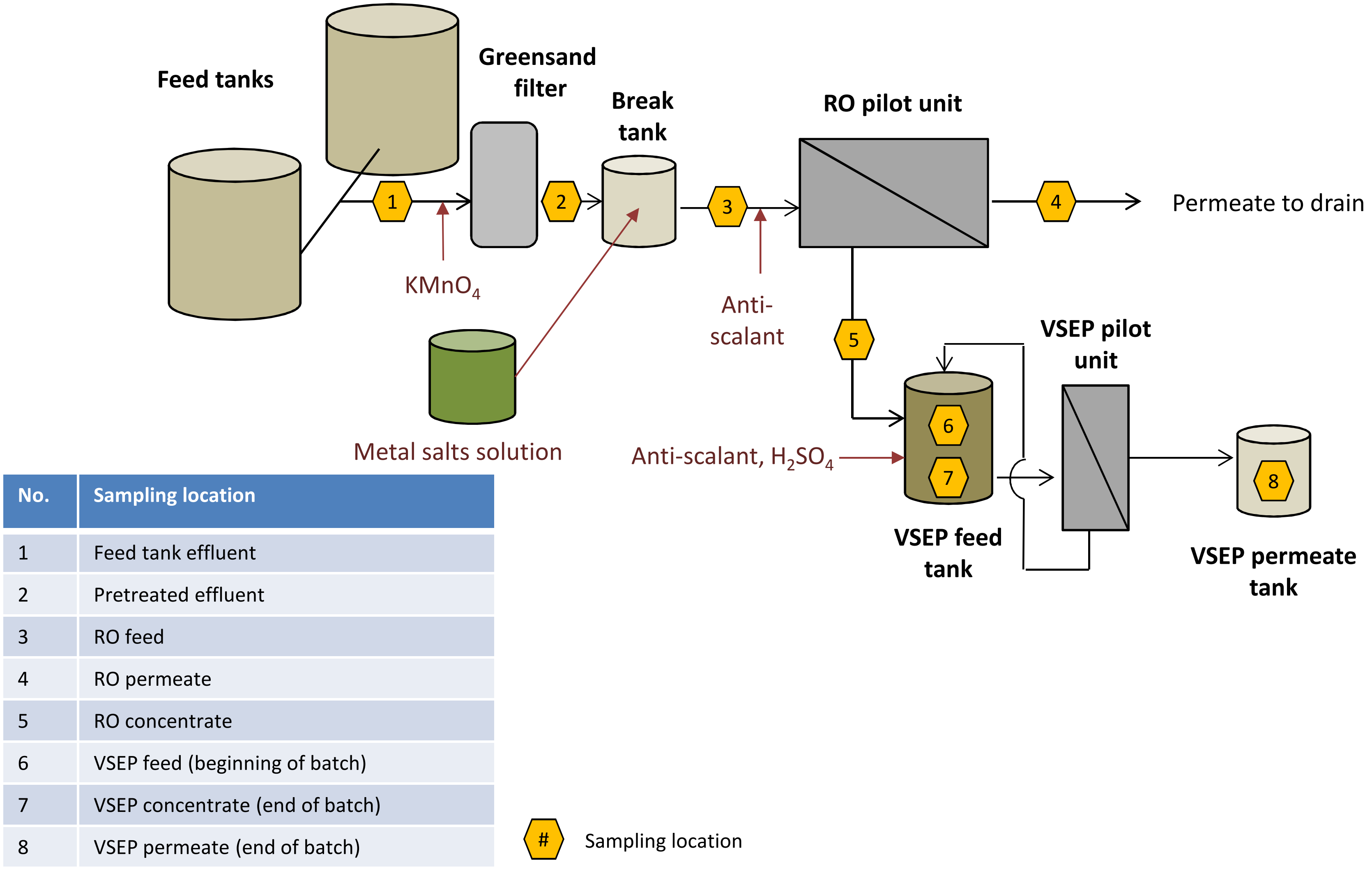
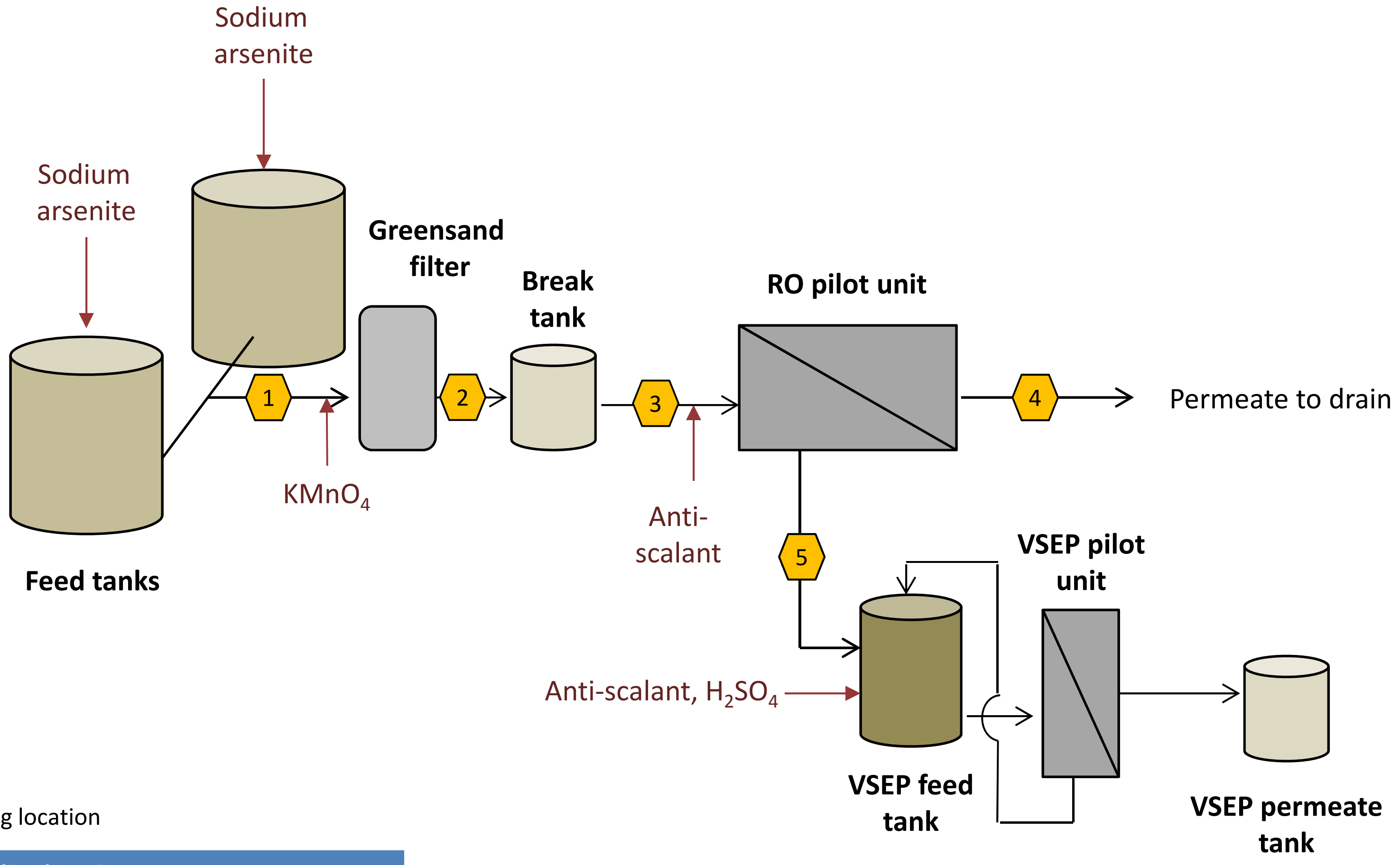


Figure 25. Metals Seeding Test Illustration



No.	Sampling location
1	Feed tank effluent
2	Pretreated effluent
3	RO feed
4	RO permeate
5	RO concentrate
6	VSEP feed (beginning of batch)
7	VSEP concentrate (end of batch)
8	VSEP permeate (end of batch)

Figure 26. Arsenic Removal Test Illustration



\# Sampling location

No.	Sampling location
1	Feed tank effluent
2	Pretreated effluent
3	RO feed
4	RO permeate
5	RO concentrate

Figure 27. HDS Test Results for Arsenic

Figure 28. HDS Test Results for Chromium

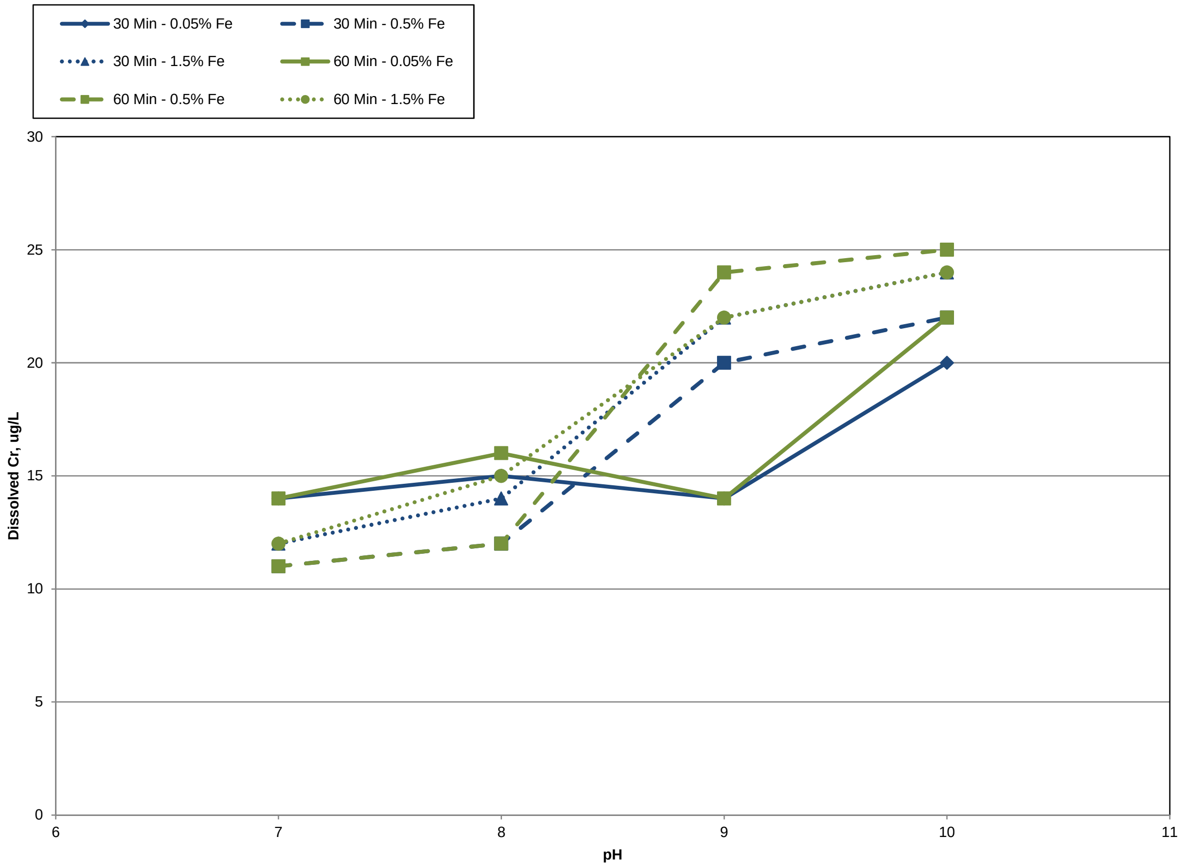


Figure 29. HDS Test Results for Cobalt

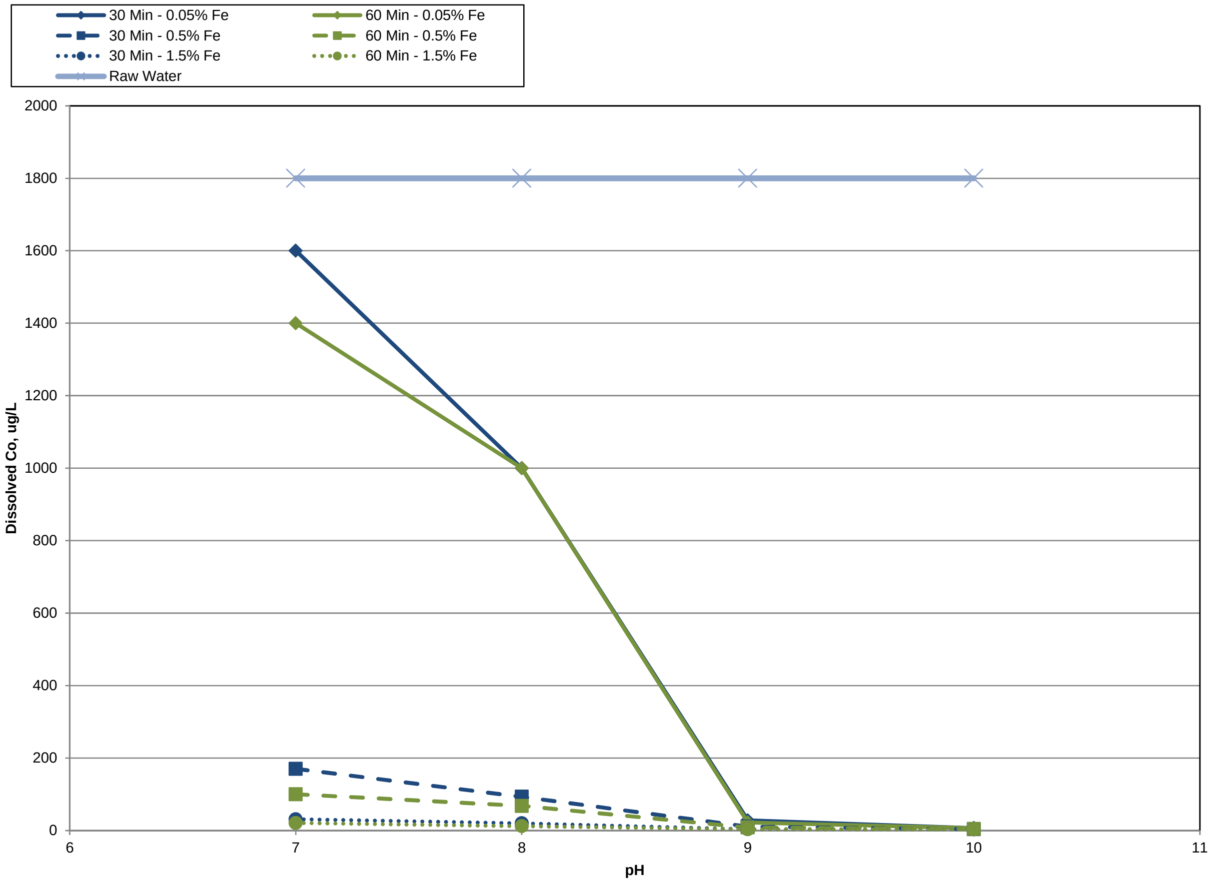


Figure 30. HDS Test Results for Copper

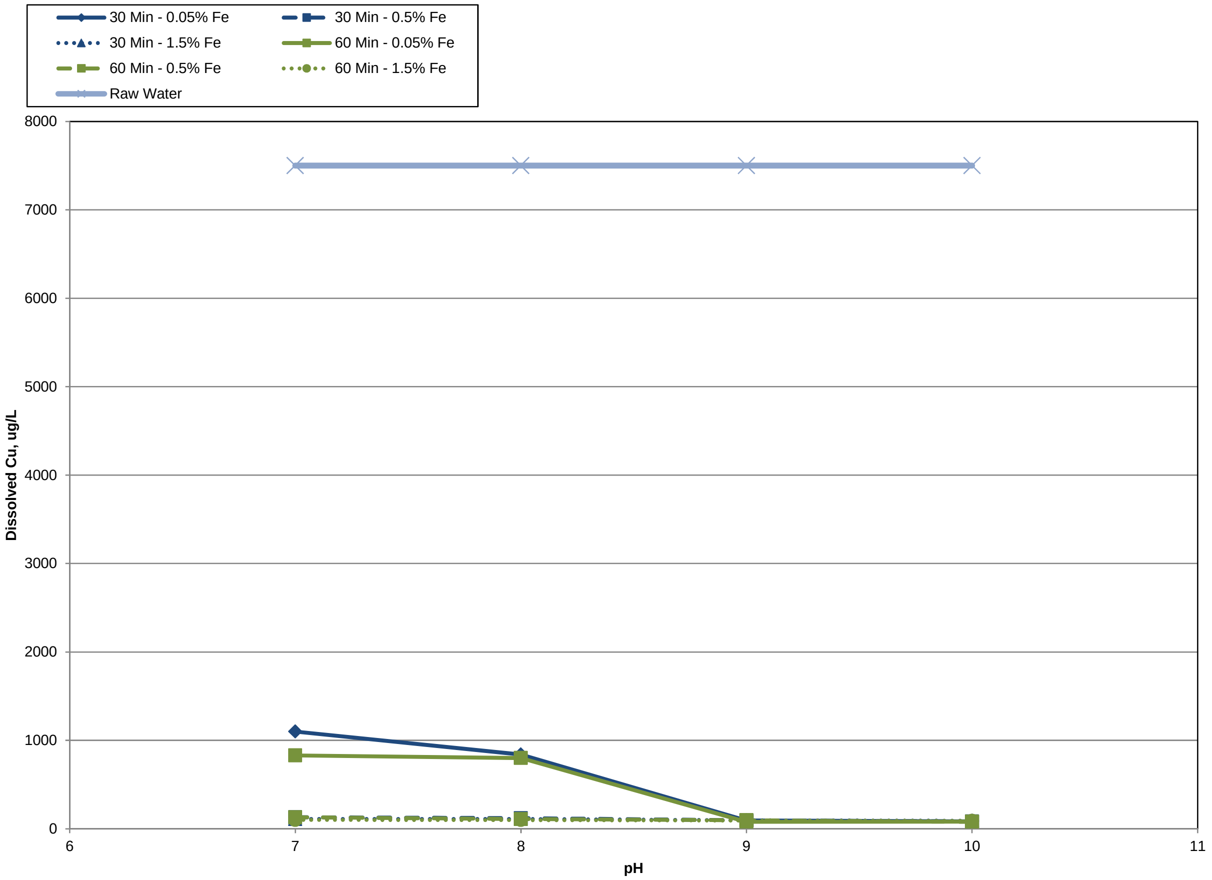


Figure 31. HDS Test Results for Lead

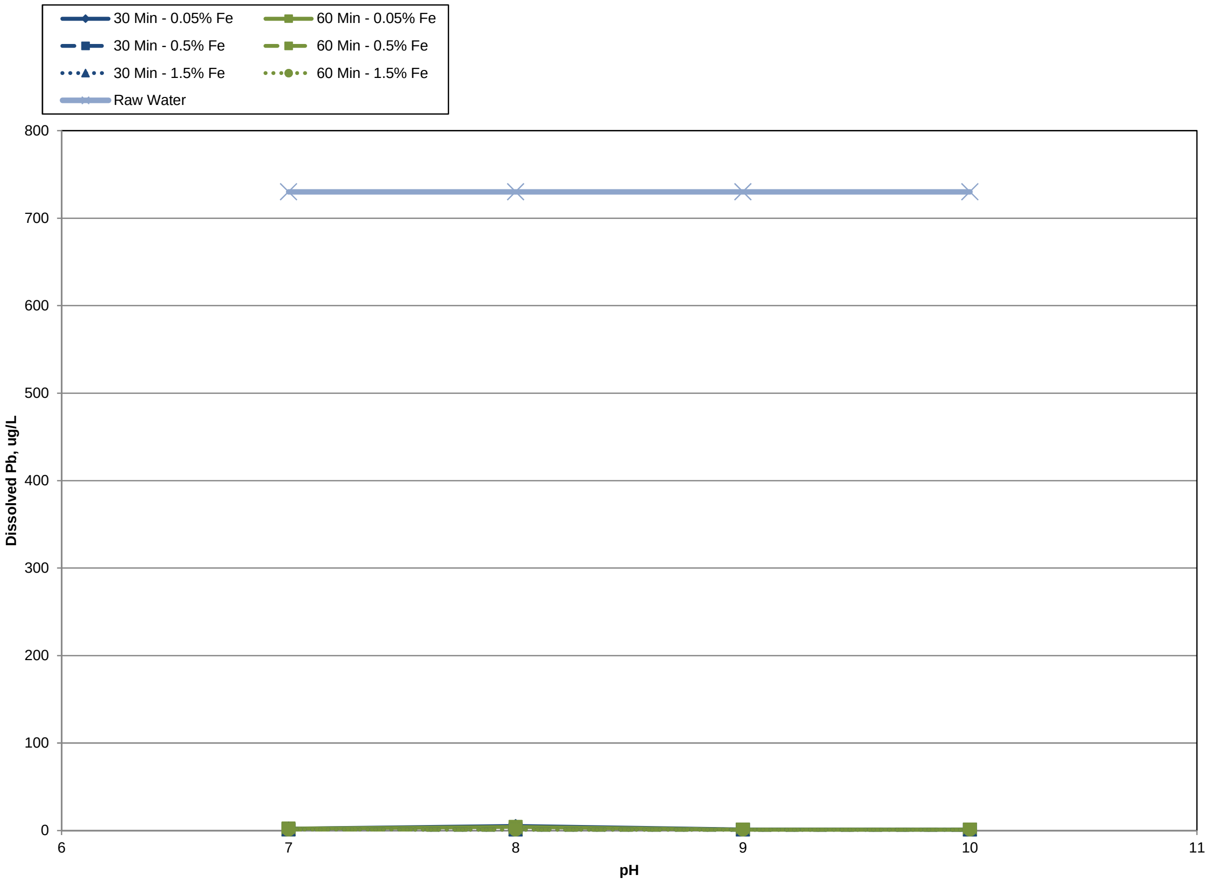


Figure 32. HDS Test Results for Manganese

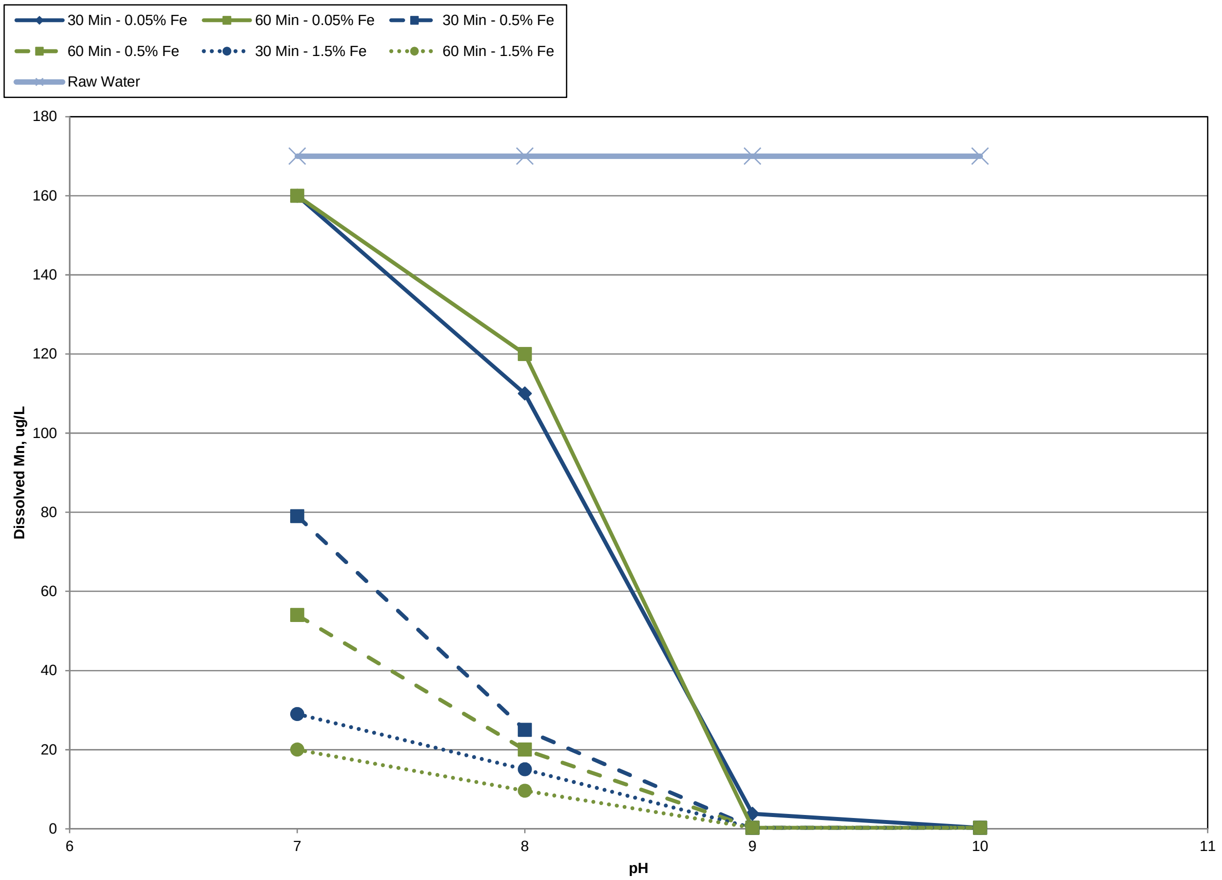


Figure 33. HDS Test Results for Nickel

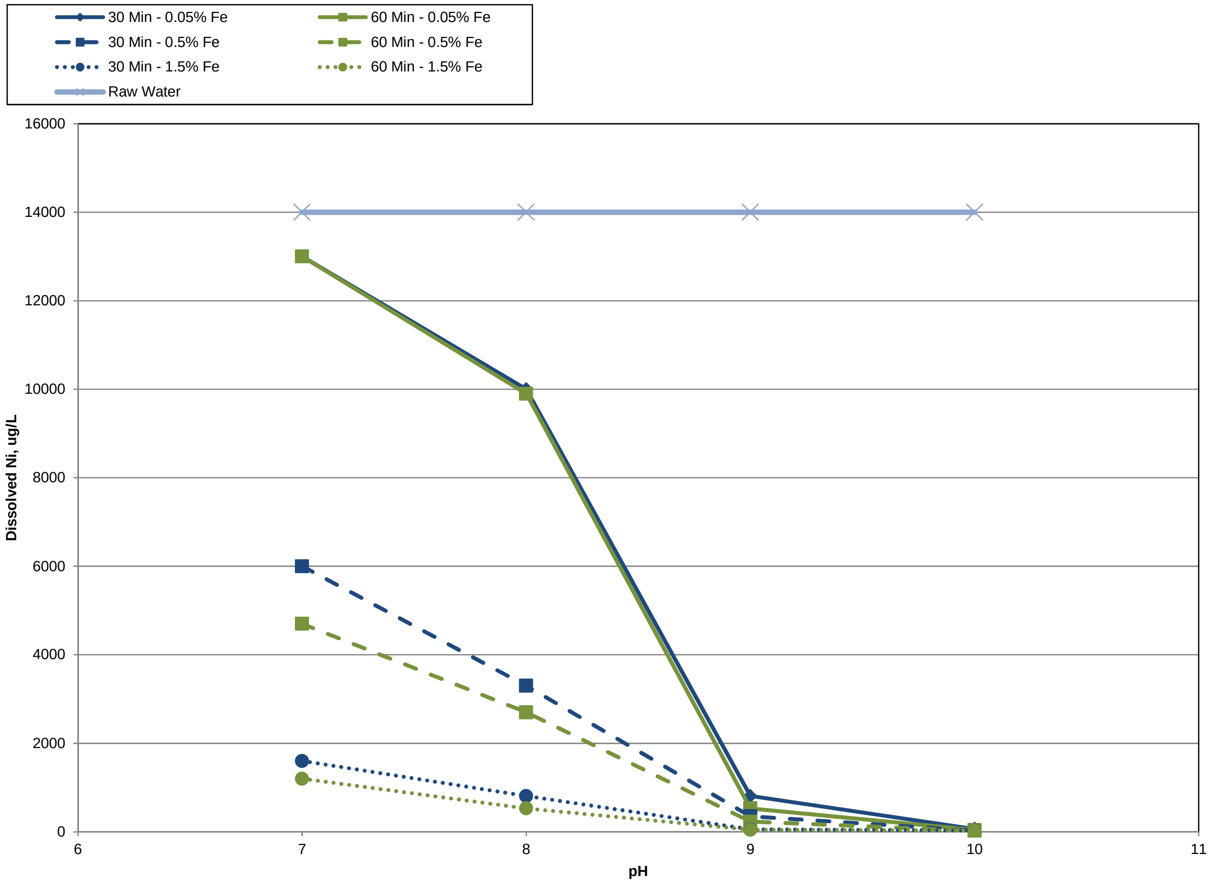


Figure 34. HDS Test Results for Selenium

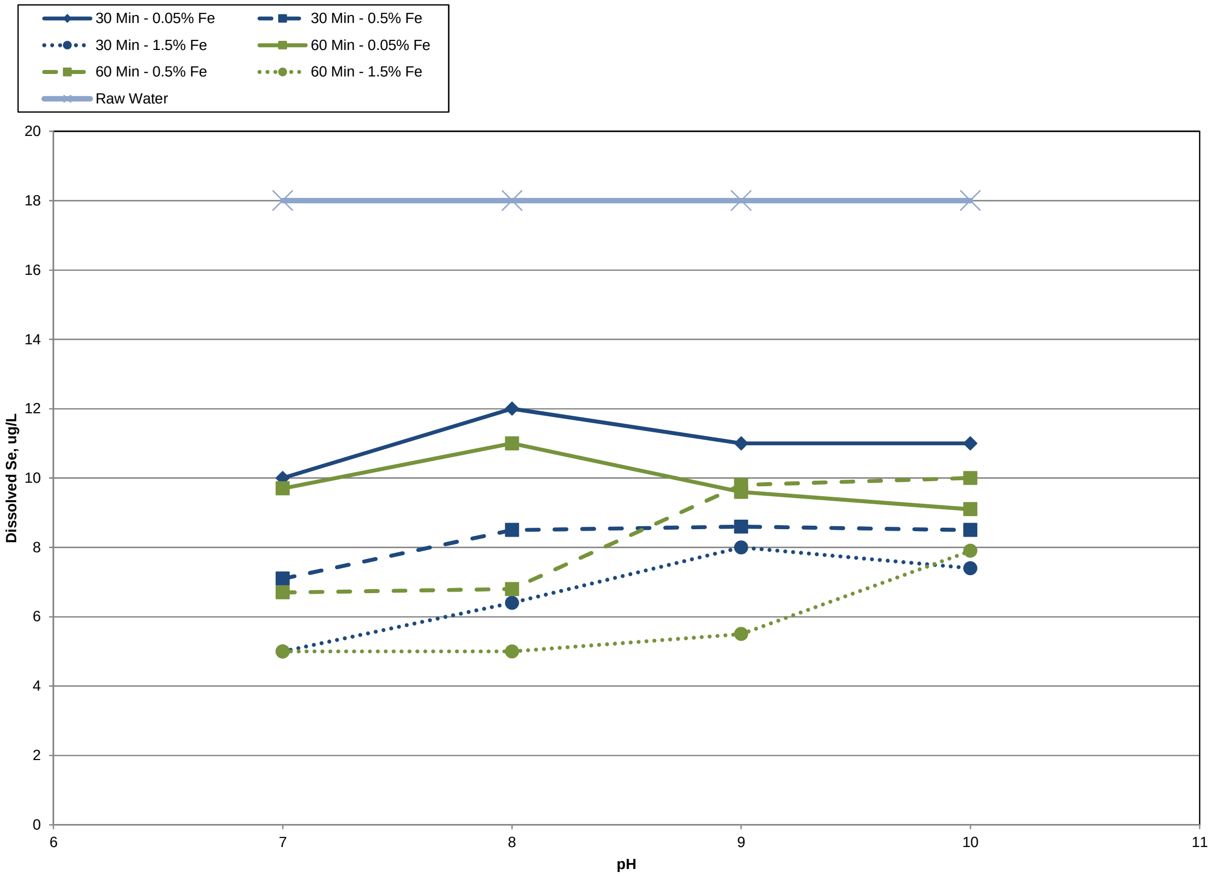


Figure 35. HDS Test Results for Zinc

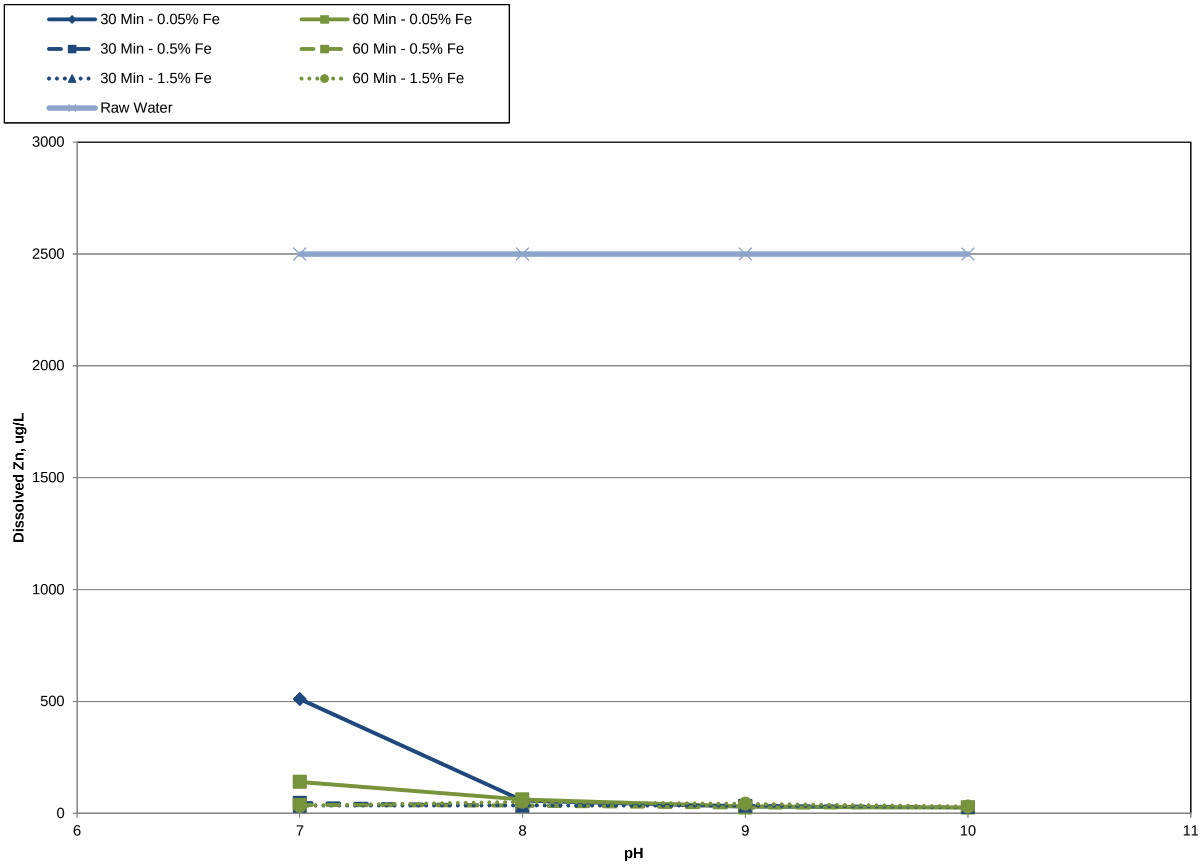


Figure 36. HDS Metals Settling, pH 7

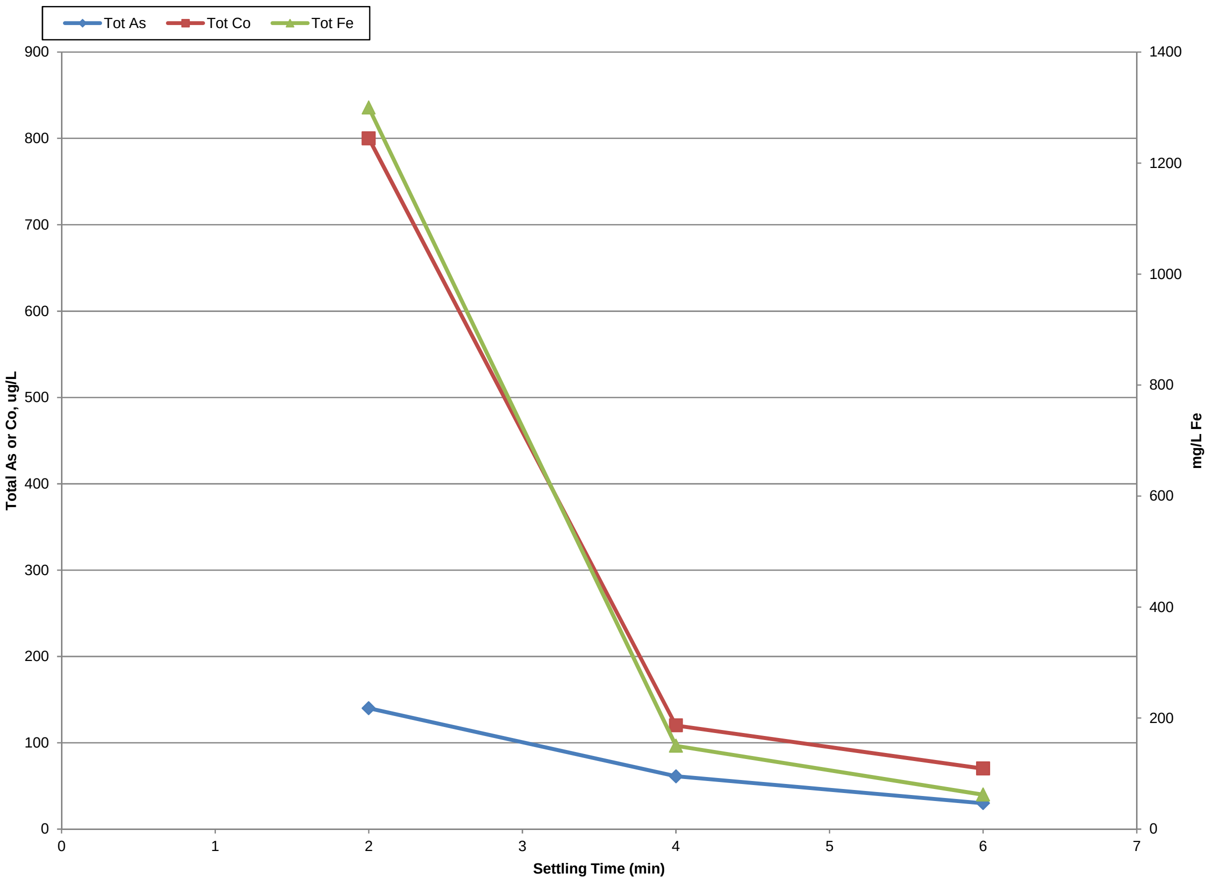


Figure 37. HDS Metals Settling, pH 8

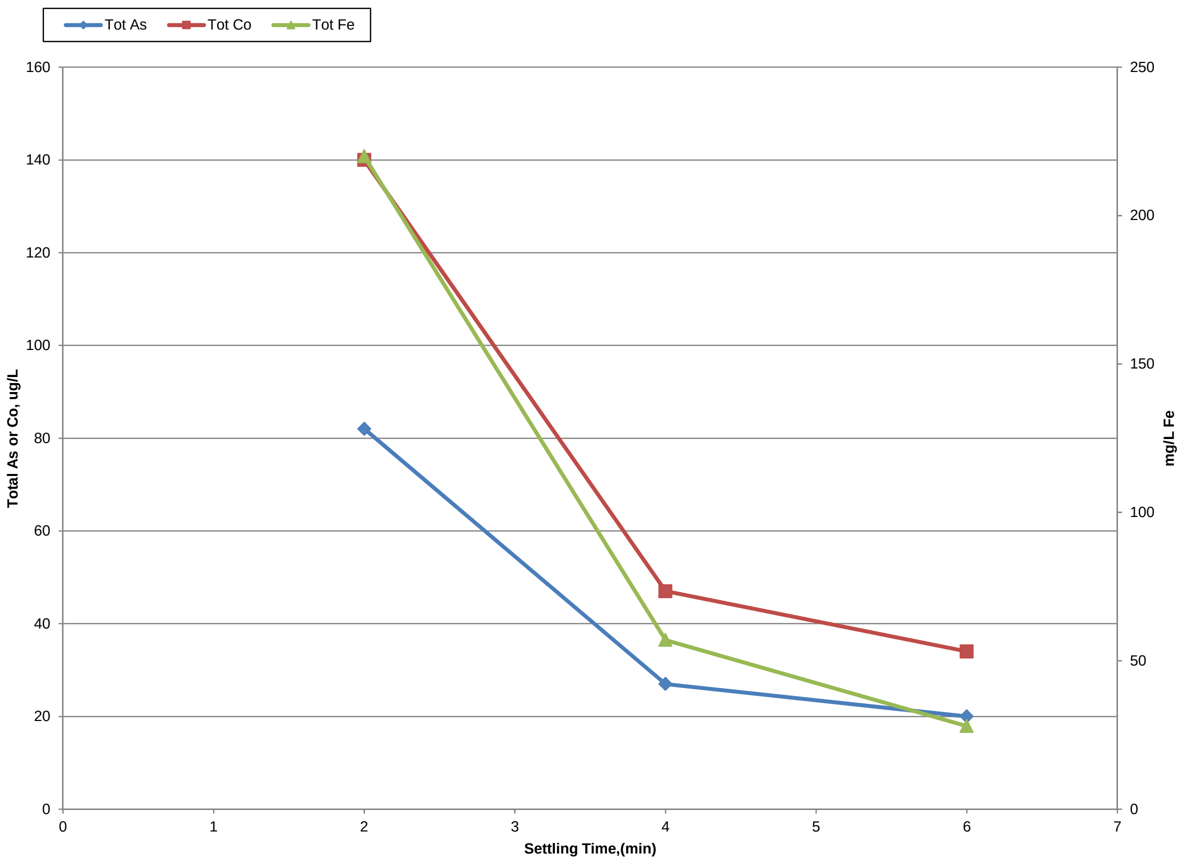


Figure 38. HDS Metals Settling, pH 9

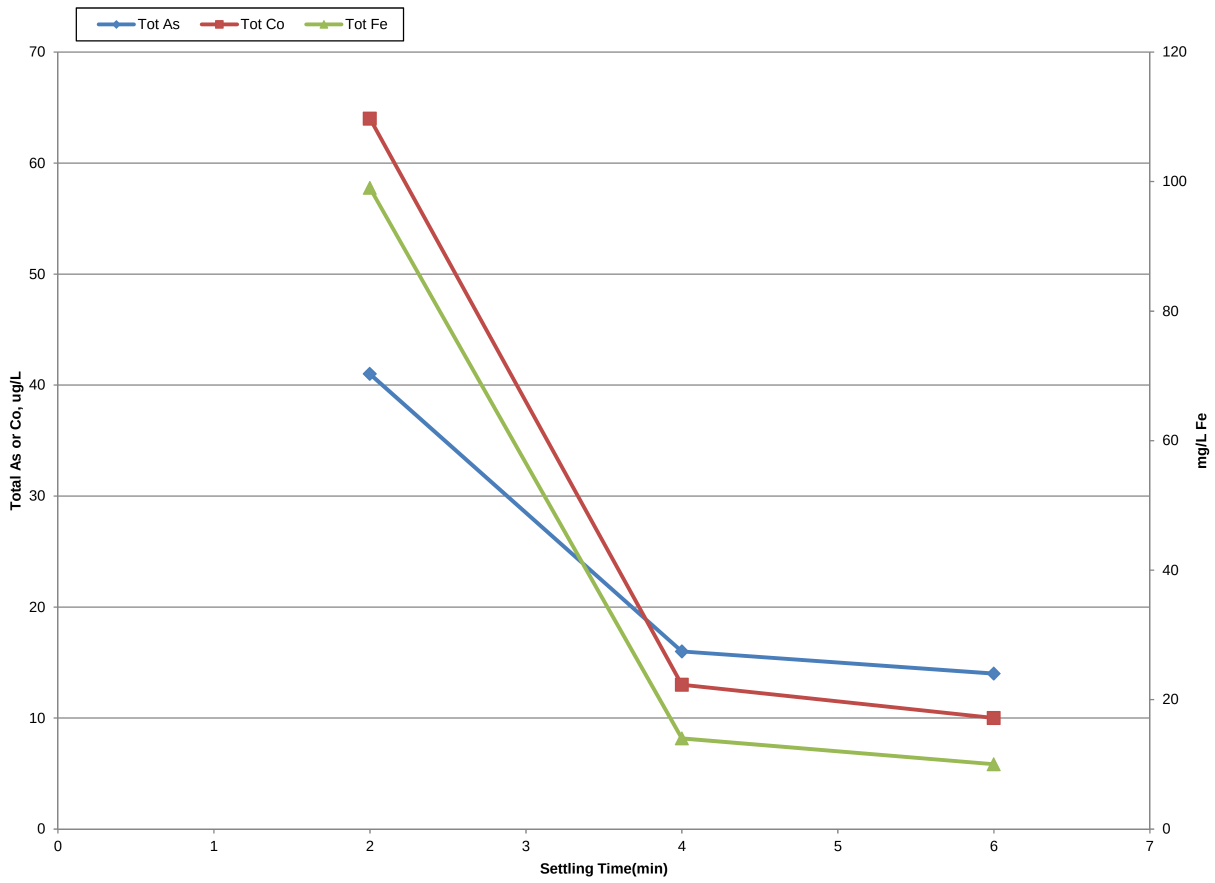
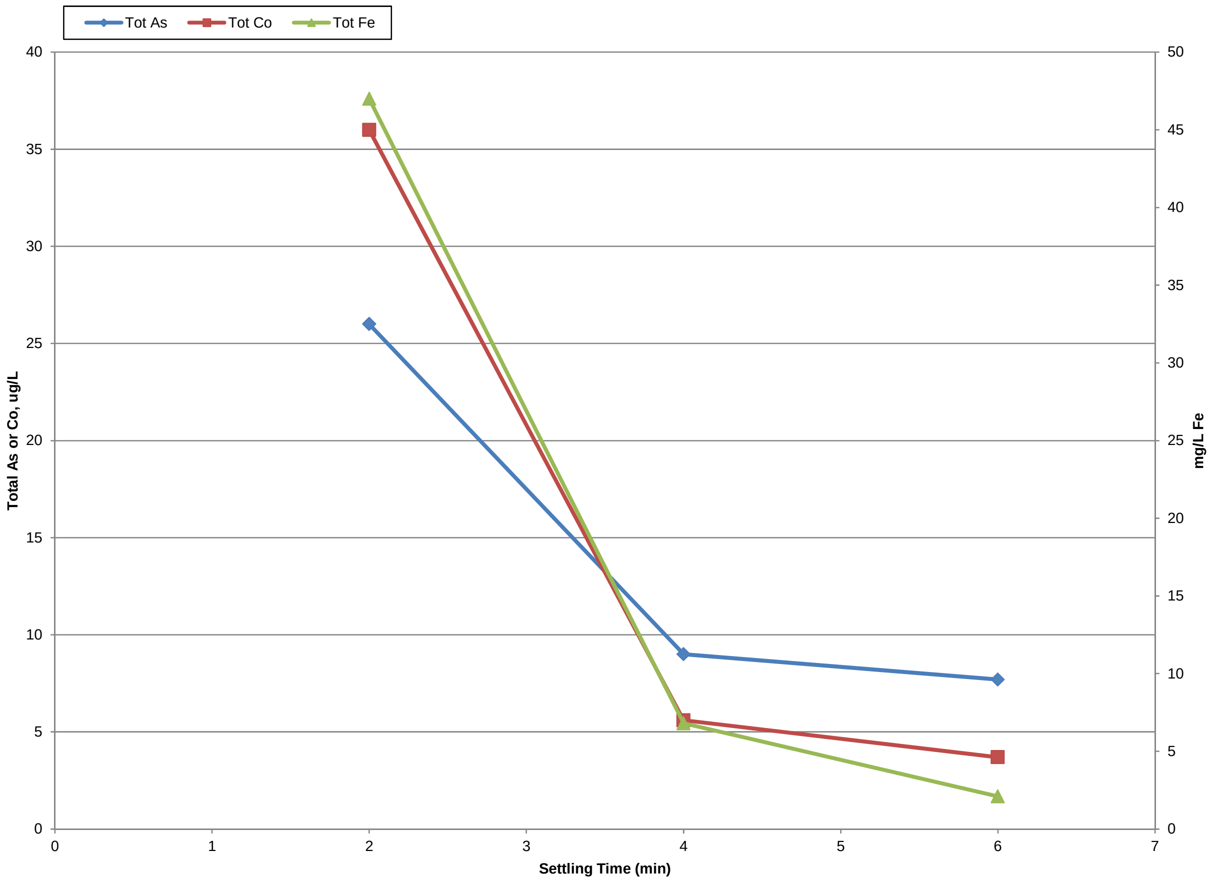


Figure 39. HDS Metals Settling, pH 10



Appendices

Appendix A

Pilot-test Well Evaluation

resourceful. naturally.
engineering and environmental consultants
BARR

Technical Memorandum

To: Paul Brunfelt, Poly Met Mining, Inc.
From: Adam Janzen, Jeré Mohr
Subject: Results from Tailings Basin Pilot Well Pumping Test and Water Level Monitoring
Date: January 8, 2013
Project: 23/69-C08
c: Jim Scott, Poly Met Mining, Inc.

Introduction

In January 2012 a pumping test was conducted on a new well located on the north side of the former LTV Steel Mining Company tailings basin near Hoyt Lakes, MN. The new well (the “pilot well”) was installed to support on-going water treatment evaluations. Drawdown data were collected from the pilot well and nearby monitoring wells GW-006, GW-012, and a piezometer as shown on Figure 1. The objectives of the aquifer testing were to determine the maximum sustainable pumping rate for the pilot well and to produce information on groundwater level responses to hydraulic stresses (i.e. pumping) at the site. These responses provide insight into hydrogeologic factors such as the interconnection between the native material under the tailings basin and the wetlands to the north, hydraulic parameter values (e.g. hydraulic conductivity and storativity), and heterogeneities within the aquifer.

This memorandum describes the methods used to collect the pumping test data, the data analysis procedures, and a compilation of the results of the data analysis in comparison to existing hydrogeological data for the tailings basin. Long-term groundwater monitoring data collected from the pilot well, GW-006, and the piezometer through early January 2013 are also presented and discussed.

Aquifer Test Sequence

The aquifer testing was conducted generally as described in the original specifications (Barr, 2011), with appropriate changes due to site conditions and unexpected difficulties with the pumping well. The pilot well (Minnesota Department of Health unique ID #786386) was used as the pumping well. Water levels were monitored in the pumping well and at three monitoring wells:

- GW-006 (MDH #625042) , a well downslope and approximately 110 feet north of the pilot well;
- a piezometer (no MDH tag) slightly upslope and approximately 11 feet southwest of the pilot well; and
- GW-012 (MDH #767968), a well in the wetlands about 1 mile northeast of the pumping well.

Water level measurements were collected using LevelTROLL dataloggers/pressure transducers with logarithmic frequency in the pumping well, GW-006, and the piezometer, and every 5 minutes at GW-012. Manual water level measurements were collected during the pumping phase and the recovery phase to supplement automated measurements whenever feasible. GW-012 was monitored to provide information on water level fluctuations outside the area of influence of the aquifer test so that background water level fluctuations could be filtered out of the data collected at the other observation wells if necessary.

The pumping well is screened from 31 to 71 feet through silty sand (31-68’) and bedrock (68-71’). GW-006 is completed in the same geologic unit(s) as the pumping well. No construction data is available for the piezometer, but based on the stratigraphy at the nearby pumping well and the measured depth of the piezometer (32.5’ below top of riser) it appears to be screened in the tailings. Figure 2 shows an approximate cross-section of the geology through these three wells and boring RS-29 (drilled in 2009).

The primary components of the aquifer testing process were:

1. Step-drawdown Test

A formal step-drawdown test was planned as per the specifications, but two attempts to perform one on January 17 and January 25 were both significantly affected by a leaking pitless adaptor in the well. A limited amount of drawdown data without leakage in the well was collected on January 25 after the problem was resolved. This data showed that a pumping rate of 10 gallons per minute (gpm) might be sustainable, but that 15 gpm would be too high. Based on this information and the client’s desire to find the maximum sustainable pumping rate for the well, a pumping rate of 11 gpm was selected for the constant-rate pumping test.

2. Background Monitoring

Background water level data were collected in the pumping well, piezometer, and GW-006 between January 18 and January 25.

3. Constant-rate Test

The constant rate pumping test commenced at 08:30 on January 26, 2012, at a rate of approximately 10.6 gpm. Flow rate measurements were collected using a bucket and stopwatch. Periodic flow measurements were collected throughout the test to make sure the pumping rate remained constant. The flow rate was reduced twice during the test, which is discussed in the results section.

4. Recovery/Post-test Monitoring

Pumping was stopped at 08:50 on January 27, 2012. The post-test monitoring was concluded once the water level in the pumping well recovered to 95% of the maximum drawdown level, as prescribed in the test specifications. The transducer in GW-012 was removed at 12:22 on January 27, 2012. Electronic monitoring of water levels continues in the pilot well, GW-006, and the piezometer. The most current data included in this memo is from January 4, 2013.

Results

Pumping rates during the constant-rate test are shown on Figure 3 along with a summary of the drawdown data collected from the monitoring locations. The drawdown in the pumping well seemed to be stabilizing by late morning on January 26, but as the day progressed drawdown continued to increase at an increasing rate. The LevelTROLL in the pumping well was located approximately 64 feet below the top of casing and directly above the pump; the pump was throttled back when the depth to water in the well reached 60 feet to prevent drawing air into the pump. The pumping rate was first reduced to approximately 8.5 gpm at 16:08 on January 26. A similar increase in drawdown was observed again during the evening, and the rate was reduced to approximately 6.5 gpm at 23:15 on January 26. As shown in Figure 3, the drawdown did not stabilize at this rate and continued to increase until the pump was turned off.

Data Analysis

Data obtained from the constant-rate test have been evaluated using conventional analytical methods to obtain values for hydraulic conductivity and storativity. A summary of the values for these parameters that have been obtained from this work are summarized in Table 1. Data were analyzed using AQTESOLV version 4.5 Professional (Hydrosolv, 2007). The procedures for data analyses using time-drawdown analytical solutions and distance-drawdown methods are discussed in this section.

General Data Trends

As shown in Figure 3, responses to pumping were apparent at both GW-006 and the piezometer. No response to pumping in the pilot well was apparent at GW-012. The changes in pumping rate are seen in the data from GW-006 but not in the piezometer data. The total drawdown in the piezometer was only approximately 3 inches during the test. Because the piezometer appears to be screened in a different unit from the pumping well and GW-006, the piezometer data was not analyzed. Initial examination of the raw test data does not appear to show any external influences not related to pumping that caused water level fluctuations at the monitoring locations.

Time-drawdown Analysis

The Theis (1935) solution for pumping in a confined aquifer was selected for the analysis of the data from GW-006. A confined aquifer solution was chosen because of the layering identified from the well logs and the different responses observed between GW-006 and the piezometer during the pumping test, as noted previously. The Theis solution allows for estimation of transmissivity and storativity of the aquifer using time-drawdown data from pumping tests. The values of these two parameters are adjusted to find a solution that provides an optimum fit to the field data.

Both the pumping period and the recovery period data collected at GW-006 were analyzed using the Theis solution. Analysis of the pumping data resulted in estimates of 1,100 ft^2/day for transmissivity and 0.0061 for storativity. Assuming an average aquifer thickness of 40 feet (silty sand is 37 feet thick at pilot well, about 43 feet thick at GW-006), the estimated hydraulic conductivity is 28 ft/day. Analysis of the recovery data (or residual drawdown) from GW-006 using the Theis solution resulted in similar estimates of 1,100 ft^2/day for transmissivity (28 ft/day for hydraulic conductivity) and 0.0052 for storativity. AQTESOLV plots for these (and all other analyses) are included as Attachment A.

Data collected from the pumping well during the first 3 hours of the test (before the water level began to decrease rapidly) was also analyzed in AQTESOLV. A good fit to this data was achieved using the Papadopulos-Cooper (1967) solution, which includes wellbore storage effects to better match the initial response. This analysis gave estimates of 160 ft^2/day for transmissivity and 0.0001 for storativity. Using a thickness of 40 feet, the hydraulic conductivity was estimated as 4 ft/day. These values are nearly an order of magnitude less than the results from the GW-006 analysis.

Distance-drawdown Analysis

The pumping well data were analyzed using the Cooper-Jacob (1946) distance-drawdown method to provide an additional estimate of transmissivity and storativity. The Cooper-Jacob method fits a straight line to a semilog plot of drawdown versus time. Omitting the nonlinear early-time data from the Papdopulos-Cooper analysis and fitting a straight line to the remaining data gave estimates of 130 ft^2/day for transmissivity and 0.0020 for storativity. The storativity estimate is similar to the GW-006 analysis, while the hydraulic conductivity (again assuming a thickness of 40 feet) of 3 ft/day is similar to the Papadopulos-Cooper pumping well analysis.

Discussion of Results

Variation of Conductivity Estimates

The hydraulic conductivity values estimated from the constant-rate test analysis fall within the range of 0.03 – 300 ft/day for silty sand, and the storativity values are close to the expected range of 0.005 to 0.00005 for confined aquifers (Freeze and Cherry, 1979). Barr conducted a series of single-well pumping tests in wells around the tailings basin in 2009, and obtained a range of hydraulic conductivity values from 1 to 50 ft/day (Barr, 2009). The new estimates from the pilot well testing are all within this range.

Barr conducted a single-well pumping test in GW-006 on May 4, 2009, and obtained hydraulic conductivity estimates of 10 and 6 ft/day from pumping and recovery data, respectively (Barr, 2009). These values are much lower than those obtained from the analysis of the GW-006 data from the 24-hour test, and a bit higher than the values from the pumping well (pilot well) analysis. In general, it is preferable to analyze drawdown data from an observation well rather than from the pumping well. This minimizes the effects of well inefficiencies on the analysis, and provides parameter estimates that are averaged over a larger volume of the aquifer. Due to spatial heterogeneity, the hydraulic conductivity may be similar near the pumping well and near GW-006, but may differ by orders of magnitude elsewhere in the aquifer. Thus the hydraulic conductivity estimates from the 24-hour test with GW-006 as an observation well may better reflect the conductivity of the aquifer as a whole.

Aquifer Boundaries and Flow Regime

The late time data collected during an aquifer test can provide insights into the flow regime of an aquifer and the presence of hydraulic boundaries. For example, encountering an aquifer boundary that supplies water to the aquifer (e.g. river, lake, or leakage boundary) will result in observed drawdown that is less than would be predicted by a Theis-type response. A low permeability boundary will result in more observed drawdown than would be predicted with a Theis-type response. The large increases in drawdown in the pumping well that prompted flow rate reductions do not fit expected Theis behavior and suggest the presence of a low permeability boundary within the aquifer, likely near the pumping well.

Another possible explanation for the difference in hydraulic conductivity estimates between the pumping well and observation well analyses is hydraulic connection with the wetlands. This would result in lower-than-expected drawdowns at GW-006 when pumping at the pilot well, and lower-than-expected drawdowns at GW-006 would correspond to a higher hydraulic conductivity estimate from the GW-006 data. Such boundary effects would be most pronounced during the latter part of the pumping period, and, as shown in the AQTESOLV plot of the GW-006 pumping period analysis in Attachment A, the Theis solution with the higher transmissivity fits the observed drawdown data better at late times than at early times. If a connection with the wetland is influencing the drawdowns at GW-006, a Theis curve with a lower transmissivity should fit the early time data better. However, this is not the case; a higher transmissivity (1,800 ft^2/day instead of 1,100 ft^2/day) is needed to better match the early time data. Therefore, the data do not conclusively show whether or not the native material under the tailings basin is hydraulically connected with the wetlands.

Maximum Pumping Rate

This pumping test indicated that the maximum sustainable long-term pumping rate for the pilot well is likely less than 6.5 gpm. The well was pumped at a rate of 6.5 gpm for a period of approximately 9 hours at the end of the aquifer test, and drawdown in the well was continuing to increase throughout this period. The fact that the drawdown in the pumping well did not stabilize, even at a relatively low pumping rate, suggests that a low permeability boundary may be present within the aquifer. Further investigation would be necessary to better characterize the location and properties of this boundary.

Long-Term Water Level Monitoring

As noted above, electronic monitoring of groundwater levels in the pilot well, GW-006, and the piezometer continued well after the conclusion of the aquifer testing. Figure 4 shows the water elevation record in these three wells from the start of the constant rate test at 8:30 on January 26, 2012 through late morning on January 4, 2013. The onset of regular pumping of the pilot well in May 2012 for the water treatment pilot testing is clearly evident in Figure 4, with the large fluctuations in water levels in the pilot well corresponding to a cyclical pumping pattern. For most of the pumping periods from May until mid-July, the pilot well was apparently pumped dry or nearly dry; the bottom of the pilot well is at an approximate elevation of 1442 feet, and the pressure sensor is mounted just above the submersible pump, which sits at the bottom. After mid-July the pumping levels did not approach the bottom of the well, which may be due to reduced pumping rates during this time period.

The natural flow direction appears to be towards the north, away from the tailing basin, as water levels are consistently highest in the piezometer and lowest at GW-006 during non-pumping periods, though the water level in GW-006 was higher than the water level in the pilot well from mid-March to late-April and again for short periods in late-May and mid-June, the latter of which may correspond to rainfall events. During pumping periods, the flow direction between GW-006 and the pilot well is reversed, as the lower water levels in the pilot well relative to GW-006 induce flow to the south towards the pilot well. Figure 5 presents the same data as shown on Figure 4, but its vertical scale has been adjusted to show more detail for GW-006 and the piezometer. Both GW-006 and the piezometer clearly respond to pumping in the pilot well, and all three wells show similar patterns of water level fluctuations during non-pumping periods. GW-006 is completed in the native unconsolidated deposits, and although it is not screened in wetland deposits, it is located adjacent to extensive wetland areas near the toe of the tailings basin. Water levels at GW-006 likely reflect hydraulic conditions in the adjacent wetlands. The clear drawdown observed at GW-006 in response to operation of the pilot test well suggests that long-term operation of the pilot-test well would likely affect water levels in the adjacent wetlands, at least while the well is being actively pumped. Water levels at GW-006 do appear to recover relatively rapidly after pumping ceases.

Summary and Conclusions

Analysis of the constant-rate pumping test data provided additional insights into the aquifer system. Transmissivity estimates using the data from GW-006 were 1,100 and 1,100 ft^2/day, and 130 and 160 ft^2/day using the pumping well data. Using an average aquifer thickness of 40 feet, these correspond to hydraulic conductivities of 28 and 28 ft/day and 3 and 4 ft/day, respectively. Storativity values were 0.0061 and 0.0052 from the GW-006 analysis and 0.0001 and 0.0020 from the pumping well analysis. The estimates from the GW-006 analysis are expected to better reflect average aquifer values, while the pumping well estimates are likely more localized and may be affected by frictional losses in the well. A low permeability boundary appears to be located within the aquifer. Long-term monitoring of the water levels in the pilot well, GW-006, and the piezometer shows strong correlations between water level fluctuations in the three wells, suggesting that there is a good hydraulic connection between these wells.

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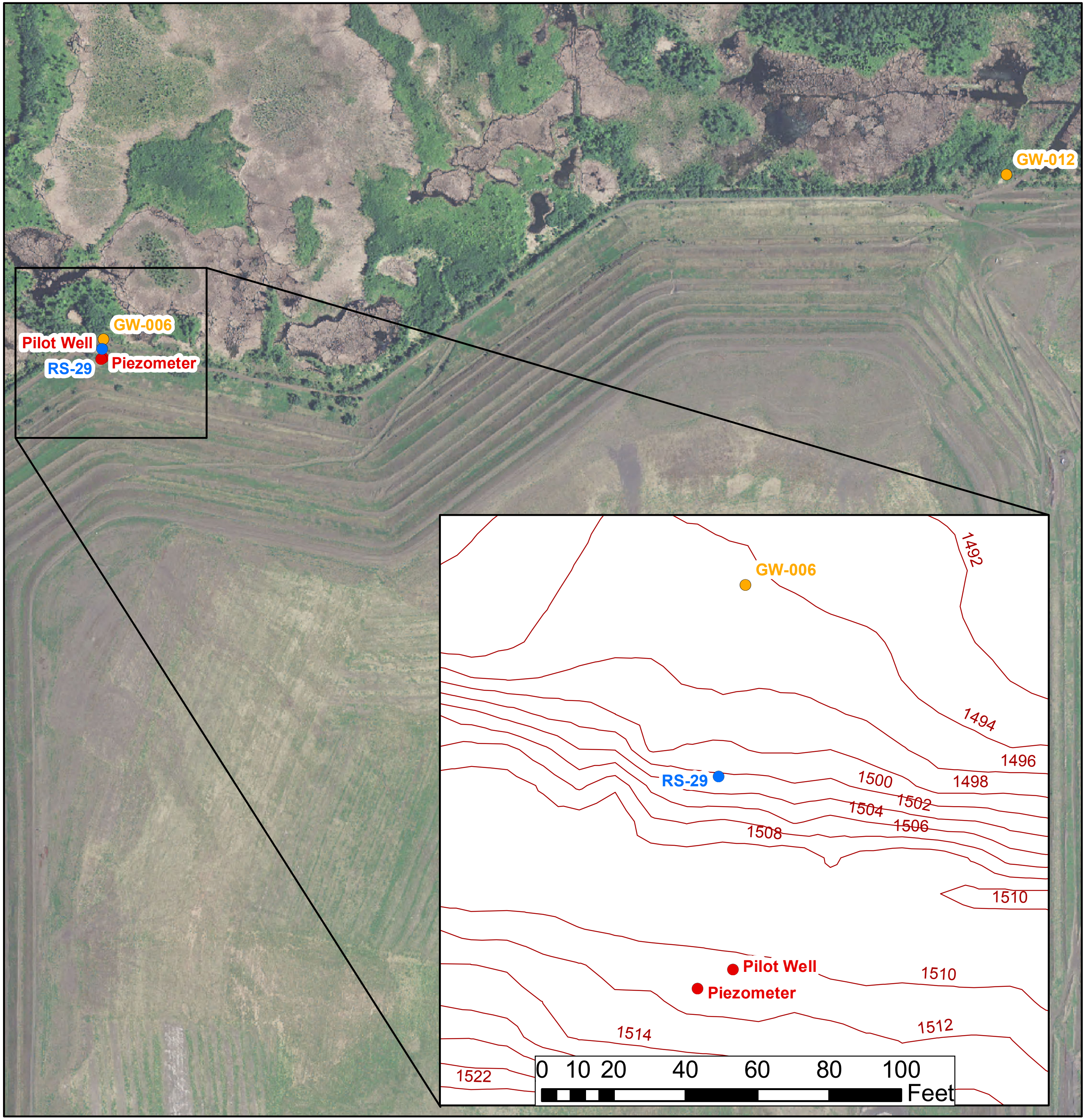
Table 1

Hydraulic conductivity (K) and storativity (S) estimates from analysis of 24-hour test data.

PolyMet Mining Corp.

Data Source	Period Analyzed	Analysis Method	K (ft/day)	S (dimensionless)
GW-006	Pumping	Theis	28	0.0061
GW-006	Recovery	Theis	28	0.0052
Pumping Well	Pumping	Papadopulos-Cooper	4	0.0001
Pumping Well	Pumping	Cooper-Jacob	3	0.0020



BARR

Figure 1

WELL LOCATIONS MAP
Pilot Well Pumping Test
PolyMet Mining Corp
Hoyt Lakes, MN

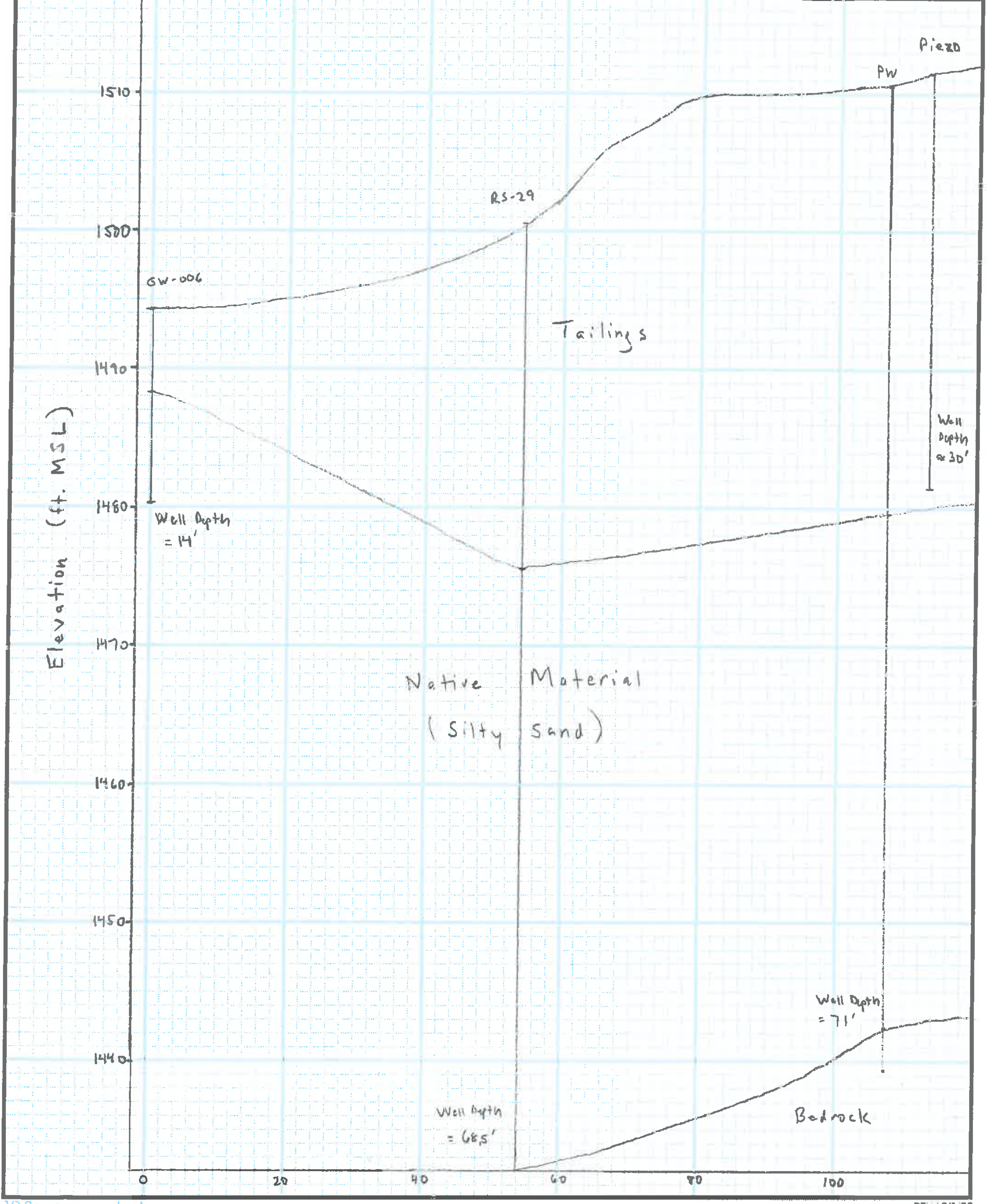
BARR

MINNEAPOLIS, MINNESOTA - HIBBING, MINNESOTA
DULUTH, MINNESOTA
ANN ARBOR, MICHIGAN - JEFFERSON CITY, MISSOURI

DATE 2/23/2012
SHEET NO. 1/1
PROJECT NAME Poly Met
PROJECT NUMBER 23/69-0862
SUBJECT Pumping Test Wells X-Section

COMPUTED	CHECKED	SUBMITTED
BY AKJ	BY	TO
DATE 2/23/12	DATE	DATE

Figure 2



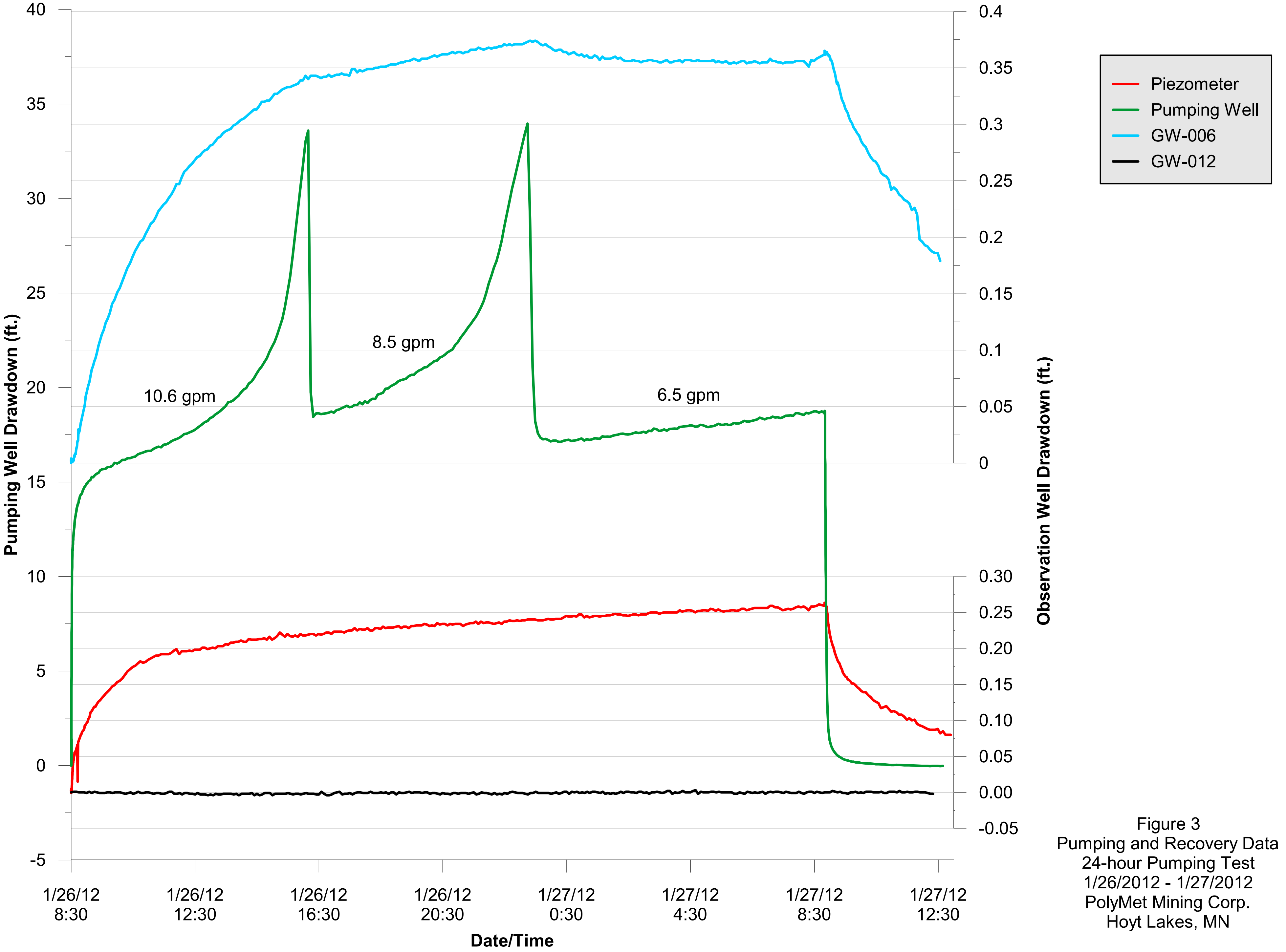


Figure 3
Pumping and Recovery Data
24-hour Pumping Test
1/26/2012 - 1/27/2012
PolyMet Mining Corp.
Hoyt Lakes, MN

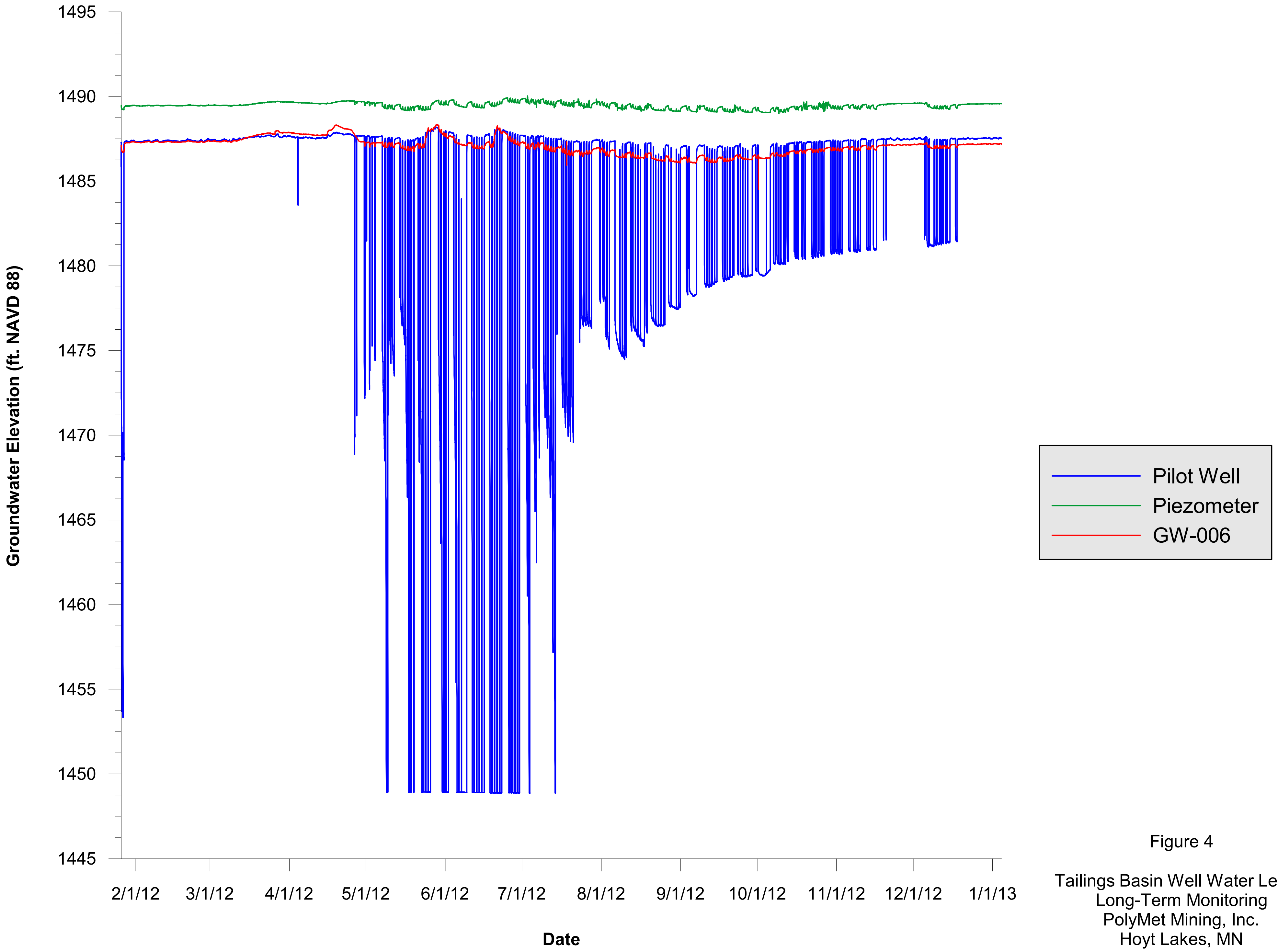


Figure 4

Tailings Basin Well Water Levels
Long-Term Monitoring
PolyMet Mining, Inc.
Hoyt Lakes, MN

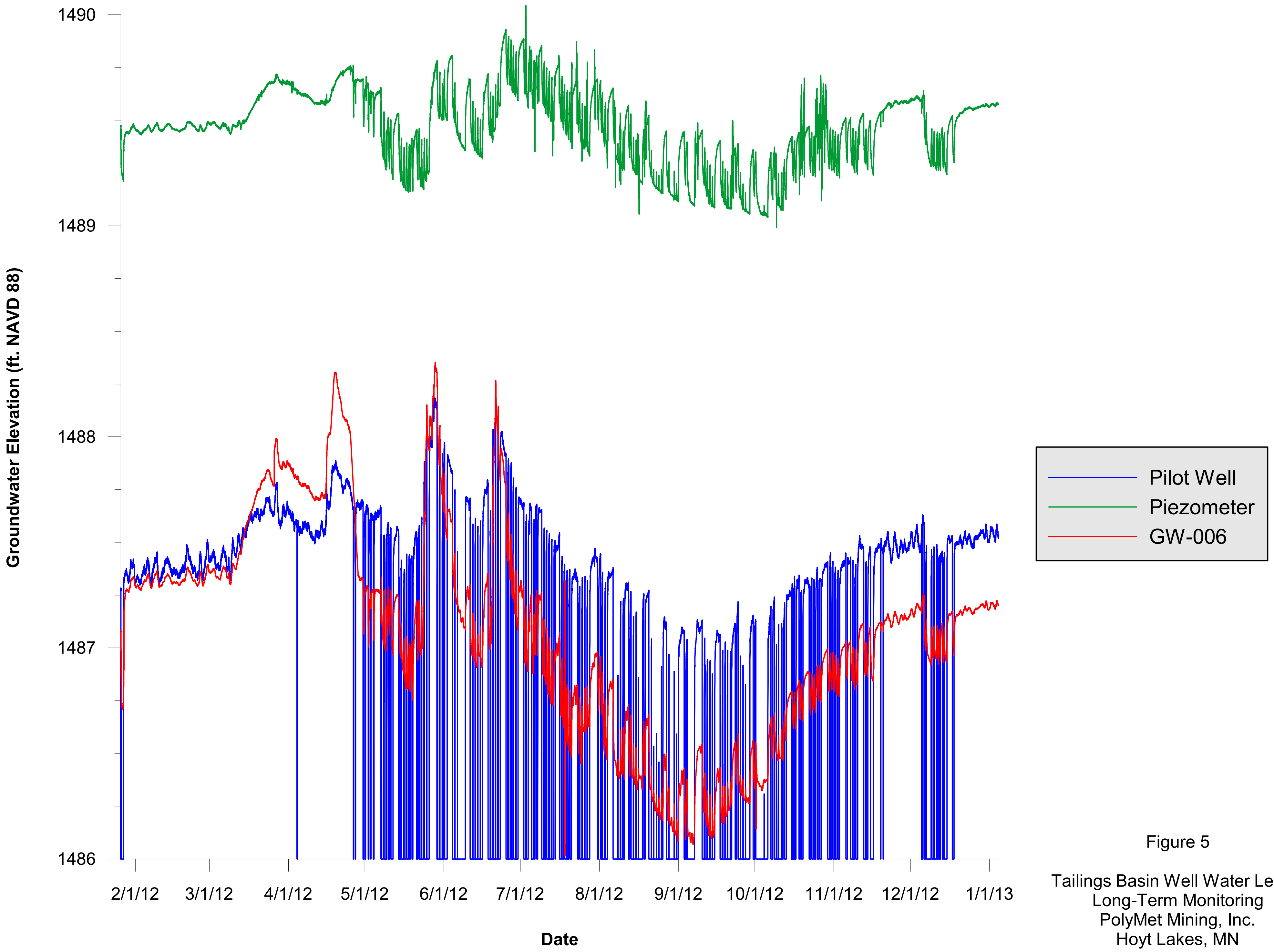
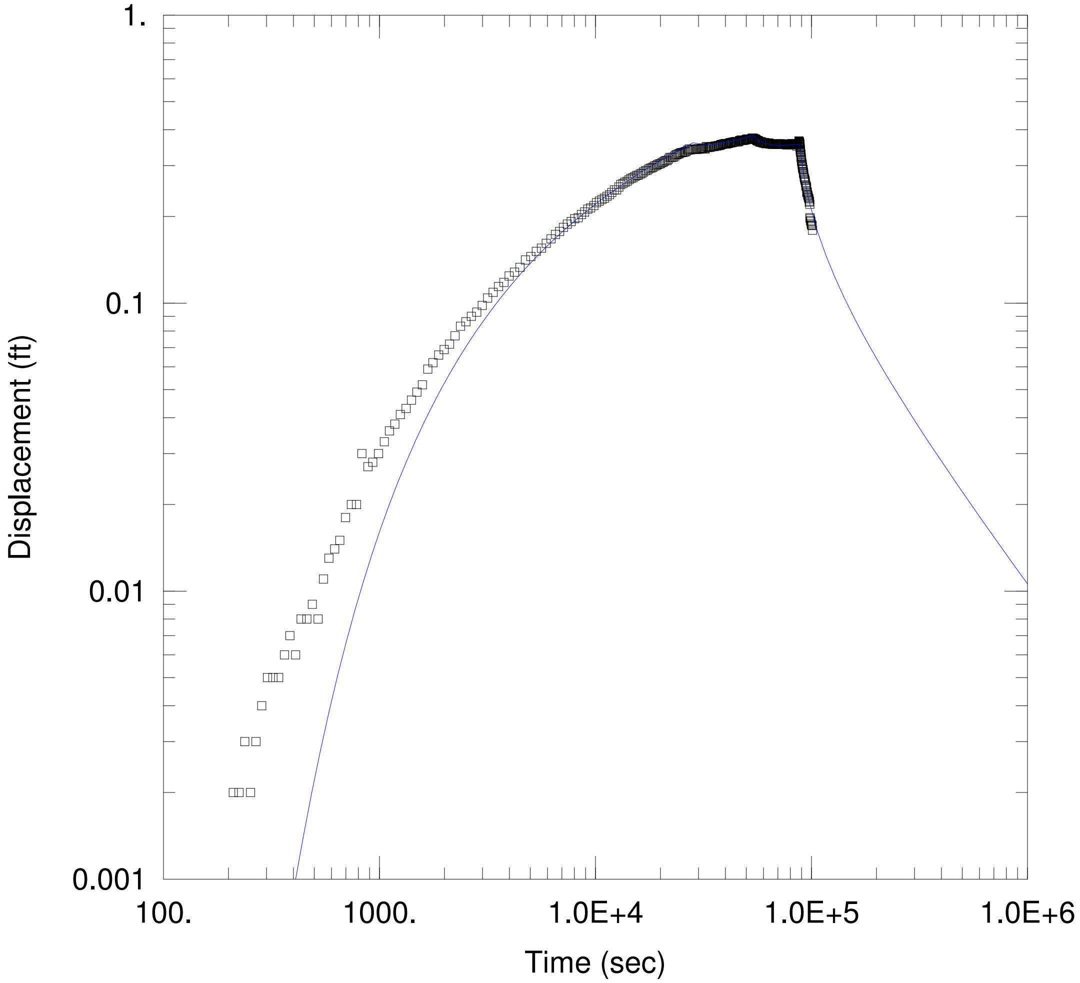


Figure 5

Tailings Basin Well Water Levels
Long-Term Monitoring
PolyMet Mining, Inc.
Hoyt Lakes, MN

Attachment A

AQTESOLV Plots



WELL TEST ANALYSIS

Data Set: P:\...\polymet_test_confined_GW006_test.aqt
Date: 02/24/12 Time: 09:11:30

PROJECT INFORMATION

Company: Barr Engineering
Client: PolyMet
Project: 23690862
Location: Hoyt Lakes, MN
Test Well: Pumping Well
Test Date: 01/26/2012

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Pumping Well	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
□ GW-006	-110	0

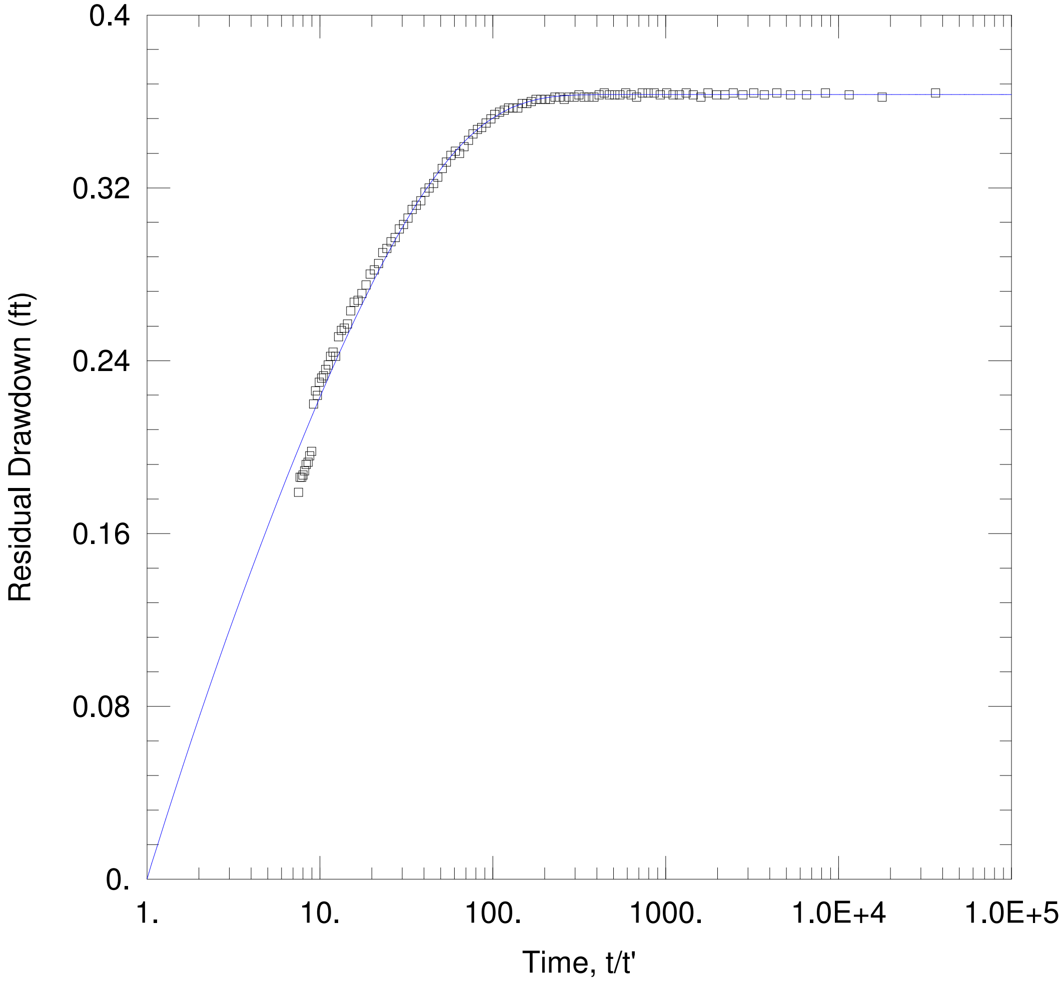
SOLUTION

Aquifer Model: Confined

Solution Method: Theis

T = 1103.7 ft^2/day
Kz/Kr = 0.1

S = 0.006096
b = 40. ft



WELL TEST ANALYSIS

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Date: 02/24/12 Time: 09:04:36

PROJECT INFORMATION

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Client: PolyMet
Project: 23690862
Location: Hoyt Lakes, MN
Test Well: Pumping Well
Test Date: 01/26/2012

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Pumping Well	0	0

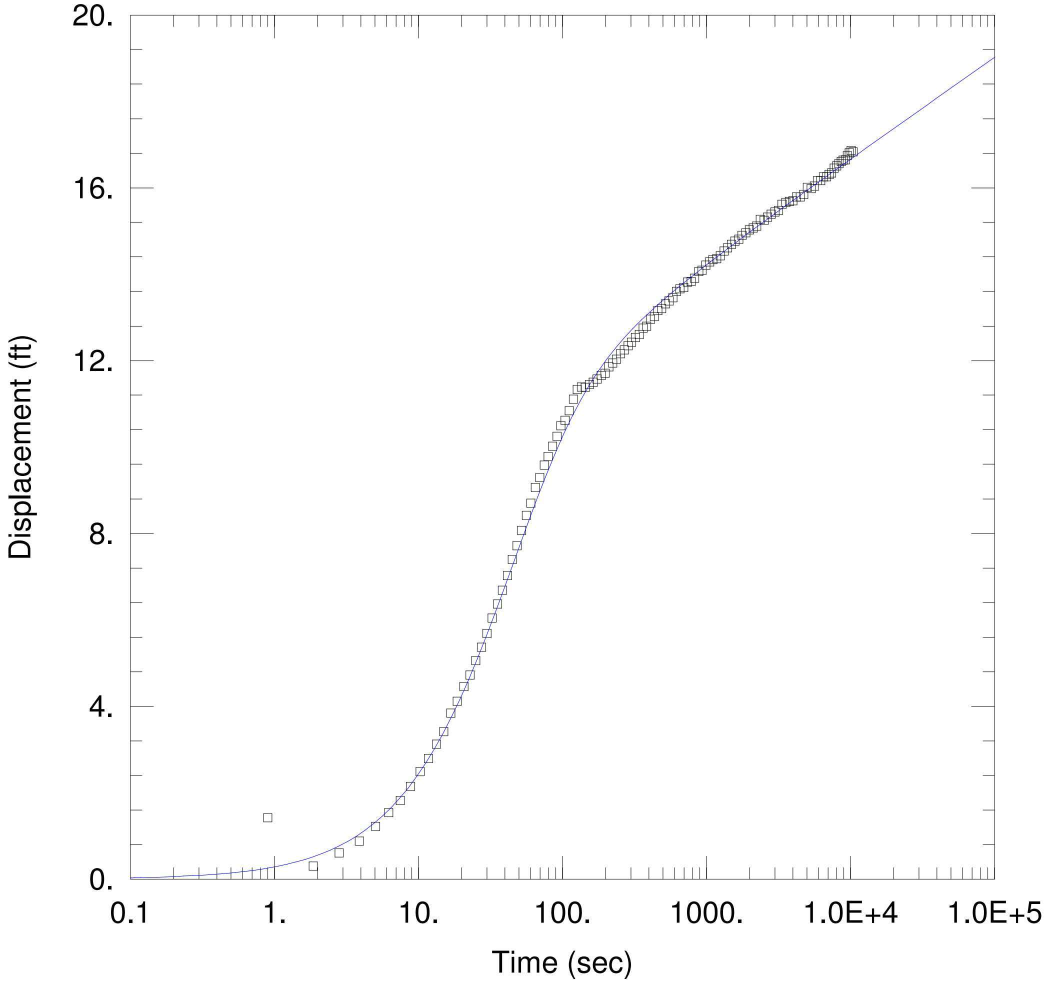
Observation Wells

Well Name	X (ft)	Y (ft)
□ GW-006	-110	0

SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1135.6 ft^2/day
S = 0.005159
Kz/Kr = 0.1
b = 40. ft



WELL TEST ANALYSIS

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Date: 02/24/12 Time: 09:04:08

PROJECT INFORMATION

Company: Barr Engineering
Client: PolyMet
Project: 23690862
Location: Hoyt Lakes, MN
Test Well: PW
Test Date: 01/26/2012

AQUIFER DATA

Saturated Thickness: 40. ft
Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Pumping Well	0	0

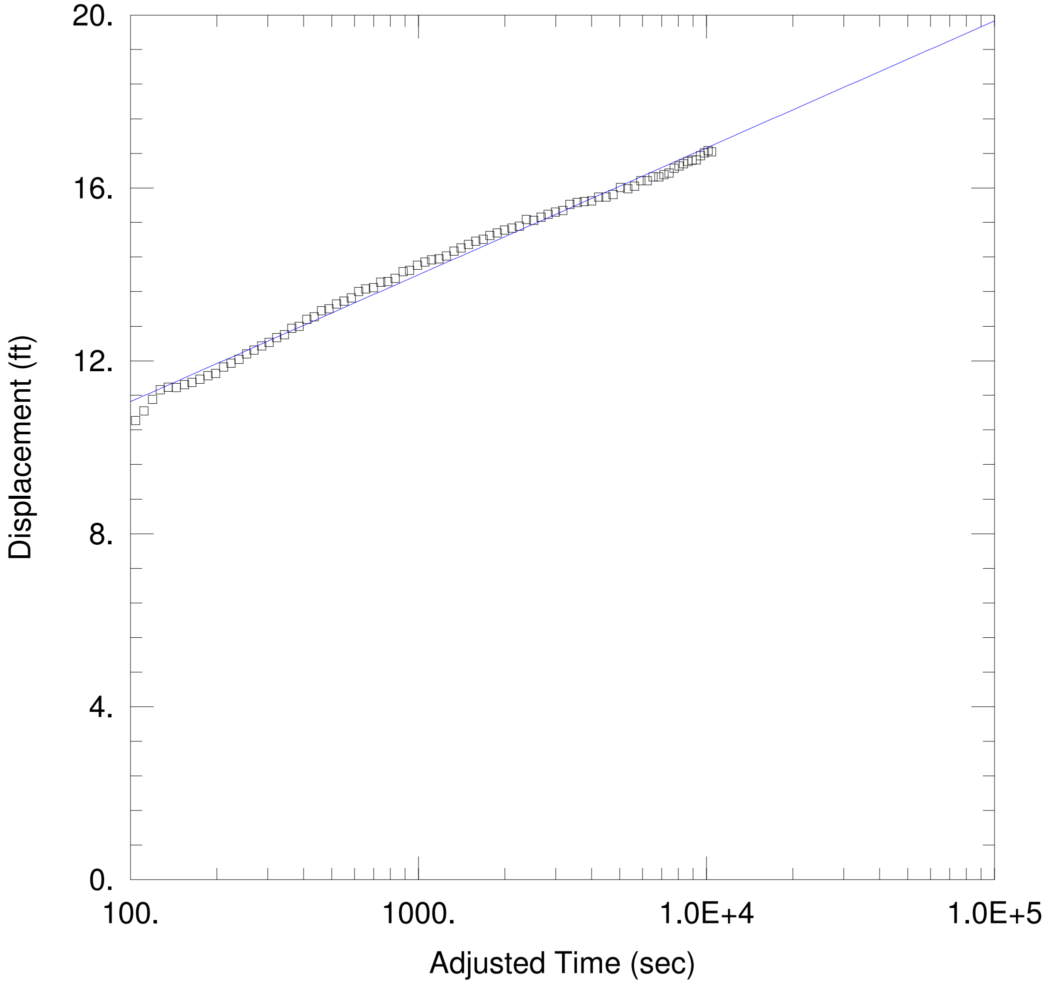
Observation Wells

Well Name	X (ft)	Y (ft)
□ Pumping Well	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Papadopulos-Cooper

T = 159.2 ft^2/day
S = 0.0001178
r(w) = 0.167 ft
r(c) = 0.167 ft



WELL TEST ANALYSIS

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Date: 02/24/12 Time: 09:03:49

PROJECT INFORMATION

Company: Barr Engineering
Client: PolyMet
Project: 23690862
Location: Hoyt Lakes, MN
Test Well: PW
Test Date: 01/26/2012

AQUIFER DATA

Saturated Thickness: 40. ft
Anisotropy Ratio (Kz/Kr): 0.1

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Pumping Well	0	0

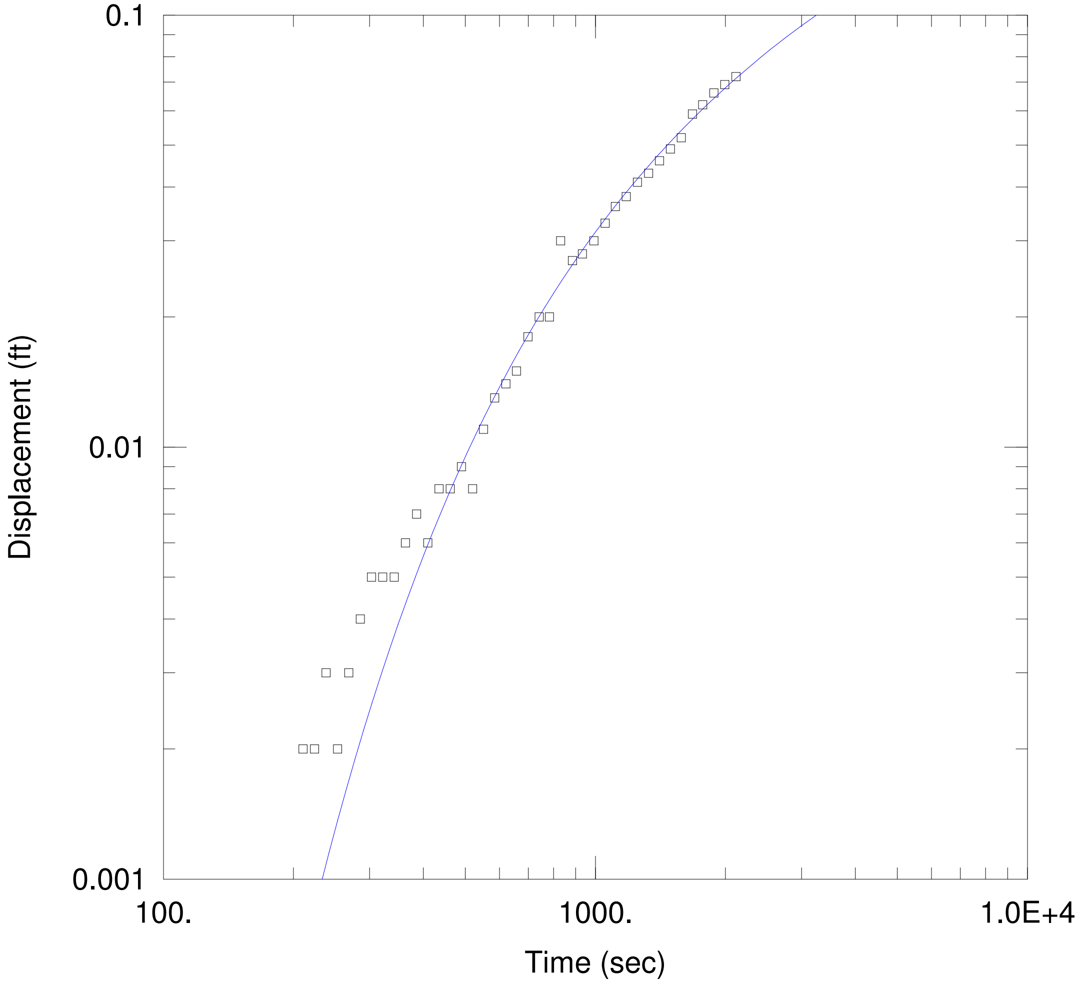
Observation Wells

Well Name	X (ft)	Y (ft)
□ Pumping Well	0	0

SOLUTION

Aquifer Model: Confined
Solution Method: Cooper-Jacob

T = 127.4 ft^2/day
S = 0.002037



WELL TEST ANALYSIS

Data Set: P:\...\polymet_test_confined_GW006_test_earlytime.aqt
Date: 02/24/12 Time: 09:30:47

PROJECT INFORMATION

Company: Barr Engineering
Client: PolyMet
Project: 23690862
Location: Hoyt Lakes, MN
Test Well: Pumping Well
Test Date: 01/26/2012

WELL DATA

Pumping Wells

Well Name	X (ft)	Y (ft)
Pumping Well	0	0

Observation Wells

Well Name	X (ft)	Y (ft)
□ GW-006	-110	0

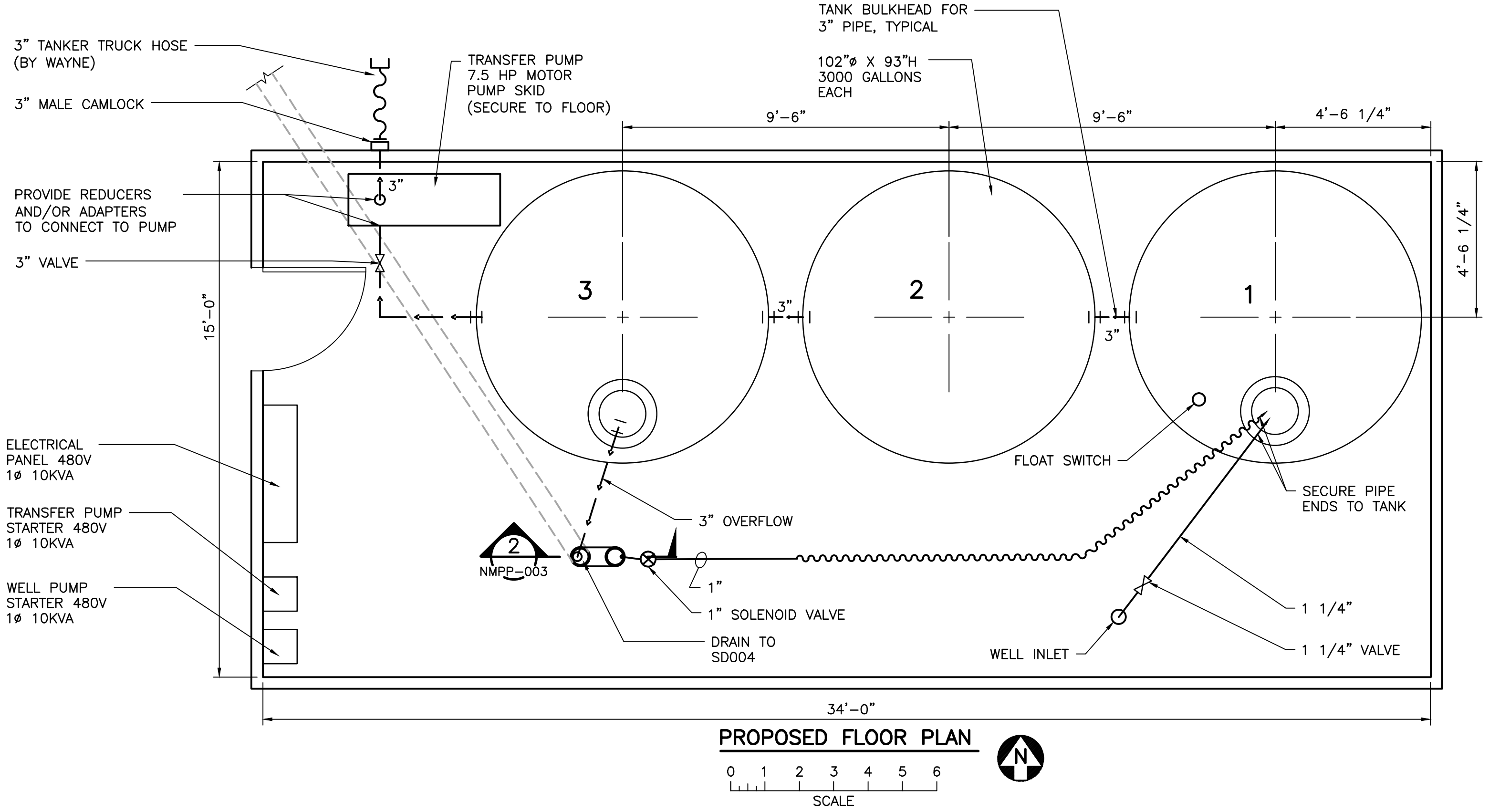
SOLUTION

Aquifer Model: Confined
Solution Method: Theis

T = 1840.3 ft^2/day
S = 0.005107
Kz/Kr = 0.1
b = 40. ft

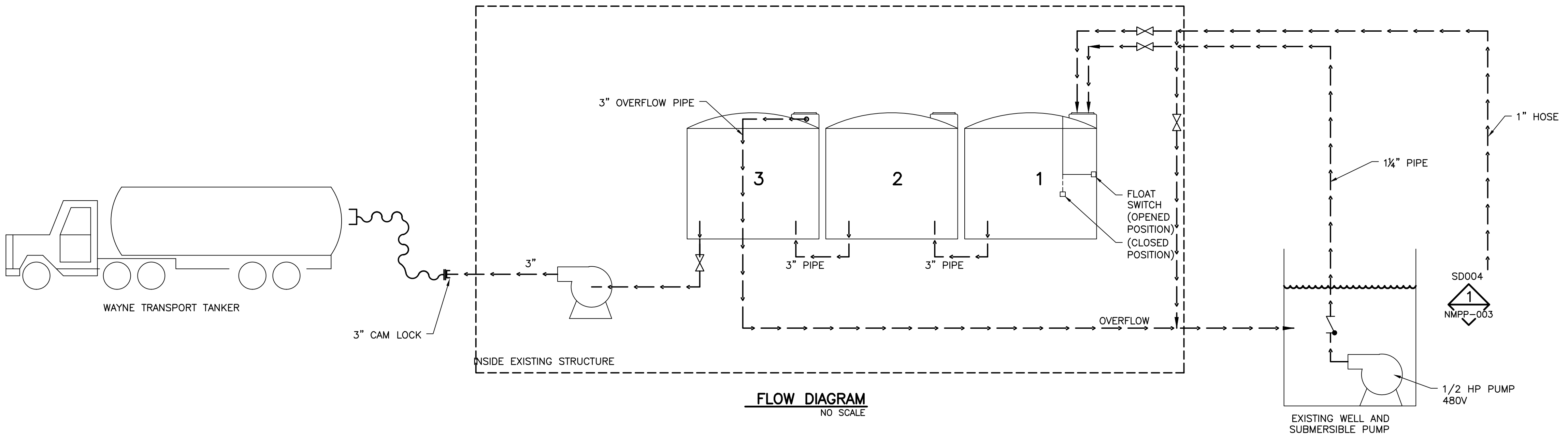
Appendix B

Pilot-test Facility Information



PROPOSED FLOOR PLAN

NOTES:
1. VENT TANKS THROUGH TOP ACCESSWAY OR PROVIDE VENT IN TANK TOP.
2. REFER TO SHEET NMPP-004 FOR FLOOR REINFORCEMENT TO SUPPORT TANKS.
3. LEVEL CONTROL FLOAT TO BE INSTALLED IN TANK 3.
4. SEE ELECTRICAL SCHEMATIC NMPP-005 FOR POWER AND CONTROL REQUIREMENTS.
5. 3" PIPING – SCHEDULE 40 PVC OR EQUAL.



FLOW DIAGRAM
NO SCALE

POLYMET DRAWING REVIEW
☒ APPROVED
☐ APPROVED AS NOTED
☐ REVISE AND RESUBMIT
BY: PAUL BRUNFELT DATE:4/13/2012

REV NO	DATE	REVISIONS	BY	CHKR
0	4/13/12	ISSUED FOR CONSTRUCTION	TEG2	JSV
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–
–	–	–	–	–

DRAWING STATUS				
ISSUED	REV	DATE	SDE	PEM
PRELIMINARY	A	4/3/12	–	–
APPROVED FOR CONSTRUCTION	0	4/13/12	–	–

NOT APPROVED FOR CONSTRUCTION UNLESS SIGNED AND DATED. DESTROY ALL PRINTS BEARING EARLIER DATE AND/OR REV.NO.

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

SIGNATURE ____________
PRINTED NAME ____________
DATE ______ REG. NO. ______

DRAWN: KRM	DATE: 3/15/12
CHECKED: –	DATE: –
BARR PROJECT NO.: 23/69-1302	
SCALE: AS SHOWN	

PLANT DRAWING NUMBER:

TAILING BASIN
PILOT PLANT ON SITE STORAGE
GENERAL ARRANGEMENTS

POLYMET MINING
POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING COMPANY
3128 14TH AVENUE EAST
HIBBING, MN
55746
Ph: 1-800-225-1966
Fax: (218) 262-3460
www.barr.com

DWG. NO. NMPP-001
REV 0

CADD USER: Adeptuser FILE: \\ADEPTXPHIB\HIBBING PW IN\565439ED-135B-4E7D-B3C2-447010DAB133\41C6324F-456C-43E7-8959-4737DF600B91\23691302_NMPP001.DWG PLOT SCALE: 1:2 PLOT DATE: 4/13/2012 3:26 PM

INCHES 1 2

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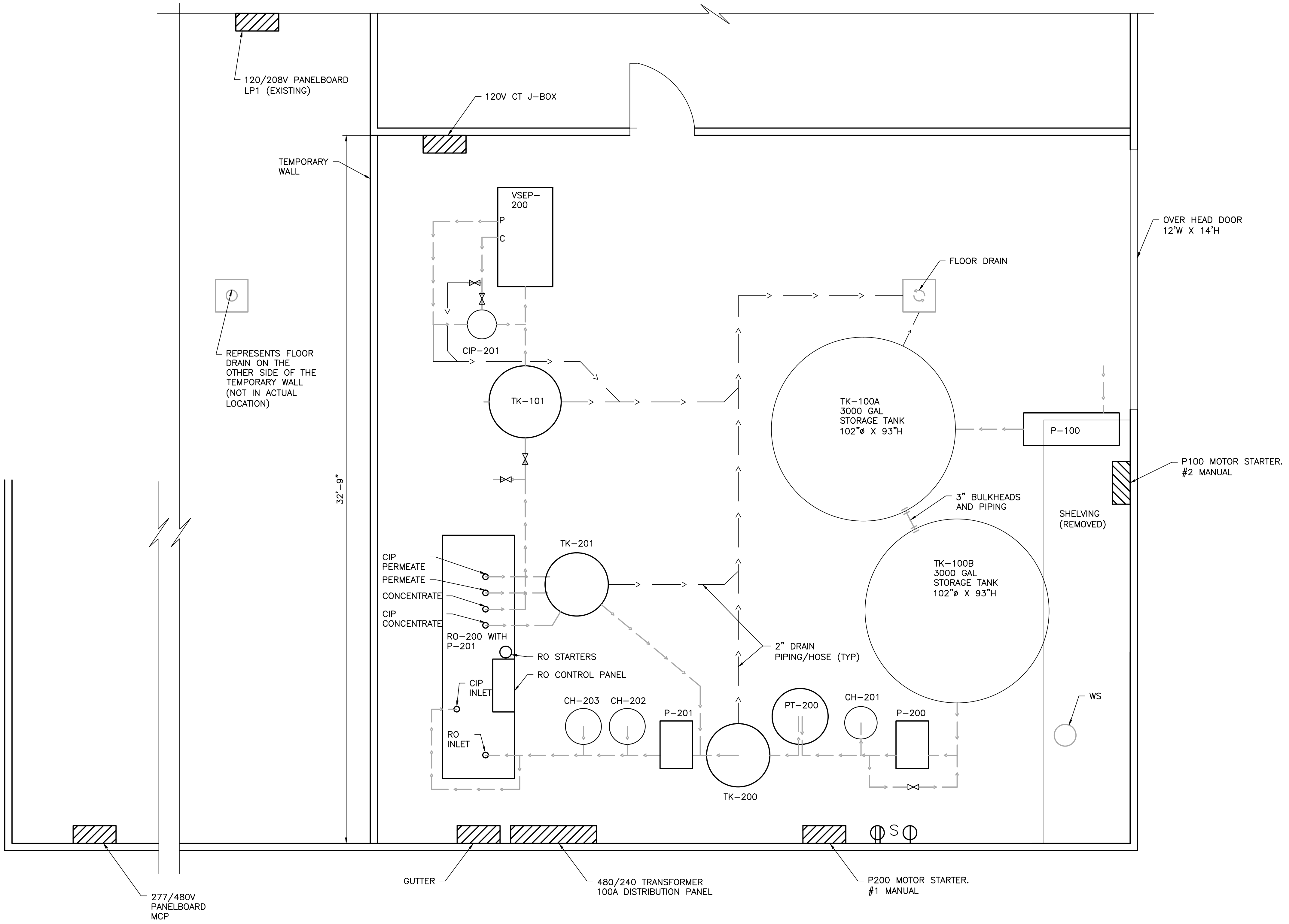

LEGEND:
P – PIPING
TK – TANK
CH – CHEMICAL FEED
PT – PRETREATMENT
RO – RO PILOT SKID
CIP – CIP TANK
VSED – VSED PILOT SKID

NOTES:
1. SEE G.E. DRAWINGS FOR PIPING SIZES.
2. "100" ITEMS BY POLYMET. "200" ITEMS BY G.E./OTHERS.

PROPOSED FLOOR PLAN

0 1 2 3 4 5 6
SCALE

N

POLYMET DRAWING REVIEW

☒ APPROVED
☐ APPROVED AS NOTED
☐ REVISE AND RESUBMIT

BY: PAUL BRUNFELT DATE: 4/13/2012

REV NO	DATE	REVISIONS	BY	CHKR
0	4/13/12	ISSUED FOR CONSTRUCTION	TEG2	JSV
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–	–	–	–	–

DRAWING STATUS				
ISSUED	REV	DATE	SDE	PEM
PRELIMINARY	A	4/3/12	–	–
APPROVED FOR CONSTRUCTION	0	4/13/12	–	–

NOT APPROVED FOR CONSTRUCTION UNLESS SIGNED AND DATED. DESTROY ALL PRINTS BEARING EARLIER DATE AND/OR REV.NO.

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

SIGNATURE ____________
PRINTED NAME ____________
DATE ________ REG. NO. ________

DRAWN: KRM DATE: 3/16/12
CHECKED: – DATE: –
BARR PROJECT NO.: 23/69-1302
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

WAYNE SITE
WASTE WATER TREATMENT PILOT PLANT
GENERAL ARRANGEMENTS

POLYMET MINING

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

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3128 14TH AVENUE EAST
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55746
Ph: 1-800-225-1966
Fax: (218) 262-3460
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DWG. NO. NMPP-002
REV 0

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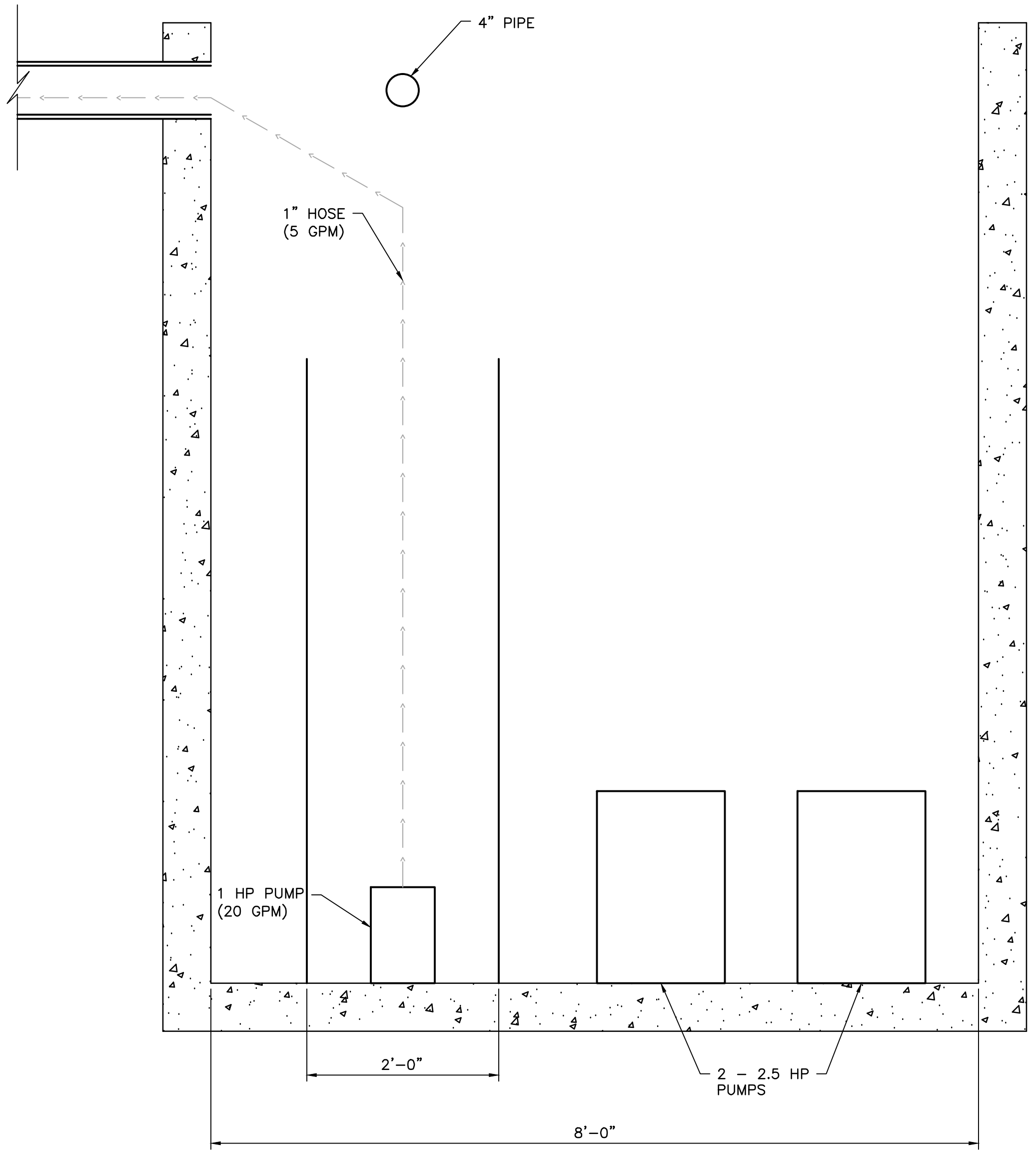
CADD USER: Adeptuser FILE: \\ADEPTXPHIB\HIBBING PW IN\565439ED-135B-4E7D-B3C2-447010DAB133\3E3A7642-7EBD-47D8-B3F8-DB068AAD2BE9\23691302_NMPP003.DWG PLOT SCALE: 1:2 PLOT DATE: 4/13/2012 3:26 PM



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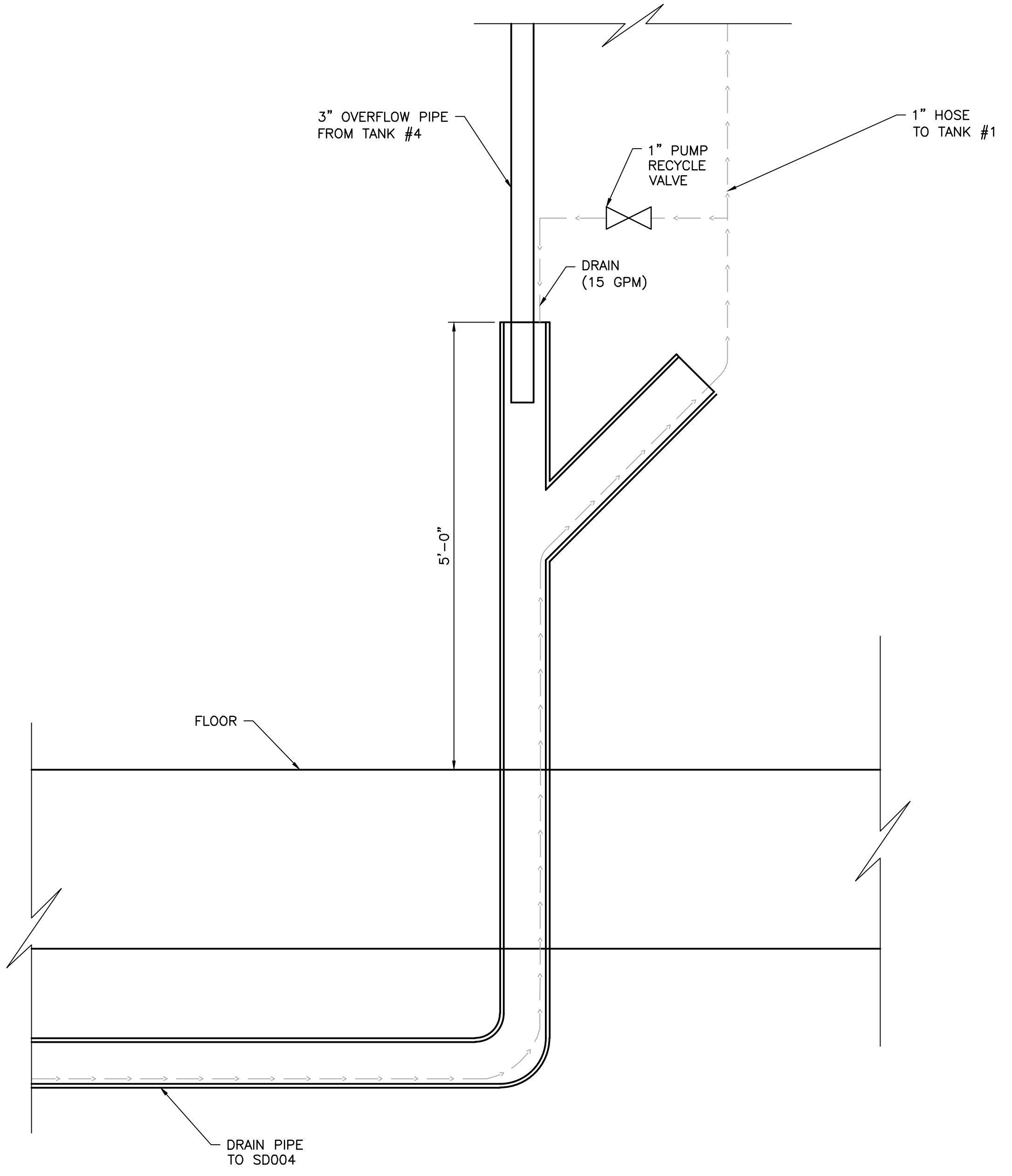

2/001 DETAIL: DRAIN PIPE TO SD004

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☐ APPROVED AS NOTED
☐ REVISE AND RESUBMIT
BY: PAUL BRUNFELT DATE: 4/13/2012

REV NO	DATE	REVISIONS	BY	CHKR
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SCALE: AS SHOWN	

PLANT DRAWING NUMBER:

TAILINGS BASIN
PILOT PLANT ON SITE STORAGE
DETAILS

POLYMET MINING

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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REV 0

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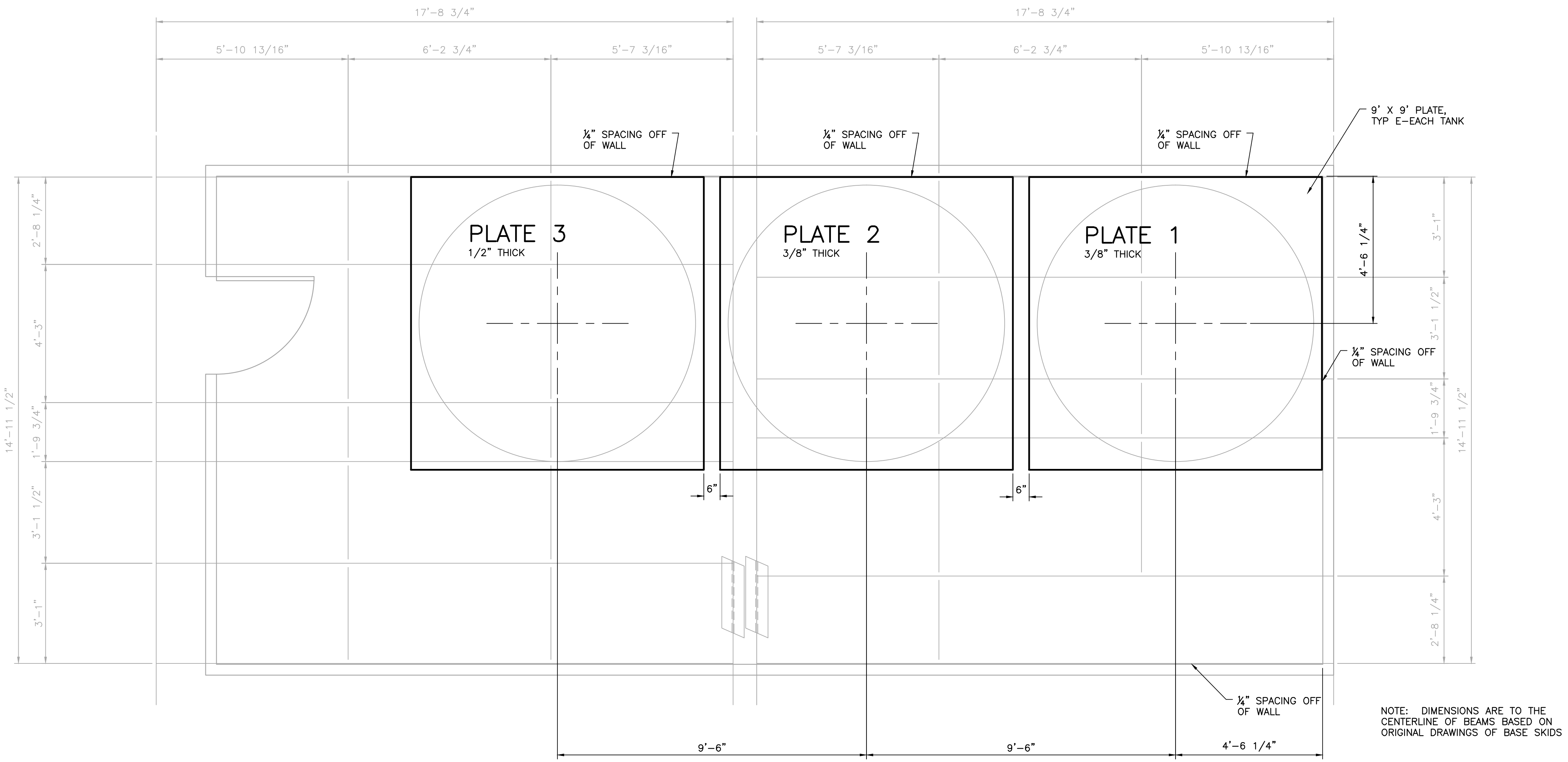

NOTE: DIMENSIONS ARE TO THE CENTERLINE OF BEAMS BASED ON ORIGINAL DRAWINGS OF BASE SKIDS

FLOOR DETAIL AT TAILINGS BASIN SITE

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SCALE

POLYMET DRAWING REVIEW
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☐ REVISE AND RESUBMIT
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REV NO	DATE	REVISIONS	BY	CHKR
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PLANT DRAWING NUMBER:

TAILINGS BASIN
PILOT PLANT ON SITE STORAGE
TANK REINFORCEMENT

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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DWG. NO. NMPP-004 REV 0

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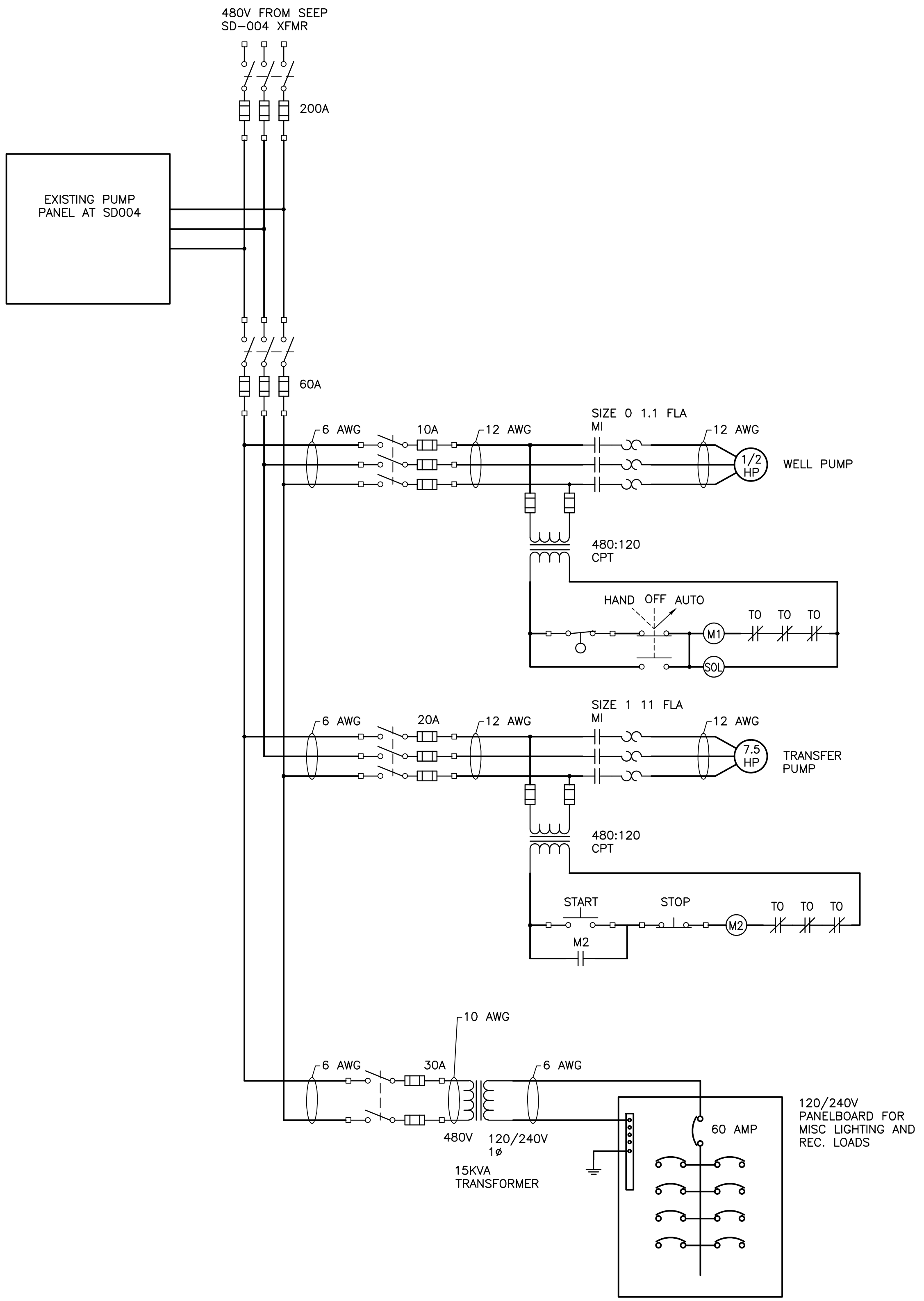

POLYMET DRAWING REVIEW
☒ APPROVED
☐ APPROVED AS NOTED
☐ REVISE AND RESUBMIT
BY: PAUL BRUNFELT DATE: 4/13/2012

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PLANT DRAWING NUMBER:

TAILINGS BASIN
PILOT PLANT ON SITE STORAGE
ELECTRICAL SCHEMATIC

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REV 0

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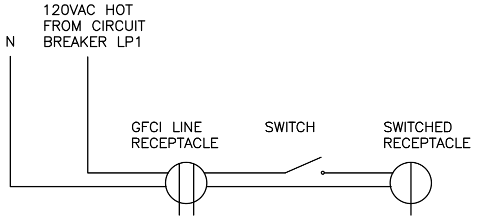

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DETAIL: SWITCHED RECEPTACLE

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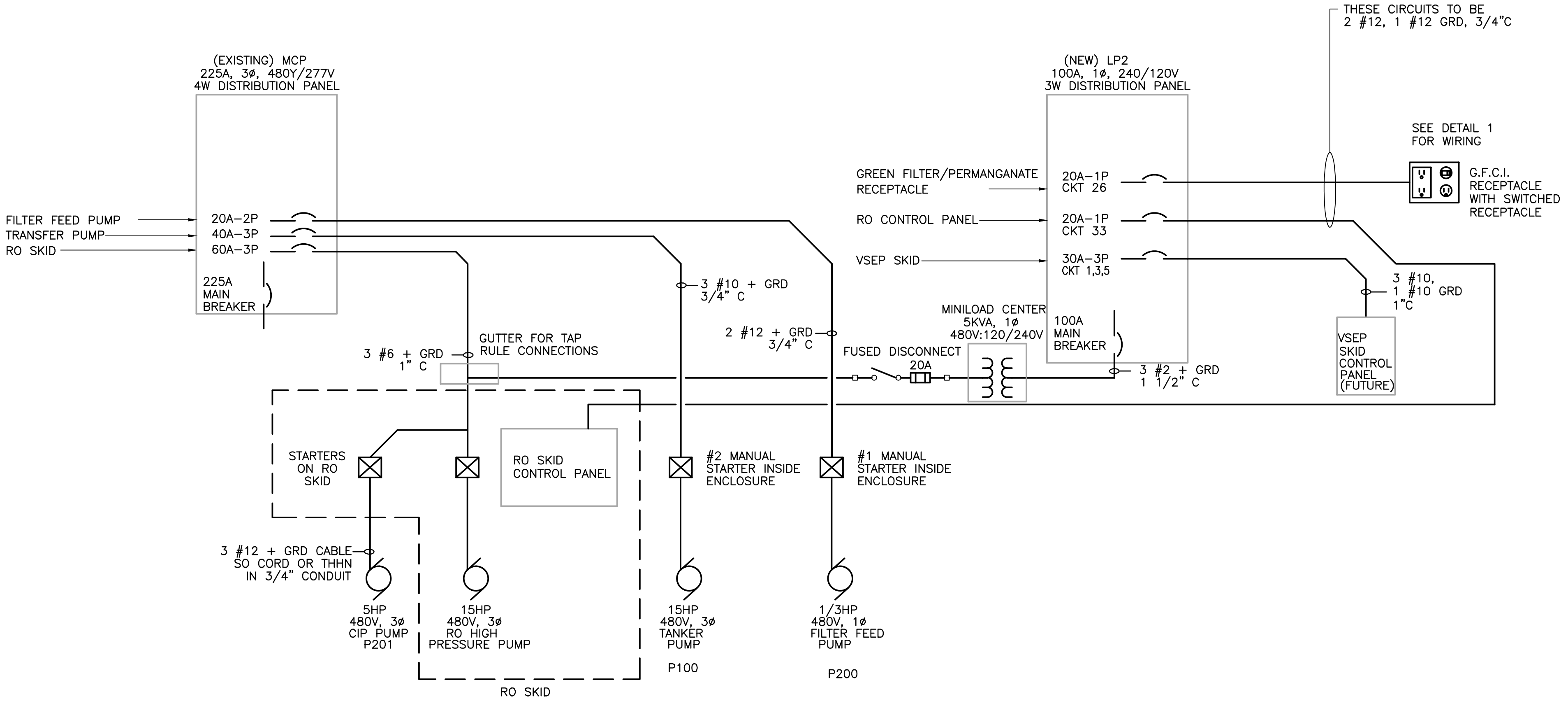

ELECTRICAL SYSTEM DIAGRAM

NO SCALE

POLYMET DRAWING REVIEW
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☐ REVISE AND RESUBMIT
BY: PAUL BRUNFELT DATE: 4/13/2012

REV NO	DATE	REVISIONS	BY	CHKR
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BARR PROJECT NO.: 23/69-1302	
SCALE: AS SHOWN	

PLANT DRAWING NUMBER:

WAYNE SITE
WASTE WATER TREATMENT PILOT PLANT
ELECTRICAL SYSTEM DIAGRAM

POLYMET MINING
POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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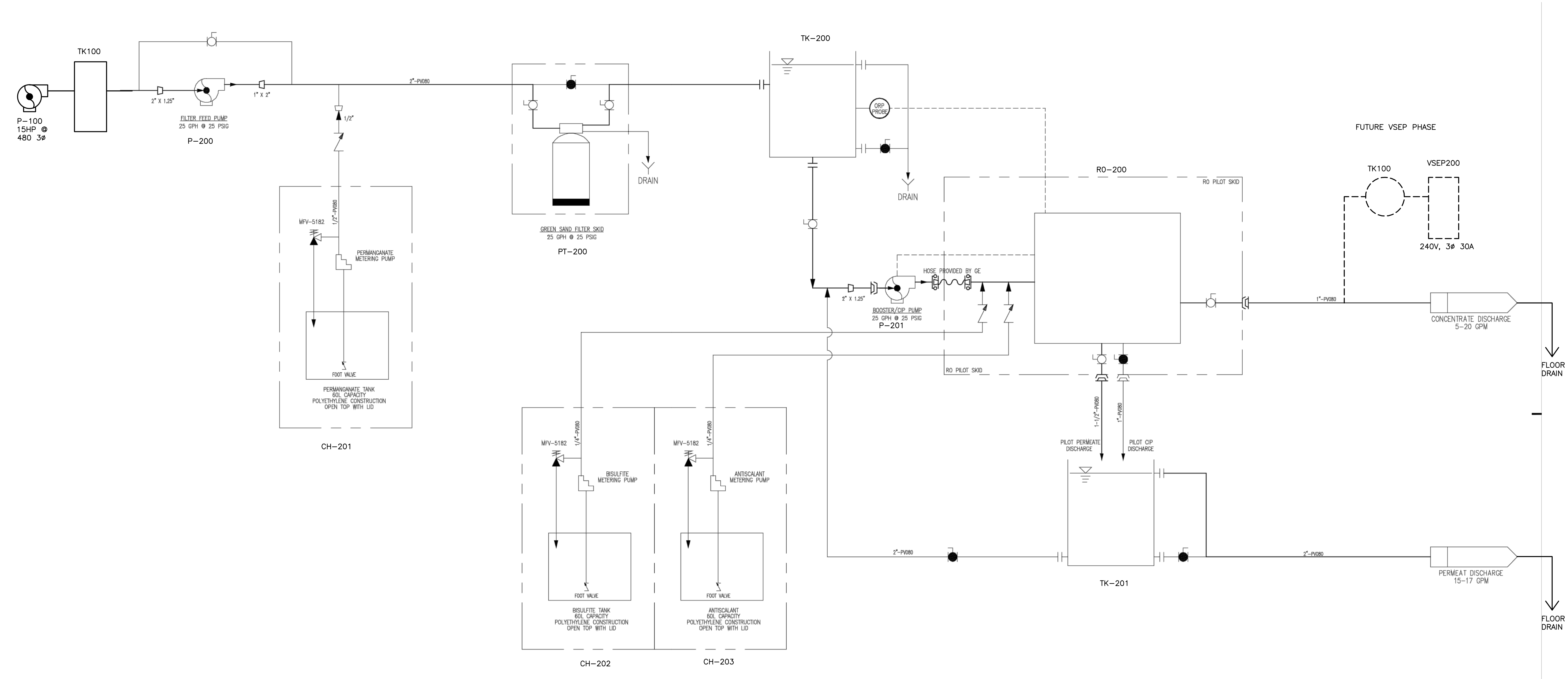
INCHES 1 2



FEED PUMP	PERMANGANTE PUMP	MEDIA FILTER	BISULFITE PUMP	ANTISCALANT PUMP	RO CONTROLS EQUIPMENT	RO PILOT PUMPS CONNECTION
208/440V / 4.25/1.95A / 1Ph / 60Hz	115V / 1A / 1Ph / 60Hz	115V / 15A / 1Ph / 60Hz	115V / 1A / 1Ph / 60Hz CAN BE PLUGGED INTO RO PILOT OR SEPARATE SUPPLY	115V / 1A / 1Ph / 60Hz CAN BE PLUGGED INTO RO PILOT OR SEPARATE SUPPLY	115V / 15A / 1Ph / 60Hz	460V / 60A / 3Ph / 60 Hz

CADD USER: Adeptuser FILE: \\ADEPTXPHIB\HIBBING PW IN\565439ED-135B-4E7D-B3C2-447010DAB133\BCAA0E7B-D25F-4BDC-A7FB-E5FD2A7D32EB\23691302_NMPP007.DWG PLOT SCALE: 1:2 PLOT DATE: 4/13/2012 3:27 PM

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POLYMET DRAWING REVIEW
☒ APPROVED
☐ APPROVED AS NOTED
☐ REVISE AND RESUBMIT
BY: PAUL BRUNFELT DATE: 4/13/2012

REV NO	DATE	REVISIONS	BY	CHKR
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PRELIMINARY	A	4/9/12	–	–
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BARR PROJECT NO.: 23/69-1302
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

WAYNE SITE
WASTE WATER TREATMENT PLAN
PIPING AND INSTRUMENT DIAGRAM

POLYMET MINING
POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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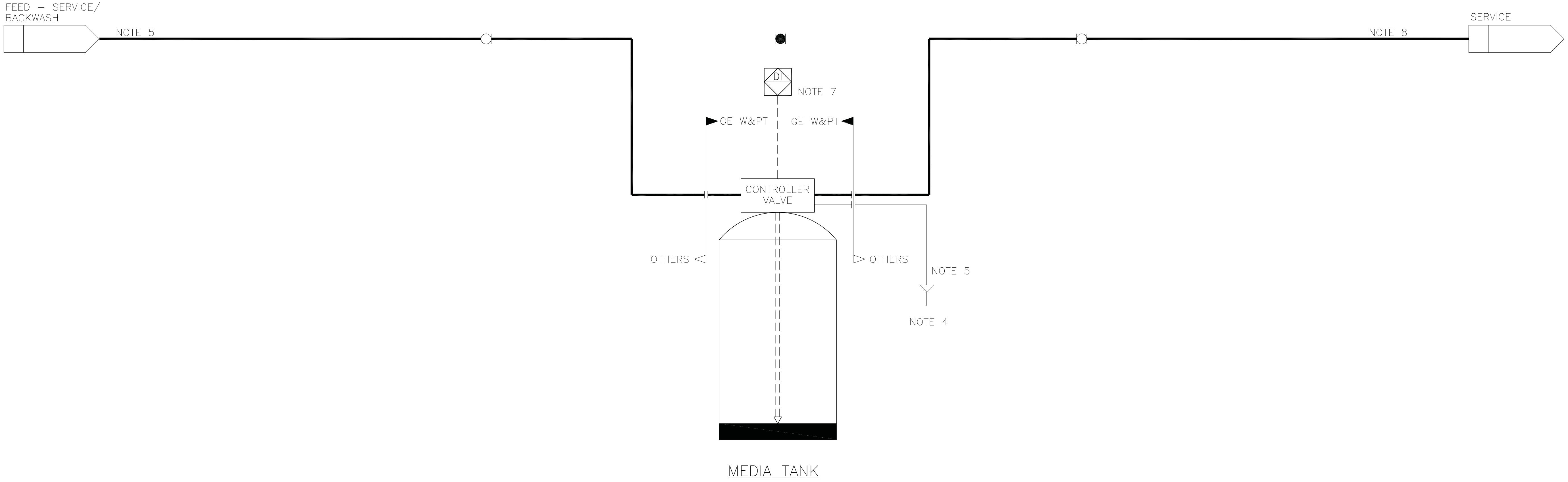
DWG. NO. NMPP-007
REV 0

Appendix C

GE Greensand Filter and Reverse Osmosis Pilot Unit Information



SYSTEM INFORMATION (EACH)				
TANK SIZE (IN.);	SERVICE (GPM): NOTE 5	BACKWASH(GPM): NOTE 5	INLET/OUTLET CONNECTIONS SIZE (IN):	DRAIN CONNECTION SIZE (IN):
10	1.5–5	6	1.0 SPG	0.75 MPT
14	3–9	10	1.0 SPG	0.75 MPT
21	6–18	25	2.0 SPG	1.5 SPG
30	15–45	50	2.0 SPG	2.0 MPT
36	20–60	75	2.0 SPG	2.5 MPT

NOTE:

1. MANUAL VALVES AND PIPING IN CUSTOMER SCOPE OF SUPPLY.
2. WATER PRESSURE 25 PSI MINIMUM AND 125 PSI MAXIMUM.
3. A 120 VOLT ELECTRICAL OUTLET SHOULD BE PROVIDED WITHIN 10 FEET OF EQUIPMENT.
4. REFER TO INSTALLATION MANUAL FOR INSTALLATION INSTRUCTION. TO MEET SANITARY REQUIREMENTS, THE DRAIN LINE MUST BE PIPED TO AN OPEN DRAIN WHERE FLOW (DURING REGENERATION) CAN BE OBSERVED AND AN AIR GAP CAN BE MAINTAINED IN ACCORDANCE WITH LOCAL PLUMBING CODES.
5. FEED LINE AND DRAIN LINE SHALL BE SIZED FOR BACKWASH FLOW.
6. MEDIA SHIPPED LOOSE AND LOADED ON SITE BY CUSTOMER.
7. CONTROLLER IS PROVIDED WITH SWITCH FOR EQUIPMENT LOCKOUT DURING REGENERATION.
8. NO AUTOMATIC UNFILTERED WATER BYPASS DURING REGENERATION
9. REFERENCE P&ID LEGEND PAGE: 1301227

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	13308	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
.X ± ±
.XX ±
.XXX ±
FRAC
±

DRAWN BY GRK	DATE 28Jun07
CHECKED BY RLD	DATE 21Sep07
APPROVED BY PWG	DATE 21Sep07
APPROVED BY	DATE

GE
Water & Process Technologies
GLOBAL HEADQUARTERS : TREVOSE, PA USA +1–215–355–3300 WWW.GEWATER.COM

CLIENT/JOB

FILE

DWG DESCRIPTION
PIPING & INSTRUMENTATION DIAGRAM
CARBON, FRP, SINGLE

MATERIAL/BOM NO.

SIZE	DRAWING NO.	REV
D	1303222	A

PROJECT

SCALE NONE
SHEET 1 OF 1

P/N 1161662–RGP01

Inversand Company
SINCE 1925
226 Atlantic Avenue, P.O. 650 • Clayton, NJ 08312
Phone 856-881-2345 Fax 856-881-6859
Email: info@inversand.com • www.inversand.com

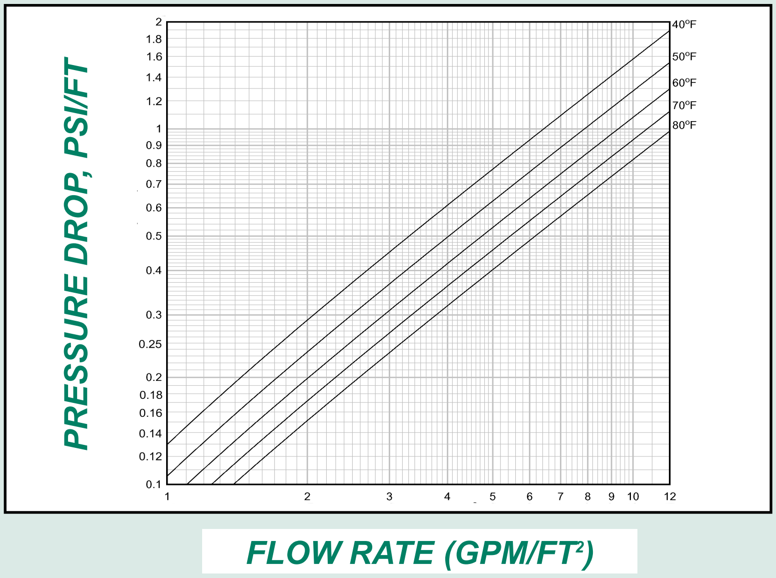
GREENSANDPLUS™ TECHNICAL DATA

GREENSANDplus™

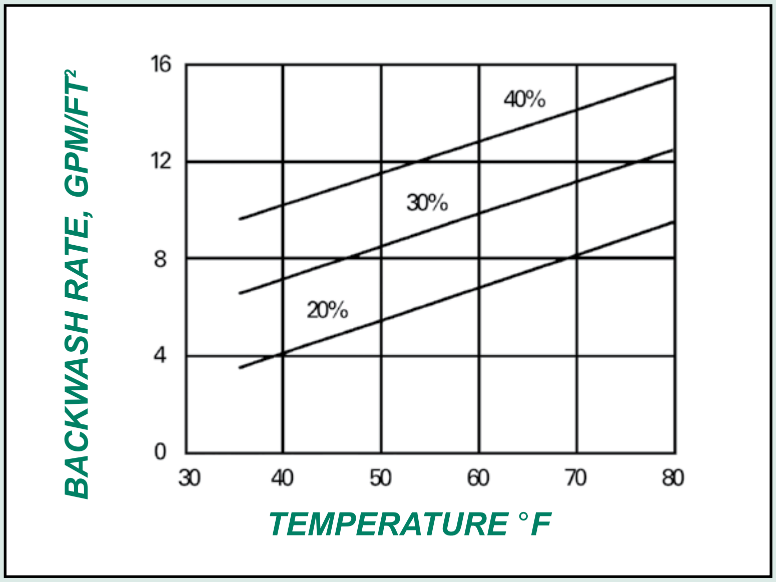
Performance Media for Water Filtration

Removes iron, manganese, hydrogen sulfide, arsenic and radium.

GREENSANDPLUS PRESSURE DROP (CLEAN BED)



BED EXPANSION DURING BACKWASHING



GreensandPlus™ is a black filter media used for removing soluble iron, manganese, hydrogen sulfide, arsenic and radium from groundwater supplies.

The manganese dioxide coated surface of GreensandPlus acts as a catalyst in the oxidation reduction reaction of iron and manganese.

The silica sand core of GreensandPlus allows it to withstand waters that are low in silica, TDS and hardness without breakdown.

GreensandPlus is effective at higher operating temperatures and higher differential pressures than standard manganese greensand. Tolerance to higher differential pressure can provide for longer run times between backwashes and a greater margin of safety.

Systems may be designed using either vertical or horizontal pressure filters, as well as gravity filters.

GreensandPlus is a proven technology for iron, manganese, hydrogen sulfide, arsenic and radium removal. Unlike other media, there is no need for extensive preconditioning of filter media or lengthy startup periods during which required water quality may not be met.

GreensandPlus is an exact replacement for manganese greensand. It can be used in CO or IR applications and requires no changes in backwash rate or times or chemical feeds.

GreensandPlus has the WQA Gold Seal Certification for compliance with NSF/ANSI 61. Packaging is available in 1/2 cubic foot bags or 1 metric ton (2,205 lbs) bulk sacks.

PHYSICAL CHARACTERISTICS

Physical Form
Black, nodular granules shipped in a dry form

Apparent Density
88 pounds per cubic foot net (1410.26 kg/m3)

Shipping Weight
90 pounds per cubic foot gross (1442.31 kg/m3)

Specific Gravity
Approximately 2.4

Porosity
Approximately 0.45

Screen Grading (dry)
18 X 60 mesh

Effective Size
0.30 to 0.35 mm

Uniformity Coefficient
Less than 1.60

pH Range
6.2-8.5 (see General Notes)

Maximum Temperature
No limit

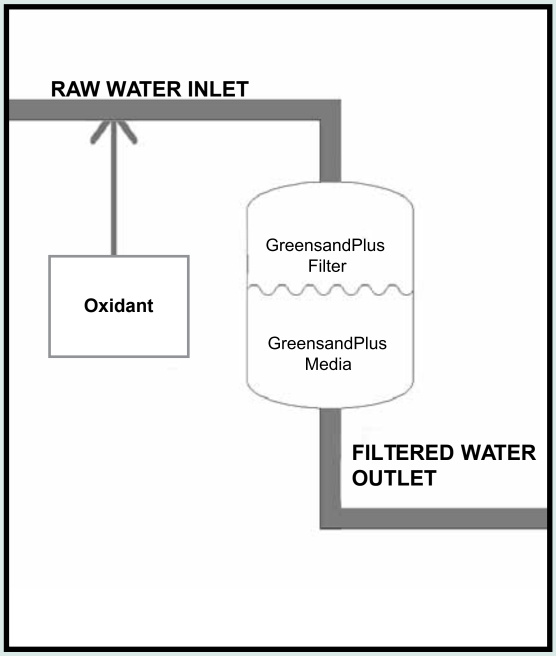
Backwash Rate
Minimum 12 gpm/sq. ft. at 55ºF
(29.4 m/hr @ 12.78*C) (see expansion chart)

Service Flow Rate
2 – 12 gpm/sq. ft. (4.9m/hr - 29.4 m/hr)

Minimum Bed Depth
15 inches (381 mm) of each media for dual media beds or 30 inches minimum (762 mm) of GreensandPlus alone.

METHOD OF OPERATION CO

GreensandPlus: Catalytic Oxidation (CO)



Catalytic Oxidation (CO) operation is recommended in applications where iron removal is the main objective in well waters with or without the presence of manganese. This method involves the feeding of a predetermined amount of chlorine (Cl_2) or other strong oxidant directly to the raw water before the GreensandPlus Filter.

Chlorine should be fed at least 10-20 seconds upstream of the filter, or as far upstream of the filter as possible to insure adequate contact time. A free chlorine residual carried through the filter will maintain GreensandPlus in a continuously regenerated condition.

For operation using chlorine, the demand can be estimated as follows:

$$\text{mg/L } Cl_2 = (1 \text{ x mg/L Fe}) + (3 \text{ x mg/L Mn}) + (6\text{x mg/L } H_2S) + (8 \text{ x mg/L } NH_3)$$

SUGGESTED OPERATING CONDITIONS

Bed Type

Dual media; anthracite 15-18 in. (381 mm-457 mm) and GreensandPlus 15-24 in. (381 mm - 610 mm)

Capacity

700-1200 grains of oxidized iron and manganese/sq.ft. of bed area based on oxidant demand and operation to iron break through or dp limitations.

Backwash

Sufficient rate using treated water to produce 40% bed expansion until waste water is clear, or for 10 minutes, whichever occurs first.

Air/Water Scour

Optional using 0.8-2.0 cfm/sq. ft. (15 m/hr -37 m/hr) with a simultaneous treated water backwash at 4.0-4.5 gpm/sq. ft. (9.8 m/hr - 11.03 m/hr)

Raw Water Rinse

At normal service flow rate for 3 minutes or until effluent is acceptable.

Flow Rate

Recommended flow rates with CO operation are 2-12 gpm/sq. ft. (4.9 m/hr - 29.4 m/hr). High concentrations of iron and manganese usually require lower flow rates for equivalent run lengths. Higher flow rates can be considered with low concentrations of iron and manganese. For optimizing design parameters, pilot plant testing is recommended.The run length between backwashes can be estimated as follows:

What is the run length for a water containing 1.7 mg/L iron and 0.3 mg/L manganese at a 4 gpm/sq. ft. service rate:

Contaminant loading
= (1 x mg/L Fe) + (2 x mg/L Mn)
= (1 x 1.7) + (2 x 0.3)
= (2.3 mg/L or 2.3/17.1 = 0.13 grains/gal. (gpg)

At 1,200 grains / sq. ft. loading ÷ 0.13 gpg
= 9,230 gal./sq. ft.

At 4 gpm / sq. ft. service rate 9,230/4
= 2,307 min.

The backwash frequency is approximately every 32-38 hours of actual operation.

The Intermittent regeneration (IR) operation is available for certain applications. Contact your Inversand representative for additional information.

GENERAL NOTES

pH

Raw waters having natural pH of 6.2 or above can be filtered through GreensandPlus without pH correction. Raw waters with a pH lower than 6.2 should be pH-corrected to 6.5-6.8 before filtration. Additional alkali should be added following the filters if a pH higher than 6.5-6.8 is desired in the treated water. This prevents the possible adverse reaction and formation of a colloidal precipitate that sometimes occurs with iron and alkali at a pH above 6.8.

Initial Conditioning of GreensandPlus

GreensandPlus media must be backwashed prior to adding the anthracite cap. The GreensandPlus backwash rate must be a minimum of 12 gpm/sq. ft. @ 55 °F.

This initial backwash could last for up to 60 minutes to thoroughly remove the fine dust. After backwashing is complete, the GreensandPlus must be conditioned. Mix 0.5 gal. (1.9 L) of 6% household bleach or

Initial Conditioning of GreensandPlus

0.2 gal (0.75 L) of 12% sodium hypochlorite for every 1 cu. ft. (28.3 L cu. m) of GreensandPlus into 6.5 gallons (25 L) of water.

Drain the filter enough to add the diluted chlorine mix. Apply the diluted chlorine to the filter being sure to allow the solution to contact the GreensandPlus media. Let soak for a minimum of 4 hours, then rinse to waste until the “free” chlorine residual is less than 0.2 mg/L. The GreensandPlus is now ready for service.

Radium and Arsenic Removal Using GreensandPlus

The GreensandPlus CO process has been found to be successful in removing radium and arsenic from well water. This occurs via adsorption onto the manganese and/or iron precipitates that are formed. For radium removal, soluble manganese must be present in or added to the raw water for removal to occur. Arsenic removal requires iron to be present in or added to the raw water to accomplish removal. Pilot plant testing is recommended in either case.

REFERENCES

USA

American Water Company, CA
San Jacinto, CA
City of Tallahassee, FL
Adedge Technologies, Inc., Buford, GA
City of Mason City, IL
City of Goshen, IN
City of Hutchinson, KS
City of Burlington, MA
Dedham Water Co., MA
Raynham Center, MA
Northbrook Farms, MD
Sykesville, MD
Tonka Equipment Company, Plymouth, MN
City of New Bern, NC
Onslow County, NC
Hungerford & Terry, Inc., Clayton, NJ
Fort Dix, NJ
Jackson Twsp. MUA, NJ

USA

Churchill County, NV
Suffolk County Water Authority, NY
City of Urbana, OH
Roberts Filter Group, Darby, PA

International

Watergroup, Saskatoon, SK Canada
BI Pure Water, Surrey, BC Canada
Sydney, Nova Scotia, Canada
PT Besflo Prima, Jakarta, Indonesia
Eurotrol, Milanese, Italy
Gargon Industrial, Mexico City, Mexico
Filtration Tech, Auckland, New Zealand
Alamo Water Poland, Izabelin, Poland
Aquatrol Company, Moscow, Russia
Impulse Group, St. Petersburg, Russia
Brenntag Nordic, Taby, Sweden
Nema Kimya, Istanbul, Turkey
Minh Tam, Ho Chi Minh City, Vietnam

The manufacturing of GreensandPlus is an ongoing, 24/7 process to ensure the highest quality water treatment media.

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GE Power & Water
Water & Process Technologies

Fact Sheet

AK LE Series

High Flow Low Energy Brackish Water RO Elements

The A-Series family of proprietary thin-film reverse osmosis membrane is characterized by high flux and high sodium chloride rejection. AK LE brackish water elements are selected when high rejection, high flow and ultra-low operating pressures are desired.

The AK LE element is a low energy high flow element for beverage, light commercial, residential and general industrial applications. AK LE Series elements feature a Fiberglass outer wrap.

Table 1: Element Specification

Membrane	Thin-film membrane (TFM*)

Model	Average permeate flow gpd (m3/day)[1,2]	Average NaCl rejection[1,2]	Minimum NaCl rejection[1,2]
AK-90 LE	2800 (10.6)	99.3%	99.0%
AK-400 LE	12300 (46.6)	99.3%	99.0%
AK-440 LE	13500 (51.1)	99.3%	99.0%

[1] Average salt rejection after 24 hours operation. Individual flow rate may vary +25%/-15%.
[2] Testing conditions: 500ppm NaCl solution at 115psi (793kPa) operating pressure, 77°F (25°C), pH7 and 15% recovery.

Model	Active area ft^2 (m^2)	Outer wrap	Part number
AK-90 LE	90 (8.4)	Fiberglass	3056683
AK-400 LE	400 (37.2)	Fiberglass	3056684
AK-440 LE	440 (40.9)	Fiberglass	3056685

Table 2: Operating and CIP parameters

Typical Operating Pressure	110 psi (758 kPa)
Typical Operating Flux	10-20GFD (15-35LMH)
Maximum Operating Pressure	400 psi (2,758 kPa)
Maximum Temperature	Continuous operation: 122°F (50°C) Clean-In-Place (CIP): 122°F (50°C)
pH range	Optimum rejection: 7.0-7.5, Continuous operation 4.0-11.0, Clean-In-Place (CIP): 2.0-11.5
Maximum Pressure Drop	Over an element: 12 psi (83 kPa) Per housing: 50 psi (345 kPa)
Chlorine Tolerance	1,000+ ppm-hours, dechlorination recommended
Feedwater[3]	NTU < 1 SDI < 5

[3] SDI is measured on a non-linear scale using a 0.45 micron filter paper. Additionally, finer colloids, particulates and microorganisms that pass through the filter paper and not measured in the SDI test, will potentially foul the RO element. For performance consistency and project warranty, please use Winflows projection software and consult your Filters with Membranes representative.

Figure 1a: Element Dimensions Diagram – Male

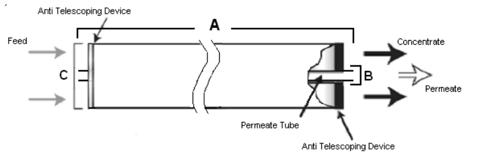
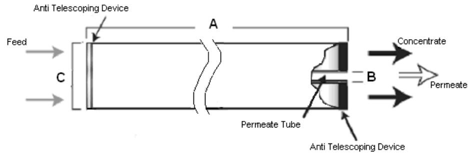


Figure 1b: Element Dimensions Diagram – Female



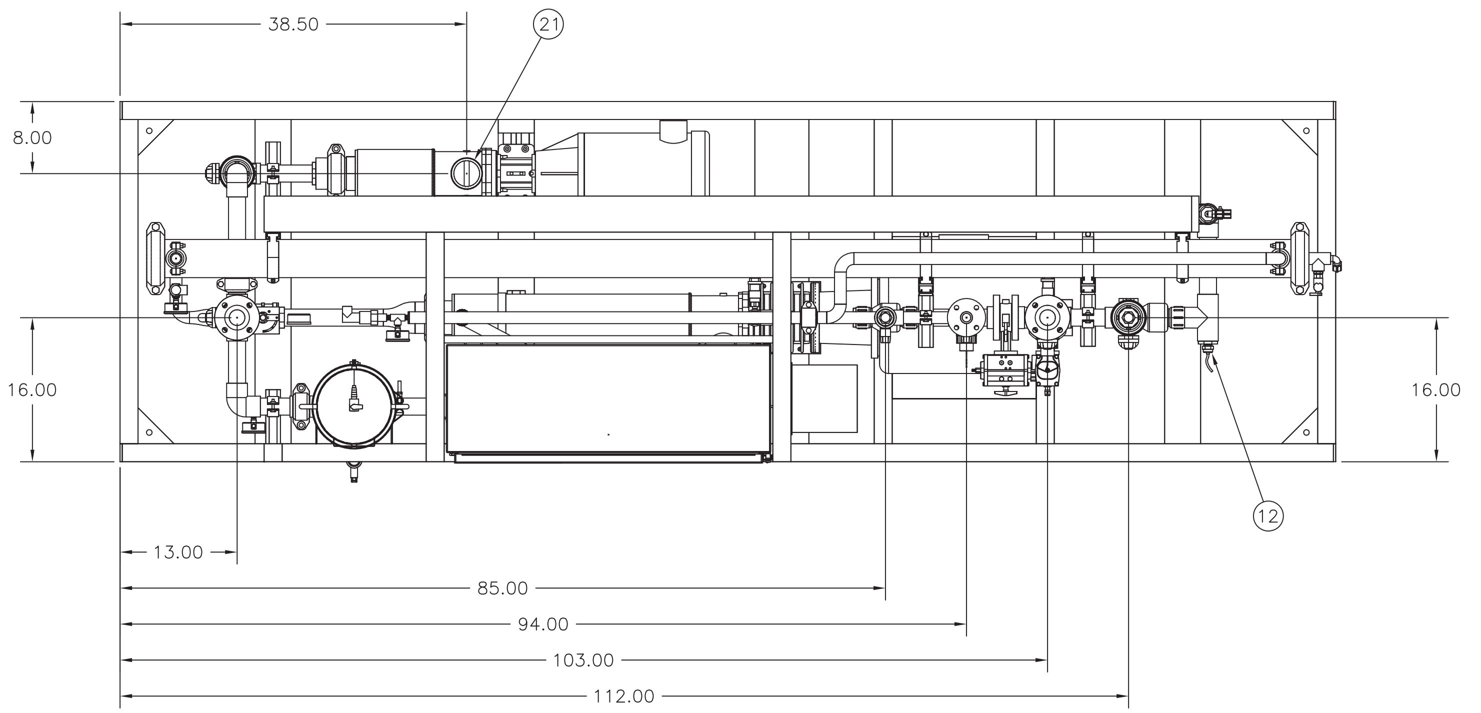
Find a contact near you by visiting www.ge.com/water and clicking on "Contact Us".
* Trademark of General Electric Company; may be registered in one or more countries.

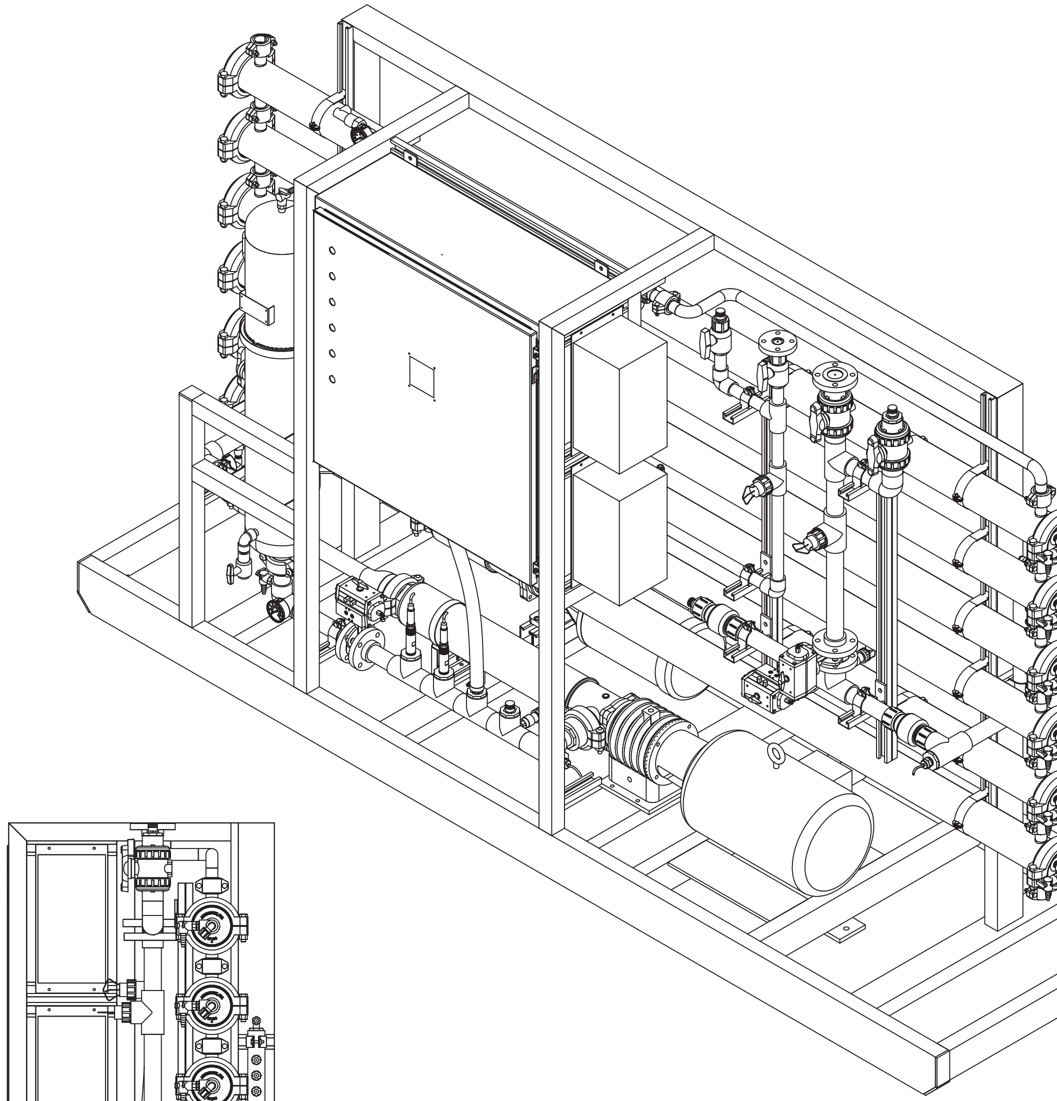
Table 3: Dimensions and Weights

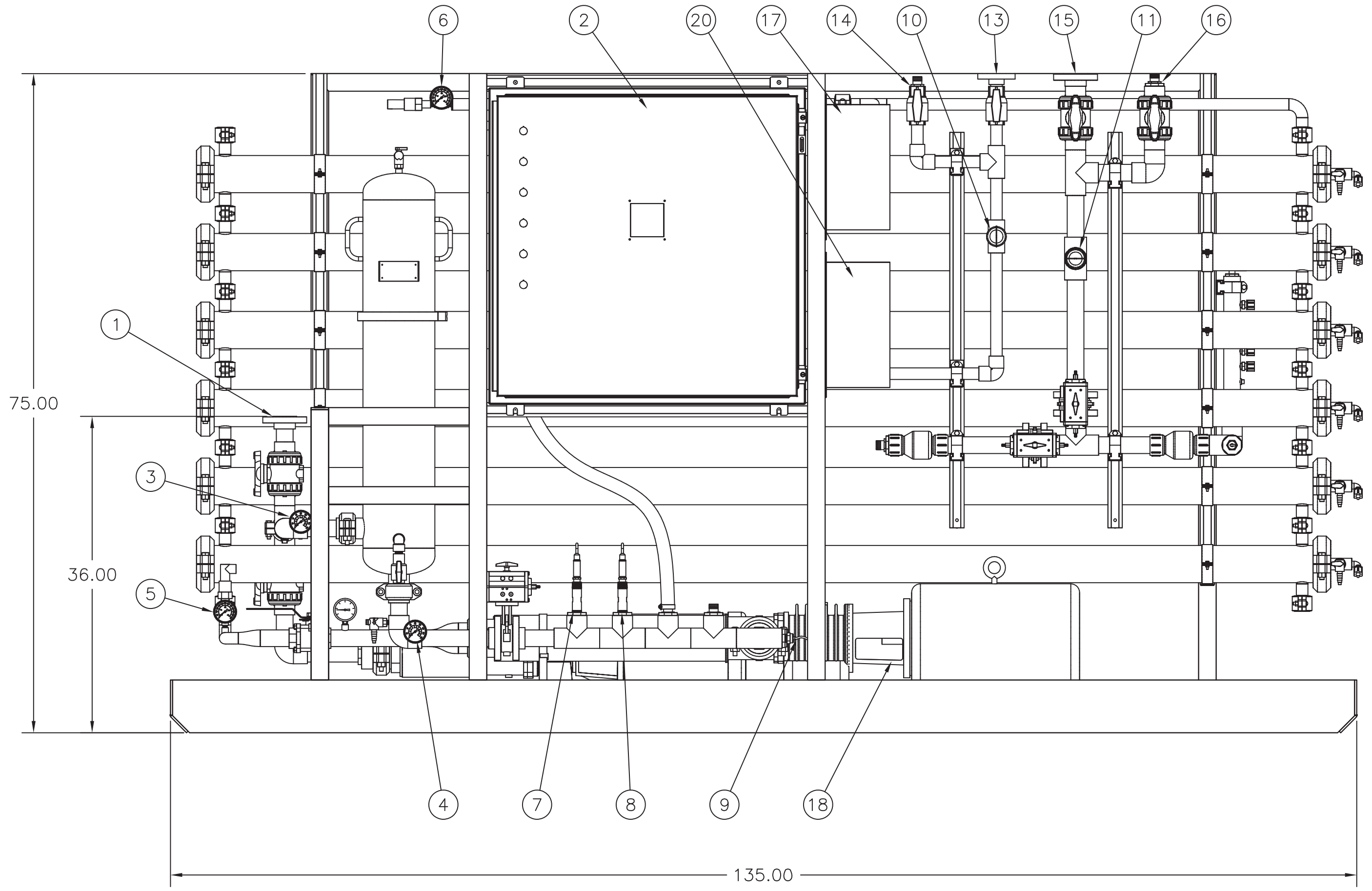
Model[1]	Type	Dimensions, inches (cm)			Boxed
		A	B[2]	C	Weight lbs (kg)
AK-90 LE	Male	40.0 (101.6)	0.75 (1.90)	3.9 (9.9)	9 (4)
AK-400 LE	Female	40.0 (101.6)	1.125 (2.86)	7.9 (20.1)	35 (16)
AK-440 LE	Female	40.0 (101.6)	1.125 (2.86)	7.9 (20.1)	35 (16)

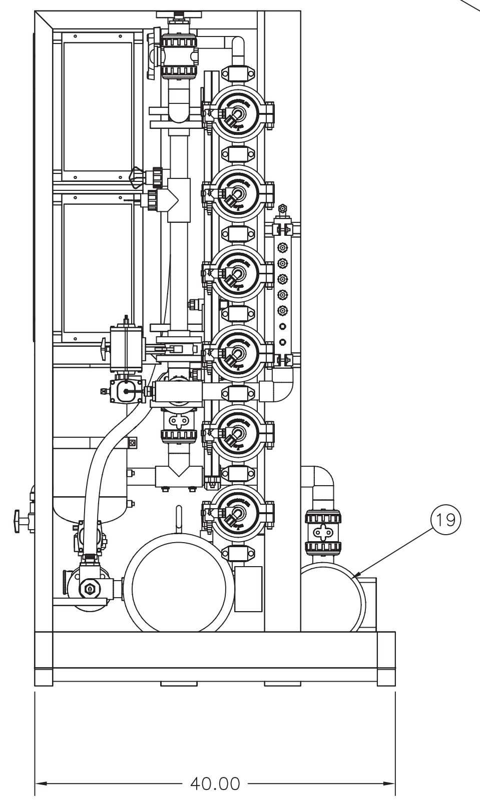
REVISION HISTORY

REV	ZONE	DESCRIPTION	ECO	DWN	DATE	APVD
A	–	INITIAL RELEASE	–	–	–	–









LEGEND

1. INLET, 1.50" FLANGE
2. ELECTRICAL ASSEMBLY
3. PRE–FILTER PRESSURE GAUGE, 1–160 PSIG
4. POST–FILTER PRESSURE GAUGE, 1–160 PSIG
5. PRIMARY PRESSURE GAUGE/TRANSMITTER, 1–600 PSIG
6. FINAL PRESSURE GAUGE/TRANSMITTER, 1–600 PSIG
7. INLET ORP, THORNTON 770MAX
8. INLET pH, THORNTON 770MAX
9. INLET CONDUCTIVITY, THORNTON 770MAX
10. CONCENTRATE FLOWMETER, THORNTON 770MAX
11. PERMEATE FLOWMETER, THORNTON 770MAX
12. PERMEATE CONDUCTIVITY, THORNTON 770MAX
13. CONCENTRATE OUTLET, 1.00" FLANGE
14. CONCENTRATE OUTLET CIP, 1.00" HOSEBARB
15. PERMEATE OUTLET, 1.50" FLANGE
16. PERMEATE OUTLET CIP, 1.00" HOSEBARB
17. RO MOTOR STARTER ASSEMBLY
18. RO PUMP AND MOTOR, SS5512KZA W/ 15 HP, TEFC
19. CIP PUMP AND MOTOR, SS5503G W/ 5 HP, TEFC
20. CIP MOTOR STARTER ASSEMBLY
21. CIP INLET, 3.00" VICTAULIC

NOTICE ON REPRODUCTIONS

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GE Water Technologies
5951 CLEARWATER DRIVE, MINNETONKA, MN 55343–8995 (952) 933–2277
WWW.GEWATER.COM

MATERIAL SEE BOM	TOLERANCES UNLESS NOTED FRAC ± DECIMALS .X ± .XX ± .50 .XXX ± ANGLES ± 1°		
FINISH			
ORDER NO.	DWN PDT	DATE 18Jan05	
CUSTOMER	CHKD BRB	DATE 19Jan05	
CUSTOMER LOC.	APVD JSS	DATE 17Jan05	
DO NOT SCALE	APVD	DATE	

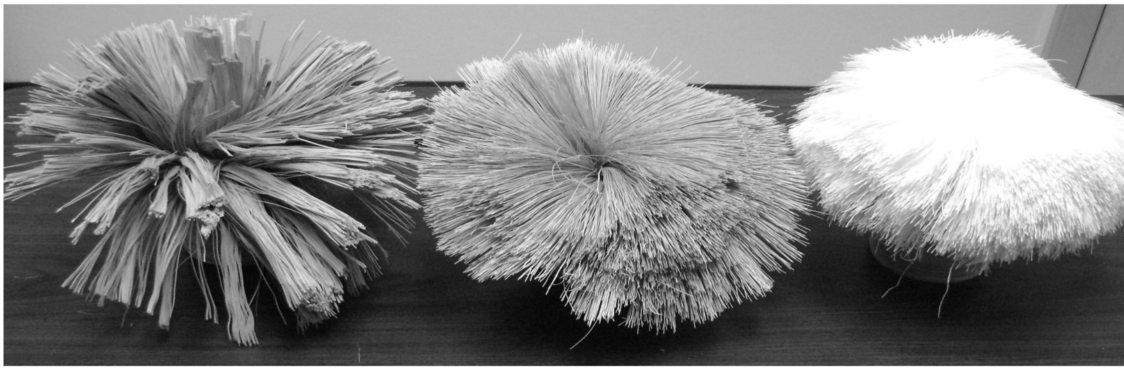
TITLE
DWG, RO, PES–18
PALL PILOT SYSTEM

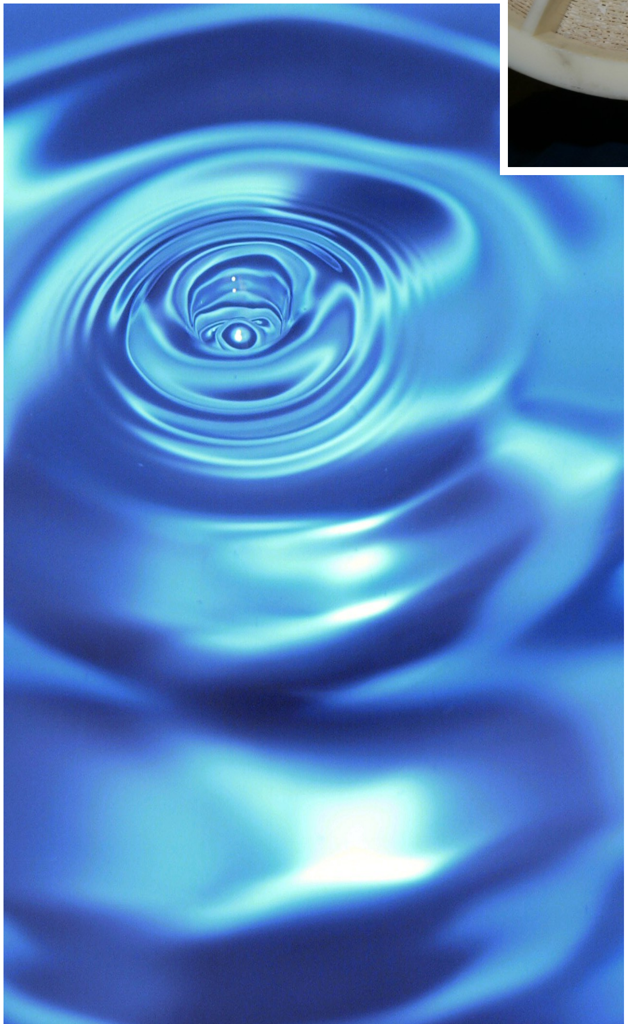
SIZE		DWG NO/PN	REV
D	THIRD ANGLE	2300026A–951	A
SCALE 3/32	FILE TYPE ACR2004	SHEET 1 OF 1	

Appendix D

Membrane Autospy Laboratory Report

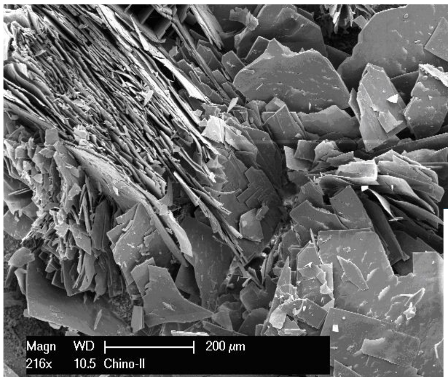
Membrane Autopsy Report

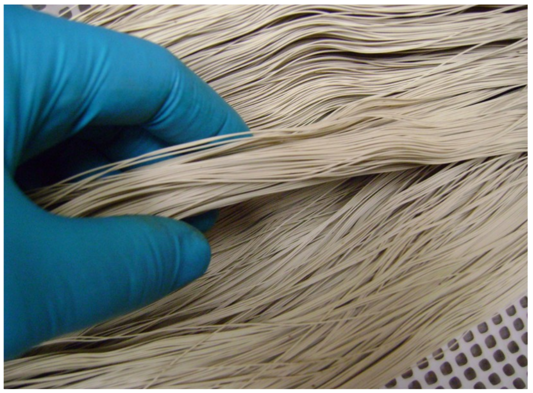




Prepared for: BARR Engineering—Polymet Mining

Distribution Date: February 2013





Separation Processes, Inc.
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Carlsbad, CA 92010

Phone: (760) 400-3660
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The Membrane Technology Consultants

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INTRODUCTION

SPI received two 4” GE-AK90 LE elements on 1/16/2013, one first stage lead and one second stage tail, labeled element ‘I’ and ‘O’, respectively. The elements were used in a pilot treating groundwater and surface water seepage from a legacy mine site that had been running since May 2012. The pilot system consisted of a traditional 2:1 array, comprised of 4 stages in a 2-2-1-1 configuration with three elements per vessel to make up 18 total elements. Pretreatment for the pilot system included a greensand filter, GE MDC 150 antiscalant, and SBS. The pilot was seeded with Pb, As, Co, Ni, Zn, Cu, and Se to confirm performance and rejection in the presence of these constituents.

Four methods were used to evaluate the condition of the elements received: physical inspection, citric acid test, cell flux tests, and SEM/EDX of samples.

Table 1 - Element Information		
Element Label	Element ‘I’	Element ‘O’
Element Position	First Stage Lead	Second Stage Tail
Serial Number	110322018	110322032

Element “I”

Element “O”

PHYSICAL EVALUATION

External Inspection

Fiberglass Shell

The fiberglass shell was in good condition for both elements. There were no visible cracks or weak areas in the fiberglass. The fiberglass roving (the strands of fiberglass) was evenly distributed on each element.

Brine Seals

The Brine seals were undamaged.

Anti-telescoping Devices (ATD)

The ATDs were undamaged and still attached to the fiberglass.

Permeate Tubes

The central tube was clean and unmarred where the inter-connector would come in contact. A defect in this area would result in permeate contamination.

Spacer Migration

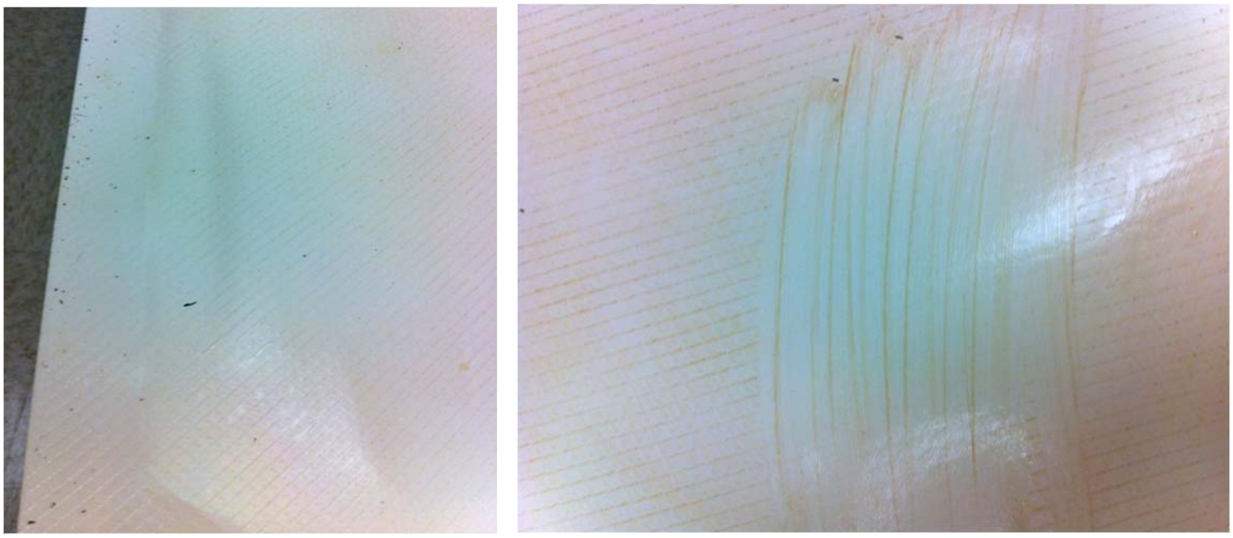
There was no apparent spacer migration or spacer damage, which can occur due to hydraulic forces toward the tail end.

Internal Inspection

Membrane Surface

Lead Element – Element 'I'

Upon opening Element 'I' the first stage lead, a light layer of brown/orange foulant was found distributed throughout the membrane. The foulant was easily wiped off. Black particulate matter was found scattered throughout the surface of the membrane, but more heavily towards the feed end. A few of the leaves had creases to the glue line, a manufacturing defect, which may have caused localized membrane damage.



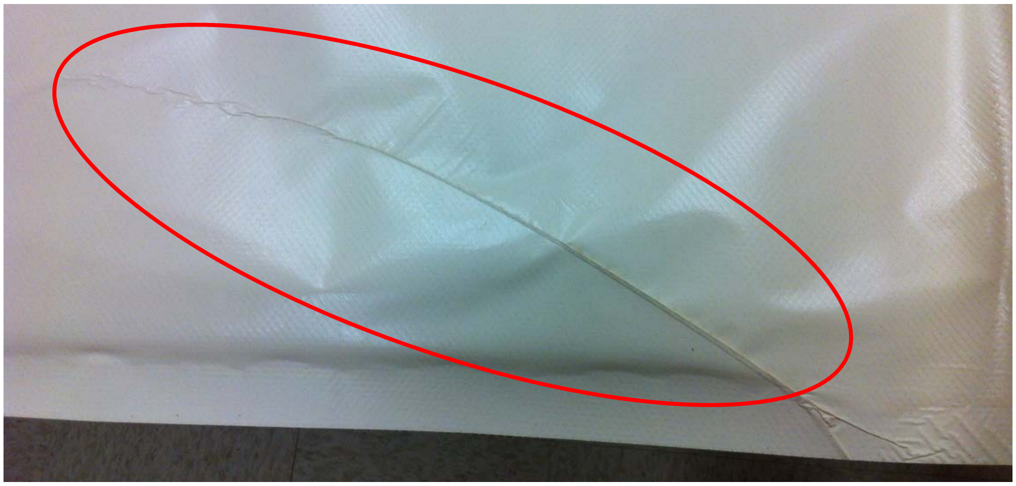
Element 'I' – Foulant Layer on Membrane: Pictured Right is the Feed End, Pictured Left is Foulant Wiped with Glove.

Element 'I' – Creases in Membrane

Tail Element – Element 'O'

Small pieces of black material were found intermittently on the membrane surface. A light foulant evenly covered the membrane surface. Similarly to the feed end element, several leaves had creases in the membrane that went through the glue line.

Element 'O' – Example of Element Fouling and Particulate Matter



Element 'O' – Creases in Membrane

Feed Spacer

Lead Element – Element 'I'

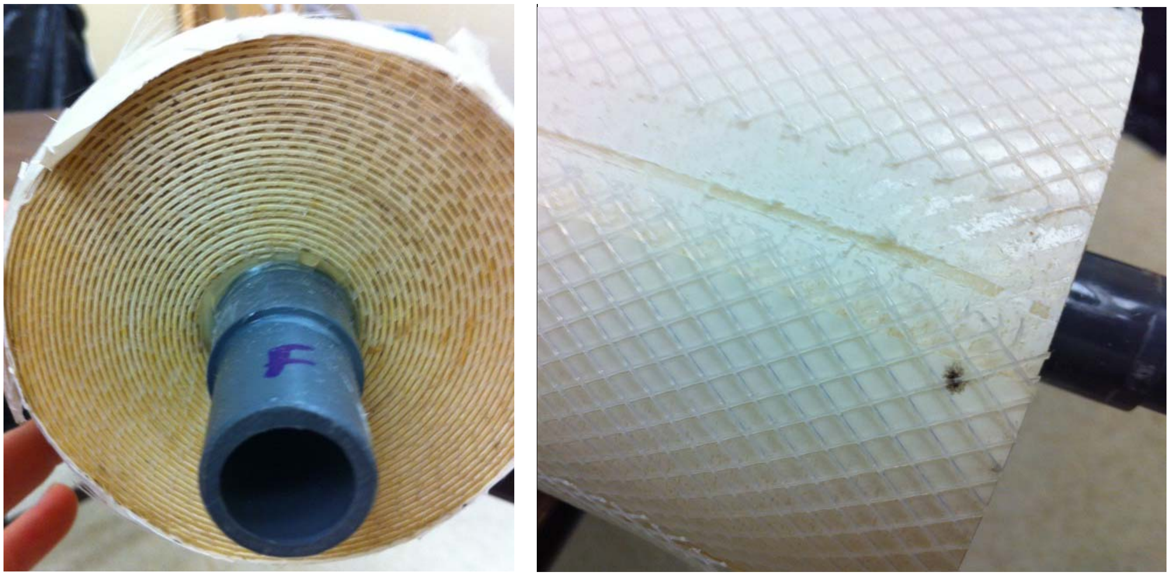
The feed spacer is made from a polypropylene mesh net. After the ATDs were removed from the feed element, traces of particulate matter and orange discoloration were found on the face of the feed side of the membrane. The particulate matter resembled strands of fabric and was found stuck in the feed spacer throughout the membrane, but most heavily on the feed end. However, it did not appear to impede water flow and there were no signs of physical damage to the feed spacer.

Element 'I' - Feed End with ATD Removed

Element 'I' - Concentrate End with ATD Removed

Tail Element – Element 'O'

On the face of the tail end element, Element 'O', some particulate matter was caught in the feed spacer, but to a much lesser degree than the feed element. There were no areas of damage to the feed spacer.



Element 'O' – Feed(L) and Concentrate(R) Side of Membrane with ATD Removed

Permeate Spacer

There was no visible damage to the permeate spacers in either element.

Glue Lines

The glue lines were fairly straight and had a width of approximately 1 inch. The adhesion between the membrane and the permeate spacer was acceptable in sampled areas. There was possible points of glue line leakages where the membrane was creased on several of the leaves in both lead and tail elements (See previous pictures).

FLUX AND REJECTION TESTING

Three samples were taken from the two elements and used for cell flux and rejection tests; one from the lead element, one from the tail, and another from the tail element with a sample of a creased glue line. The purpose of this testing was to compare performance with factory test conditions, and to determine whether the creased membrane represented damaged membrane. The samples were tested on a 500 mg/L feed at 115 psig and results are as follows:

Element Location	Average permeate flow gpd [1,2]	Average NaCl rejection[1,2]	Minimum NaCl rejection[1,2]
Nominal Performance	2800	99.3	99.0
1st Stage Lead, "I"	2691	98.2	--
2nd Stage Tail, "O"	2700	97.9	--
2nd Stage Tail, "O" (crease in flat sheet)	2817	96.2	--

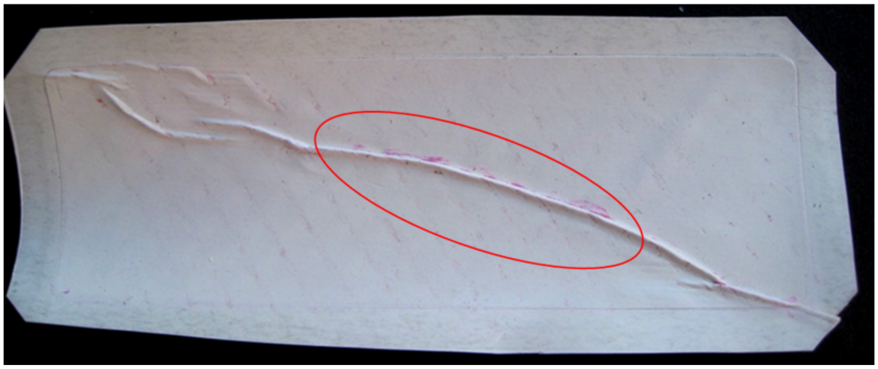
[1] Average salt rejection after 24 hours operation. Individual flow rate may vary +25%/-15%.

[2] Testing conditions: 500ppm NaCl solution at 115psi (793kPa) operating pressure, 77°F (25°C), pH7 and 15% recovery.

The manufacturer's specification sheet for the AK-90 LE is attached at the end of this report.

The Flux and Rejection test revealed that the foulant observed on the membrane surface has not substantially impacted the membrane permeability. The normalized permeate flows are within the manufacturer's specification of +25% and -15% of nominal permeate flow. The reported rejections of both samples retrieved from the lead and tail element was slightly low compared to expected performance.

The sample with the creased membrane showed slightly higher permeate flow and significantly lower rejection that the other two samples. While this performance is consistent with damaged membrane, it is possible that the crease hindered the ability to attain a good gasket seal, allowing leakage flow during the test that contributed to these results. The creased membrane sample was also exposed to a Rhotamine B dye in the test cell. As indicated by the picture below, there was some dye uptake at the membrane crease indicating a potential for membrane damage.

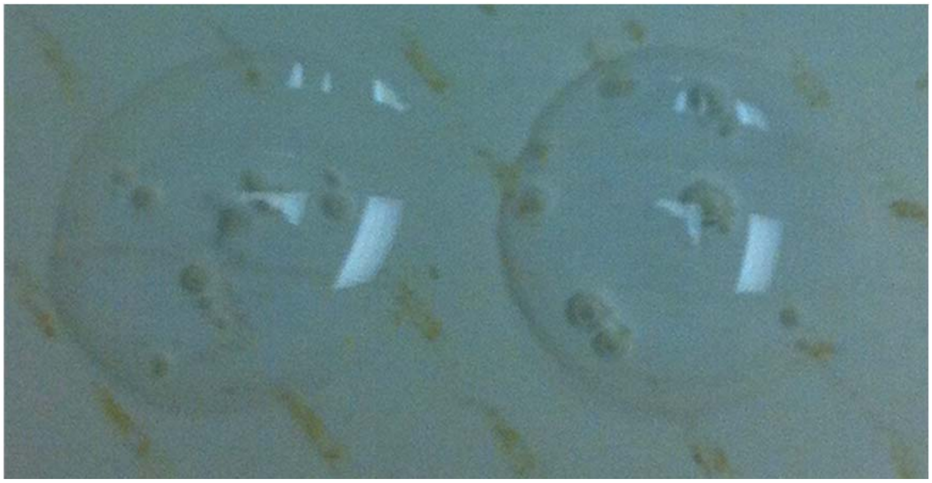


Element 'O' – Creased Cell Test Sample After Introducing Dye.

FOULANT ANALYSES

ACID TEST

To verify if calcium carbonate scale is present within the foulant on the membrane surface of the tail end element, a solution of 50% citric acid was dropped directly onto the membrane surface. Carbon dioxide bubbles were observed along the feed spacer lines where the foulant was deposited, indicating that some portion of the fouling is composed of carbonate scaling.



Element 'O' – Carbon dioxide Bubbles Forming in Citric Acid

SCANNING ELECTRON MICROSCOPY / ENERGY DISPERSIVE X-RAY ANALYSIS (SEM/EDX)

SEM and EDX analyses are tools used in conjunction for studying the surface features of the membrane. The SEM is a type of electron microscope that images the sample surface by scanning it with a high-energy beam of electrons. The EDX is an analytical technique used for the elemental analysis or chemical characterization of a sample and can be used to identify the makeup of an inorganic foulant. A characteristic spectrum is produced and the composition of the foulant by weight percentage of elements present is determined.

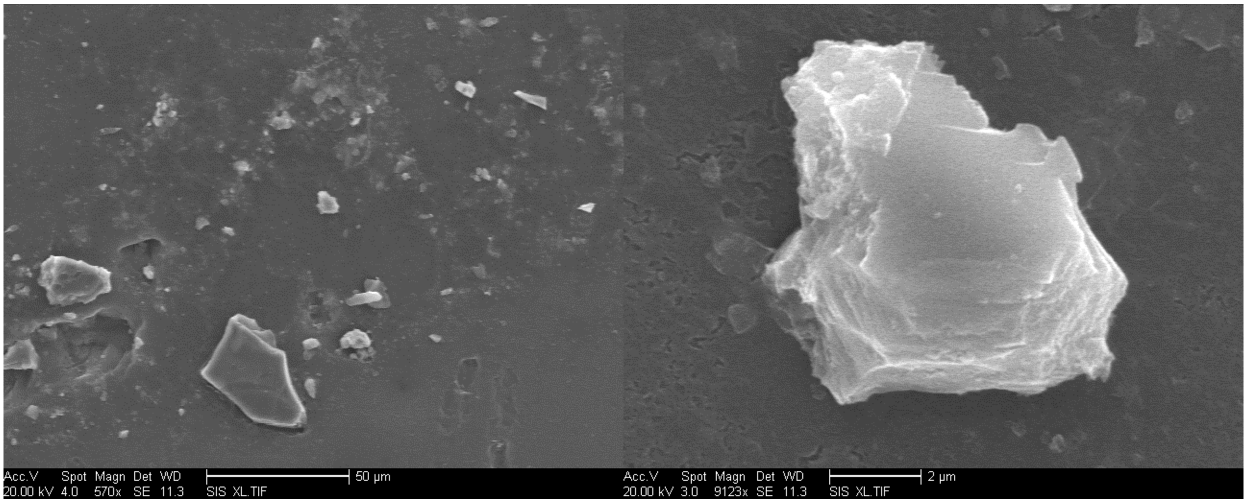
EDX was performed on a total of four samples, two from each membrane. One sample was taken from the feed side of the element, while the other was taken from the concentrate side. The foulant was not sufficient on either membrane to isolate it for this testing. The elemental makeup of both the foulant and membrane are included in the results of this analysis. As a consequence, there are large contributions of carbon (C), oxygen (O), and sulfur (S) that are known to be part of the membrane chemistry and support structure. The presence of Iridium (Ir) is known to be a consequence of the test process.

Lead Element – Element 'I'

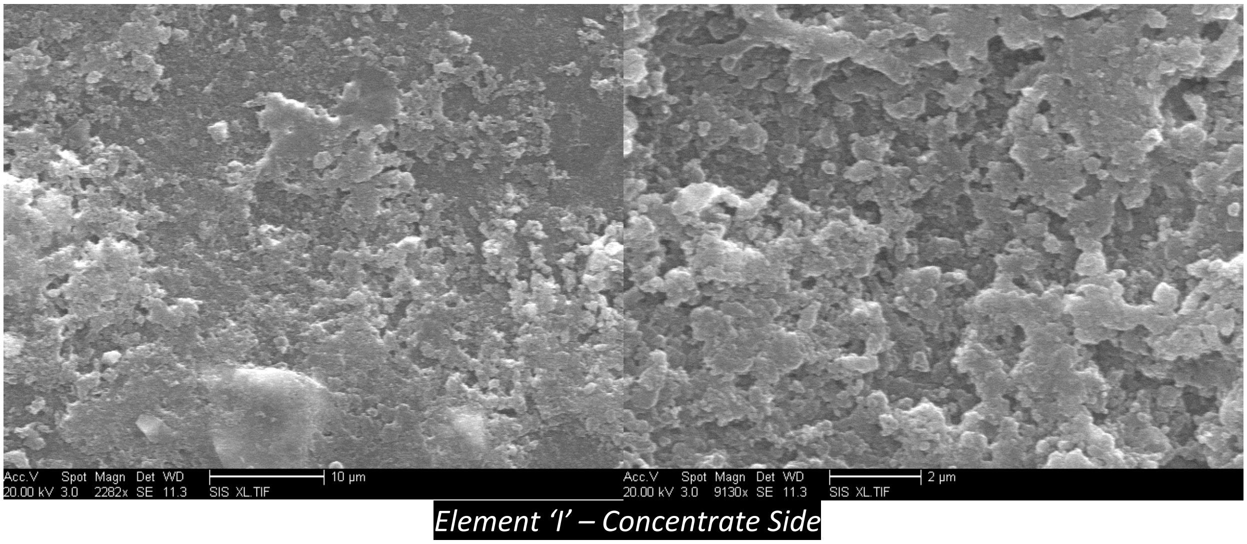
The EDX of the lead element found the majority of the foulant to be composed of Silicon (Si) and Iron (Fe), with traces of Aluminum (Al), Sodium (Na) and Chloride (Cl). Tables 2 and 3 below show the weight percentages for the EDX performed for membrane samples on both feed and concentrate side. The makeup of this foulant is consistent with silt and clays typical of groundwater or surface water sources.

Table 2 – Element ‘I’ Feed		
Element	Weight%	Atomic%
C K	62.52	73.34
O K	24.90	21.93
Na K	0.19	0.12
Al K	0.14	0.08
Si K	2.08	1.04
S K	6.62	2.91
Cl K	0.39	0.15
Fe K	1.13	0.29
Ir M	2.02	0.15
Totals	100.00	

Table 3 – Element ‘I’ Concentrate		
Element	Weight%	Atomic%
C K	51.13	62.37
O K	34.42	31.52
Na K	0.18	0.11
Al K	0.14	0.08
Si K	5.29	2.76
S K	6.48	2.96
Fe K	0.13	0.03
Ir M	2.24	0.17
Totals	100.00	



Element ‘I’ – Feed Side



Element ‘I’ – Concentrate Side

Tail Element

EDX analysis of the Tail element found similar signs of silt and clay contributing to this foulant, as evidenced by trace elements of manganese (Mn), aluminum (Al), silica (Si), iron (Fe), and phosphorus (P). The concentrate side of the membrane element revealed a significant proportion of calcium (Ca) and Oxygen (O). This supports the acid test and suggests the presence of calcium carbonate scaling at this location. Table 4 and 5 have all the weight percentages listed.

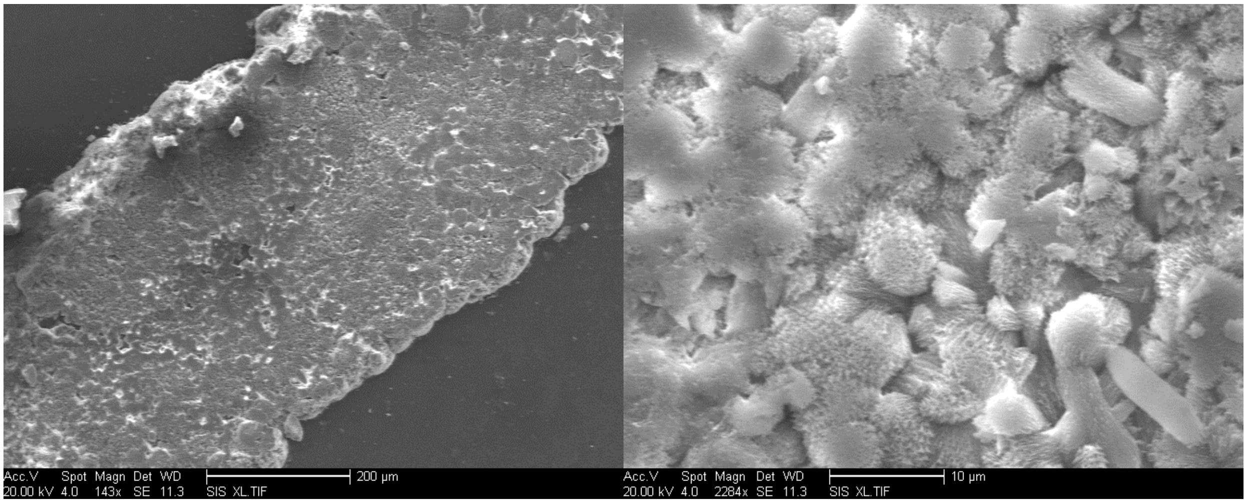
Table 4 – Element 'O' Feed

Element	Weight%	Atomic%
C K	61.77	71.50
O K	28.08	24.40
Mg K	0.21	0.12
Al K	0.24	0.12
Si K	2.07	1.02
P K	0.13	0.06
S K	5.76	2.50
Ca K	0.18	0.06
Fe K	0.56	0.14
Ir M	1.00	0.07
Totals	100.00	

Table 5 – Element 'O' Concentrate

Element	Weight%	Atomic%
C K	10.69	17.84
O K	49.84	62.45
Mg K	1.23	1.02
Si K	0.18	0.13
P K	0.19	0.12
S K	0.65	0.40
Ca K	35.58	17.80
Mn K	0.28	0.10
Ir M	1.37	0.14
Totals	100.00	

Element 'O' – Feed Side



Element 'O' – Concentrate Side

CONCLUSION

The lead end Element 'I' from the pilot was observed to have slight layer of foulant that was easily removed via wiping. The foulant was considered to be consistent with silts and clays, as well as obvious signs of particulate matter, consistent with the feed source. The condition of the membrane was otherwise in good condition. While the membrane foulant was considered very slight and appears to have had little impact on the membrane's permeability thus far, the cartridge filtration step should be reviewed to determine whether tighter cartridge filters would be beneficial.

The foulant on the tail end Element 'O' also exhibited symptoms of silts and clay. However, the foulant on the concentrate side of the membrane also included calcium carbonate scaling, as evidenced by a significant presence of calcium and oxygen in this location, and the evolution of carbon dioxide bubbles when the foulant was exposed to acid. The magnitude of the calcium carbonate scaling was not substantial, suggesting the scale was in the early stages of formation. It is likely that longer operation will eventually result in further scaling. The antiscalant product, dose, and recovery setpoint should be reviewed to confirm suitability for this application.

The pilot was seeded with Pb, As, Co, Ni, Zn, Cu, and Se. Based on findings from the scanning electron microscope, none of these constituents contributed to the observed fouling.

The flux test found that the rejection of the membrane is below what is expected based on the manufacturer's specifications. Both element samples had a rejection of approximately 98%, whereas the minimum rejection should be 99.0%. The polyamide chemistry layer is very thin and fragile, and creases such as those observed in both elements are likely to be contributing to a poorer salt rejection. The creases are considered to be a manufacturing defect and appear to be reducing the rejection of the elements due to damage of the membrane chemistry layer. It is suggested that the feed and permeate water quality data collected during the pilot test be compared with the RO membrane manufacturer's software output to confirm the membrane's performance during the pilot test.

Appendix E

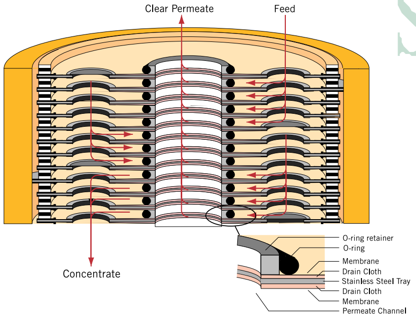
New Logic Research VSEP Pilot Unit Information

VSEP - Vibratory Shear Enhanced Process

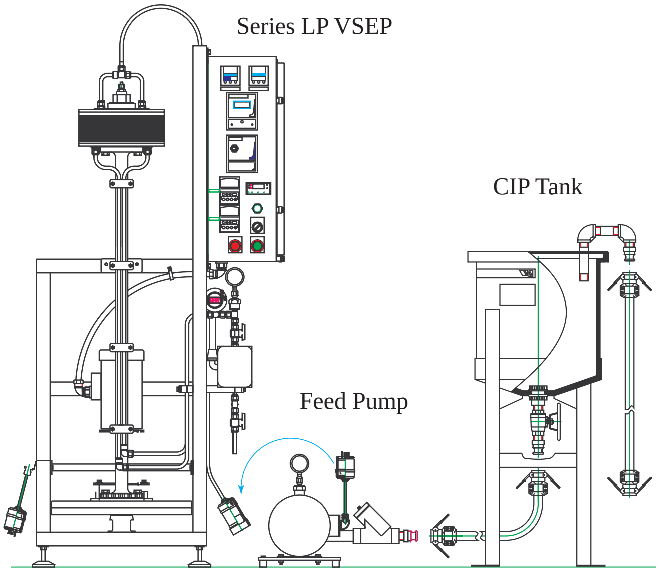
Description:

The V✧SEP Filtration System incorporates the patented Vibrating Membrane Filtration Technology. The key ingredient that comes from the vibrational oscillation is highly focused shear energy at the membrane surface. The combination of this plus pressure creates a non-fouling, high yielding, and efficient way of filtration for previously difficult separation applications. Throughputs of up to 225,000 GPD per module, (based on 150 GFD) are possible with a footprint of only 16 SF (1.5 m2). Torsional vibration created by an induced wobble in an opposing mass creates the necessary shear at the membrane.

Filter Pack Cross Section



Series LP



Series LP V✧SEP Equipment Set Up

The pilot scale VSEP unit is known as the *Series L/P*. This unit is inter-convertible between pilot (P), and laboratory modes (L). In the laboratory L mode, the system acts as a *Series L* with 0.4785 ft^2 of membrane area. However, in pilot P mode, with the addition of a small membrane stack, the membrane area is 16.44 ft^2. For most Microfiltration and Ultrafiltration applications, the Series L/P will filter between 62.5 and 125 gallons per hour (236-473 liters per hour). For Nanofiltration and RO applications, the system will filter approximately 25 to 94 gallons per hour (95-356 liters per hour). These ranges will vary according to feed material, pressure, temperature, and membrane selection.

Specifications:

1] Filter Pack

Membrane:	Reverse Osmosis-Microfiltration
Membrane Area:	16.8 square ft. (1.5 m2)
Max. Temperature:	up to 284 °F (140°C)
Allowable Ph Range:	1-14
Elastomers (O-rings):	EPDM,(Options for Buna, Viton)
Wetted Steel Trays:	304 .018 Gauge Stainless Steel

2] Piping

Maximum Pressure:	600 psi
Process Piping:	1/2” 316L Stainless Steel
Clean in Place Tank:	15 Gallon Polyethylene
Flow Control Valves:	Parker 12Z-PR4-VT-SS

3] Vibration System

Motor:	Baldor, 2HP, 3525 RPM
Speed Controller:	“ABB” ACS400501635
Maximum Decibels:	65

4] Electrical Specifications:

Power Supply Voltage:	240VAC 3 Phase 50/60Hz
Full Load Amp Rating:	30 Amps
Normal Load Amps:	9-26 Amps
Pressure Sensors:	Wika 0-600 Analog Gauge

5] Feed Pump Specifications:

Feed Pump Type:	Hydra-Cell M-10MRSEHHC
Power Supply Voltage:	240VAC 3 Phase 50/60Hz
Motor:	Baldor, 5HP, 1725 RPM, TEFC
Pressure Relief:	Wanner Bypass C22ADBESSEF

6] Pre-Screen Bag Filter:

Filter Housing Type:	316 SS Y-Strainer
Filter Size:	100 Mesh
Capacity:	10 GPM Each

7] Operating Site Conditions:

Equipment Rating:	NEMA 4, Indoor/Outdoor
Ambient Temperature:	5 - 37°C
Storage Temperature:	2 - 70°C (Protect from Freezing)
Relative Humidity:	<95%, non-condensing
Elevation:	3300 ft max without derating

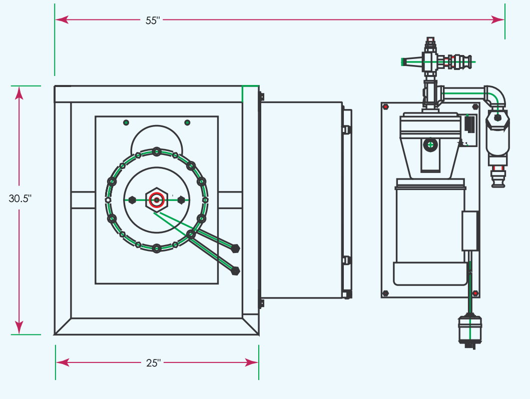
8] Instrumentation:

Temperature:	Ashcroft Digital Thermometer
pH:	Oakton Model EW-27011-11
Conductivity:	Myron L Company Model 758

VSEP Applications:

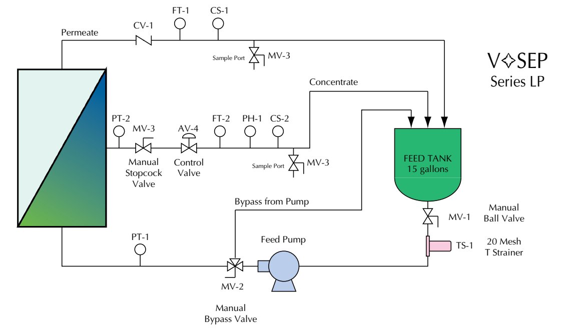
- Ultrapure Water
- Industrial Wastewater
- Chemical Processing
- Mineral Slurry Dewatering
- Glycol Recovery
- Waste Oil Recycling
- Phosphate Clarification
- Pulp & Paper Closed Loop
- Water Recycling
- Mining
- Oil Production & Processing
- Ethanol Production
- Polymer & Pigment Diafiltration
- Latex Concentration
- Laundry Wastewater Recycling
- Scrubber Blowdown

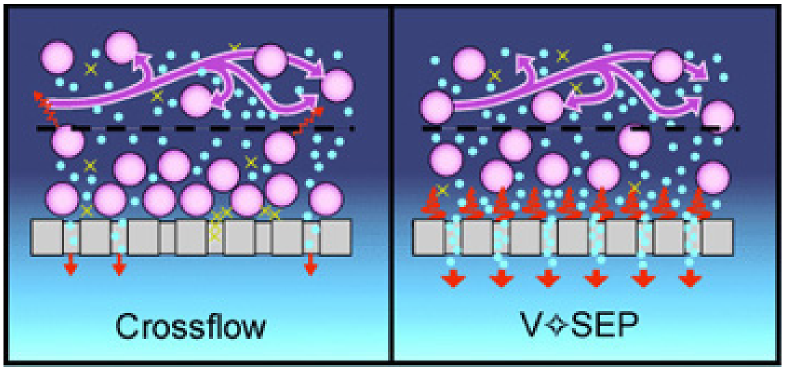
Footprint:



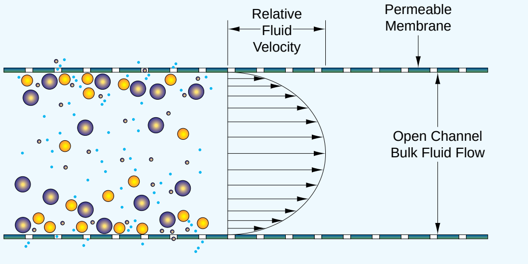
VSEP Series LP Footprint Drawing
(Tank not Shown)

Typical Simplified Flow Diagram:

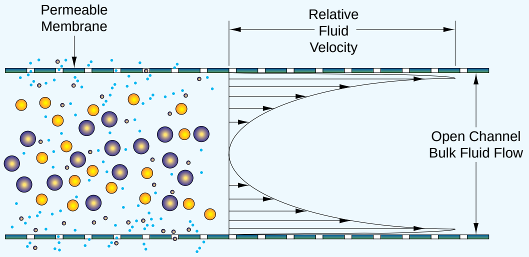




Tangential Flow Pattern in Crossflow Membrane Systems



Tangential Flow Pattern in Vibratory V✧SEP Membrane Systems



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NLR doc 300-40

Appendix F

Whole Effluent Toxicity Laboratory Reports

TOXICITY TEST RESULTS

POLYMET MINING

Report Date: October 2, 2012

Project No. 12-236

Prepared for:

Barr Engineering
4700 W. 77th Street
Minneapolis, MN 55435

ENVIRONMENTAL TOXICITY CONTROL INC.

6265 Applewood Road • Woodbury, Minnesota 55125
Phone 651 501-2075 • Fax 651 501-2076

Notes:
Dose 1-6 refer to stabilization with lime.
Q3-Q6 refer to limestone stabilization.
For limestone stabilization results, see WET test report dated 11/20/2013.

PROJECT: CHRONIC TOXICITY TESTING
POLYMET MINING

PROJECT NUMBER: 12-236

TOXICITY TEST RESULTS

INTRODUCTION:

This report presents the results of toxicity testing on water samples received by Environmental Toxicity Control (ETC) on September 24, 2012. The samples identified as Dose 1, 2, 3, 4, 5, 6, Q3, Q4, and Q5 were from the PolyMet Mining facility and were collected on September 23, 2012. Chronic toxicity testing was conducted on the water samples as requested by personnel from Barr Engineering. The scope of our services was limited to conducting 7 day chronic toxicity tests on the invertebrate, *Ceriodaphnia dubia*, in the laboratory.

TEST METHODS:

Tests were conducted in accordance with the procedures outlined in Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms, Fourth Edition, EPA-821-R-02-013.

Control water used in the test consisted of moderately hard Reconstituted Water prepared in the laboratory.

Testing was started on 9/24/12, approximately 24 hours after sample collection.

RESULTS:

Toxicity test results are summarized in Table 1, test conditions are summarized in Table 2.

QUALITY ASSURANCE AND QUALITY CONTROL:

Satisfactory laboratory performance on an ongoing basis is demonstrated by conducting at least one acceptable toxicity test per month with a reference toxicant. Control charts for a reference toxicant and successive endpoints (LC50 and IC25) are plotted to determine if results are within prescribed limits. Results from our most recent reference tests are shown in the following table:

Reference Toxicity Test		
Species	IC_{25}	Test Date
Ceriodaphnia dubia	0.620 g/l NaCl	09/18/12

Our results are within range of EPA expected results for the type of tests conducted.

Test methods and procedures are documented in ETC's Standard Operating Procedures (SOPs). Test and analysis protocols are reviewed by ETC's Quality Assurance/Quality Control Officer. Procedures are documented and followed as written. Any deviation from a QA/QC procedure is documented and kept in the project file. During this project, no deviation in method was warranted.

ENVIRONMENTAL TOXICITY CONTROL

Walter Koenst
Bioassay Manager

See WET lab report dated 11/20/2013 for limestone stabilization results

Table 1. Survival and Reproduction of *Ceriodaphnia dubia*.

Concentration (%)	% Survival	Mean # of Young Produced
Control	100	14.4
~~Q3~~	~~100~~	~~13.8~~
~~Q4~~	~~100~~	~~14.1~~
~~Q5~~	~~100~~	~~12.9~~
Dose 1	90	7.7
Dose 2	100	12.2
Dose 3	100	14.0
Dose 4	100	14.6
Dose 5	100	13.8
Dose 6	90	10.9

Table 2. Summary of Chemical and Physical Data of Toxicity Tests

% Effluent	pH	Dissolved Oxygen (mg/L)	Temperature (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Control	7.95 - 8.23	7.8 - 8.2	25	84	64	298
~~Q3~~	~~6.37 - 8.01~~	~~7.8 - 10.0~~	~~25~~	~~40~~	~~52~~	~~101~~
~~Q4~~	~~6.37 - 8.03~~	~~7.9 - 10.2~~	~~25~~	~~60~~	~~48~~	~~100~~
~~Q5~~	~~6.49 - 8.08~~	~~7.8 - 10.2~~	~~25~~	~~60~~	~~56~~	~~125~~
Dose 1	5.38 - 7.99	7.9 - 9.8	25	12	12	30
Dose 2	6.59 - 8.22	7.9 - 10.0	25	68	80	152
Dose 3	7.12 - 8.34	7.9 - 10.1	25	120	112	212
Dose 4	7.54 - 8.39	7.9 - 10.1	25	108	124	229
Dose 5	7.75 - 8.37	7.9 - 10.2	25	104	136	218
Dose 6	7.61 - 8.41	8.0 - 10.4	25	112	168	256

BIOASSAY TEST CONDITIONS

Client: Barr Engineering Project No.: 12-236
Type of sample: Test type: Chronic
Test length: Species: Ceriodaphnia dubia Organism age: <24h
# of treatments: 10 # of replicates: 10 mL/replicate: 140
Organisms/rep.: 1 Organisms/treatment: 10
Temperature (°C): 25 Light intensity: 60-65 ft-c Photoperiod: 16/8
Type of dilution water: Reconstituted Source: Lab D.I.
Collection date/time of sample/effluent: 9/23/12

TEST SOLUTION PREPARATION

Nominal conc. or % effluent							
mL of effluent or stock							
mL of dilution water							
TOTAL mL							

JS

Comments: Collection Times:

Dose 1: 1300 9/23/12
Dose 2: 1330 9/23/12
Dose 3: 1400 9/23/12
Dose 4: 1415 9/23/12
Dose 5: 1430 9/23/12
Dose 6: 1500 9/23/12

Q3: 1200 9/23/12
Q4: 1700 9/23/12
Q5: 1900 9/23/12

Analyst: JS/KM Reviewed by: WK

See WET lab report dated 11/20/2013 for limestone stabilization results

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr Engineering Project No.: 12-236
Test Dates/Time ● Initiation: 1330 9/24/12 Termination: 1100 10/1/12

Concentration	Day	Replicate 1	2	3	4	5	6	7	8	9	10	Remarks
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	2	2	4	4	2	2	4	4	2	
	5	5	5	6	6	6	5	4	3	5	6	
	6	0	6	6	0	7	6	0	0	7	8	
	7	5	2	0	6	0	0	5	7	0	0	
	Total	12	15	14	16	17	13	11	14	16	16	X̄ = 14.4
Q3	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	4	3	2	1	4	2	2	0	4	
	5	7	6	6	5	6	5	5	5	5	4	
	6	9	0	0	6	7	0	0	0	0	0	
	7	0	8	9	0	0	6	4	5	4	2	
	Total	18	18	18	13	14	15	11	12	9	10	X̄ = 13.8
Q4	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	3	2	3	1	2	2	0	3	4	4	
	5	6	7	7	6	5	5	6	4	5	5	
	6	0	6	9	0	0	6	4	8	0	0	
	7	5	0	0	6	4	0	4	0	4	5	
	Total	14	15	19	13	11	13	14	15	13	14	X̄ = 14.1

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing
(-#) = No. of Dead Young

Analyst: JS/KM/SW Reviewed By: WK

See WET lab report dated 11/20/2013 for limestone stabilization results

ENVIRONMENTAL TOXICITY CONTROL

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr Engineering Project No.: 12-236
Test Dates/Time ● Initiation: 1330 9/24/12 Termination: 1100 10/1/12

Concentration	Day	Replicate										Remarks
		1	2	3	4	5	6	7	8	9	10	
Q5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	4	3	2	2	1	3	4	2	2	3	
	5	6	0	7	5	5	5	5	6	6	4	
	6	0	8	0	7	0	6	0	7	0	5	
	7	3	0	5	0	4	0	5	0	3	1	
Total		13	11	14	14	10	14	14	15	11	13	$\bar{x}$ = 12.9

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing
(-#) = No. of Dead Young

Analyst: JS/KM/SW Reviewed By: WK

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr Engineering Project No.: 12-236
Test Dates/Time ● Initiation: 1335 9/24/12 Termination: 1100 10/1/12

Concentration	Day	Replicate										Remarks
		1	2	3	4	5	6	7	8	9	10	
Dose 1	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	1	2	1	2	3	0	0	2	4	1	
	5	6	6	2	2	2	8	0	4	2	0	
	6	X	0	0	0	2	6	3	0	0	3	
	7		5	0	0	0	2	0	3	5	0	
	Total	7	13	3	4	7	16	3	9	11	4	X̄ = 7.7
Dose 2	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	1	2	3	2	2	3	1	1	2	2	
	5	4	6	5	6	5	6	6	5	5	6	
	6	0	0	6	0	0	7	10	3	9	0	
	7	2	3	0	0	5	0	0	0	0	4	
	Total	7	11	14	8	12	16	17	9	16	12	X̄ = 12.2
Dose 3	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	3	2	2	0	3	4	2	2	2	2	
	5	5	5	7	6	7	6	6	5	7	5	
	6	5	0	9	10	6	8	0	8	7	0	
	7	0	3	0	0	0	0	3	0	0	0	
	Total	13	10	18	16	16	18	11	15	16	7	X̄ = 14.0

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: JS/KM/SW Reviewed By: WK

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr Engineering Project No.: 12-236

Test Dates/Time ● Initiation: 1335 9/24/12 Termination: 1100 10/1/12

Concentration	Day	Replicate										Remarks
		1	2	3	4	5	6	7	8	9	10	
Dose 4	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	0	3	2	3	3	4	1	2	2	0	
	5	5	5	4	7	7	8	6	6	7	5	
	6	7	0	0	9	7	7	0	6	9	9	
	7	0	2	5	0	0	0	3	0	0	2	
	Total	12	10	11	19	17	19	10	14	18	16	$\bar{X}$ = 14.6
Dose 5	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	1	2	2	3	2	2	2	2	4	2	
	5	5	4	6	6	6	7	7	6	8	5	
	6	0	2	0	5	0	7	8	0	10	8	
	7	4	0	3	2	4	0	0	3	0	0	
	Total	10	8	11	16	12	16	17	11	22	15	$\bar{X}$ = 13.8
Dose 6	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	1	1	2	3	0	0	1	2	2	3	
	5	6	4	5	5	0	6	7	6	6	6	
	6	0	6	0	0	X	11	8	0	9	0	
	7	0	0	3	4		0	0	2	0	0	
	Total	7	11	10	12	0	17	16	10	17	9	$\bar{X}$ = 10.9

✓ = Alive # = No. of Live Young (-#) = No. of Dead Young 0 = No Young X = Dead y = Male M= Missing

Analyst: JS/KM/SW Reviewed By: WK

See WET lab report dated 11/20/2013 for limestone stabilization results

Toxicity Test
Daily Chemistries

Page 1 of 3

Client: Barr Engineering
Project Number: 12-236
Test Type: chronic
Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Sample ID						Remarks
		0	Q3	Q4	Q5			
Day: 0	pH	7.95	6.37	6.37	6.49			
	Dissolved Oxygen (mg/l)	8.0	10.0	10.0	10.2			
Date: 9/24/12	Temperature (°C)	25.0	25.0	25.0	25.0			
	Conductivity (µmhos)	298	100.8	100.4	125.3			
Analyst: JS	Total Alkalinity (mg/l)	64	52	48	56			
	Total Hardness (mg/l)	84	40	60	60			
	Total Ammonia (mg/l)							
Day: 1 old	pH	8.06	8.00	7.98	8.04			
	Dissolved Oxygen (mg/l)	7.8	7.8	8.0	7.8			
Date: 9/25/12	Temperature (°C)	25.1	25.1	25.1	25.1			
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	8.06	6.71	6.73	6.86			
	Dissolved Oxygen (mg/l)	8.0	9.0	8.9	9.1			
Date: 9/25/12	Temperature (°C)	25.0	25.0	25.0	25.0			
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 Old	pH	8.06	8.00	7.96	8.01			
	Dissolved Oxygen (mg/l)	7.9	7.9	7.9	7.8			
Date: 9/26/12	Temperature (°C)	25.2	25.2	25.2	25.2			
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 New	pH	8.14	6.59	6.64	6.76			
	Dissolved Oxygen (mg/l)	8.0	9.0	9.4	9.6			
Date: 9/26/12	Temperature (°C)	25.0	25.0	25.0	25.0			
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by:

Date: 10/1/12

See WET lab report dated
11/20/2013 for limestone
stabilization results

Toxicity Test
Daily Chemistries

Page 2 of 3

Client: Barr Engineering	Project Number: 12-2316
Test Type: Chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Sample ID 0	Q3	Q4	Q5			Remarks
Day: 3 old	pH	8.08	8.01	7.97	8.08			
	Dissolved Oxygen (mg/l)	8.1	8.1	8.1	8.1			
Date: 9/27/12	Temperature (°C)	25.3	25.3	25.3	25.3			
	Conductivity (μmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	8.02	6.61	6.63	6.78			
	Dissolved Oxygen (mg/l)	8.0	9.4	9.6	10.0			
Date: 9/27/12	Temperature (°C)	25.0	25.0	25.0	25.0			
	Conductivity (μmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 old	pH	8.08	8.01	7.99	8.03			
	Dissolved Oxygen (mg/l)	8.0	8.0	8.0	8.1			
Date: 9/28/12	Temperature (°C)	25.2	25.2	25.2	25.2			
	Conductivity (μmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	8.08	6.76	6.76	7.03			
	Dissolved Oxygen (mg/l)	8.1	10.0	10.2	10.1			
Date: 9/28/12	Temperature (°C)	25.0	25.0	25.0	25.0			
	Conductivity (μmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 old	pH	8.08	7.96	7.83	7.95			
	Dissolved Oxygen (mg/l)	7.8	7.9	7.9	8.0			
Date: 9/29/12	Temperature (°C)	25.2	25.2	25.2	25.2			
	Conductivity (μmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by:

Date: 10/1/12

Bio.102

See WET lab report dated 11/20/2013 for limestone stabilization results

Toxicity Test
Daily Chemistries

Page 3 of 3

Client: Barr Engineering		Project Number:	12-236
Test Type: Chronic		Species:	C. dubia

Day/Date/Analyst	Parameter	Sample ID 0	Q3	Q4	Q5			Remarks
Day: 5 New	pH	8.20	7.13	7.18	7.50			
	Dissolved Oxygen (mg/l)	8.0	9.1	9.1	8.9			
Date: 9/29/12	Temperature (°C)	25.0	25.0	25.0	25.0			
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 Old	pH	8.13	8.01	7.97	8.03			
	Dissolved Oxygen (mg/l)	8.1	8.3	8.1	8.1			
Date: 9/30/12	Temperature (°C)	25.3	25.3	25.3	25.3			
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 6 New	pH	8.23	7.38	7.21	7.43			
	Dissolved Oxygen (mg/l)	8.1	9.5	9.7	9.6			
Date: 9/30/12	Temperature (°C)	25.0	25.0	25.0	25.0			
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 7 Final	pH	8.06	7.96	8.03	8.04			
	Dissolved Oxygen (mg/l)	8.2	8.2	8.1	8.1			
Date: 10/1/12	Temperature (°C)	25.2	25.2	25.2	25.2			
	Conductivity (µmhos)							
Analyst: SW	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: ____________________ Date: 10/1/12

Toxicity Test
Daily Chemistries

Page 1 of 3

Client: Barr Engineering	Project Number: 12-236
Test Type: Chronic	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Sample ID Dose 1	Dose 2	Dose 3	Dose 4	Dose 5	Dose 6	Remarks
Day: 0	pH	5.38	6.59	7.12	7.54	7.75	7.61	
	Dissolved Oxygen (mg/l)	9.8	10.0	9.9	9.8	10.0	10.4	
Date: 9/24/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)	29.8	151.8	212	229	218	256	
Analyst: JS	Total Alkalinity (mg/l)	12	80	112	124	136	168	
	Total Hardness (mg/l)	12	68	120	108	104	112	
	Total Ammonia (mg/l)							
Day: 1 Old	pH	7.45	8.11	8.29	8.31	8.27	8.21	
	Dissolved Oxygen (mg/l)	8.0	7.9	8.1	8.0	8.0	8.0	
Date: 9/25/12	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	5.63	7.12	7.51	7.80	7.93	7.81	
	Dissolved Oxygen (mg/l)	8.9	9.3	8.9	9.0	9.0	9.3	
Date: 9/25/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 Old	pH	7.37	8.11	8.30	8.33	8.31	8.25	
	Dissolved Oxygen (mg/l)	7.9	7.9	7.9	7.9	7.9	8.0	
Date: 9/26/12	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 New	pH	5.78	7.11	7.45	7.79	7.91	7.84	
	Dissolved Oxygen (mg/l)	9.1	9.1	9.2	9.3	9.3	9.5	
Date: 9/26/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by:

Date: 10/1/12

Toxicity Test
Daily Chemistries

Page 2 of 3

Client: Barr Engineering	Project Number: 12-236
Test Type: chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Sample ID						Remarks
		Dose 1	Dose 2	Dose 3	Dose 4	Dose 5	Dose 6	
Day: 3 Old	pH	7.45	8.11	8.33	8.39	8.37	8.41	
	Dissolved Oxygen (mg/l)	8.0	8.1	8.0	8.1	8.1	8.2	
Date: 9/27/12	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	5.79	7.14	7.48	7.79	7.89	7.84	
	Dissolved Oxygen (mg/l)	9.7	10.0	10.0	9.9	10.0	10.1	
Date: 9/27/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 Old	pH	7.99	8.22	8.34	8.37	8.33	8.40	
	Dissolved Oxygen (mg/l)	8.0	8.0	8.1	8.1	8.1	8.1	
Date: 9/28/12	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	5.79	7.30	7.53	7.82	7.90	7.85	
	Dissolved Oxygen (mg/l)	9.8	9.8	10.1	10.1	10.2	10.1	
Date: 9/28/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 old	pH	7.59	7.91	8.16	8.34	8.32	8.24	
	Dissolved Oxygen (mg/l)	8.1	8.2	8.2	8.1	8.0	8.1	
Date: 9/29/12	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Tount

Date: 10/1/12

Toxicity Test
Daily Chemistries

Page 3 of 3

Client: Barr Engineering	Project Number: 12-236
Test Type: Chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Sample ID Dose 1	 Dose 2	 Dose 3	 Dose 4	 Dose 5	 Dose 6	Remarks
Day: 5	pH	6.43	7.77	7.95	8.08	8.04	8.01	
New	Dissolved Oxygen (mg/l)	8.6	8.9	8.9	8.9	8.9	9.0	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
9/29/12	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
KM	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6	pH	7.60	8.11	8.30	8.33	8.32	8.31	
Old	Dissolved Oxygen (mg/l)	8.0	8.0	7.9	7.9	8.0	8.0	
Date:	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
9/30/12	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 6	pH	6.39	7.67	7.83	7.98	7.98	7.95	
New	Dissolved Oxygen (mg/l)	9.2	9.7	9.5	9.6	10.0	10.1	
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
9/30/12	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 7	pH	7.74	8.13	8.32	8.30	8.26	8.32	
Final	Dissolved Oxygen (mg/l)	8.2	8.2	8.2	8.1	8.0	8.1	
Date:	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
10/1/12	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
SW	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date:	Temperature (°C)							
/ /	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: ______

Date: 10/1/12

Chain of Custody

BARR

4700 West 77th Street
Minneapolis, MN 55435-4803
(952) 832-2600

COC 1 of 1

Project Number: 23690C08 tb 205

Project Name: RO Effluent Stabilization Test

Sample Origination State M N (use two letter postal state abbreviation)

COC Number: № 29092

Project Manager: EJA

Project QC Contact: MDD

Sampled by: SJR

Laboratory: ETC

	Location	Start Depth	Stop Depth	Depth Unit (m./ft. or in.)	Collection Date (mm/dd/yyyy)	Collection Time (hh:mm)	Matrix: Water	Matrix: Soil	Matrix	Type: Grab	Type: Comp.	Type: QC
1.	Dose 1				09/23/2012	13:00	|					
2.	Dose 2					13:30						
3.	Dose 3					14:00						
4.	Dose 4					14:15						
5.	Dose 5					14:30						
6.	Dose 6					15:00						
7.	Q3					12:00						
8.	Q4					17:00						
9.	Q5					19:00						
10.												

Number of Containers/Preservative

	Water: VOCs (HCl) #1	Water: SVOCs (unpreserved) #2	Water: Dissolved Metals (HNO_3)	Water: Total Metals (HNO_3)	Water: General (unpreserved) #3	Water: Diesel Range Organics (HCl)	Water: Nutrients (H_2SO_4) #4	Water	Water	Water	Soil: VOCs (tared MeOH) #1	Soil: GRO, BTEX (tared MeOH) #1	Soil: DRO (tared unpreserved)	Soil: Metals (unpreserved)	Soil: SVOCs (unpreserved) #2	Soil: % Solids (plastic vial, unpres.)	Soil	Soil	Total Number Of Containers	
1.					1															Test:
2.					1															Chronic whole
3.					1															Effluent Toxicity
4.					1															with C. dubia, Only 100%.
5.					1															dilution. Use
6.					1															lab water for
7.					1															control.
8.					1															
9.					1															
10.																				

Relinquished By:	On Ice?	Date	Time	Received by:	Date	Time
SJR	[✓ Y] N	9/24/12	10:00	Jennie Schorn	6.0 9/24/12	1150
	Y N					

Samples Shipped VIA: ☐ Air Freight ☐ Federal Express ☐ Sampler ☐ Other: ____

Air Bill Number:

Common Parameter/Container - Preservation Key

#1 - Volatile Organics = BTEX, GRO, TPH, 8260 Full List
#2 - Semivolatile Organics = PAHs, PCP, Dioxins, 8270 Full List, Herbicide/Pesticide/PCBs
#3 - General = pH, Chloride, Fluoride, Alkalinity, TSS, TDS, TS, Sulfate
#4 - Nutrients = COD, TOC, Phenols, Ammonia Nitrogen, TKN

Distribution: White-Original Accompanies Shipment to Lab; Yellow - Field Copy; Pink - Lab Coordinator

TOXICITY TEST RESULTS

RO EFFLUENT STABILIZATION TEST

Report Date: November 20, 2012

Project No. 12-267

Prepared for:

Barr Engineering
4700 W. 77th Street
Minneapolis, MN 55435

6265 Applewood Road • Woodbury, Minnesota 55125
Phone 651 501-2075 • Fax 651 501-2076

PROJECT: **<u>RO EFFLUENT TOXICITY TESTING</u>**

PROJECT NUMBER: 12-267

TOXICITY TEST RESULTS

INTRODUCTION:

This report presents the results of toxicity testing on water samples received by Environmental Toxicity Control (ETC) on October 25, 2012. The samples identified as Raw, Q1 No Treatment, Q1 Sparge, Q1 Caustic, Q2 No Treatment, Q2 Sparge, Q2 Caustic, Q3 No Treatment, Q3 Sparge, and Q3 Caustic were collected by employees from Barr Engineering on October 24, 2012. Personnel from Barr Engineering requested that we conduct chronic toxicity testing on the water samples. The scope of our services was limited to conducting chronic toxicity tests on the invertebrate, *Ceriodaphnia dubia*, in the laboratory.

TEST METHODS:

Tests were conducted in accordance with the procedures outlined in <u>Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms</u>, Fourth Edition, EPA-821-R-02-013.

Control water used for testing consisted of moderately hard laboratory water.

Testing was started on 10/25/12, approximately 24 hours after sample collection.

RESULTS:

Toxicity test results are summarized in Tables 1, test conditions are summarized in Table 2.

QUALITY ASSURANCE AND QUALITY CONTROL:

Satisfactory laboratory performance on an ongoing basis is demonstrated by conducting at least one acceptable toxicity test per month with a reference toxicant. Control charts for a reference toxicant and successive endpoints (LC50 and IC25) are plotted to determine if results are within prescribed limits. Results from our most recent reference test is shown in the following table:

Reference Toxicity Test		
Species	IC_{25}	Test Date
Ceriodaphnia dubia	0.838 g/l NaCl	10/09/12

Our results are within range of EPA expected results for the type of tests conducted.

Test methods and procedures are documented in ETC's Standard Operating Procedures (SOPs). Test and analysis protocols are reviewed by ETC's Quality Assurance/Quality Control Officer. Procedures are documented and followed as written. Any deviation from a QA/QC procedure is documented and kept in the project file. During this project, no deviation in method was warranted.

ENVIRONMENTAL TOXICITY CONTROL

Walter Koenst

Walter Koenst
Bioassay Manager

Table 1. ***Ceriodaphnia dubia*** **Survival and Reproduction Results of Pit Water**

Screen Test: Ceriodaphnia dubia		
Sample ID	**% Survival**	**Mean # of Young Produced**
Lab Water	100	19.3
Raw	90	11.1
Q1 No Treatment	100	16.5
Q1 Sparge	100	16.6
Q1 Caustic	100	13.6
Q2 No Treatment	100	12.8
Q2 Sparge	100	14.5
Q2 Caustic	100	12.0
Q3 No Treatment	100	12.9
Q3 Sparge	100	12.0
Q3 Caustic	90	10.0

able 2. Summary of Chemical and Physical Data of Toxicity Tests

Sample ID	pH	Dissolved Oxygen (mg/L)	Temp (°C)	Total Hardness (mg/L)	Total Alkalinity (mg/L)	Conductivity (µmhos/cm)
Lab Water	7.94 - 8.30	7.8 - 8.5	25	100	80	206
Raw	5.55 - 8.31	8.0 - 10.4	25	4	4	34
Q1 No Tx	7.47 - 8.42	8.1 - 10.1	25	112	112	224
Q1 Sparge	7.80 - 8.42	8.1 - 10.2	25	108	112	221
Q1 Caustic	7.51 - 8.39	8.2 - 10.1	25	108	112	225
Q2 No Tx	7.40 - 8.37	8.0 - 9.4	25	104	104	218
Q2 Sparge	7.92 - 8.39	8.0 - 9.9	25	100	100	209
Q2 Caustic	7.52 - 8.41	8.1 - 10.0	25	100	100	216
Q3 No Tx	7.40 - 8.44	8.2 - 10.0	25	100	100	209
Q3 Sparge	7.94 - 8.42	8.2 - 10.2	25	88	92	201
Q3 Caustic	7.76 - 8.41	8.1 - 10.2	25	100	100	207

EPA Methods:

Parameter	EPA Method Number
Dissolved Oxygen (mg/L)	360.1
pH	150.1
Total Hardness (as mg/$CaCO_3$/L)	130.2
Total Alkalinity (as mg/$CaCO_3$/L)	310.2
Specific Conductivity (µmhos/cm)	120.1

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr engineering Project No.: 12-267

Test Dates/Time ● Initiation: 1430 10/25/12 Termination: 1135 10/31/12

Concentration	Day	Replicate										Remarks
		1	2	3	4	5	6	7	8	9	10	
0	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	5	0	4	4	4	2	1	3	0	4	
	4	8	0	1	1	9	6	6	6	~~0~~ 7	~~8~~ 7	
	5	0	7	0	0	0	0	0	0	0	0	
	6	13	9	10	9	11	12	12	10	10	12	
	Total	26	16	15	14	24	20	19	19	17	23	$\bar{x}$ = 19.3
Raw	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	0	0	0	0	0	0	0	0	0	
	4	2	0	0	2	4	0	4	4	0	0	
	5	0	6	4	0	0	4	0	0	4	X	
	6	7	8	7	8	9	11	9	9	9		
	Total	9	14	11	10	13	15	13	13	13	0	$\bar{x}$ = 11.1
Q1	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
No	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Treatment	3	2	3	4	0	0	0	1	1	0	0	
	4	8	7	0	6	7	0	7	7	0	0	
	5	0	6	5	0	0	6	0	0	7	6	
	6	12	9	6	9	10	9	10	9	8	6	
	Total	22	19	15	15	17	15	18	17	15	12	$\bar{x}$ = 16.5

✓ = Alive
= No. of Live Young
(-#) = No. of Dead Young
0 = No Young
X = Dead
y = Male
M= Missing

Analyst: KM/JS

Reviewed By: WK

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr Engineering Project No.: 12-267
Test Dates/Time ● Initiation: 1430 10/25/12 Termination: 1135 10/31/12

Concentration	Day	Replicate										Remarks
		1	2	3	4	5	6	7	8	9	10	
Q1	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Sparge	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	4	4	2	4	0	4	3	2	2	3	
	4	6	5	0	8	7	0	6	5	0	6	
	5	0	0	6	0	0	7	0	0	0	0	
	6	8	8	9	6	9	8	7	9	10	8	
	Total	18	17	17	18	16	19	16	16	12	17	$\bar{x} = 16.6$
Q1	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Caustic	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	1	0	3	0	0	0	3	2	1	
	4	3	6	3	7	6	5	6	5	0	4	
	5	6	0	4	0	0	0	0	0	4	0	
	6	7	5	5	8	4	7	8	8	8	7	
	Total	16	12	13	18	10	13	14	16	14	12	$\bar{x} = 13.6$

✓ = Alive # = No. of Live Young 0 = No Young X = Dead y = Male M= Missing
(-#) = No. of Dead Young

Analyst: km / JS

Reviewed By: WK

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr Engineering Project No.: 12-267
Test Dates/Time • Initiation: 1435 10/25/12 Termination: 1135 10/31/12

Concentration	Day	Replicate										Remarks
		1	2	3	4	5	6	7	8	9	10	
Q2	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
NO	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Treatment	3	3	3	0	4	3	4	4	1	3	4	
	4	0	0	3	0	0	0	0	0	0	2	
	5	0	0	0	0	0	0	5	0	0	0	
	6	10	9	9	11	7	9	7	10	9	8	
	Total	13	12	12	15	10	13	16	11	12	14	$\bar{x}$ = 13.8
Q2	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
sparge	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	1	2	3	0	4	0	4	4	4	
	4	0	0	0	0	3	3	4	0	0	0	
	5	0	0	0	1	0	0	0	7	6	0	
	6	10	11	8	9	11	8	11	12	10	9	
	Total	10	12	10	13	14	15	15	23	20	13	$\bar{x}$ = 14.5
Q2	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
caustic	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	5	1	0	0	0	0	2	3	0	
	4	0	0	2	2	0	0	0	0	3	0	
	5	5	0	0	0	0	0	7	0	0	6	
	6	3	6	9	9	11	10	10	8	8	10	
	Total.	8	11	12	11	11	10	17	10	14	16	$\bar{x}$ = 12.0

✓ = Alive
= No. of Live Young
(-#) = No. of Dead Young
0 = No Young
X = Dead
y = Male
M= Missing

Analyst: KM/JS/SW

Reviewed By: WK

CHRONIC TOXICITY TEST
CERIODAPHNIA REPRODUCTION AND SURVIVAL

Client: Barr Engineering Project No.: 12-267
Test Dates/Time ● Initiation: 1435 10/25/12 Termination: 1135 10/31/12

Concentration	Day	Replicate										Remarks
		1	2	3	4	5	6	7	8	9	10	
Q3	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
NO	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
Treatment	3	2	5	0	3	2	0	3	0	1	2	
	4	3	0	3	0	0	1	0	0	3	0	
	5	0	0	2	0	0	7	0	6	0	0	
	6	8	7	10	9	8	8	11	10	8	7	
Total		13	12	15	12	10	16	14	16	12	9	$\bar{X}$ = 12.9
Q3	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
sparge	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	0	6	0	5	0	0	0	0	3	0	
	4	1	0	2	2	2	3	3	0	2	3	
	5	1	1	0	0	0	0	0	0	0	0	
	6	8	10	11	6	8	9	10	9	9	6	
Total		10	17	13	13	10	12	13	9	14	9	$\bar{X}$ = 12.0
Q3	1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
caustic	2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
	3	3	3	0	0	0	3	1	0	0	2	
	4	2	0	1	2	0	0	0	0	0	0	
	5	0	0	0	0	8	0	0	0	2X	7	
	6	9	7	4	9	0	11	8	10		8	
Total		14	10	5	11	8	14	9	10	2	17	$\bar{X}$ = 10.0

✓ = Alive   # = No. of Live Young   0 = No Young   X = Dead   y = Male   M= Missing
(-#) = No. of Dead Young

Analyst: KM/JS/SW

Reviewed By: WK

Toxicity Test
Daily Chemistries

Page 1 of 3

Client: Barr Engineering	Project Number: 12-267
Test Type: Chronic	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Sample ID						Remarks
		0	Raw	Q1 No tx	Q1 Sparge	Q1 Caustic		
Day: 0	pH	7.97	5.55	7.47	7.80	7.51		
	Dissolved Oxygen (mg/l)	7.8	9.1	9.1	9.3	9.5		
Date: 10/25/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0		
	Conductivity (µmhos)	206	34	224	221	225		
Analyst: km	Total Alkalinity (mg/l)	80	4	112	112	112		
	Total Hardness (mg/l)	100	4	112	108	108		
	Total Ammonia (mg/l)							
Day: 1 Old	pH	8.30	8.31	8.42	8.42	8.39		
	Dissolved Oxygen (mg/l)	8.3	8.3	8.3	8.3	8.5		
Date: 10/26/12	Temperature (°C)	24.7	24.7	24.7	24.7	24.7		
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	8.10	6.26	7.77	8.01	7.94		
	Dissolved Oxygen (mg/l)	8.0	8.6	8.7	8.7	8.7		
Date: 10/26/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0		
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 old	pH	8.11	7.36	8.24	8.27	8.28		
	Dissolved Oxygen (mg/l)	8.1	8.1	8.1	8.1	8.2		
Date: 10/27/12	Temperature (°C)	25.1	25.1	25.1	25.1	25.1		
	Conductivity (µmhos)							
Analyst: km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 New	pH	8.13	5.96	7.73	7.95	7.88		
	Dissolved Oxygen (mg/l)	8.0	8.7	8.8	8.9	9.0		
Date: 10/27/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0		
	Conductivity (µmhos)							
Analyst: km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by:

Date: 10/31/12

Toxicity Test
Daily Chemistries

Page 2 of 3

Client:	Barr Engineering	Project Number:	12-267
Test Type:	Chronic	Species:	C. dubia

Day/Date/Analyst	Parameter	Sample ID						Remarks
		0	Raw	Q1 No tx	Q1 Sparge	Q1 Caustic		
Day: 3	pH	8.12	7.82	8.25	8.35	8.35		
old	Dissolved Oxygen (mg/l)	8.4	8.4	8.4	8.4	8.5		
Date:	Temperature (°C)	25.2	25.2	25.2	25.2	25.2		
10/28/12	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
KM	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3	pH	8.30	7.17	7.70	7.92	7.77		
new	Dissolved Oxygen (mg/l)	8.5	10.4	10.1	10.2	10.1		
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0		
10/28/12	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
KM	Total Hardness (mg/l)							
Day: 4	pH	8.21	7.61	8.40	8.38	8.36		
old	Dissolved Oxygen (mg/l)	8.2	8.4	8.50	8.5	8.4		
Date:	Temperature (°C)	25.1	25.1	25.1	25.1	25.1		
10/29/12	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
JK	Total Hardness (mg/l)							
Day: 4	pH	8.22	6.14	8.00	8.02	8.00		
new	Dissolved Oxygen (mg/l)	8.0	8.9	8.9	9.0	9.0		
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0		
10/29/12	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
JK	Total Hardness (mg/l)							
Day: 5	pH	8.09	7.86	8.29	8.34	8.33		
Old	Dissolved Oxygen (mg/l)	8.4	8.3	8.4	8.4	8.5		
Date:	Temperature (°C)	25.2	25.2	25.2	25.2	25.2		
10/30/12	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by:

Date: 10/31/12

Toxicity Test
Daily Chemistries

Client: Barr Engineering	Project Number: 12-267
Test Type: Chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Sample ID						Remarks
		0	Raw	Q1 No tx	Q1 Sparge	Q1 Caustic		
Day: 5	pH	8.17	6.23	7.73	7.92	7.94		
New	Dissolved Oxygen (mg/l)	8.2	9.0	9.6	9.6	9.4		
Date:	Temperature (°C)	25.0	25.0	25.0	25.0	25.0		
10/30/12	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
JS	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6	pH	7.94	7.63	8.14	8.17	8.17		
Final	Dissolved Oxygen (mg/l)	8.1	8.0	8.2	8.2	8.3		
Date:	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	~~25.3~~ Km	
10/31/12	Conductivity (µmhos)							
Analyst: Km	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date:	Temperature (°C)							
/ /	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date:	Temperature (°C)							
/ /	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date:	Temperature (°C)							
/ /	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by:

Date: 10/31/12

ENVIRONMENTAL TOXICITY CONTROL

Toxicity Test
Daily Chemistries

Page 1 of 3

Client: Barr Engineering	Project Number: 12-267
Test Type: Chronic	Species: Ceriodaphnia dubia

Day/Date/Analyst	Parameter	Sample ID						Remarks
		Q2 No tx	Q2 Sparge	Q2 Caustic	Q3 No tx	Q3 Sparge	Q3 Caustic	
Day: 0	pH	7.40	7.92	7.52	7.40	8.03	7.76	
	Dissolved Oxygen (mg/l)	9.3	9.3	9.4	9.5	9.3	9.4	
Date: 10/25/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)	218	209	216	209	201	207	
Analyst: KM	Total Alkalinity (mg/l)	104	100	100	100	92	100	
	Total Hardness (mg/l)	104	100	100	100	88	100	
	Total Ammonia (mg/l)							
Day: 1 Old	pH	8.33	8.31	8.32	8.30	8.24	8.24	
	Dissolved Oxygen (mg/l)	8.4	8.4	8.4	8.3	8.3	8.4	
Date: 10/26/12	Temperature (°C)	24.7	24.7	24.7	24.7	24.7	24.7	
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 1 New	pH	7.86	8.03	7.95	7.90	8.04	8.04	
	Dissolved Oxygen (mg/l)	8.6	8.6	8.6	8.6	8.6	8.7	
Date: 10/26/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 Old	pH	8.23	8.25	8.30	8.27	8.22	8.27	
	Dissolved Oxygen (mg/l)	8.1	8.1	8.3	8.2	8.2	8.1	
Date: 10/27/12	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 2 New	pH	7.80	8.03	7.88	7.86	8.01	7.98	
	Dissolved Oxygen (mg/l)	8.7	8.8	8.6	8.8	8.8	8.9	
Date: 10/27/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by:

Date: 10/31/12

Bio.102(2)

Toxicity Test
Daily Chemistries

Page 2 of 3

Client:	Barr engineering	Project Number:	12-267
Test Type:	Chronic	Species:	C. dubia

Day/Date/Analyst	Parameter	Sample ID Q2 No tx	Q2 Sparge	Q2 Caustic	Q3 No tx	Q3 Sparge	Q3 Caustic	Remarks
Day: 3 old	pH	8.32	8.34	8.36	8.35	8.32	8.33	
	Dissolved Oxygen (mg/l)	8.4	8.5	8.5	8.5	8.5	8.4	
Date: 10/28/12	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 3 New	pH	7.72	8.00	7.82	7.76	8.05	7.93	
	Dissolved Oxygen (mg/l)	9.4	9.9	10.0	10.0	10.2	10.2	
Date: 10/28/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: KM	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 ~~New~~ gk old	pH	8.37	8.39	8.41	8.44	8.42	8.41	
	Dissolved Oxygen (mg/l)	8.7	8.8	8.6	8.6	8.7	8.6	
Date: 10/29/12	Temperature (°C)	25.1	25.1	25.1	25.1	25.1	25.1	
	Conductivity (µmhos)							
Analyst: gK/SW	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 4 New	pH	7.98	8.09	8.00	7.95	8.08	8.02	
	Dissolved Oxygen (mg/l)	8.9	8.9	8.9	8.9	8.9	8.9	
Date: 10/29/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: gK	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day: 5 Old	pH	8.29	8.33	8.34	8.35	8.33	8.33	
	Dissolved Oxygen (mg/l)	8.4	8.3	8.4	8.3	8.4	8.3	
Date: 10/30/12	Temperature (°C)	25.2	25.2	25.2	25.2	25.2	25.2	
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Date: 10/31/12

Toxicity Test
Daily Chemistries

Page 3 of 3

Client: Barr Engineering	Project Number: 12-267
Test Type: Chronic	Species: C. dubia

Day/Date/Analyst	Parameter	Sample ID						Remarks
		Q2 No tx	Q2 Sparge	Q2 Caustic	Q3 No tx	Q3 Sparge	Q3 Caustic	
Day: 5 New	pH	7.73	7.94	7.92	7.85	7.94	7.93	
	Dissolved Oxygen (mg/l)	9.4	9.7	9.8	9.8	9.8	9.6	
Date: 10/30/12	Temperature (°C)	25.0	25.0	25.0	25.0	25.0	25.0	
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
	Total Ammonia (mg/l)							
Day: 6 Final	pH	8.13	8.15	8.23	8.20	8.17	8.15	
	Dissolved Oxygen (mg/l)	8.0	8.0	8.1	8.2	8.2	8.4	
Date: 10/31/12	Temperature (°C)	25.3	25.3	25.3	25.3	25.3	25.3	
	Conductivity (µmhos)							
Analyst: JS	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							
Day:	pH							
	Dissolved Oxygen (mg/l)							
Date: / /	Temperature (°C)							
	Conductivity (µmhos)							
Analyst:	Total Alkalinity (mg/l)							
	Total Hardness (mg/l)							

Reviewed by: Walter Ford

Date: 10/31/12

BARR

Chain of Custody

4700 West 77th Street
Minneapolis, MN 55435-4803
(952) 832-2600

COC 1 of 1

Project Number: 23690C08.01 TB 250

Project Name: RO Effluent Stabilization Test

Sample Origination State M N (use two letter postal state abbreviation)

COC Number: № 37980

Project Manager: EJA

Project QC Contact: DLB

Sampled by: SJR

Laboratory: ETC

Number of Containers/Preservative

Location	Start Depth	Stop Depth	Depth Unit (m./ft. or in.)	Collection Date (mm/dd/yyyy)	Collection Time (hh:mm)	Matrix: Water	Matrix: Soil	Matrix	Type: Grab	Type: Comp.	Type: QC	Water: VOCs (HCl) #1	Water: SVOCs (unpreserved) #2	Water: Dissolved Metals (HNO_3)	Water: Total Metals (HNO_3)	Water: General (unpreserved) #3	Water: Diesel Range Organics (HCl)	Water: Nutrients (H_2SO_4) #4	Water	Water	Water	Soil: VOCs (tared MeOH) #1	Soil: GRO, BTEX (tared MeOH) #1	Soil: DRO (tared unpreserved)	Soil: Metals (unpreserved)	Soil: SVOCs (unpreserved) #2	Soil: % Solids (plastic vial, unpres.)	Soil	Soil	Total Number Of Containers	
1. Raw				10/24/2012	11:30	|										1															Test: Chronic
2. Q1 No Treatment				|	12:00	|										1															Whole Effluent
3. Q1 sparge				|	12:15	|										1															Toxicity with
4. Q1 Caustic				|	12:30	|										1															C. Dubia.
5. Q2 No Treatment				|	13:00	|										1															Only 100%
6. Q2 Sparge				|	13:15	|										1															dilution. Use
7. Q2 Caustic				|	13:30	|										1															lab ~~contro~~
8. Q3 No Treatment				|	14:00	|										1															water for
9. Q3 Sparge				|	14:15	|										1															control
10. Q3 Caustic				↓	14:30	|										1															

Common Parameter/Container - Preservation Key

#1 - Volatile Organics = BTEX, GRO, TPH, 8260 Full List
#2 - Semivolatile Organics = PAHs, PCP, Dioxins, 8270 Full List, Herbicide/Pesticide/PCBs
#3 - General = pH, Chloride, Fluoride, Alkalinity, TSS, TDS, TS, Sulfate
#4 - Nutrients = COD, TOC, Phenols, Ammonia Nitrogen, TKN

Relinquished By: SJR	On Ice? [✓ Y] N	Date 10/25/12	Time 7:30	Received by:	Date	Time
Relinquished By:	On Ice? Y N	Date	Time	Received by:	Date	Time

Samples Shipped VIA: ☐ Air Freight ☐ Federal Express ☐ Sampler ☐ Other: ____________

Air Bill Number:

Distribution: White-Original Accompanies Shipment to Lab; Yellow - Field Copy; Pink - Lab Coordinator

H:\RLG\STDFORMS\Chain Of Custody Form 2009 RLG Rev. 09/01/09

Appendix G

Limestone Information

COLUMBIA RIVER CARBONATES
P.O. Box 2350 – 300 North Pekin Road
Woodland, Washington 98674
TEL: (360) 225 – 6505
FAX: (360) 225 – 5082
WATS: (800) 735 – 6690

Puri-Cal™ RO

DATA SHEET

Puri-Cal™ RO

Typical Physical Characteristics

Moisture (%)	< 0.2
Specific Gravity	2.7

Typical Chemical Analysis

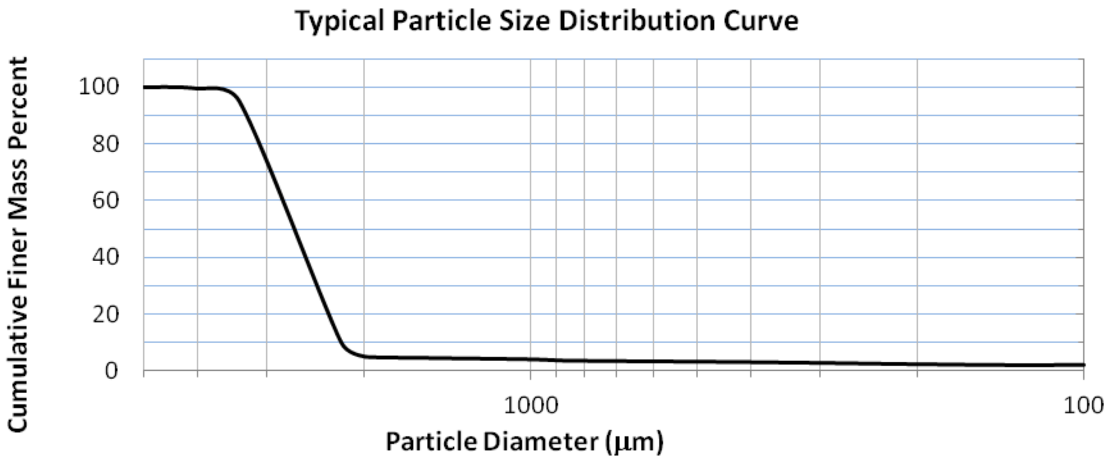
$CaCO_3$ (%)	> 95
$MgCO_3$ (%)	< 3
Acid Insoluble (%)	< 2

CAS# 1317-65-3

Typical Size Distribution

6% Plus 6 mesh (U.S. Standard)
5% Minus 10 mesh (U.S. Standard)

Certified to NSF/ANSI 60
MUL 400 gm/L



Revised by Leif Backstrom
June 2012

CRC

MATERIAL SAFETY DATA SHEET

COLUMBIA RIVER CARBONATES

Version: Puri-Cal
Page: 1 of 3
Valid: 6/5/2012

Material Safety Data Sheet

SECTION 1 – PRODUCT INFORMATION

Product:	Calcium Carbonate (Limestone)
Trade Names:	Puri-Cal™, Puri-Cal™ C, Puri-Cal™ RO
Chemical Formula:	Primarily Calcium Carbonate ($CaCO_3$)
CAS #:	1317 – 65 – 3
Manufacturer:	COLUMBIA RIVER CARBONATES
Address:	P.O. Box 2350, 300 N. Pekin Road, Woodland, WA 98674
Telephone:	(360) 225-6505
Emergency Phone:	(800) 424-9300 (CHEMTREC)

NSF®
Certified to
NSF/ANSI 60

SECTION 2 – HAZARDOUS INGREDIENTS

Ingredients:	**Wt. %(typical):**	**CAS#:**	**Exposure Limits (TWA) mg/m^3:**	
Limestone	>99.0	1317 – 65 – 3	ACGIH TLV	Inhalable dust, 10 [for PNOS] Respirable dust, 3 [for PNOS]
			OSHA PEL:	Total dust, 15 Respirable dust, 5
Silica, quartz (naturally-occurring component of limestone)	<0.75	14808 – 60 – 7	OSHA PEL:	Total dust, 30 / % silica + 2
Silica, respirable quartz (naturally-occurring component of limestone) – <u>typical value</u>	< 0.35	14808 – 60 – 7	ACGIH TLV:	Respirable dust, 0.025
			OSHA PEL:	Respirable dust, 10 / % silica + 2

SECTION 3 – PHYSICAL DATA

Appearance and Odor:	White powder – no odor.
Solubility in Water:	0.0014 g/100 ml @ 25 degrees Celcius.
Specific Gravity; (of solids)	2.71 g/ml.
Maximum Use Level:	400 gm/l.

SECTION 4 - FIRE & EXPLOSION DATA

Flash Point:	Non-Flammable.
Extinguishing Media:	Not Applicable.
Special Fire Fighting Procedures:	None.
Unusual Fire & Explosion Hazards:	None.

SECTION 5 – REACTIVITY DATA

Stability:	Stable.
Reactivity in Water:	None.
Incompatibility (Material to Avoid):	Reacts with acids and liberates carbon dioxide. Ignites on contact with fluorine. Also incompatible with alum and ammonium salts.
Hazardous Polymerization:	Will not occur.
Hazardous Decomposition Products:	Thermal decomposition can produce calcium oxide and carbon dioxide.

SECTION 6 – TOXILOGICAL PROPERTIES

EFFECTS AND HAZARDS OF ACUTE EXPOSURE:

Inhalation: Dust may irritate the respiratory tract. Symptoms include sneezing and slight nose irritation.

Eye Contact: Irritation. Symptoms include watering and irritation.

Skin Contact: Repeated or prolonged exposure may have a drying effect on the skin, and may also cause irritation.

Ingestion: Ingestion of very large quantities may result in intestinal obstruction and/or constipation.

EFFECTS AND HAZARDS OF CHRONIC EXPOSURE:

Chronic exposure to limestone dust at concentrations exceeding occupational exposure limits may cause pneumoconiosis (lung disease). This product contains crystalline silica (quartz) as an impurity. Chronic exposure to crystalline silica dust at concentrations exceeding occupational exposure limits may cause silicosis. The NTP's Ninth Report on Carcinogens lists crystalline silica (respirable size) as a known human carcinogen. IARC concluded that there is sufficient evidence in humans for the carcinogenicity of inhaled (respirable) crystalline silica.

SECTION 7 – FIRST AID MEASURES

Eye Contact: Flush thoroughly with water. If irritation persists, seek medical attention.

Skin Contact: Wash with mild soap and warm water.

Inhalation: Remove to fresh air. Obtain medical advice if required.

Ingestion: Never give anything by mouth if victim is rapidly losing consciousness or is unconscious or convulsing. Rinse mouth thoroughly with water. Do not induce vomiting. Drink 8 to 10 ounces (240 to 300 ml)of water to dilute material in stomach. Obtain medical advice immediately.

SECTION 8 – PREVENTATIVE MEASURES

Spills/Leaks: Measures should be taken to minimize and protect against airborne dust during cleanup operations, including use of respiratory protective equipment if necessary.

Disposal: From a waste perspective, this product is not considered hazardous and may be disposed of as solid waste in accordance with applicable federal, state, provincial, and local regulations.

Handling: Administrative and/or engineering control methods such as, but not limited to, process enclosure and exhaust ventilation may be necessary to control dust exposures. Supply sufficient replacement air to make up for air removed by exhaust systems. If engineering controls and work practices are not effective in controlling exposures, appropriate personal protective equipment including a NIOSH/OSHA approved dust respirator should be worn. Appropriate eye protection should be worn. Selection of all personal protective equipment should be performed by an Industrial Hygienist or other qualified professional.

HAZARDOUS MATERIAL IDENTIFICATION SYSTEM (National Paint & Coatings Association):

CATEGORY	RATING
Health	**1***
Flammability	**0**
Physical Hazard	**0**

SECTION 9 –REGULATORY INFORMATION

TSCA:	This product primarily is natural calcium carbonate from limestone ore which is listed on the U.S. EPA TSCA inventory under Limestone, CAS# 1317-65-3. In addition, all other ingredients and/or processing aids are also on the TSCA inventory.
DSL:	BY virtue of its status as a “substance occurring in nature”, ground limestone is considered to be on the Canadian Domestic Substances List. In addition, all other ingredients and/or processing aids are also on the DSL.
CONEG:	Being derived from limestone ore, this product may contain incidental trace levels of naturally occurring metals. However, no metals are intentionally added and this product complies with the CONEG requirement of <100 ppm of Cd, Cr^{+6}, Pb, and Hg.
ODCs:	This product does not contain, nor is it produced with, any U.S. EPA-defined Class I or Class II ozone-depleting chemicals.
FDA:	This product may be used as an indirect food additive in food packaging applications under 21 CFR (FDA) 174.5, 175.300, and 178.3297. It does not qualify as a substance permitted for direct addition to human food or animal feed.

SECTION 10 – PREPARATION INFORMATION

Prepared by Technical Support Group

The information contained herein has been compiled by Columbia River Carbonates from sources it considers reliable, and is accurate to the best of Columbia River Carbonates’ knowledge. Before using the product identified hereon, the foregoing MSDS and the product label should be read carefully. The information contained herein relates only to the product identified hereon, and does not relate to its use in combination with any other material or in any process. Customers are encouraged to conduct their won tests concerning the use of the product identified hereon as each customer’s manner and conditions of use and handling may involve additional considerations. Columbia River Carbonates assumes and shall incur no liability for any damages, losses, injures, costs, or consequential damages that may result from the uses or misuse of the product identified hereon, and the recipient assumes all of such liability.

Attachment C

Waste Water Flow and Load Design Basis Report – Mine Water Treatment Trains

Waste Water Flow and Load Design Basis Report

Waste Water Treatment System - Mine Water Inputs
NorthMet Project

Prepared for
Poly Met Mining, Inc.

October 2017

4300 MarketPointe Drive, Suite 200
Minneapolis, MN 55435
952.832.2600
www.barr.com

Waste Water Flow and Load Design Basis Report
Waste Water Treatment System - Mine Water Inputs
NorthMet Project

October 2017

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Certifications

I hereby certify that this report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota, specifically Waste Water Flow and Load Design Basis Report, Waste Water Treatment System - Mine Water Inputs, NorthMet Project.

Don E. Richard, P.E.
PE #: 21193

10/06/2017
Date

1.0 Introduction

This Waste Water Flow and Load Design Basis Report provides a summary of the procedures that have been used to evaluate the available information and establish the waste water flows and loads that will be used to design the mine water treatment trains at the Waste Water Treatment System (WWTS) for the first 10 years of the NorthMet Project (Project). This represents the first half of the operations phase for the Project and two full permit cycles for the NPDES/SDS Permit.

The flow and load information presented in this report has been obtained from the results of the GoldSim model simulations for the Mine Site water quality and quantity estimates in support of the Final Environmental Impact Statement (FEIS) prepared for the Project. This information is presented in the Water Modeling Data Package – Volume 1, Mine Site (v14) (Reference (1)). Additional information developed to describe the Mine Site hydrology and proposed Mine Site dewatering operations were also considered.

This report is organized into three sections, including this introduction. The following sections include:

- Section 2.0 contains a description of the mine water input quantities to the mine water treatment trains at the WWTS – including a statistical evaluation of the mine water flows obtained from GoldSim model simulations results, and documentation of the basis for the recommended Mine Site mine water quantities that will be used to design the mine water treatment trains at the WWTS based on consideration of the GoldSim flows, storm flows, proposed Mine Site operations, and equalization of Mine Site flows to the extent practical based on-site constraints. This section also includes a discussion of the construction mine water flows.
- Section 3.0 provides a summary of the statistical analysis of the GoldSim water quality results and documents the procedure used for establishing the water qualities that will be used to design the mine water treatment trains at the WWTS.

2.0 Description of Mine Water Quantity Inputs and Flow Design Basis

Mine water sources to the WWTS include:

- Stockpile drainage from Category 1, Category 2/3, and Category 4 Waste Rock Stockpiles, and the Ore Surge Pile (OSP),
- Mine pit dewatering flows from the East, West, and Central Pits, and
- Drainage from the Rail Transfer Hopper (RTH) load-out area and haul roads.

Mine water quantities are probabilistic outputs of the GoldSim model based on 100 realizations. The distribution of these probabilistic outputs can be described in terms of percentile values, such as the 10th percentile (P10), 50th percentile (P50), and 90th percentile (P90).

Table 2-1 and Large Table 1 summarize mine water quantities by source. Values presented in these tables represent the P90 values for the respective sources and average flows. Mine water is derived from both groundwater and precipitation on the Mine Site. It is considered mine water when it has contacted surfaces disturbed by mining activities, such as drainage collected on stockpile liners, pit dewatering water, and runoff contacting ore, waste rock, and Mine Site haul road surfaces. Runoff from the construction dewatering of saturated mineral overburden, which is a subset of mine water called construction mine water, is routed to the Construction Mine Water Basin. Runoff from the Overburden Storage and Laydown Area (OSLA), which is collected in the OSLA pond and routed to the Construction Mine Water Basin is also a subset of mine water. Construction mine water and OSLA runoff are not treated at the WWTS.

Generally, mine water from the mine pits, haul roads, Category 1 Stockpile Groundwater Containment System, and RTH area is characterized by higher flow volumes with lower concentrations of metals and sulfate, while the mine water from the temporary waste rock stockpiles and OSP is characterized by lower volumes with higher concentrations of metals and sulfate. The distinction between these two groups of mine water sources is the basis for the use of two separate treatment trains: membrane separation using nanofiltration (NF) membranes for the high volume, low concentration flows, and chemical precipitation for the low volume, high concentration flows. The two treatment trains are described in more detail in the main text of the Waste Water Treatment System Design and Operations Report. These two groups of flows will report to separate equalization basins, with the high-volume, low-concentration water reporting to the Low Concentration Equalization Basins (LCEQ Basins 1 and 2) and the low-volume, high-concentration water reporting to the High Concentration Equalization Basin (HCEQ). Outflows from the LCEQ Basins and HCEQ Basin are routed in two separate Mine to Plant Pipelines via the Central Pumping Station (CPS) to the WWTS at the Plant Site.

2.1 Water Quantity Projections

The water quantity projections summarized in Table 2-1 are the annual average flow rates from each of the mine water source areas based on the P90 results of 100 GoldSim model simulations for the mine water. Actual flow rates are expected to fluctuate seasonally. The annual variation in flow including the spring snowmelt event, average summer, and average winter flow rates are summarized in Large Table 1. The values listed in Large Table 1 are based on Mine Site design and associated hydrology with respect to historical precipitation records.

In addition to annual average flows, a peak pumped flow was considered from the mine pits during the spring snowmelt event. The design includes a three-day, high volume pit dewatering event during the 30-day spring snowmelt event. The predicted discharge rates from this three-day event and 30-day event are also included in Large Table 1.

Table 2-1 Mine Water Flows to the Equalization Basins

Source	Reports to	Estimated Annual Average Flow (gpm) in Mine Year(1)							
		1	2	5	10	11	14	15	20
East Pit	LCEQ	245	385	582	1,052	642(2)	1,035(2)	1,049(2)	0
Central Pit	LCEQ	0	0	0	0	12(2)	56(2)	55(2)	0
West Pit	LCEQ	11	76	160	307	357	367	344	332
Haul Roads and Rail Transfer Hopper	LCEQ	68	66	66	70	67	66	66	69
Category 1 Stockpile Groundwater Containment System	LCEQ	171	163	326	409	374	373	319	81
Category 2/3 Waste Rock Stockpile	HCEQ	53	52	99	151	142	144	130	12
Category 4 Waste Rock Stockpile	HCEQ	24	24	45	47	36	0	0	0
Ore Surge Pile	HCEQ	24	24	24	25	24	24	23	24
Low Concentration Equalization Basins Total(1)		483	670	1,090	1,755	1,344	1,781	1,724	490
High Concentration Equalization Basin Total(1)		101	100	168	222	201	168	153	36
Mine Water Total to WWTS(1)		**680**	**864**	**1,338**	**2,096**	**1,675**	**2,063**	**1,970**	**619**

Source: Reference (1)
LCEQ=Low Concentration Equalization Basins, HCEQ=High Concentration Equalization Basin
(1) P90 flows; column values do not sum to total value due to probabilistic modeling.
(2) Can be held in pits during the spring snowmelt event.

Figure 2-1 presents the P90 annual average flow from each of the individual sources at the Mine Site as well as the aggregate flow to the LCEQ Basins and the HCEQ Basin. These flow estimates were obtained from probabilistic modeling of each source as well as probabilistic modeling of the combined influent to the equalization basins. Because each of these processes was modeled independently, the sum of the individual results from each source do not necessarily match (sum to) the modeled P90 annual average for the basins, because the P90 flow from all sources may not occur simultaneously within the model year. Summing the individual results would provide additional conservatism to the design and result in over-sizing of the WWTS.

The combined flow to the LCEQ Basins is comprised of the flows from the East Pit, Central Pit, West Pit, haul roads, RTH, and Category 1 Stockpile Groundwater Containment System. The annual average flows from the haul roads and the RTH remain relatively constant over the operations phase of the Project. The dewatering water from the West Pit increases from Mine Year 1 through Mine Year 12, and decreases slightly until Mine Year 20. The Central Pit flow peaks from Mine Year 12 through Mine Year 15. The average annual flow from the Category 1 Stockpile Groundwater Containment System peaks between Mine Years 7 and 12, then gradually decreases over the remaining operations phase. Flow from the East Pit gradually increases until Mine Year 10, and then decreases as the East Pit is flooded and backfilled with waste rock. In Mine Years 13 through 16, some dewatering is projected to be necessary in the East Pit to maintain the desired water level; however, this can be held during periods of peak mine water flow at the WWTS. Mining of the West Pit is the main source of ore from Mine Year 10 through Mine Year 20, although the Central Pit is also being mined between Mine Year 11 through Mine Year 16.

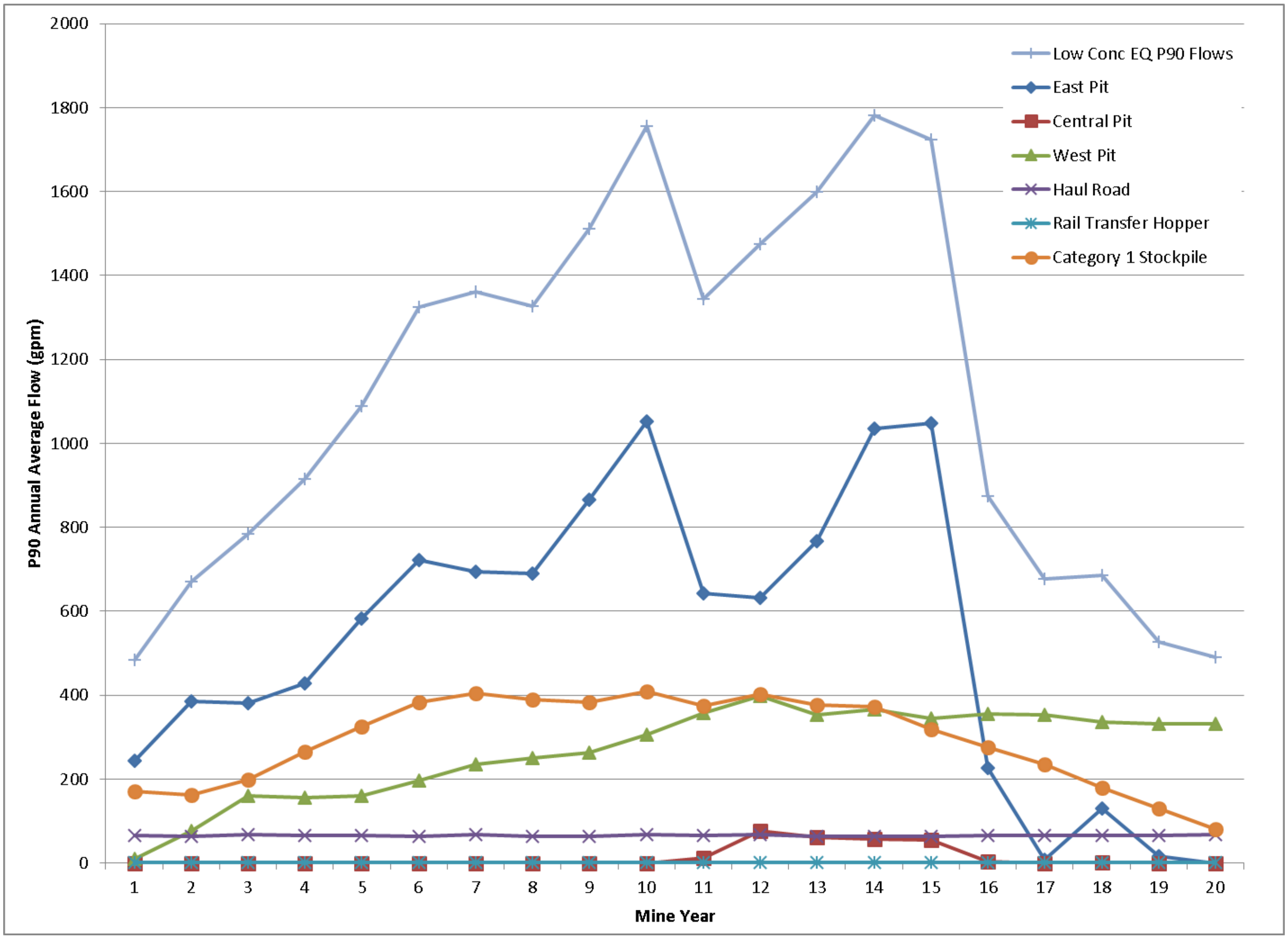


Figure 2-1 P90 Annual Average Flows to the Low Concentration Equalization Basins

Figure 2-2 presents the P90 annual average flow to the HCEQ Basin and comprises the flows from the drainage from the Category 2/3 Waste Rock Stockpile, the Category 4 Waste Rock Stockpile, and the Ore Surge Pile. The mine water flows from the Category 2/3 Waste Rock Stockpile increases from Mine Year 1 through Mine Year 7, remains relatively constant from Mine Years 7 through 14, and then slowly decreases thereafter. The average annual flow from the Category 4 Waste Rock Stockpile peaks in Mine Years 4 through 10, then decreases to zero in Mine Year 12, where it remains through the remaining years of operations.

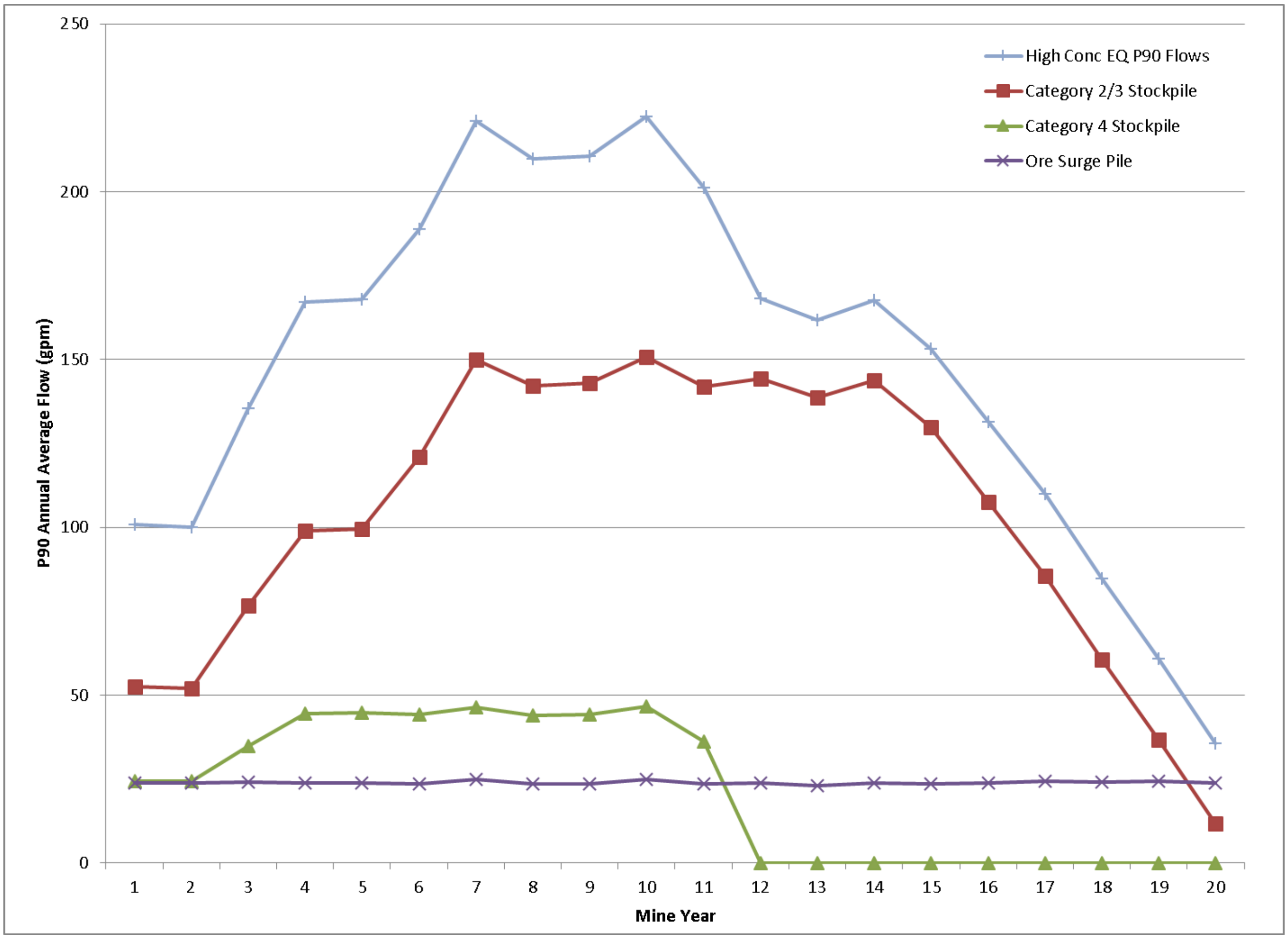


Figure 2-2 P90 Annual Average Flows to the High Concentration Equalization Basin

Figure 2-3 (LCEQ Basins Annual Average) and Figure 2-4 (LCEQ Basins Summer Average) present the statistical variability of the mine water quantities for the combined mine water streams flowing to the LCEQ Basins. In addition to P90 values, the mean and 10th percentiles (P10) are also plotted for reference purposes. As shown in these figures, the peak annual average flow to the LCEQ Basins occurs in Mine Year 14 while the peak summer average mine water flow occurs in Mine Year 13.

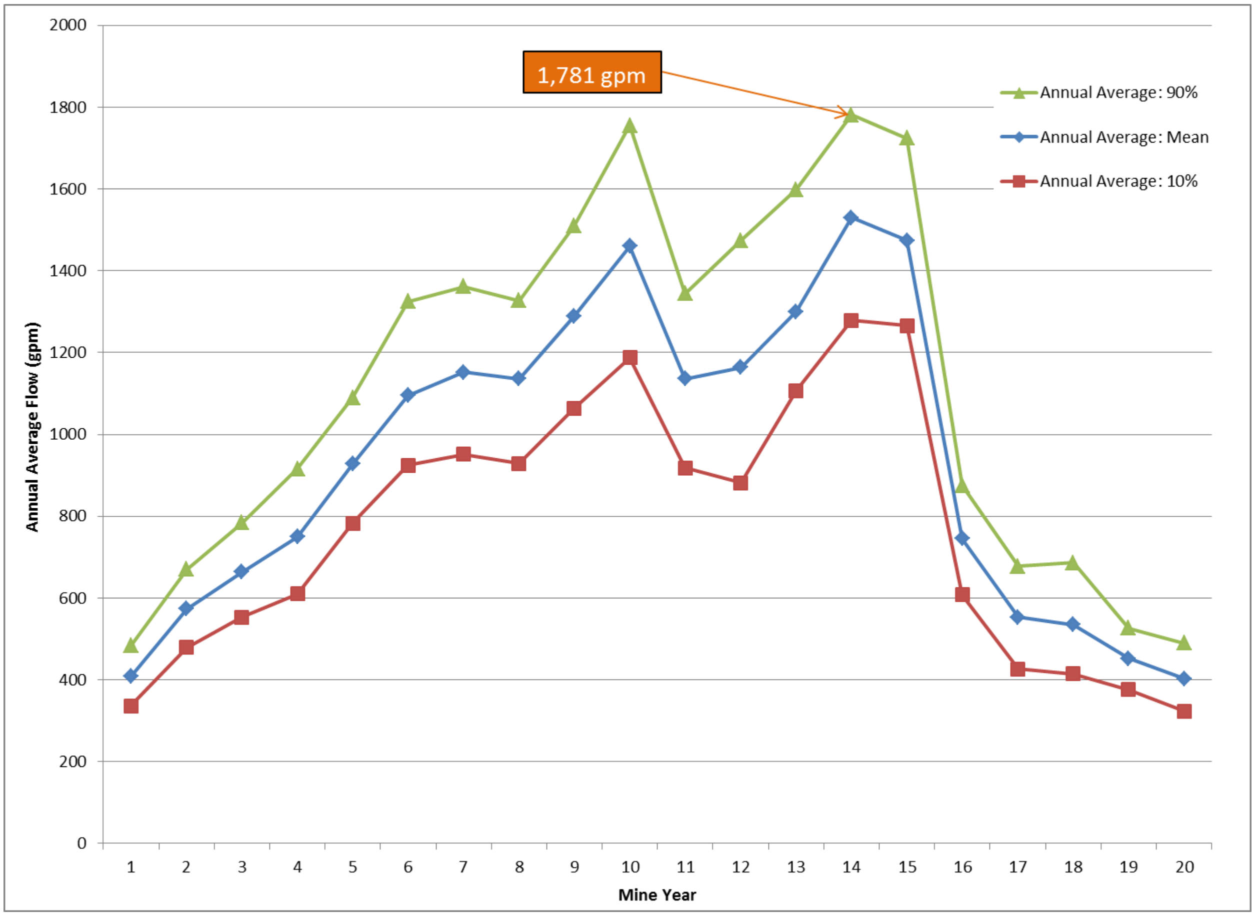


Figure 2-3 Annual Average Flow to the Low Concentration Equalization Basins – Statistical Summary

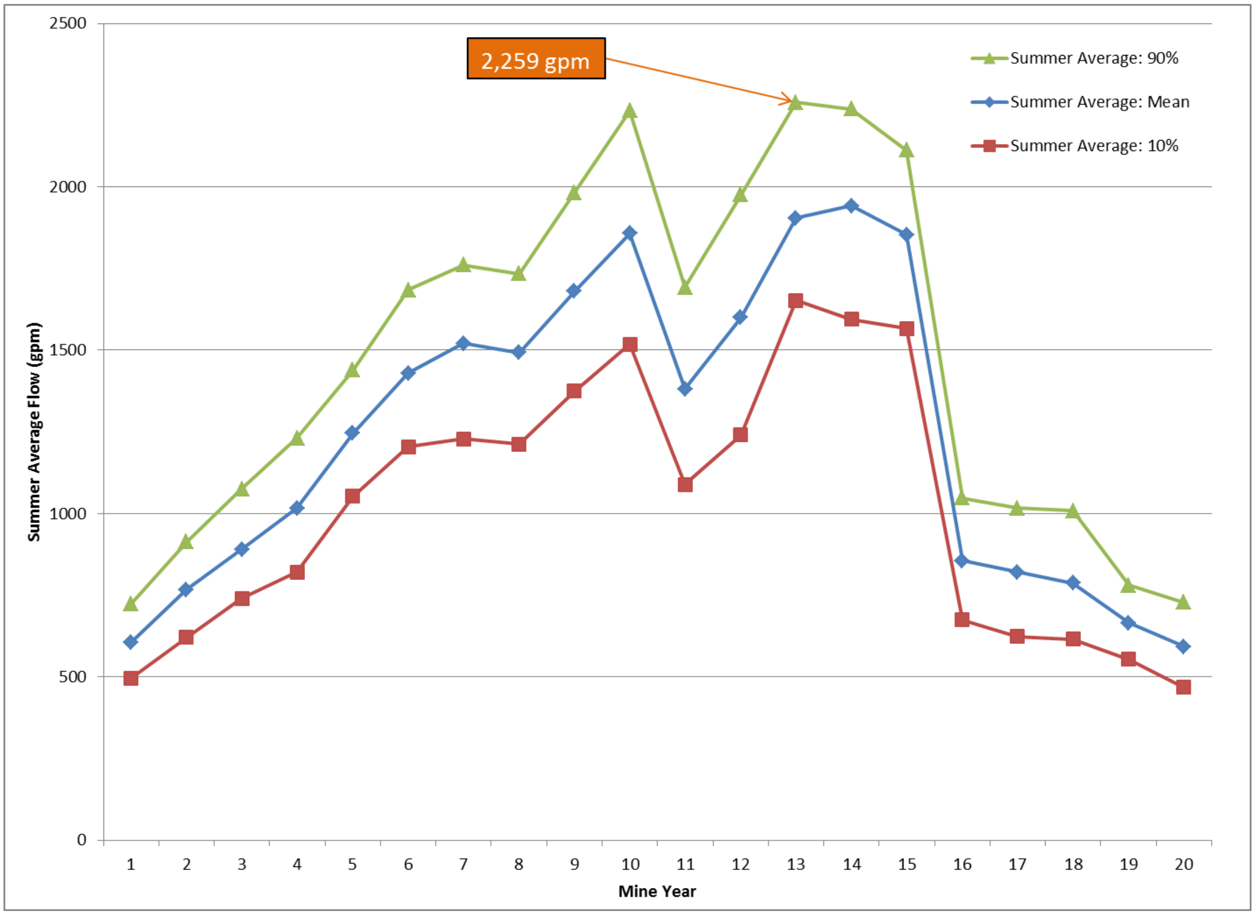


Figure 2-4 **Summer Average Flow to the Low Concentration Equalization Basins – Statistical Summary**

Figure 2-5 (HCEQ Basin Annual Average) and Figure 2-6 (HCEQ Basin Summer Average) present the statistical variability of the mine water for the combined mine water streams reporting to the HCEQ Basin. In addition to P90 values, the mean and P10 are also plotted for reference purposes. As shown on these figures, the peak flow to the HCEQ Basin occurs in Mine Year 10 under both annual average and average summer conditions.

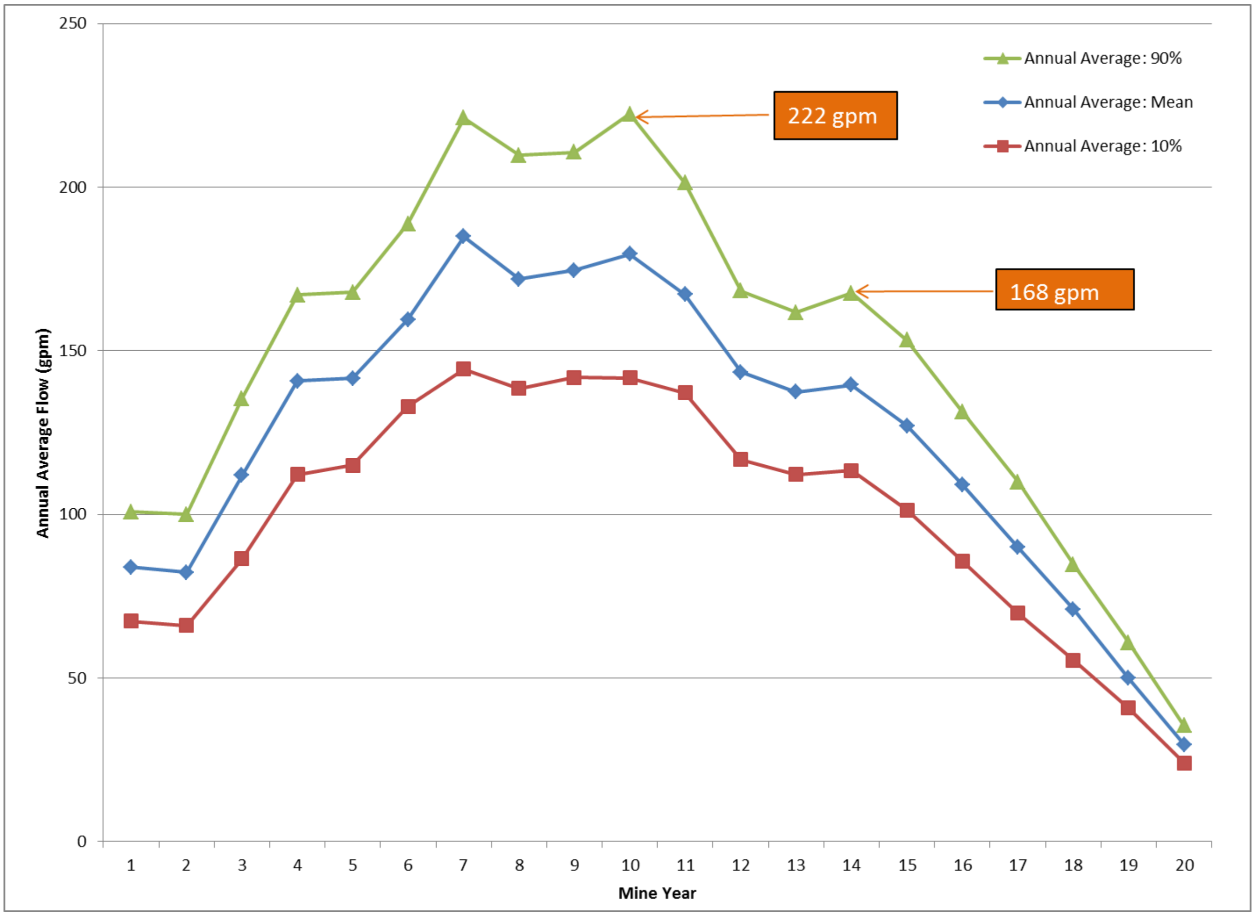


Figure 2-5 Annual Average Flow to the High Concentration Equalization Basin – Statistical Summary

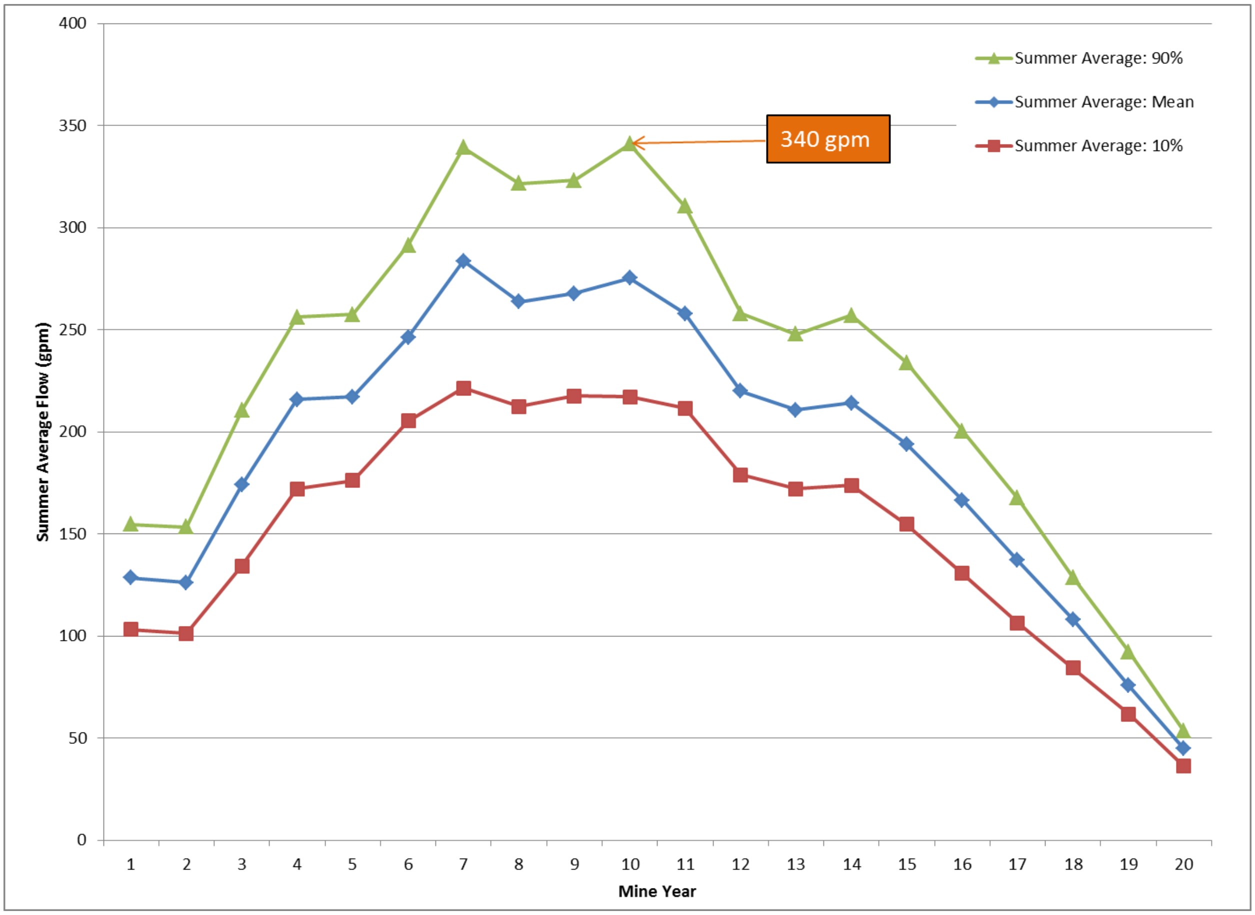


Figure 2-6 **Summer Average Flow to the High Concentration Equalization Basin – Statistical Summary**

The GoldSim modeling results suggest that the peak mine water flow to the LCEQ Basins occurs between Mine Years 10 and 14 and the HCEQ Basin peak occurs around Mine Year 10. The sizes for the basins were determined from the spring snowmelt event flow rate, which is greater than the annual average flow rates. The annual average and summer average flow rates for the mean and P90 conditions for each equalization basin are outlined in Table 2-2.

Table 2-2 Design Flow Rates for the Equalization Basins during Annual Average and Summer Average Conditions in Key Mine Years

	Annual Average(1)		Summer Average(1)	
	Mean	**P90**	**Mean**	**P90**
Low Concentration Equalization Basins (Mine Year 10)	1,460 gpm	1,755 gpm	1,858 gpm	2,233 gpm
Low Concentration Equalization Basins (Mine Year 13)	1,300 gpm	1,599 gpm	1,904 gpm	**2,259 gpm**
Low Concentration Equalization Basins (Mine Year 14)	**1,530 gpm**	**1,781 gpm**	**1,941 gpm**	2,239 gpm
High Concentration Equalization Basin (Mine Year 10)	180 gpm	222 gpm	275 gpm	341 gpm

Bold font denotes values used for basin design.
(1) Source: Reference (1)

As shown in Table 2-2, both the LCEQ Basins and HCEQ Basin P90 annual average flows are less than the mean summer average values.

2.2 Mine Water Flow Design Basis

The previous sections of this report present the flow information for the mine water streams for the combined flows to the LCEQ Basins and HCEQ Basin. The flows to the LCEQ Basins include the mine water that will be conveyed to the headworks of the membrane separation treatment train. The HCEQ Basin flows include the mine water that will be conveyed to the chemical precipitation treatment train. The hydraulic capacity design for the chemical precipitation treatment train must also include the membrane separation concentrate process stream and the VSEP Concentrate from the tailings basin seepage treatment train at the WWTS. P90 flow values for these streams were used as the design basis.

In addition to the variability of the hydraulic loading to the mine water treatment trains at the WWTS over the operations phase, hydraulic loading will also vary within any year. While groundwater inflow to the pits provides a baseline flow, seasonal variations in precipitation will often result in a high volume hydraulic load for a limited duration, which is anticipated to occur in the spring as a result of snowmelt (Large Table 1). While the overall capacity of the mine water treatment trains at the WWTS will be matched to the range of annual summer flows, equalization capacity will be used to contain the volume of water generated during seasonal events. A detailed assessment of the required volumes for the equalization basins and the flow rates for the two treatment trains is described below.

2.2.1 Equalization Basin Hydraulic Load and Storage Volume Requirements

To address the seasonal variability of the flows, while minimizing the overall size of the mine water treatment trains at the WWTS to the extent practical, the LCEQ Basins and HCEQ Basin will be sized to contain the volume of mine water that will report to the basins during the one-month spring snowmelt event and then will be emptied over the course of the summer, so that the basins are empty during the winter months and ready to accept the spring snowmelt volume in subsequent years. Mine water from floods larger than described above will be stored in the sumps and/or mine pits and conveyed to the equalization basins as basin capacity becomes available.

The required equalization basin volumes and associated mine water flow rates are calculated concurrently, assuming the following constraints:

- The equalization basins must have sufficient volume to hold the P90 spring and summer flows less the treatment rate without overfilling at any time.
- The treatment rate must be sufficient to treat the volume of water delivered to the equalization basins prior to day 245, which is the projected duration of time between when ice completely melts from the basins in the spring until ice starts to form again in the fall each year.
- The LCEQ Basins will be constructed as two basins to provide operational flexibility.
- The equalization basins must fit within the proposed configuration of the Mine Site boundary.

2.2.1.1 Low Concentration Equalization Basins

Table 2-3 shows the projected spring snowmelt volumes to the LCEQ Basins and the required outflow to the membrane separation train by Mine Year. Based on these flows and the constraints of the Equalization Basin Area site, Table 2-3 also shows the potential volume sizing requirements for the LCEQ Basins, with a maximum value of 107 ac-ft. The cumulative volume in the LCEQ Basins at any time is based on the spring snowmelt entering at the 3-day rate for the first 3 days, followed by an additional 27 days at the 30-day rate, and the P90 summer average flow for the remainder of the 245-day period, with varying discharge rates from the LCEQ Basins represented by different line types for different Mine Years shown on Figure 2-7, Figure 2-8, and Figure 2-9.

Table 2-3 Peak Spring Snowmelt Flows for the Low Concentration Equalization Basins

Low Concentration Equalization Basin Flows	Mine Year 1	Mine Year 5	Mine Year 10	Mine Year 11	Mine Year 14	Mine Year 20
Cumulative 3-day Spring Snowmelt (gpm), Day 1-3 (1)	1,936 gpm	3,853 gpm	6,225 gpm	3,916 gpm	3,889 gpm	3,002 gpm
Cumulative 1-month Spring Snowmelt (gpm), Day 4-30(1)	874 gpm	1,891 gpm	3,050 gpm	1,701 gpm	1,675 gpm	1,007gpm
P90 Summer Average (gpm), Day 30-215(2)	724 gpm	1,438 gpm	2,233 gpm	1,692 gpm	2,239 gpm	591 gpm
P90 Winter Average (gpm), Day 216+(2)	107 gpm	528 gpm	1,124 gpm	1,172 gpm	1,175 gpm	124 gpm
Required Low Concentration Equalization Basin Outflow to Prevent Basins from Overfilling and to Empty Basin Prior to Day 245	678(4) gpm	1,416(3) gpm	2,561(3) gpm	1,653(4) gpm	2,079(4) gpm	609(4) gpm
Maximum Accumulation in Low Concentration Equalization Basin	77 ac-ft	107 ac-ft	107 ac-ft	63 ac-ft	107 ac-ft	77 ac-ft

(1) Source: Large Table 1
(2) Source: Reference (1)
(3) Basin outflow controlled by the limit of available basin capacity
(4) Basin outflow controlled by winter emptying of basin

Figure 2-7, Figure 2-8, and Figure 2-9 are graphical representations of how influent flow and LCEQ Basin size are used to determine the design capacity for the membrane separation treatment train. Based on these graphs, the membrane separation treatment train will need to have a minimum Mine Year 5 capacity of 1,416 gpm and Mine Year 10 capacity of 2,561 gpm to maintain the LCEQ Basins volume at a reasonable capacity of 107 acre-feet and avoid overfilling the basins during spring snowmelt flows.

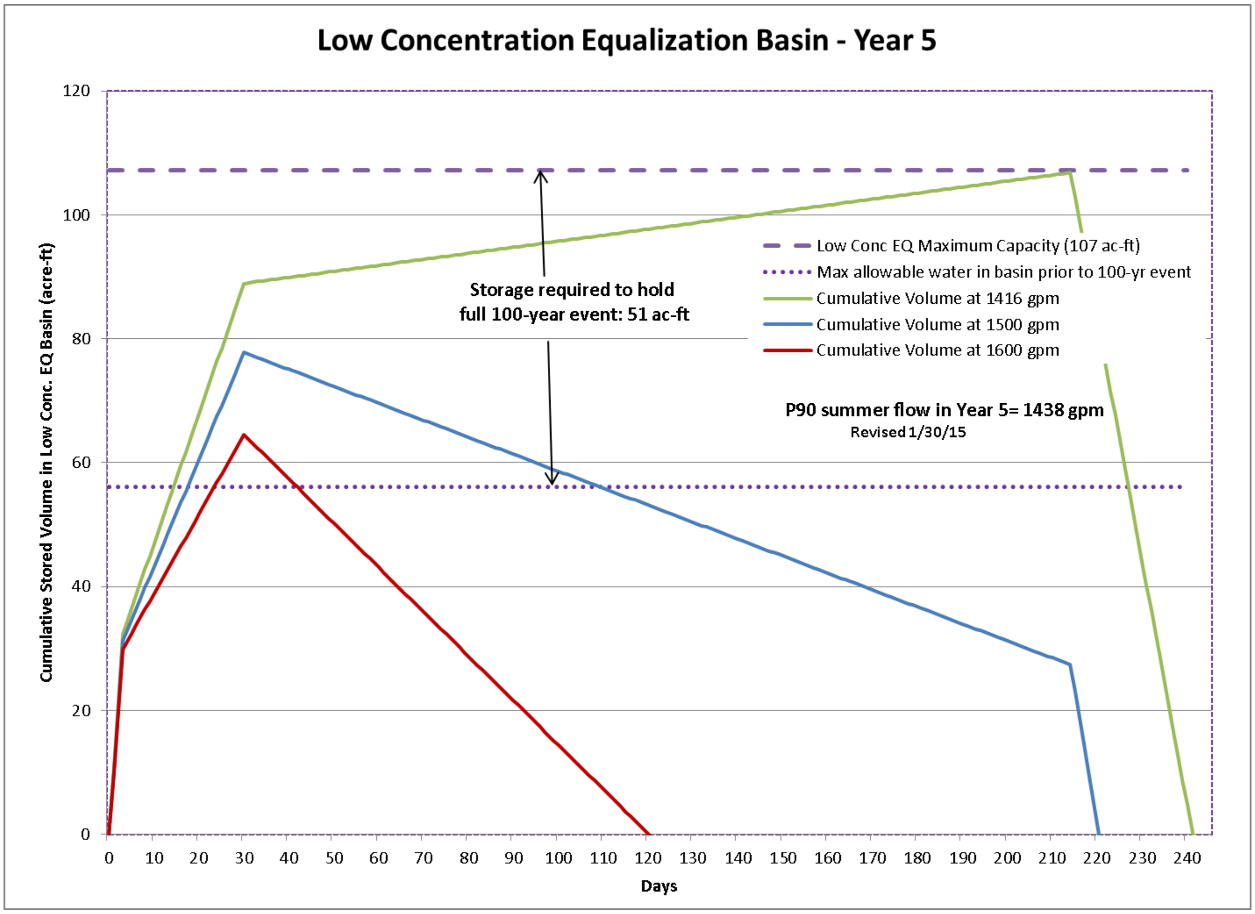


Figure 2-7 **Low Concentration Equalization Basins Mine Year 5 Storage Volumes at Varying Treatment Capacity**

As shown in Figure 2-7, the spring flow in Mine Year 5 is higher than the summer flow due primarily to groundwater and surface runoff from the East Pit. In that year, the maximum equalization basin elevation will likely occur in late spring at the end of snowmelt.

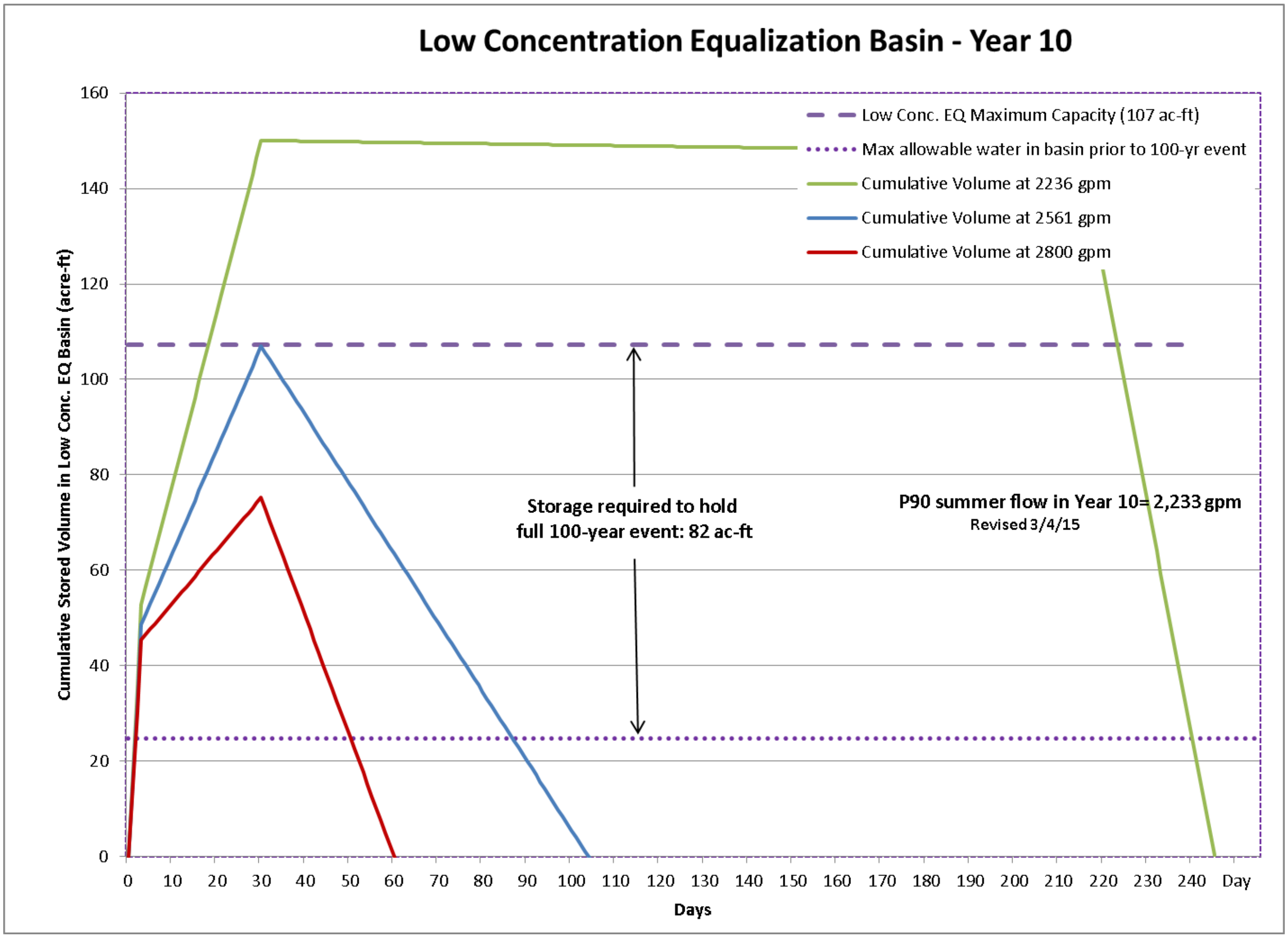


Figure 2-8 **Low Concentration Equalization Basins Mine Year 10 Storage Volumes at Varying Treatment Capacity**

Mine Year 10 will require the largest treatment capacity to prevent overfilling of the LCEQ Basins during high spring flows.

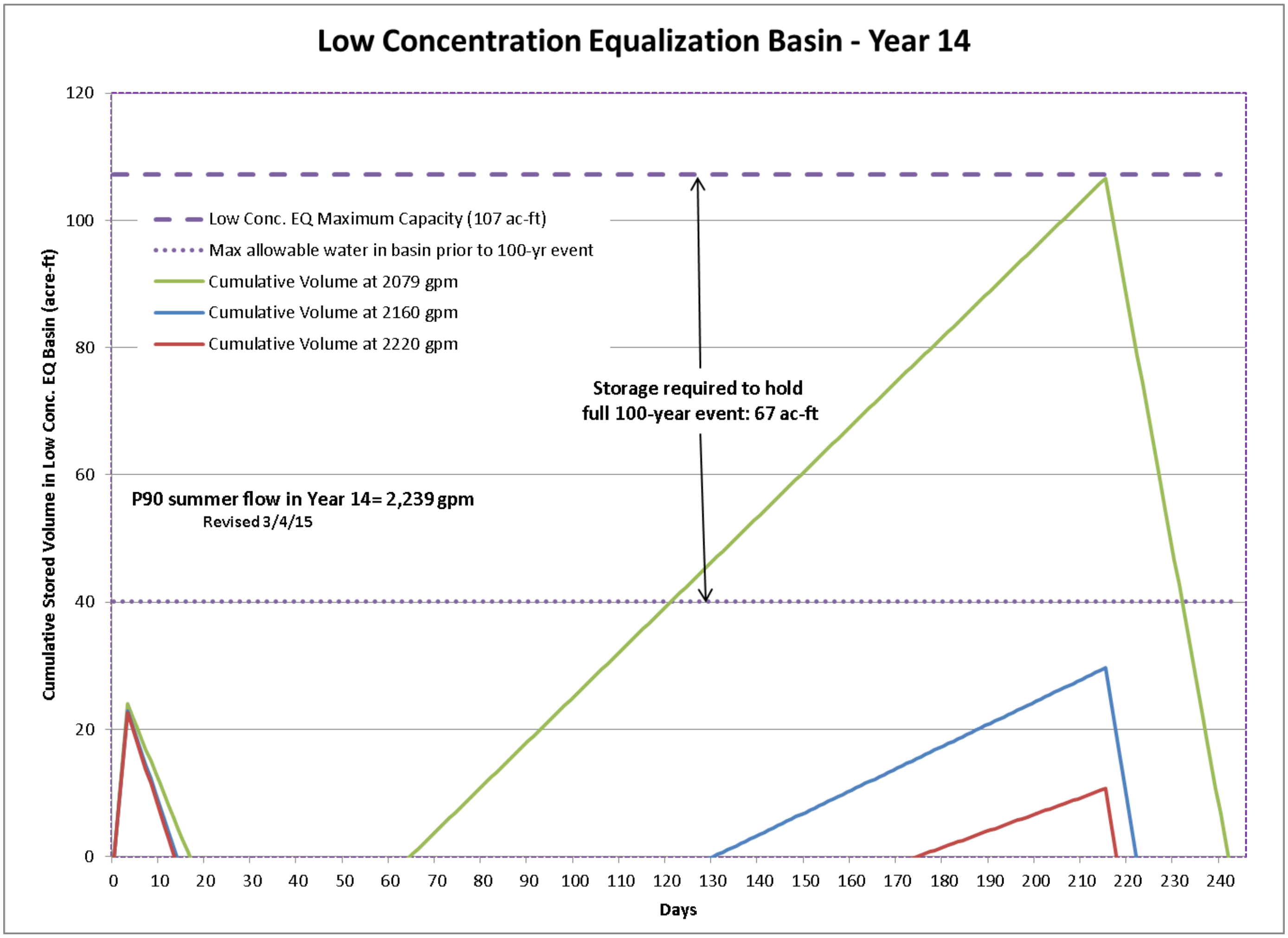


Figure 2-9 Low Concentration Equalization Basins Mine Year 14 Storage Volumes at Varying Treatment Capacity

Mine Year 14 has the highest summer average flow; however, this year will not have the highest treatment requirement. In contrast to Mine Years 5 and 10, the Mine Year 14 summer flow is greater than the spring flow because snowmelt can be held in the East and Central Pits until high spring flows are done. This reduces the required treatment capacity in Mine Year 14.

Because the spring snowmelt flows are much higher than the summer flows into the LCEQ Basins in Mine Years 5 and 10, the design capacity of the mine water treatment trains at the WWTS can be reduced significantly because of the flow equalization capacity of the LCEQ Basins even with size constraints of the site. For Mine Years 1, 5, 11, and 14, the minimum design influent to the membrane separation treatment train is lower than the P90 summer average flow. However, in Mine Year 10, the minimum required flow to the membrane separation treatment train is higher than the P90 summer average flow, as shown on Table 2-3.

As noted previously, the total LCEQ Basins volume will be split into two separate basins: LCEQ Basin 1 and LCEQ Basin 2 for operational flexibility. Apportionment of these basins is described in the following section.

2.2.1.2 Low Concentration Equalization Basins Apportionment

To apportion the sizes of LCEQ Basins 1 and 2, a maximum volume for the smaller of the two basins was calculated based on the volume needed to accommodate the highest instantaneous peak mine water flow rate to the WWTS for various scenarios listed in Table 2-4. The maximum instantaneous flow to the LCEQ Basin 2 is the Category 1 Stockpile Groundwater Containment System flows associated with a 1.5-inch rainfall event with a duration of one day. Based on this inflow, the LCEQ Basin 2 should be sized at a minimum volume of 26 acre-feet to accommodate this maximum peak flow. Flow out of this basin could also be routed to either the membrane separation treatment train or the chemical precipitation train, depending on the water quality and treatment needed.

Table 2-4 Low Concentration Equalization Basin 2 Sizing

Peak Flow Rate Event	Flow Rate into Low Concentration Equalization Basin 2	Event Duration	Storage Duration	Total Volume (MG)	Total Volume (ac-ft)
Category 1 Stockpile High Flow Pumping, 1.5-inch Rainfall	5,785 gpm	24-hour	1 day	8.33 MG	25.6 ac-ft
Category 1 Stockpile High Flow Pumping, Spring Snowmelt	1,175 gpm	3 days	3 days	5.08 MG	15.6 ac-ft
Category 1 Stockpile Low Flow Pumping, Spring Snowmelt	839 gpm	30 days	7 days	8.46 MG	26.0 ac-ft

Note: Category 1 Stockpile low flow pumping rates and Low Concentration Equalization Basins annual summer flow rates were included in the total flows to the Low Concentration Equalization Basin 2 for this sizing exercise.

Both LCEQ Basins will work together to provide the total equalization storage required for the membrane separation treatment train, which was previously established as 107 acre-feet based on Figure 2-8 and Figure 2-9. Therefore, the storage required within the LCEQ Basin 1 is the difference between the total storage required and the LCEQ Basin 2 storage. The final sizes of both LCEQ Basins are shown in Table 2-5.

Table 2-5 Low Concentration Equalization Basins Storage Volumes

Basin	Size (acre-feet)
Low Concentration Equalization Basin 1	81 acre-feet
Low Concentration Equalization Basin 2	26 acre-feet
Total Storage	107 acre-feet

2.2.1.3 High Concentration Equalization Basin

Table 2-6 and Figure 2-10 show the potential volume sizing requirements for the HCEQ Basin. The cumulative volume is based on the Spring Flood entering the HCEQ Basin at the 30-day rate. The cumulative volume is calculated for three different potential flow rates for the chemical precipitation treatment train.

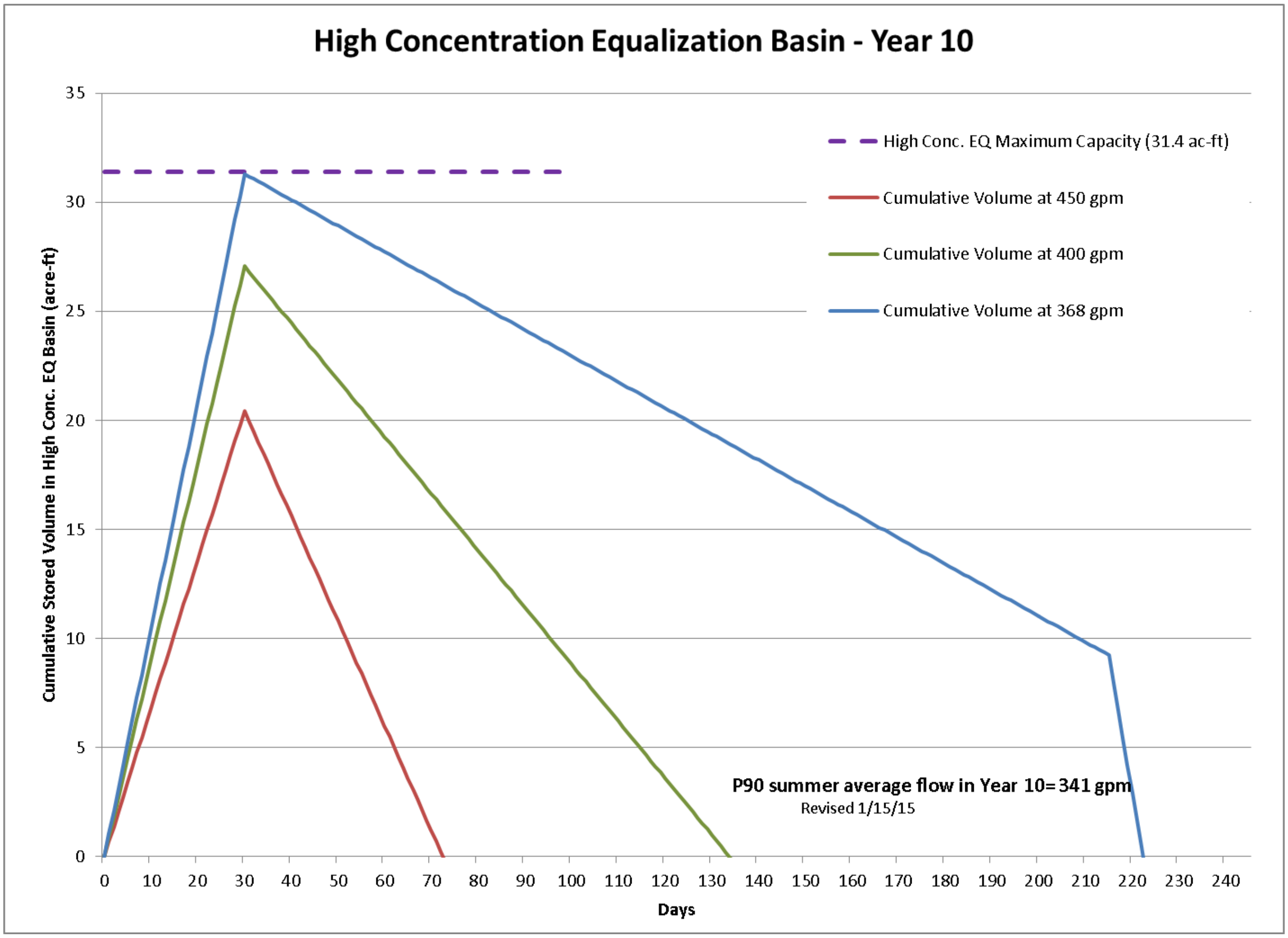
Table 2-6 shows the required spring snowmelt volumes into the HCEQ Basin and the required outflow to the chemical precipitation treatment train by Mine Year.

Table 2-6 Peak Spring Snowmelt Flows for the High Concentration Equalization Basin

High Concentration Equalization Basin Flows	Mine Year 1	Mine Year 5	Mine Year 10	Mine Year 14	Mine Year 20
Cumulative 3-day Spring Snowmelt, Day 1-3$^{(1)}$	291 gpm	471 gpm	604 gpm	479 gpm	72 gpm
Cumulative 1-month Spring Snowmelt, Day 4-30$^{(1)}$	291 gpm	471 gpm	604 gpm	479 gpm	72 gpm
P90 Summer Average, Day 30-215$^{(2)}$	155 gpm	258 gpm	341 gpm	257 gpm	53 gpm
P90 Winter Average, Day 215+$^{(2)}$	34 gpm	66 gpm	83 gpm	64 gpm	19 gpm
Required Equalization Basin Outflow to Prevent Basin Overfilling and to Empty Basin Prior to Day 245$^{(1)}$	157 gpm	260 gpm	368 gpm	260 gpm	52 gpm
Maximum Accumulation in High Concentration Equalization Basin$^{(1)}$	18 ac-ft	28 ac-ft	31 ac-ft	29 ac-ft	4 ac-ft

(1) Source: Large Table 1
(2) Source: Reference (1)

Figure 2-10 is a graphical representation of how influent flow and treatment capacity is used to determine the HCEQ Basin size and outflow rate. Based on this graph, the flow from the HCEQ Basin into the chemical precipitation treatment train will need to be 368 gpm or greater to maintain the HCEQ Basin at a reasonable volume of 31 acre-feet and avoid overfilling the basin during spring snowmelt flows.



High Concentration Equalization Basin - Year 10

P90 summer average flow in Year 10=341 gpm
Revised 1/15/15

Figure 2-10 **Potential High Concentration Equalization Basin Storage Volumes**

2.2.2 Construction Mine Water Treatment and Equalization Basin

Construction mine water, a dilute type of mine water, will be generated during the construction of the waste rock stockpile foundations and other mining features. Specifically, this will include water from dewatering of saturated mineral overburden, which will have the potential to release dissolved metals and other constituents during the dewatering process. This water will not be treated at the WWTS, but will be captured and treated, as needed, to remove turbidity and suspended or dissolved materials prior to being discharged to the FTB Pond. Construction mine water quality predictions (see Section 3.5) indicate that some level of water treatment may be necessary to meet the mine water quality targets for discharge from the Mine Site to the FTB Pond. A preliminary evaluation of the water quality data and potential treatment alternatives suggests that chemical precipitation and settling will be able to treat the construction mine water to acceptable concentrations.

2.2.2.1 Construction Mine Water Flows

Based on the construction sequencing developed for stockpiles and other mining facilities, a weekly estimate of construction mine water quantity was calculated. These weekly construction mine water quantity estimates were totaled for each design year, yielding the annual construction mine water volumes shown in Table 2-7.

Table 2-7 Estimated Construction Mine Water Flows

Mine Year	Groundwater Sources (MG)	Excavation Runoff (MG)	Total Flow (MG)
Construction Phase	287.9	33.1	321.0
1	0	0	0
2	86.6	10.9	97.5
3	47.2	0.7	47.9
4	3.8	0.1	3.9
5	37.8	1.7	39.6
6	32.4	0.5	32.9
8	62.4	5.9	68.3
10	68.0	5.6	73.6
11	112.0	8.6	120.5

Source: Exhibit 1

2.2.2.2 Construction Mine Water Treatment

The predicted water quality of the construction mine water and the treatment required to remove parameters to concentrations below the water quality targets at the flow rates listed on Table 2-7 was evaluated. Water quality parameters of concern are expected to be removed to acceptable levels through the addition of ferric chloride, sodium hydroxide, and sodium silicate. Solids generated by this treatment process are projected to be approximately 11 acre-feet for the construction phase prior to the start of mining. Segregation of the construction mine water basin into treatment, settling, and clean water zones will likely be necessary to prevent re-dissolution of the parameters of concern. This segregation can be achieved by the installation of temporary baffles. Solids removal from the settling zone at regular intervals during the construction phase is recommended to provide adequate settling capacity and prevent a wash-out during a high precipitation event.

2.2.2.3 Construction Mine Water Basin

The Construction Mine Water Basin is designed to accommodate both construction mine water and runoff from the Overburden Storage and Laydown Area (OSLA). The peak year for construction mine water generation is the construction phase when approximately 321 million gallons (MG) of construction mine water is expected to need treatment. Once in the operations phase, construction activities are reduced significantly for the duration of the Project, ranging from zero in years without construction activities to approximately 121 MG in Mine Year 11. Mine Year 11 is the last year of projected construction mine water flows and the peak year of construction mine water flow rates during the operations phase. Construction mine water is not expected to be generated after Mine Year 11. Runoff from the OSLA, which will be routed to the Construction Mine Water Basin, is estimated to average approximately 2.9 MG per year.

The capacity of the HCEQ Basin, 32 ac-ft, is sufficient to provide both treatment capacity and storage capacity of solids generated from treatment of construction mine water during the construction phase. The HCEQ Basin was sized to utilize the available footprint of the site, as described in Section 2.2.1.

The Mine Year 11 inflow to the Construction Mine Water Basin of approximately 121 MG construction mine water plus 2.9 MG OSLA runoff will generate approximately 4.1 acre-feet of treatment solids. A Construction Mine Water Basin sized for approximately 10 acre-feet will provide sufficient capacity for both treatment and solids storage during the Mine Year 11 construction season. The Construction Mine Water Basin will be designed to include baffles or internal dikes for treatment, sludge storage, settling, and clean water zones to prevent re-dissolution of the parameters of concern and wash-out that may occur during high precipitation events.

3.0 Water Quality Design Basis

This section summarizes the statistical evaluation of the GoldSim modeling results for the Mine Site to determine the design loads to the mine water treatment trains at the WWTS. Establishment of the basis for the mine water influent quality to the WWTS treatment units will allow the development of treatment models that can be used to determine power requirements, chemical usage rates, sludge generation rates, and other design parameters.

3.1 Statistical Evaluation of GoldSim Water Quality Estimates

The water quality values generated by the GoldSim modeling that was conducted for the FEIS (Reference (1)) establish a range of potential water quality values for mine water flows routed to the WWTS. A statistical evaluation of the data was completed to refine this information into values that could be used as the basis for design as described in the following sections.

3.1.1 Mine Water Influent Chemistry Data

The water quality predictions summarized in Table 2-5 and Table 2-6 represent the P90, mean, and P10 values for the average annual water quality projections from the GoldSim model for each of the two equalization basins that serve as mine water inputs to the WWTS based on the results of 100 model realizations. In addition, the solutions represented by the water quality data are not charge balanced.

To develop appropriate design values for the mine water influent quality to the WWTS, the GoldSim output values needed to be adjusted and evaluated to narrow the range of potential input values that can be evaluated in the treatment system modeling. First, the values were adjusted as outlined in Table 3-1 to achieve ion balance, assuming a pH of 7 for LCEQ Basin water and a pH of 5 for HCEQ Basin water. Silicon concentrations were estimated using a molar ratio of 1.4:1 Si:Ca, in accordance with the stoichiometry of the weathering reaction that generates those constituents from rocks similar to those that will be mined for the Project, with the maximum concentration of silica capped at 54 mg/L. Next, the following factors were considered in the development of the water quality design basis:

- Some constituents and sources may have concentrations that are positively correlated or independent of flow rate (i.e., solubility-limited at the source). For these constituents and sources, the upper distributions of flow and concentration could be concurrent.
- Some constituents and sources may have concentrations that are negatively correlated to flow rate. For such constituents and sources, assuming that the upper end of the concentration distribution is concurrent with the upper end of the flow distribution will be overly-conservative from a mass loading standpoint.

Thus, a key step in developing the water quality design basis was identifying those constituents and sources whose concentrations appear to be positively or negatively correlated with flow rate. A principal component analysis (PCA) was completed to identify these potential correlations, as described further below.

Table 3-1 Concentration Design Basis for the Mine Water Treatment Trains at the WWTS

		Low Concentration Equalization Basin			High Concentration Equalization Basin		
Parameter	**Units**	**Mine Year 1**	**Mine Year 5**	**Mine Year 10**	**Mine Year 1**	**Mine Year 5**	**Mine Year 10**
pH	std units	7	7	7	5	5	5
Silver	µg/L	0.1	0.2	0.2	15.0	33.9	43.0
Aluminum	µg/L	1.4	1.7	1.7	133.8	213.3	372.8
Alkalinity	mg/L as HCO3-	666.0	1387.8	738.0	22.8	15.7	17.5
Arsenic	µg/L	56.9	77.9	55.0	304.0	409.3	337.1
Boron	µg/L	78.1	88.8	76.8	371.7	739.2	680.9
Barium	µg/L	33.6	26.9	29.6	137.8	209.3	165.4
Beryllium	µg/L	0.3	0.4	0.4	22.8	37.6	35.9
Inorganic Carbon	mg/L as HCO3-	694.2	1,621.2	865.8	1.0	1.0	1.0
Calcium	mg/L	201.2	300.0	223.2	380.1	380.2	1557.9
Cadmium	µg/L	7.3	4.7	4.9	56.3	87.6	119.8
Chloride	mg/L	144.5	56.0	24.8	208.2	50.4	46.5
Cobalt	µg/L	343.9	271.2	185.7	3,252.4	7,342.4	14,483.5
Chromium	µg/L	5.4	5.0	3.7	9.5	23.1	26.7
Copper	µg/L	2,415.7	1,410.0	1,528.8	8.6	11.0	61.2
Fluoride	mg/L	1.4	1.1	0.7	2.2	2.0	1.8
Iron	µg/L	157.1	184.2	189.6	190.3	539.4	526.0
Potassium	mg/L	25.2	25.0	18.9	31.7	46.8	41.8
Magnesium	mg/L	72.3	127.8	95.8	182.4	362.0	915.4
Manganese	µg/L	483.8	430.3	351.0	5.1	10.4	41.9
Sodium	mg/L	85.1	105.8	83.4	72.3	234.1	221.4
Nickel	µg/L	3,755.3	3,595.8	2,618.2	12.1	34.4	223.4
Lead	µg/L	2.2	7.0	7.1	106.8	146.0	260.0
Antimony	µg/L	38.4	38.1	26.9	226.0	422.0	1,456.0
Silicon	mg/L	54.0	54.0	54.0	54.0	54.0	54.0
Selenium	µg/L	5.9	11.0	7.2	36.9	135.0	144.0
Sulfate	mg/L	309.6	409.0	553.2	2,614.1	4,980.0	11,210.1

		Low Concentration Equalization Basin			High Concentration Equalization Basin		
Parameter	Units	Mine Year 1	Mine Year 5	Mine Year 10	Mine Year 1	Mine Year 5	Mine Year 10
Thallium	µg/L	0.1	0.2	0.2	0.5	1.8	7.5
Vanadium	µg/L	8.4	9.9	9.8	45.1	59.8	63.2
Zinc	µg/L	633.0	460.0	518.9	6.5	9.4	13.9

🟩 cell values modified to achieve charge balance using PHREEQC
🟧 cells contain values from P90 percentile load concentrations
🟦 cell values estimated from 1.4:1 Si:Ca molar ratio, capped at 54 mg/L

3.1.2 Principal Component Analysis Methods

Each of the 100 realizations generated by GoldSim included a flow and corresponding concentrations for all parameters. For each mine water source, the 100 realization values for Mine Year 14, the stage of the project that controls the ultimate design from a constituent loading standpoint were subjected to PCA testing. PCA is a multivariate statistical method that allows rapid, graphical examination of the result sets for potential correlations between all parameters (Reference (2)). As some of the sources routed to the same equalization basin behaved differently during Mine Year 14, additional PCA analysis was performed to evaluate flow and concentration trends of the combined influent to each equalization basin over the life of the mine.

In the PCA figures, the GoldSim output parameters are each depicted as individual vectors. Those vectors pointing in the same direction contribute to variability in a similar manner, and those constituents, therefore, correlate positively to one another. Vectors pointing in opposite directions (i.e., at 180 degrees) generally correlate negatively to one another, while vectors pointing orthogonally to one another (i.e., at 90 degrees) generally do not correlate to one another. Because these figures are two-dimensional representations of multi-dimensional relationships, both the direction of the vectors and the relative length of the vectors are important in interpreting a potential correlation. Longer vectors generally suggest that the constituent vector is more closely aligned to the plane through the PCA represented on the figure. Thus, longer vectors in the same direction (or opposite directions) suggest greater significance for the correlation inferred by the two vectors in the plane that is represented, while vectors appearing as very short lines are projecting in a direction that is not aligned with the plot and may suggest that the variability of the constituent is not well-described by the plot.

3.1.3 Principal Component Analysis Results and Discussion

The results of the principal component analyses for the individual sources are shown in Figure 3-1 through Figure 3-7. The figures are graphical representations of the variability in the datasets, with the GoldSim output parameters depicted as vectors.

A review of the graphs provides the following summary of mine water quality from the various sources:

- The flow from the East/Central Pit (Figure 3-1) and the West Pit (Figure 3-2) demonstrated similar behavior, with several parameters negatively correlated to flow.

- Mine water from the Category 1 Stockpile Groundwater Containment System (Figure 3-3), shows sodium, sulfate, and lead correlated negatively with flow.
- Mine water from the Category 2/3 Waste Rock Stockpile (Figure 3-4), shows sodium and thallium correlated negatively with flow.
- Mine water from the Lean Ore Surge Pile (Figure 3-5), shows thallium correlated negatively with flow.
- Mine water from the Rail Transfer Hopper (Figure 3-6), shows calcium, sulfate, magnesium, selenium, sodium, potassium, and chromium correlated negatively with flow.
- Mine water from haul road runoff (Figure 3-7), shows calcium, sulfate, magnesium, potassium, arsenic, and chromium correlated negatively with flow.

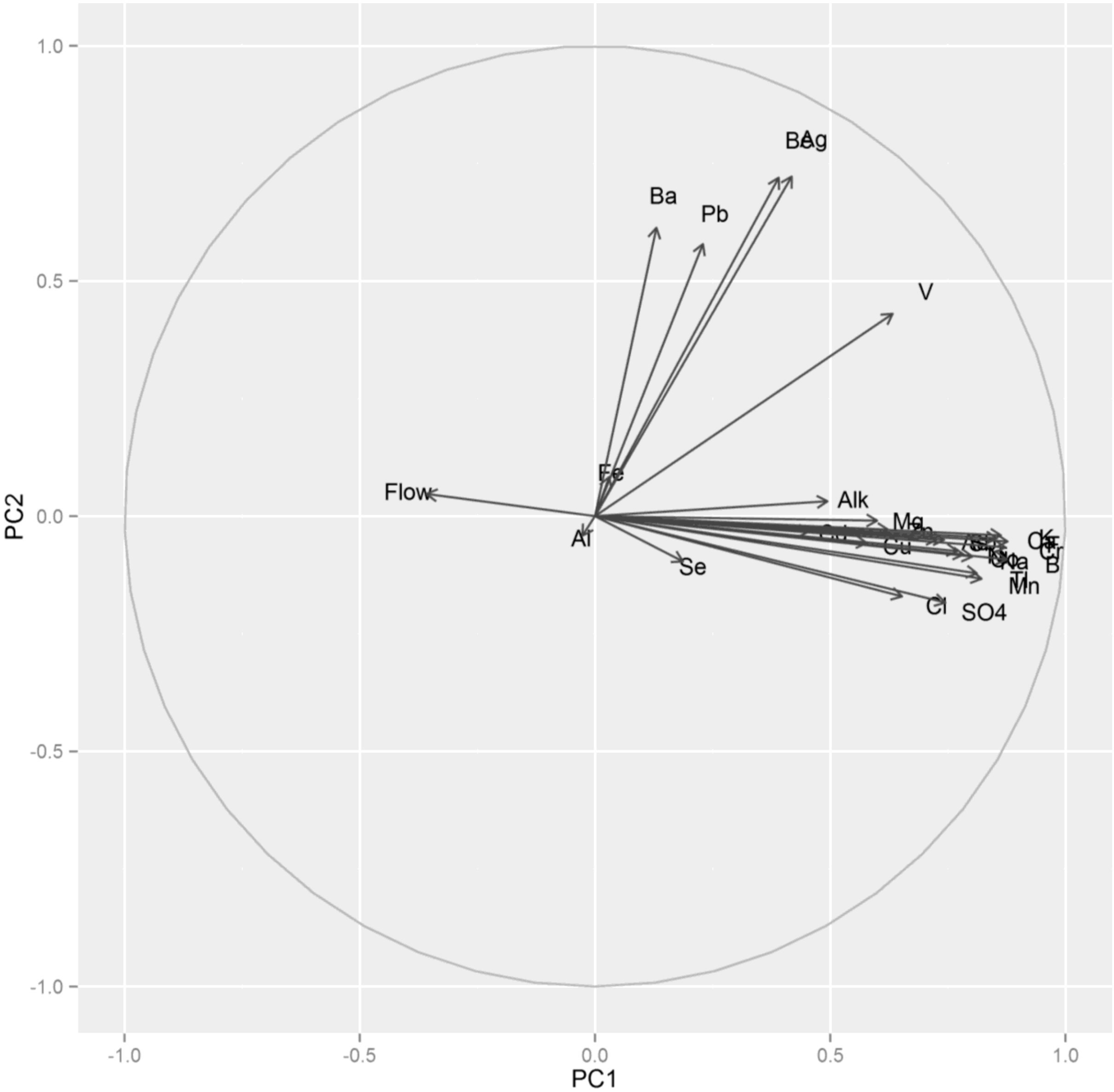


Figure 3-1 Principal Component Plot – East and Central Pits, Mine Year 14

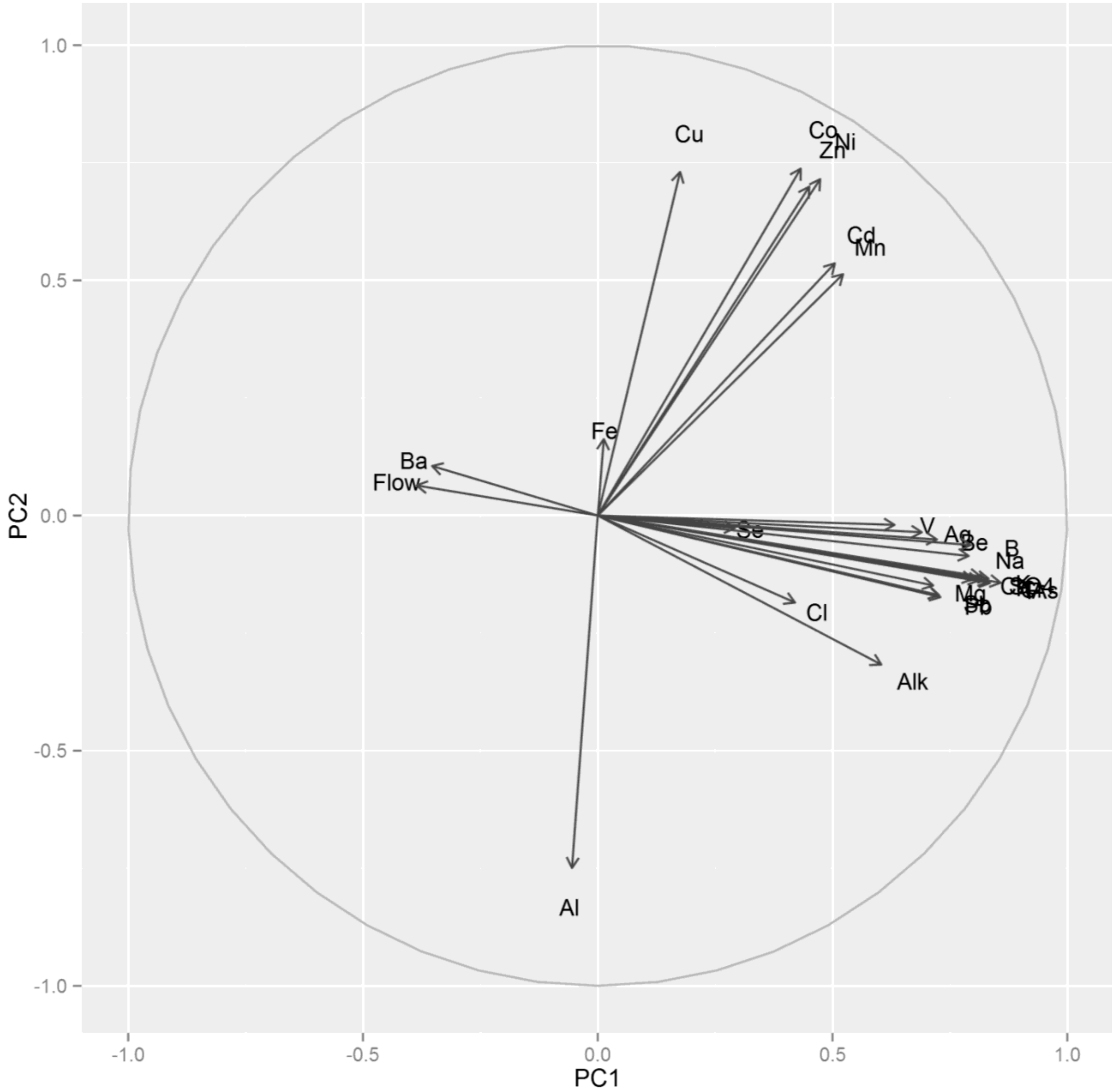


Figure 3-2 Principal Component Plot – West Pit, Mine Year 14

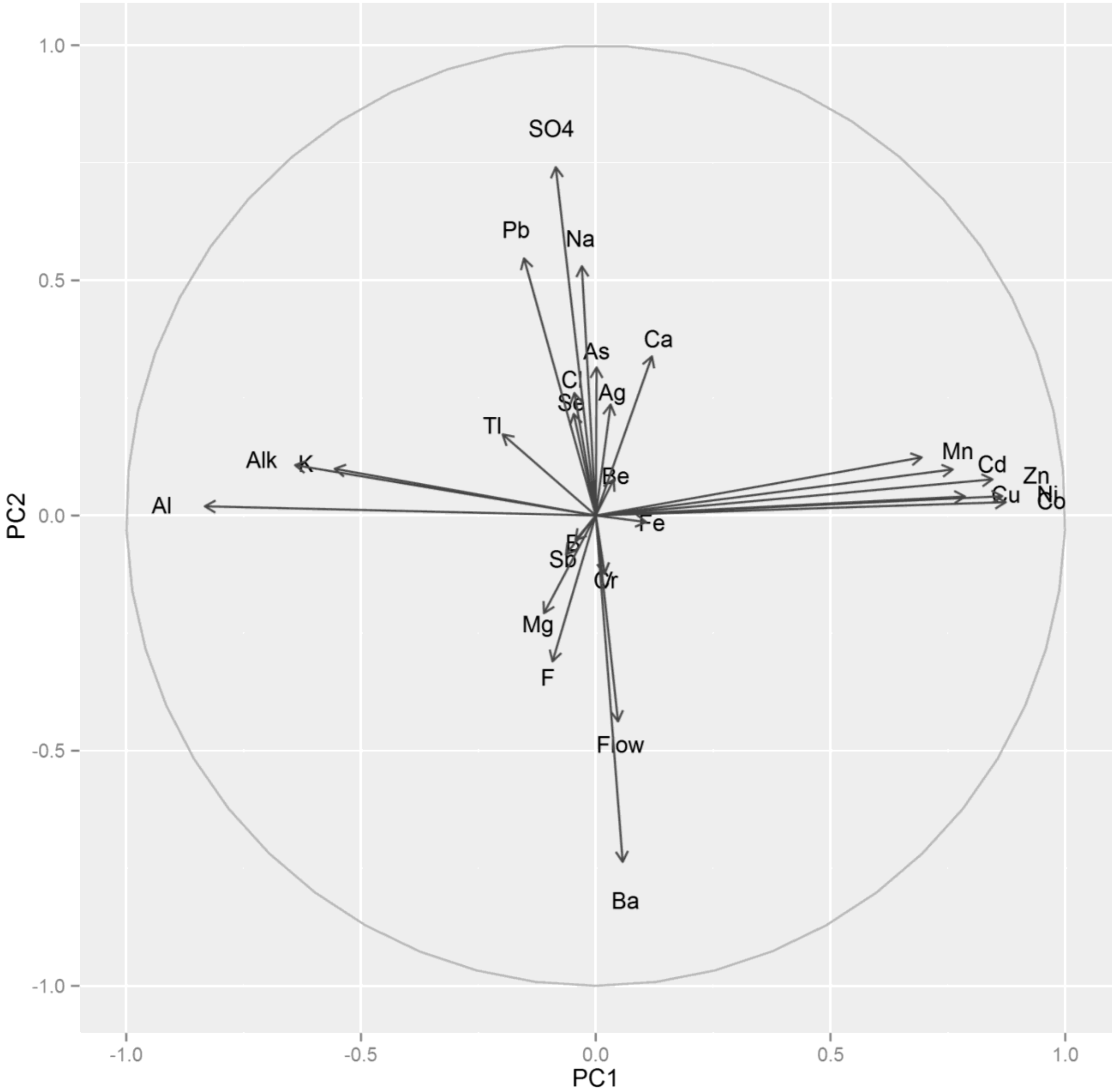


Figure 3-3 **Principal Component Plot – Category 1 Stockpile Groundwater Containment System, Mine Year 14**

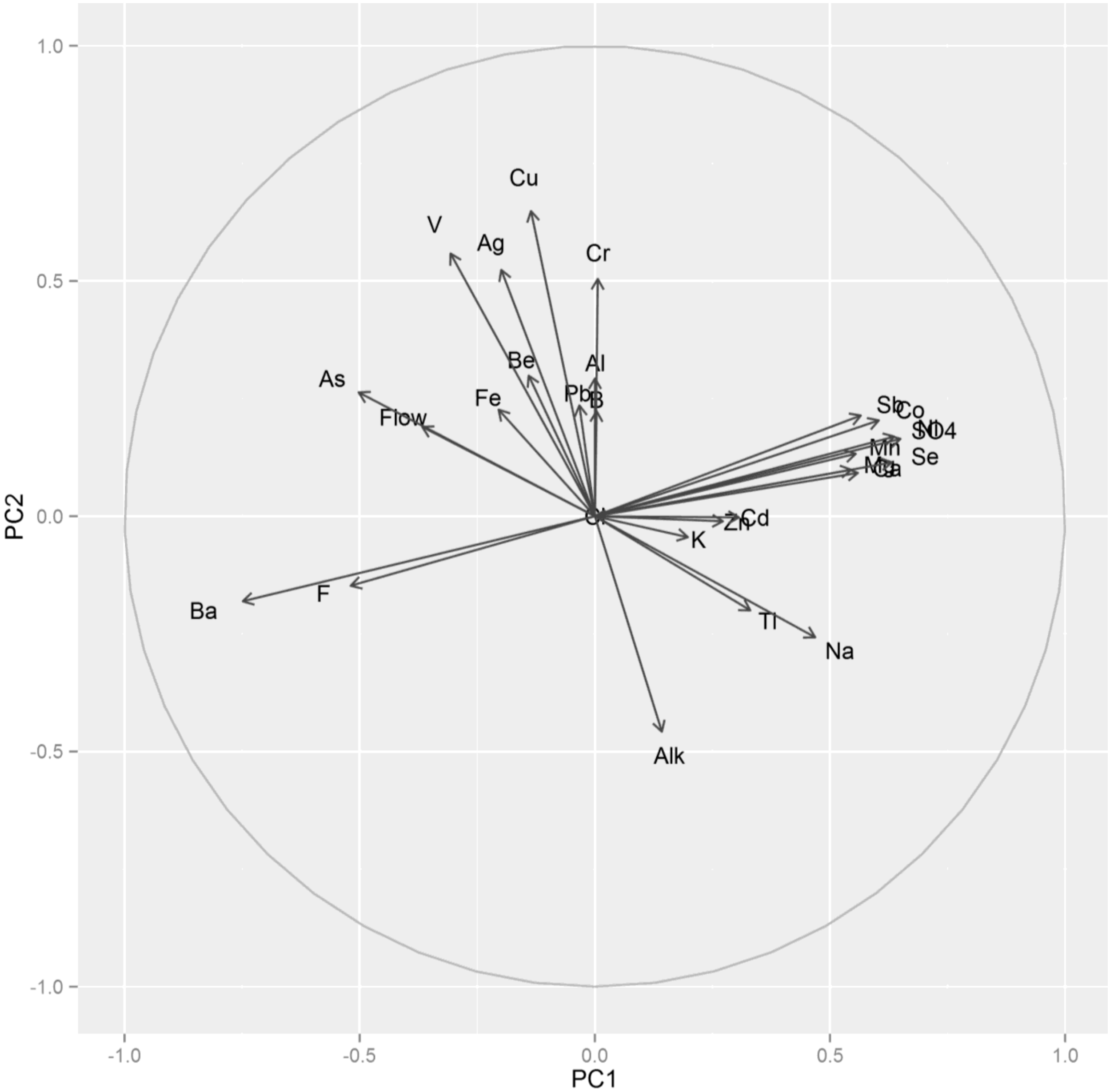


Figure 3-4 Principal Component Plot – Category 2/3 Waste Rock Stockpile, Mine Year 14

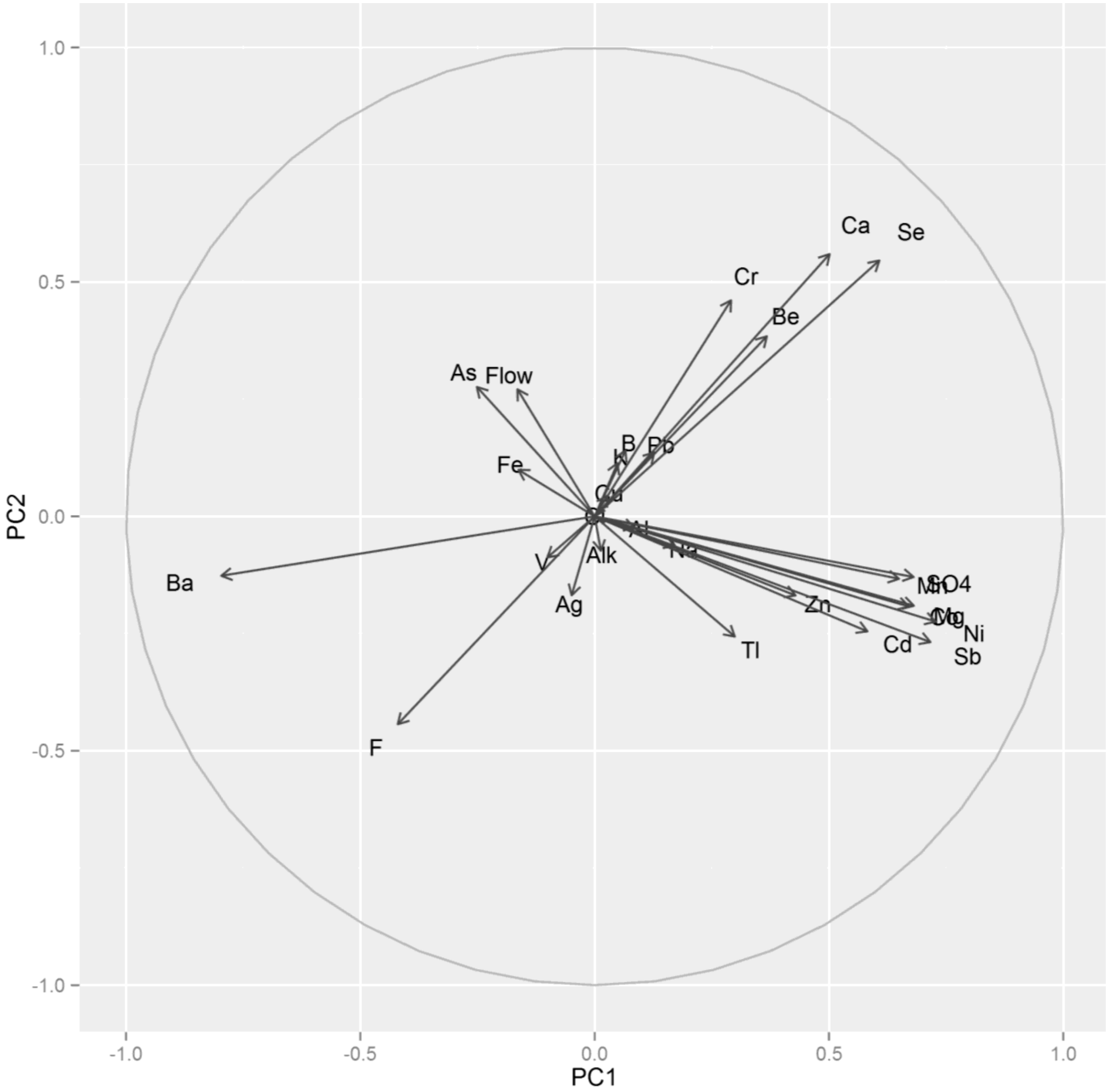


Figure 3-5 Principal Component Plot – Ore Surge Pile, Mine Year 14

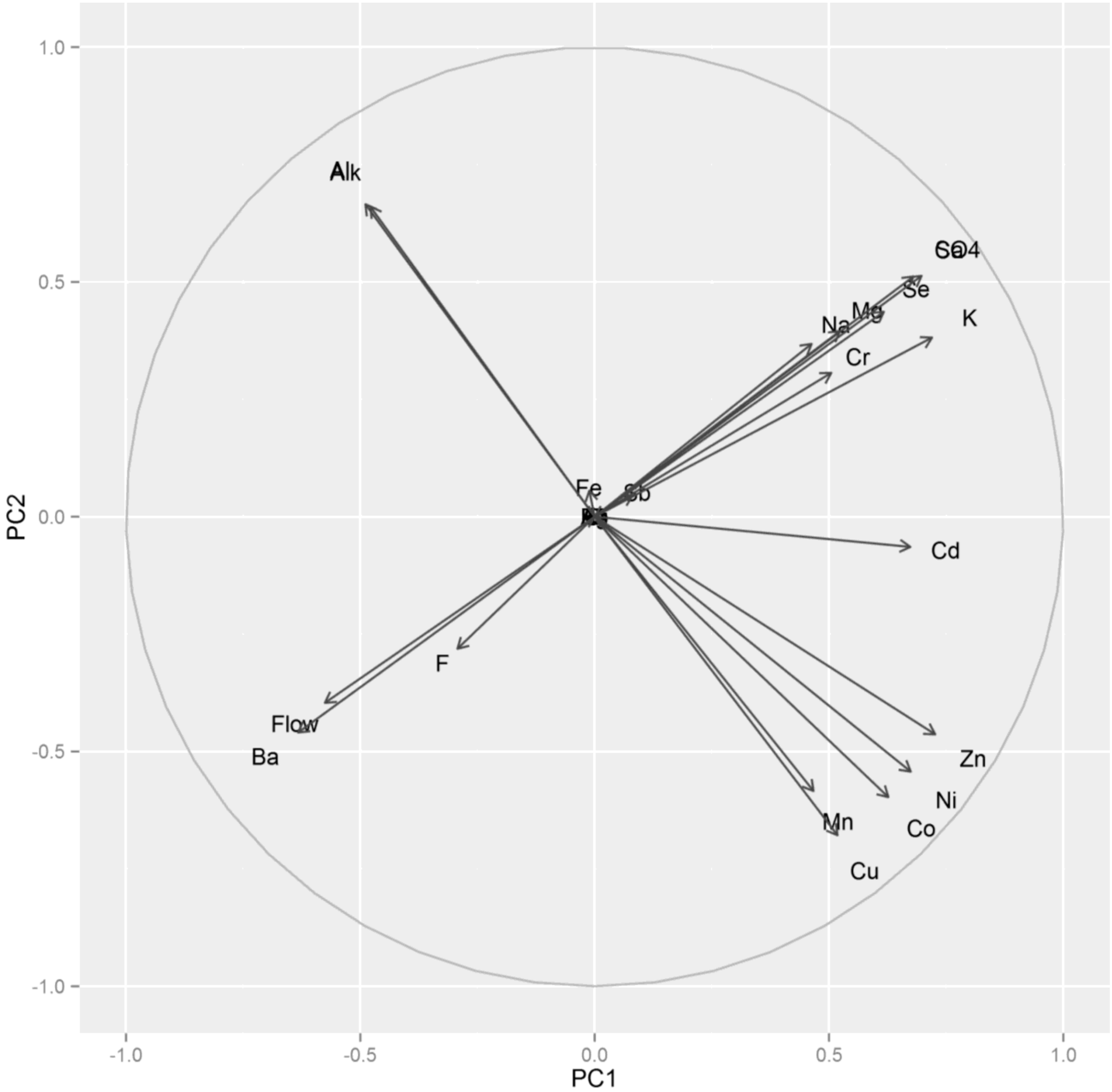


Figure 3-6 Principal Component Plot – Rail Transfer Hopper Runoff, Mine Year 14

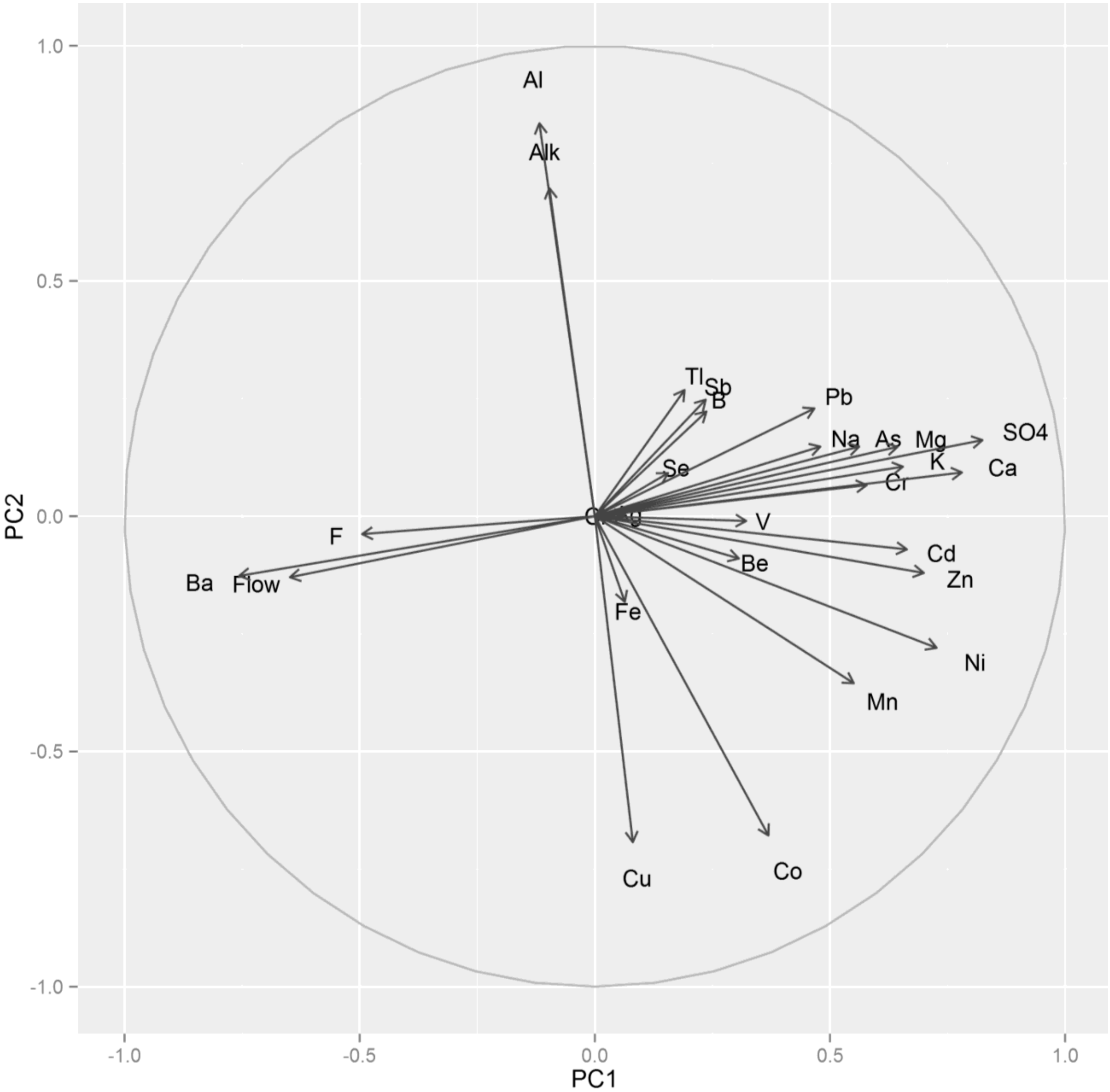


Figure 3-7 Principal Component Plot – Haul Road Runoff, Mine Year 14

The results of the PCA of the combined flows to the equalization basins for different Mine Years are shown in Figure 3-8 through Figure 3-21. A review of these graphs provides the following summary:

- In Mine Year 1, the influent to both the LCEQ Basins and the HCEQ Basin exhibited limited correlations between flow and any dissolved constituents.
- In Mine Years 4 and 5, the influent to the LCEQ Basins exhibited a negative correlation between flow and sulfate, and some metals, while the influent to the HCEQ Basin exhibited a negative correlation between flow and sulfate, selenium, antimony, calcium, and manganese.

- In Mine Year 10, the influent to the LCEQ Basins exhibited a negative correlation between flow and sulfate and beryllium, while the influent to the HCEQ Basin exhibited a negative correlation between flow and sulfate, calcium, and selenium.
- In Mine Year 14, the influent to the LCEQ Basins exhibited a negative correlation between flow and sulfate and boron, while the influent to the HCEQ Basin exhibited a negative correlation between flow and sodium and thallium.
- In Mine Year 14, the influent to the HCEQ Basin exhibited a negative correlation between flow and sodium, and thallium. This trend suggests influence of the Category 2/3 Waste Rock Stockpile on the HCEQ Basin quality in Mine Year 14.
- In Mine Year 15, the influent to the LCEQ Basins exhibited a negative correlation between flow and sulfate, boron, arsenic, and thallium. The influent to the HCEQ Basin exhibited a negative correlation between flow and sodium and thallium in Mine Year 15.
- In Mine Year 20, the influent to the LCEQ Basins showed a negative correlation between flow and sulfate, calcium, boron, potassium, and arsenic. The influent to the HCEQ Basin showed a negative correlation between flow and copper and silver, although this correlation is weak, as suggested by the short length of the flow vector.

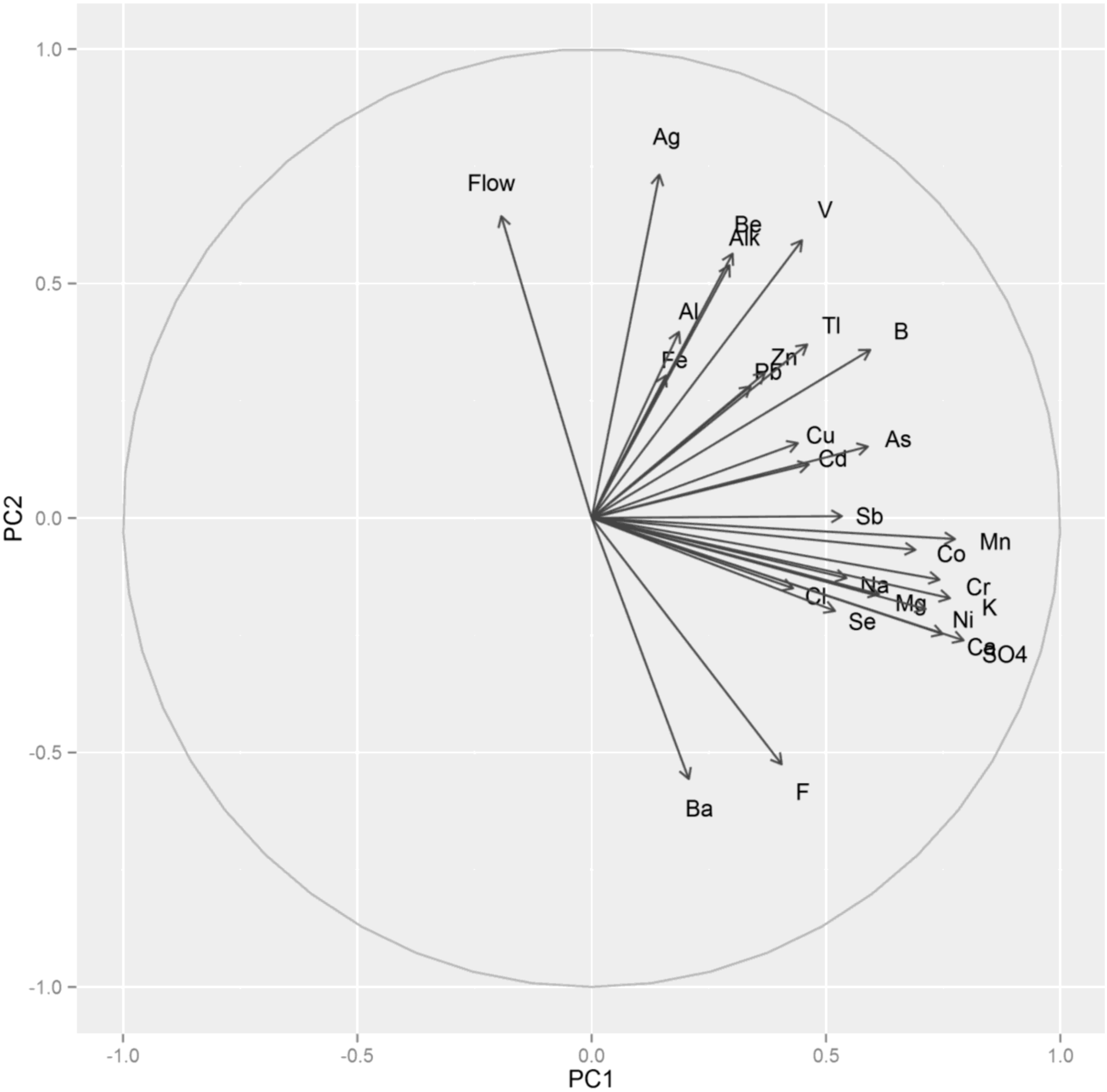


Figure 3-8 Principal Component Plot – Low Concentration Equalization Basins, Mine Year 1

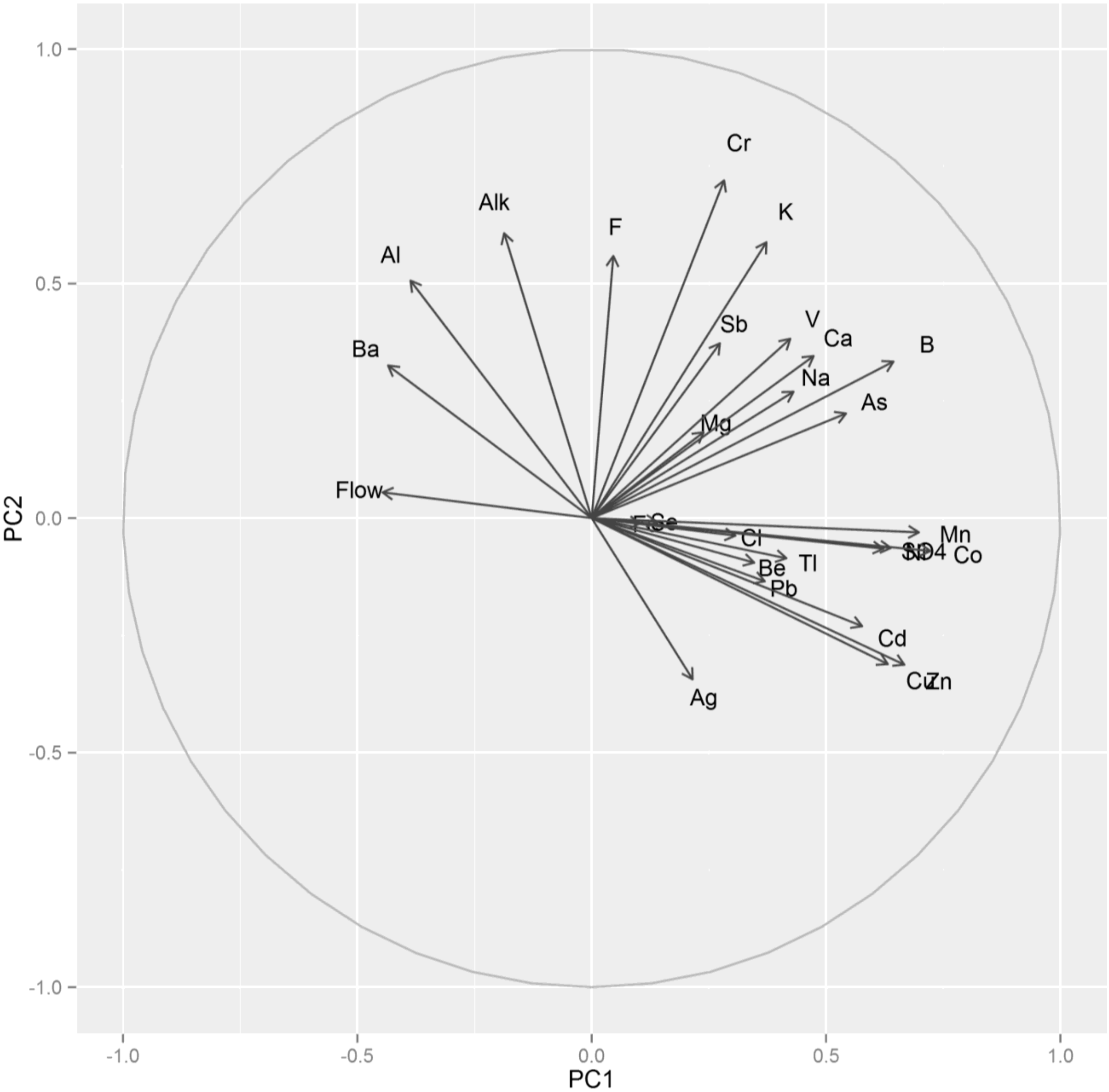


Figure 3-9 Principal Component Plot – Low Concentration Equalization Basins, Mine Year 4

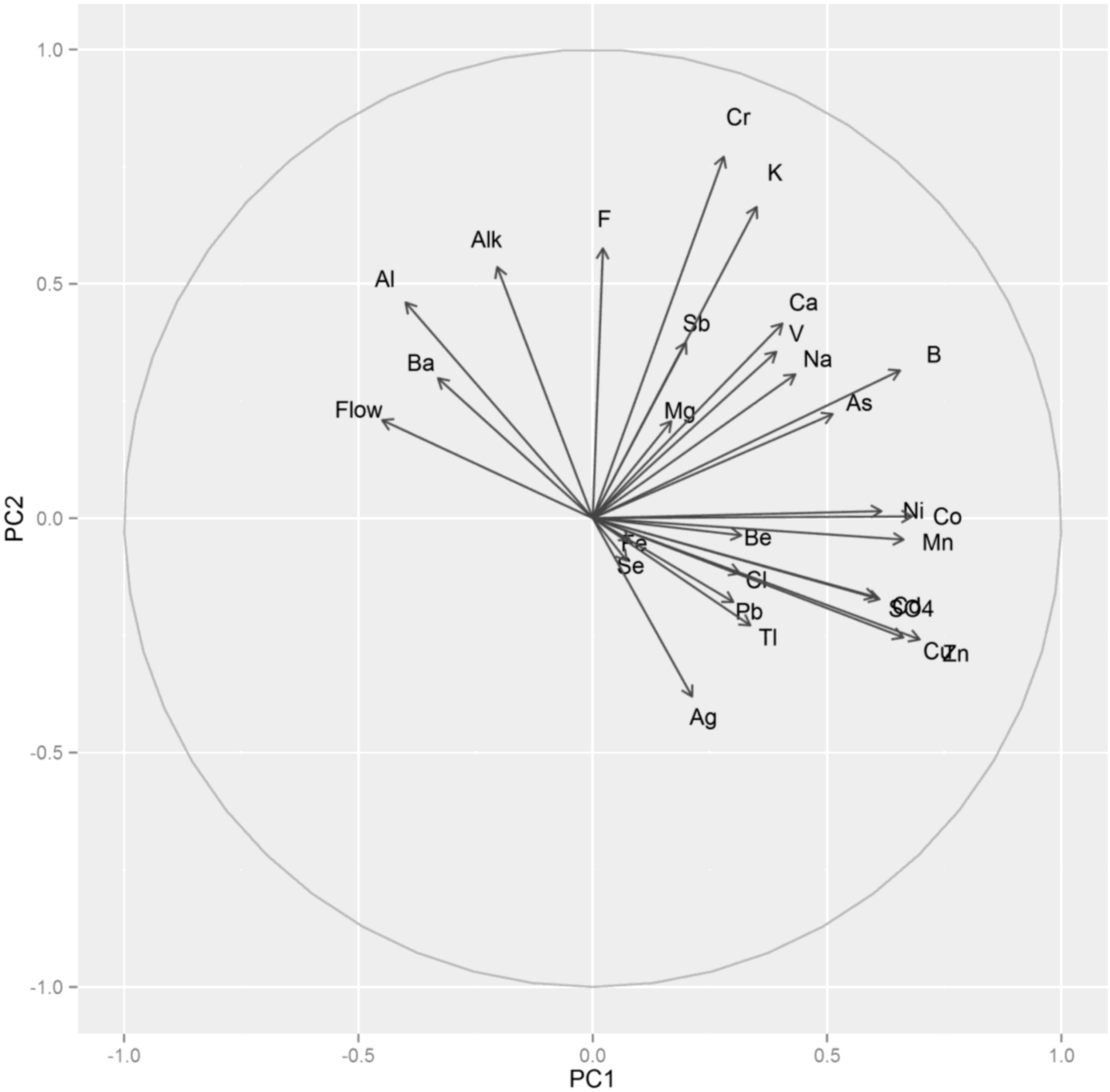


Figure 3-10 Principal Component Plot – Low Concentration Equalization Basins, Mine Year 5

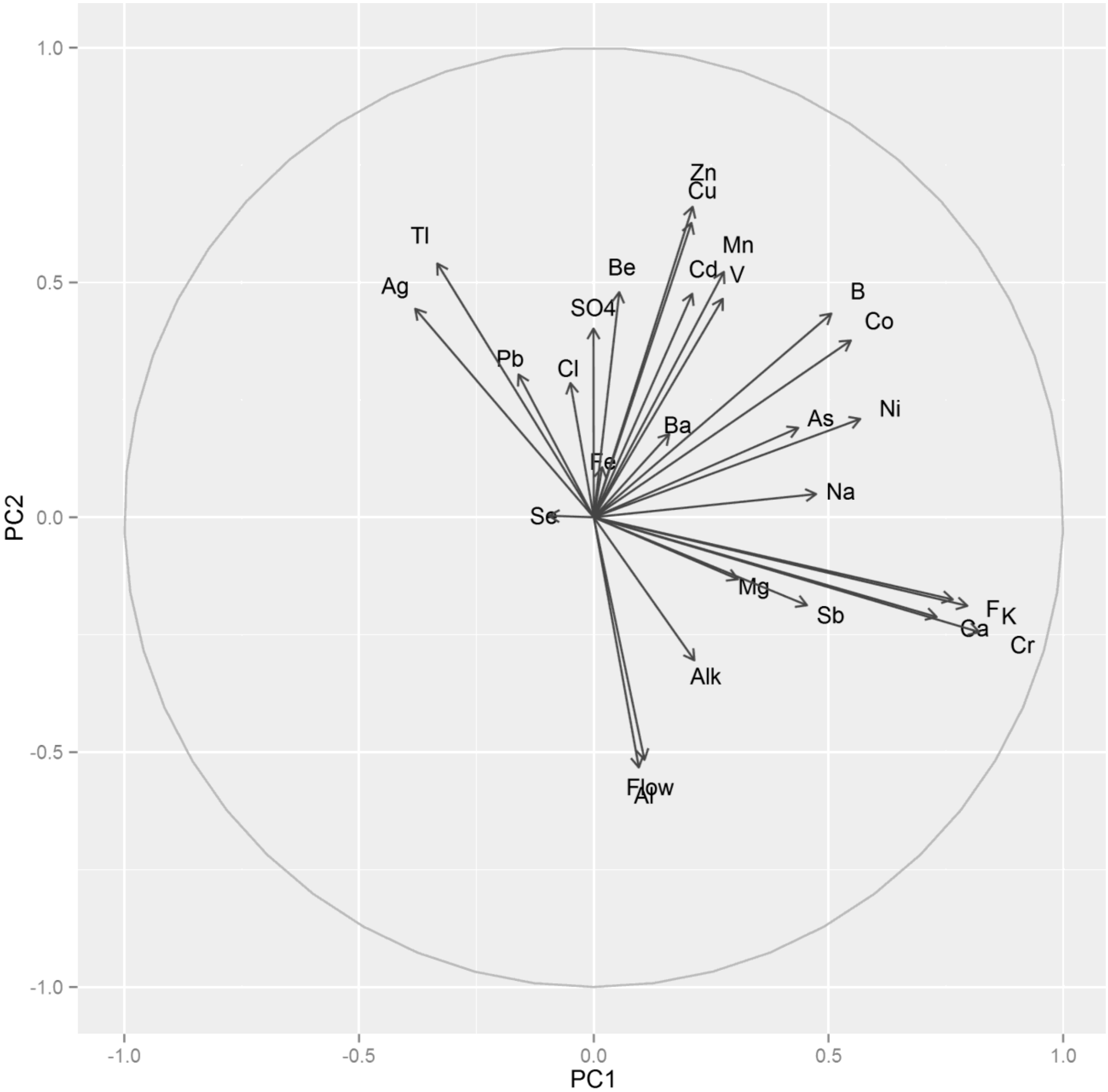


Figure 3-11 Principal Component Plot – Low Concentration Equalization Basins, Mine Year 10

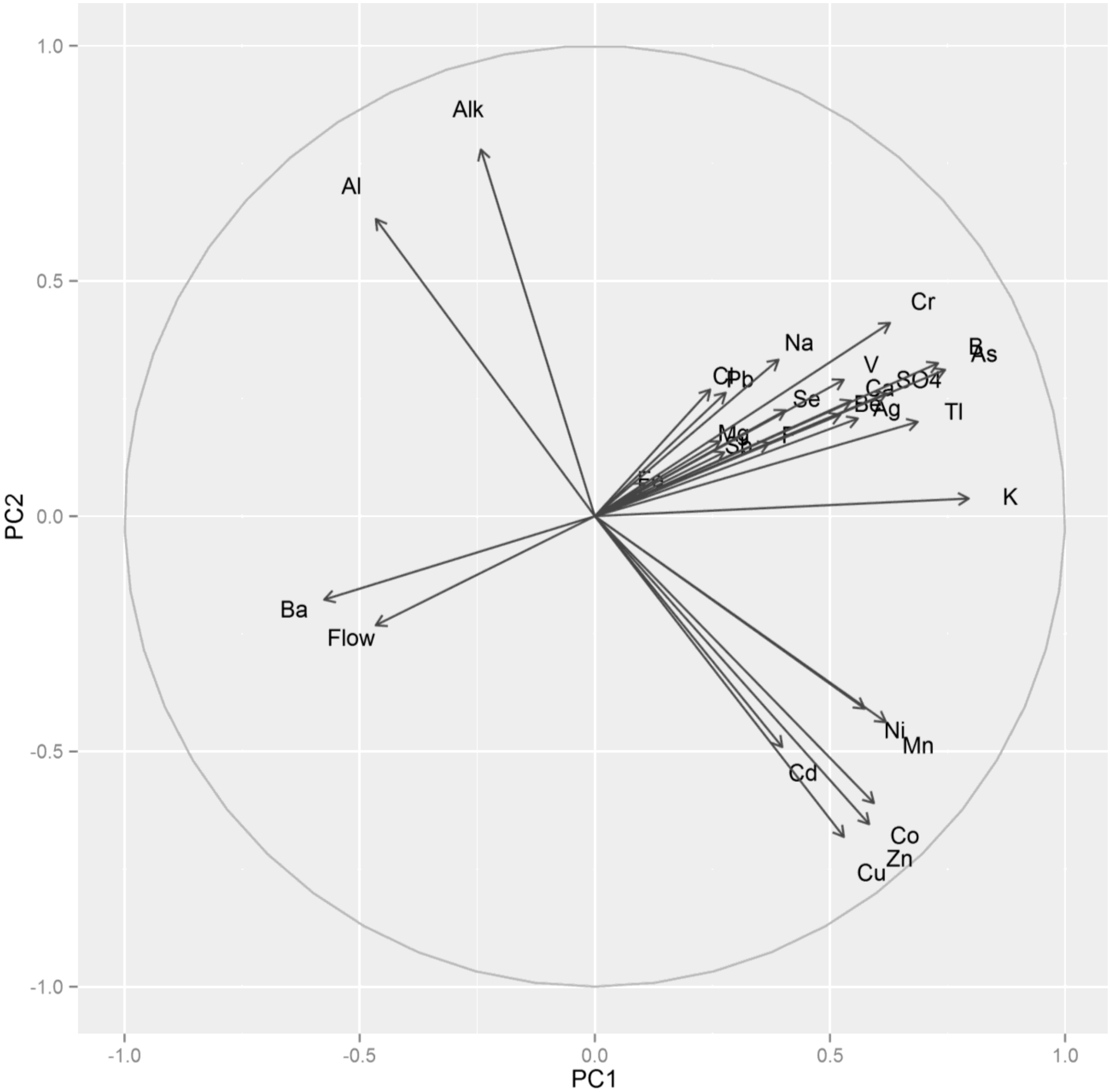


Figure 3-12 Principal Component Plot – Low Concentration Equalization Basins, Mine Year 14

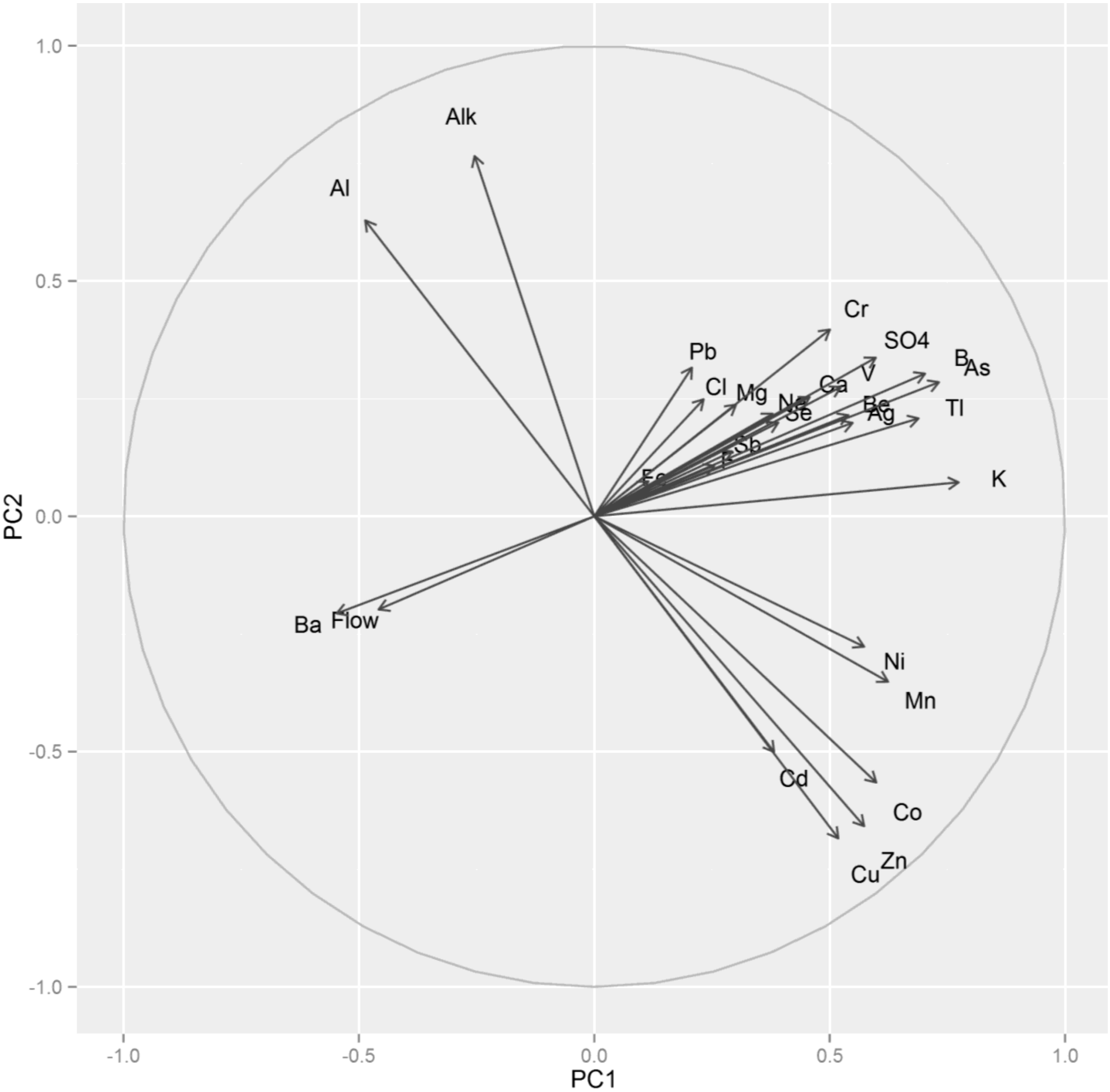


Figure 3-13 Principal Component Plot – Low Concentration Equalization Basins, Mine Year 15

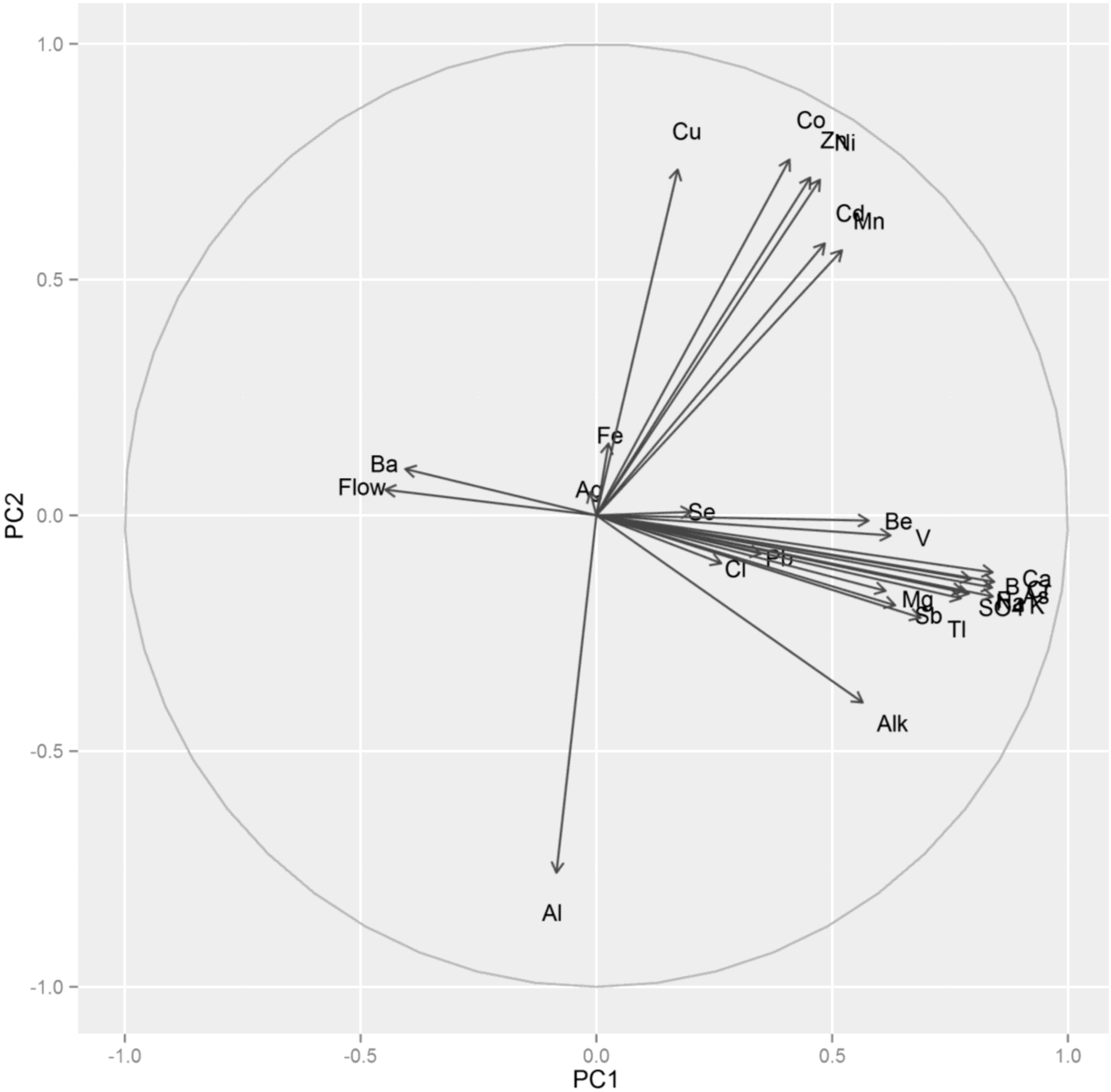


Figure 3-14 Principal Component Plot – Low Concentration Equalization Basins, Mine Year 20

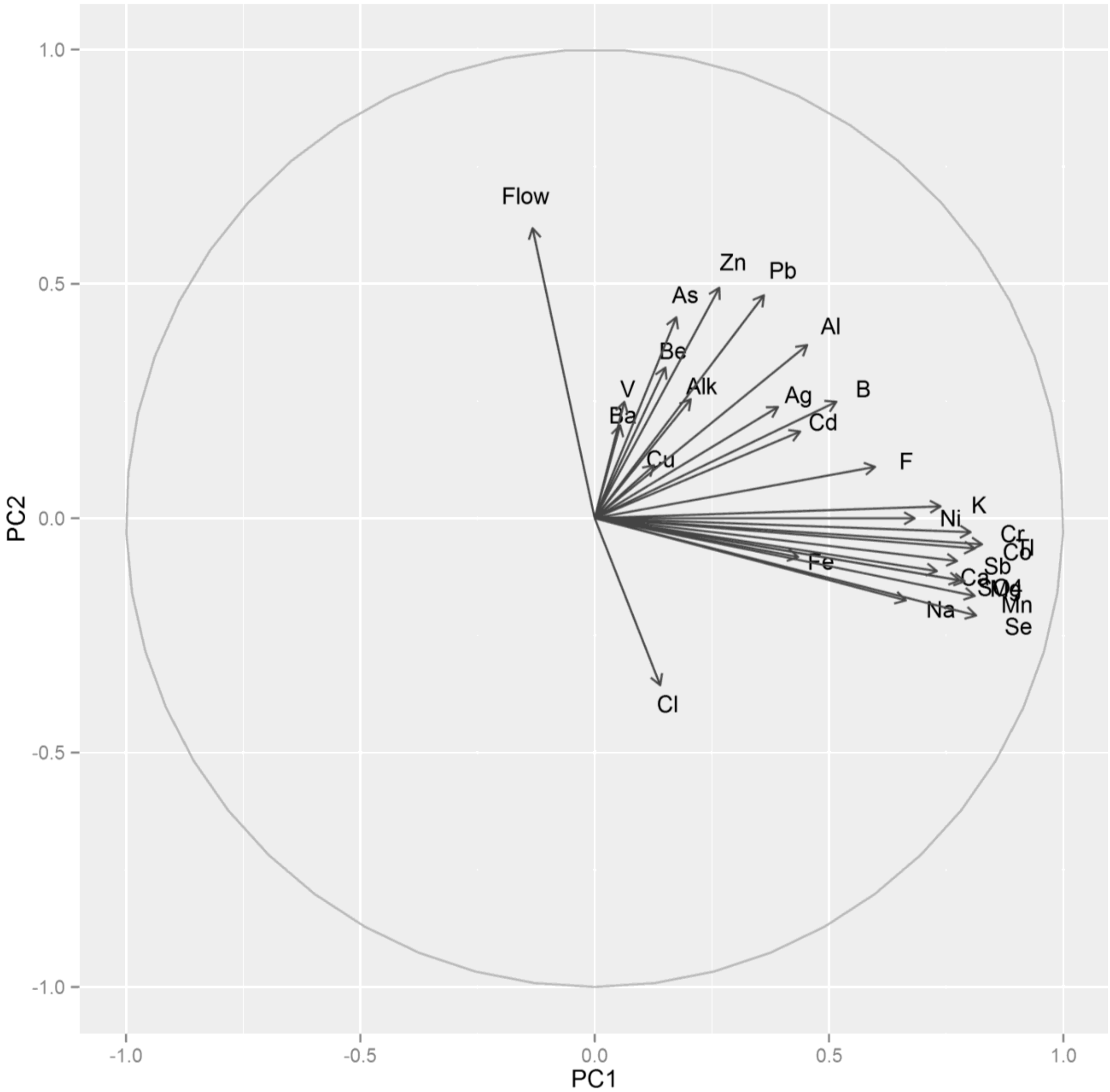


Figure 3-15 **Principal Component Plot – High Concentration Equalization Basin, Mine Year 1**

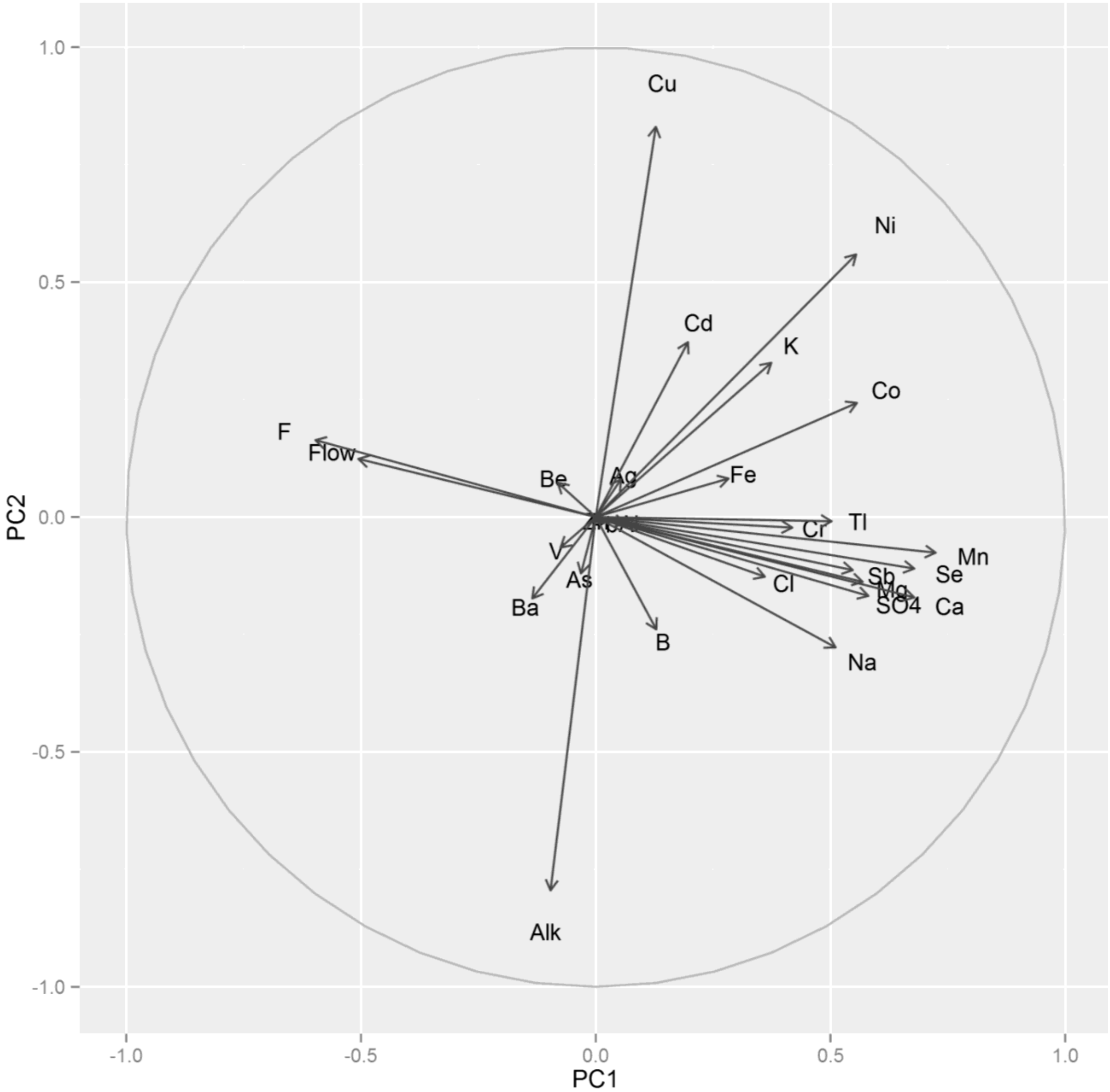


Figure 3-16 Principal Component Plot – High Concentration Equalization Basin, Mine Year 4

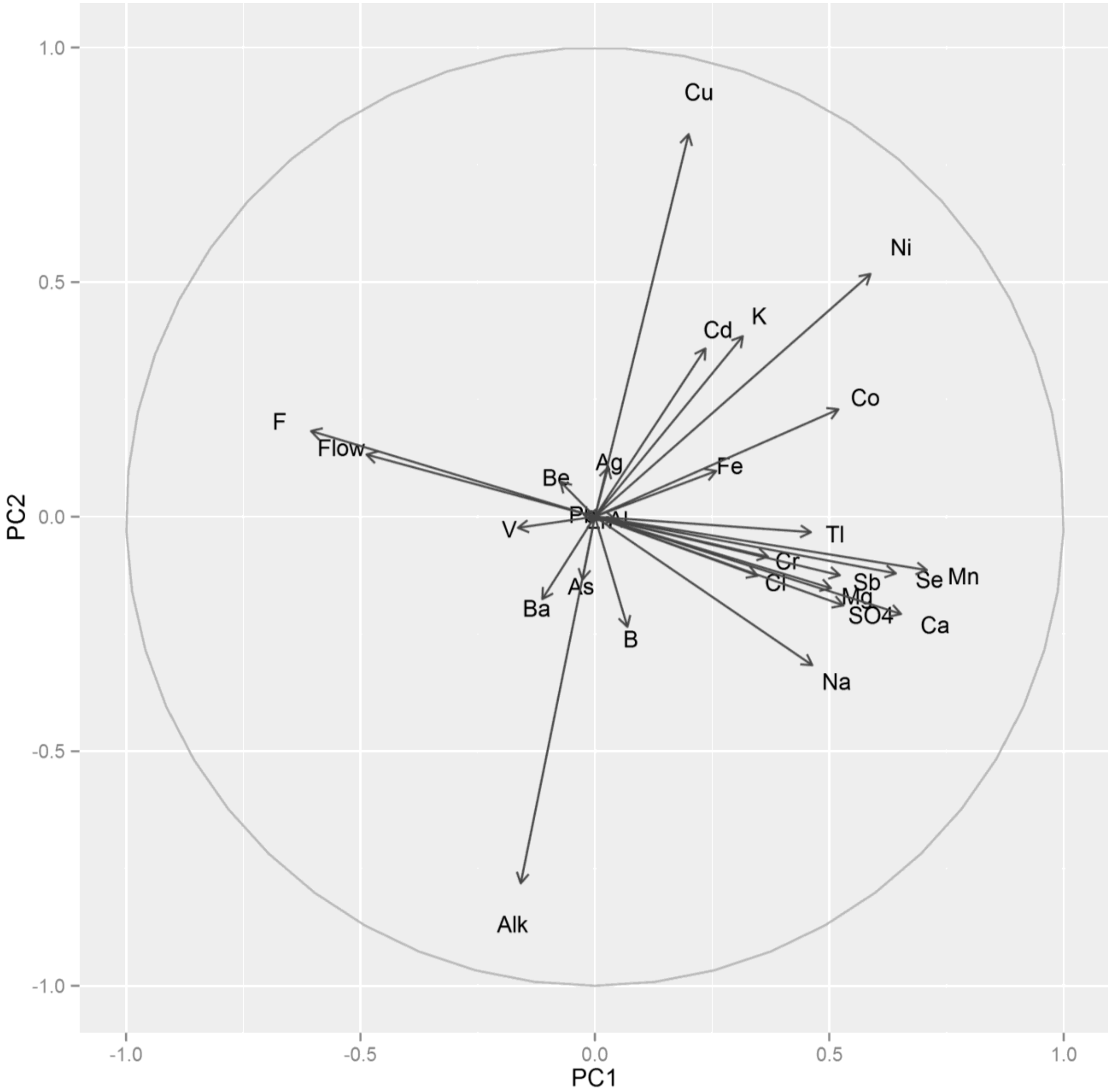


Figure 3-17 Principal Component Plot – High Concentration Equalization Basin, Mine Year 5

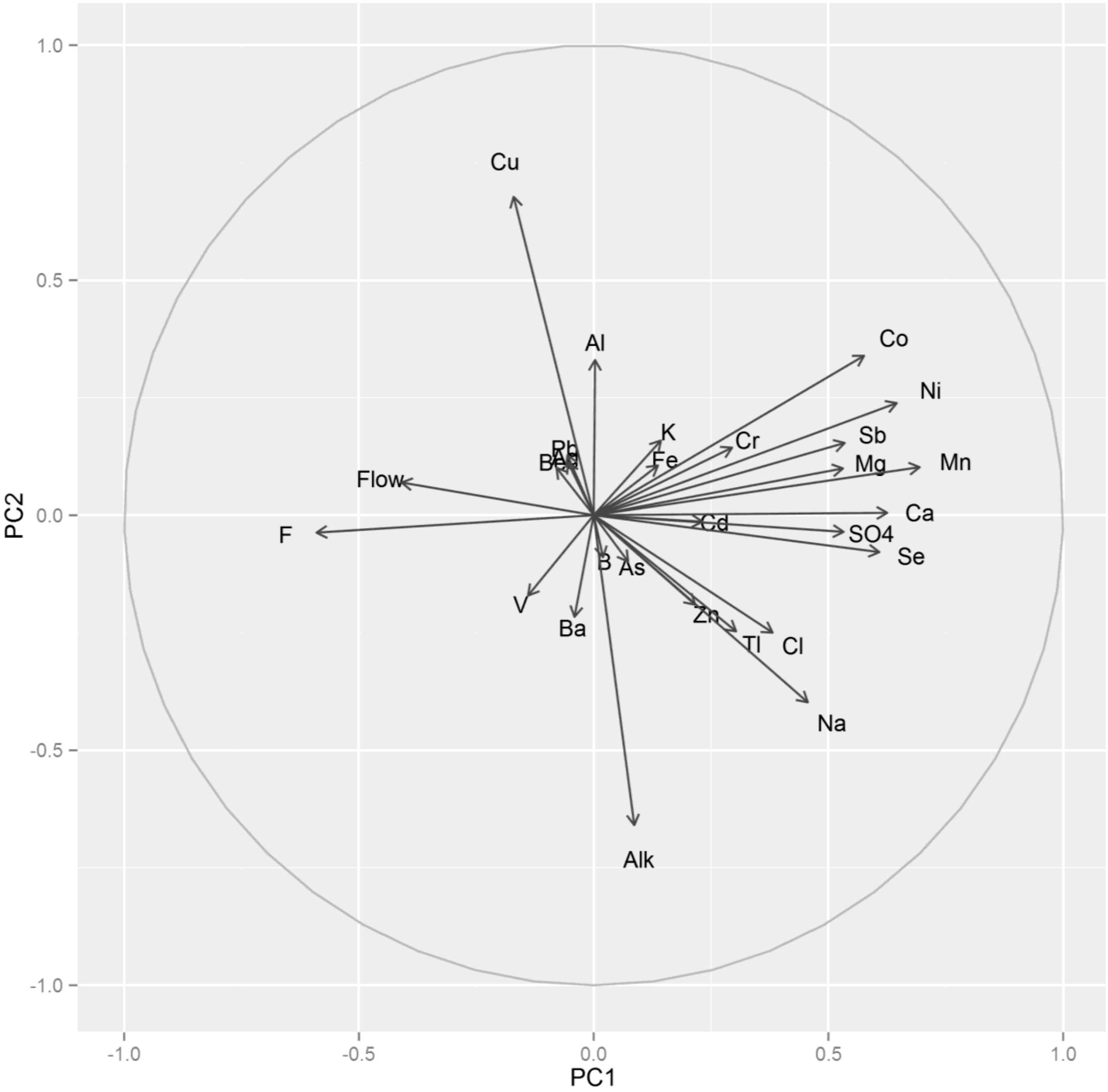


Figure 3-18 **Principal Component Plot – High Concentration Equalization Basin, Mine Year 10**

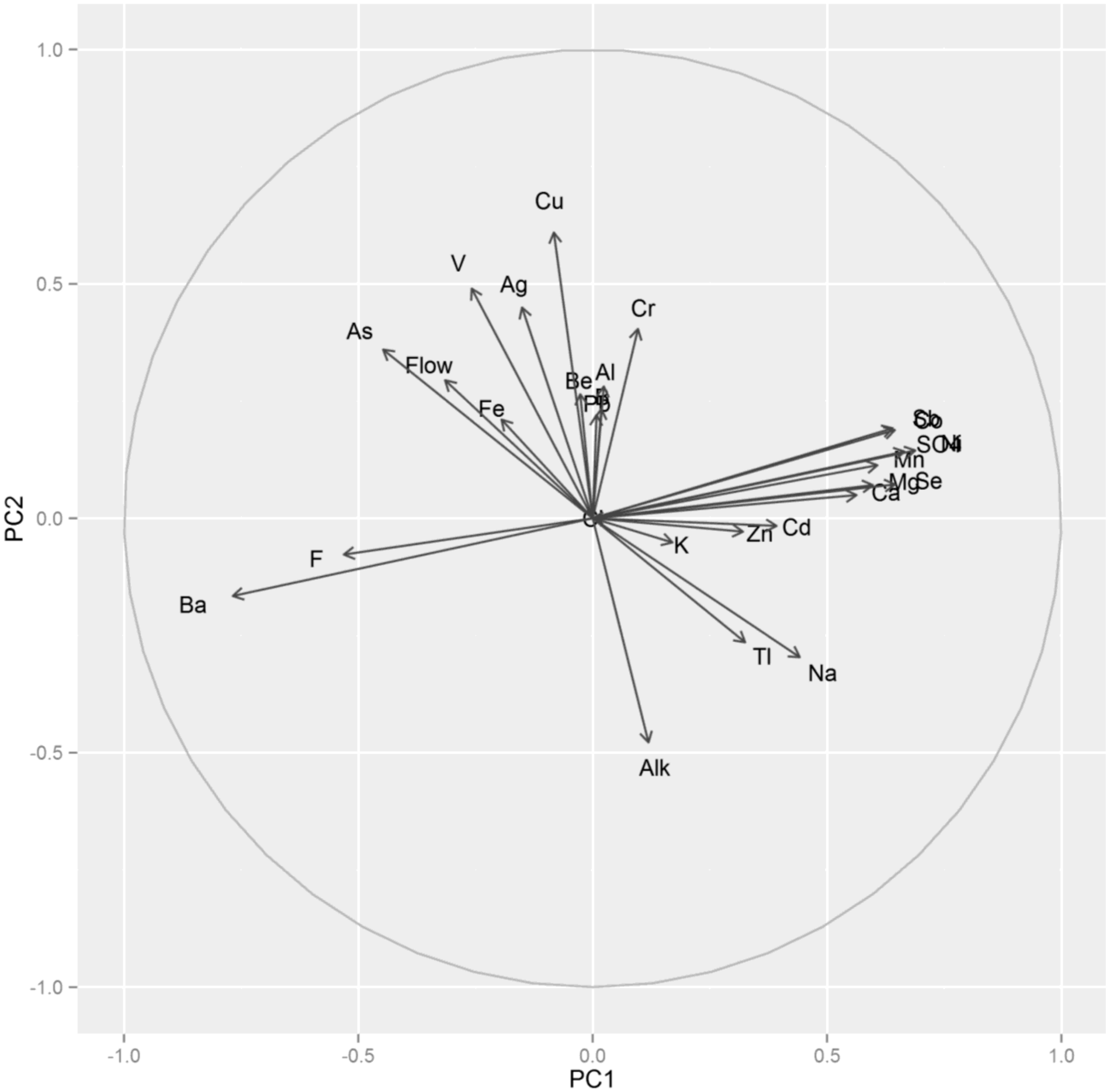


Figure 3-19 Principal Component Plot – High Concentration Equalization Basin, Mine Year 14

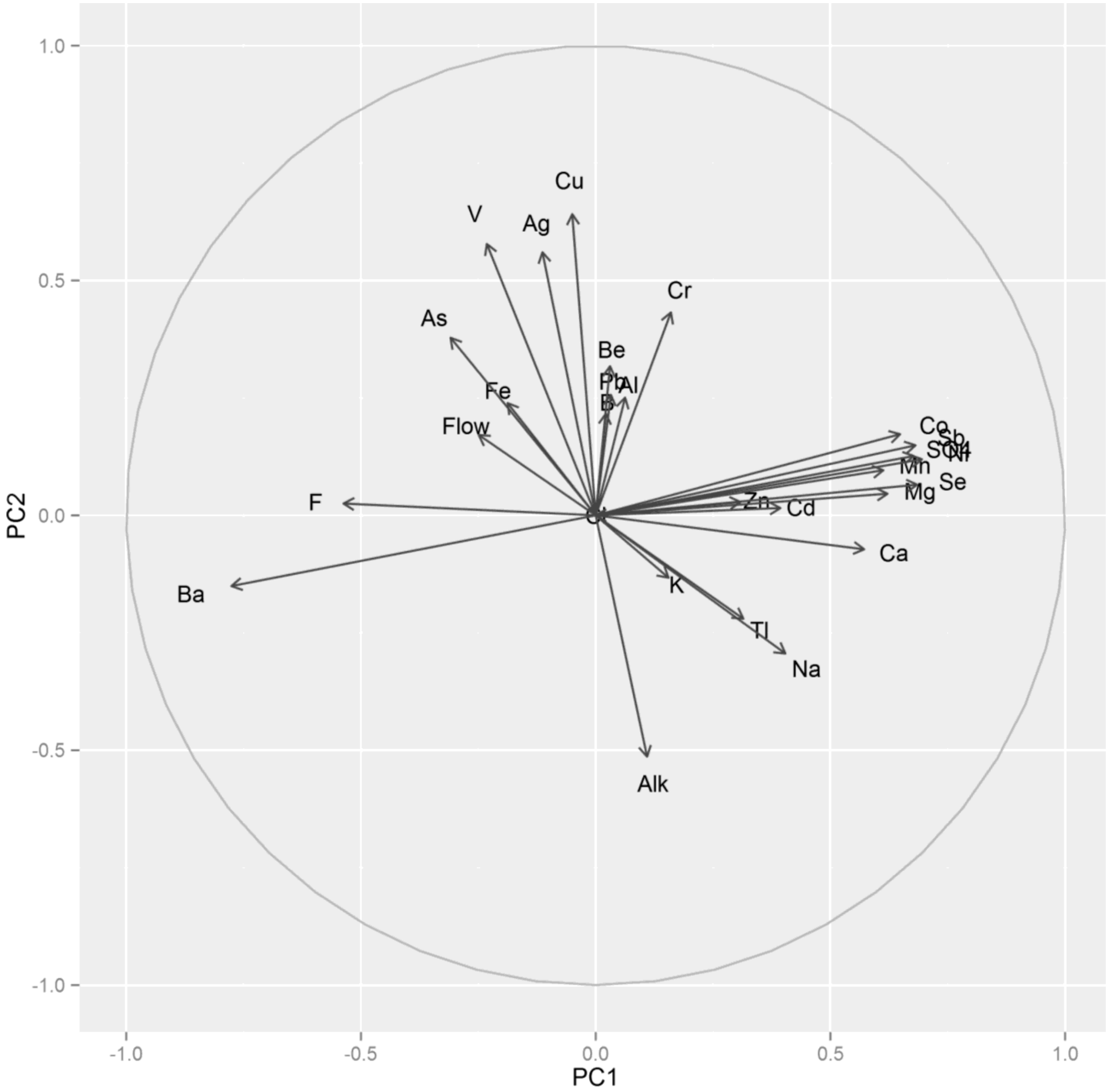


Figure 3-20 Principal Component Plot – High Concentration Equalization Basin, Mine Year 15

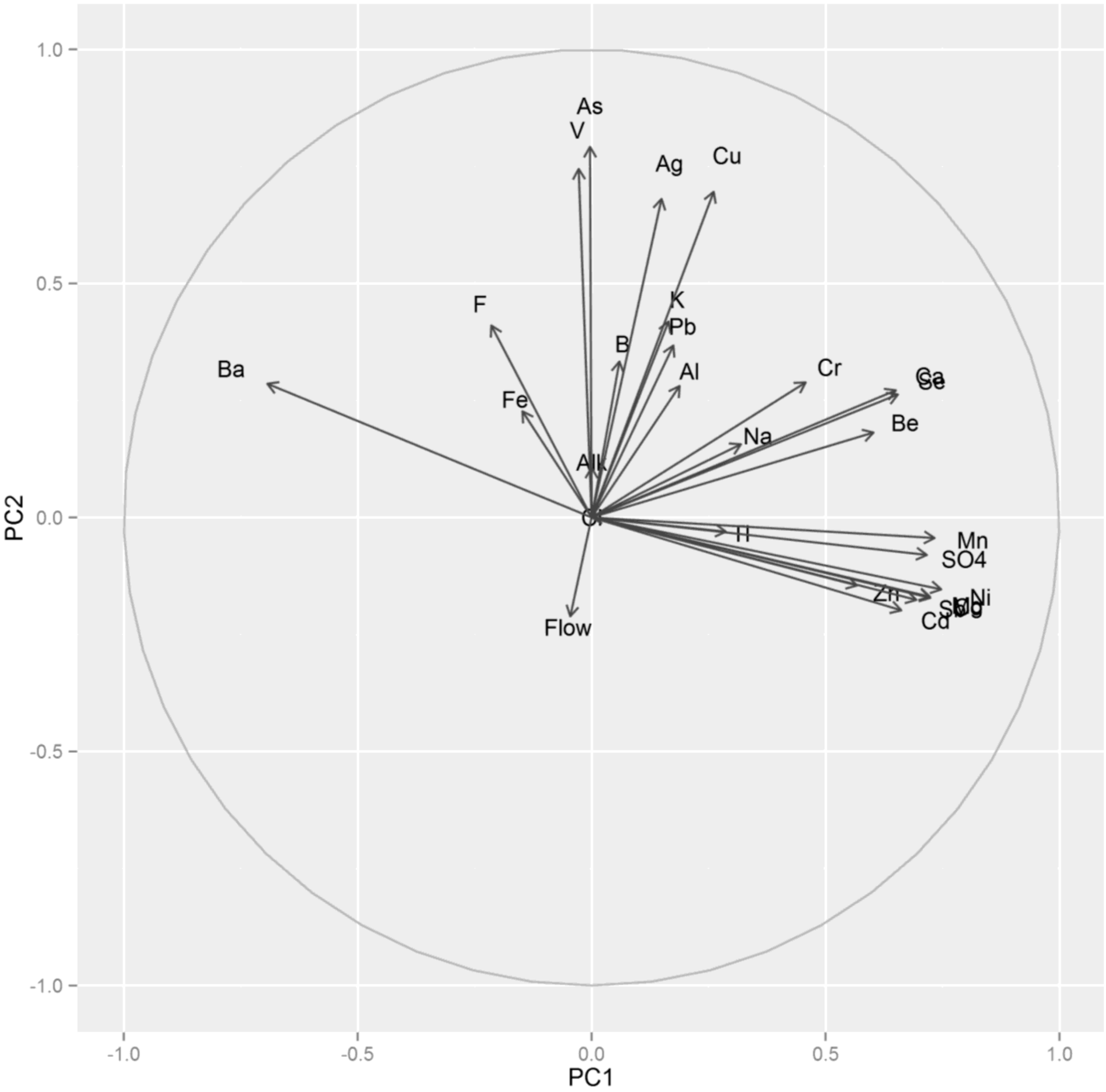


Figure 3-21 Principal Component Plot – High Concentration Equalization Basin, Mine Year 20

3.2 Mine Water Treatment Trains Water Quality Design Basis

The following sections describe the selection of a water quality design basis for the mine water treatment trains at the WWTS based on the preceding analysis.

3.3 Selection of Design Basis – Low Concentration Equalization Basins

In instances where constituents are correlated negatively with flow, using the P90 concentrations in conjunction with the P90 flow will result in an overly-conservative membrane design (i.e., maximum design membrane recovery required at maximum design flow rate). In reality, as flow rate decreases from the design capacity (spring snowmelt flow) and concentration increases, the operator will likely respond by lowering the recovery of the membrane system. This will maintain the target effluent concentrations in the permeate while holding the hydraulic load for reject to the chemical precipitation train constant.

It is therefore proposed to use the P90 average annual mass loading divided by the P90 average annual flow rate as the water quality design basis for those constituents exhibiting negative correlations with flow in the LCEQ Basin. Based on the analysis described in the previous section, the parameters affected by this calculation are as follows:

- Mine Year 1 – barium and fluoride
- Mine Year 4 – cobalt, manganese, nickel, sulfate, and thallium
- Mine Year 5 – cadmium, copper, sulfate, and zinc
- Mine Year 10 – no parameters affected.
- Mine Year 14 – silver, arsenic, beryllium, calcium, sulfate, thallium, and vanadium
- Mine Year 15 – arsenic, boron, beryllium, sulfate, thallium, and vanadium
- Mine Year 20 – boron, potassium, and sulfate

A pH of 7 was assumed for LCEQ Basin flows. The results of this calculation for each of the affected constituents entering the LCEQ Basins are listed in Large Table 2.

3.4 Selection of Design Basis – High Concentration Equalization Basin

As previously described, in instances where constituents are correlated negatively with flow, using the P90 concentrations in conjunction with the P90 flow will result in an overly-conservative design (i.e., maximum chemical dose required at maximum flow rate). As the overall demand on the equipment is based on the mass removal required, it is appropriate to consider the relationship between flow and concentration in design.

It is therefore proposed to use the P90 average annual mass loading divided by the P90 average annual flow rate as the water quality design basis for those constituents exhibiting negative correlations with flow in the influent to the HCEQ Basin. Based on the analysis described in the previous section, the parameters affected by this calculation are as follows:

- Mine Year 1 – chloride
- Mine Year 4 – magnesium, manganese, antimony, sulfate
- Mine Year 5 – magnesium, manganese, antimony and sulfate
- Mine Year 10 – no parameters affected

- Mine Year 14 – sodium and thallium
- Mine Year 15 – sodium and thallium
- Mine Year 20 – no parameters affected

A pH value of 5 was assumed for HCEQ Basin flows. The results of this calculation for each of the affected constituents entering the HCEQ Basin are listed in Large Table 3.

3.5 Selection of Design Basis for Construction Mine Water

Construction mine water at the Mine Site will be sent to the Construction Mine Water Basin, including water from dewatering of saturated mineral overburden. A portion of this flow can be attributed to excavation runoff, but the majority of this water is from groundwater; see Table 2-7 for more information on the estimated quantity from each source. The quality of groundwater collected is expected to be similar to background water quality from the surficial aquifer at the Mine Site.

The water quality of construction mine water was estimated as follows:

- The groundwater contribution was assumed to match the water quality from the surficial aquifer at the Mine Site as described in the Water Modeling Data Package, Volume 1 - Mine Site (Reference (1)).
- Water quality of the excavation runoff was based on overburden waste characterization data collected from the Mine Site. These data are based on P90 results from Meteoric Water Mobility Procedures (MWMP) performed by SRK Consulting on saturated mineral overburden, unsaturated mineral overburden, and peat (see Section 7.0 of Reference (3)). The purpose of MWMP is to evaluate the potential for dissolution and mobility of certain constituents from earthen materials (in this case, overburden) from rainwater. Therefore, MWMP results are appropriate to use as an estimate of excavation runoff from these materials. The ratio of overburden materials in the construction footprint of each mine feature was reported in the Rock and Overburden Management Plan (Table 2-6 of Reference (4)) and used to estimate water quality from excavation limits of each feature.

The overall quality of construction mine water was calculated using the source quantity information from Table 2-6 of Reference (4) and the source quality information as discussed above (based on Table 2-6 of Reference (4)). The water quality for years with construction mine water flows are presented in Large Table 4.

4.0 References

1. **Poly Met Mining Inc.** NorthMet Project Water Modeling Data Package Volume 1 - Mine Site (v14). February 2015.

2. **Jolliffe, I. T.** *Principal Component Analysis.* Second. New York : Springer-Verlag New York, Inc., 2002.

3. **Poly Met Mining Inc.** NorthMet Project Waste Characterization Data Package (v12). February 2015.

4. —. NorthMet Project Rock and Overburden Management Plan (v9). July 2017.

Large Tables

Large Table 1 Seasonal Variations in Mine Site Mine Water Flows (gpm)

Source	Mine Year 1				Mine Year 2				Mine Year 5				Mine Year 10				Mine Year 11				Mine Year 14				Mine Year 15				Mine Year 20			
	Estimated Spring Snowmelt (3-day) (2)	Spring Snowmelt (1-month) (2)	Average Summer (1,2,3)	Average Winter Flow (1,2,3)	Estimated Spring Snowmelt (3-day) (2)	Spring Snowmelt (1-month) (2)	Average Summer (1,2,3)	Average Winter Flow (1,2,3)	Estimated Spring Snowmelt (3-day) (2)	Spring Snowmelt (1-month) (2)	Average Summer (1,2,3)	Average Winter Flow (1,2,3)	Estimated Spring Snowmelt (3-day) (2)	Spring Snowmelt (1-month) (2)	Average Summer (1,2,3)	Average Winter Flow (1,2,3)	Estimated Spring Snowmelt (3-day) (2)	Spring Snowmelt (1-month) (2)	Average Summer (1,2,3)	Average Winter Flow (1,2,3)	Estimated Spring Snowmelt (3-day) (2)	Spring Snowmelt (1-month) (2)	Average Summer (1,2,3)	Average Winter Flow (1,2,3)	Estimated Spring Snowmelt (3-day) (2)	Spring Snowmelt (1-month) (2)	Average Summer (1,2,3)	Average Winter Flow (1,2,3)	Estimated Spring Snowmelt (3-day) (2)	Spring Snowmelt (1-month) (2)	Average Summer (1,2,3)	Average Winter Flow (1,2,3)
East Pit	1,317	384	348	24	1,240	310	449	274	1,641	708	664	341	2,206	1,272	1,123	898	0	0	565	942	0	0	1,092	912	1,240	310	1,105	919	0	0	0	0
Central Pit	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	10	0	0	0	81	14	420	105	78	13	0	0	0	0
West Pit	0	0	17	4	720	180	118	8	1,086	301	233	48	2,640	706	462	49	2,640	706	519	53	2,641	707	538	75	2,580	645	508	62	2,632	698	494	56
Haul Roads and Rail Transfer Hopper	105	105	104	23	147	147	101	26	147	147	102	27	153	153	108	27	153	153	102	56	129	129	101	26	150	150	100	26	129	129	106	26
Category 1 Stockpile Groundwater Containment System(4)	513	385	262	57	1,000	1,000	250	63	979	734	503	113	1,226	919	627	150	1,123	842	574	151	1,119	839	570	148	1,000	1,000	487	133	242	181	121	42
Category 2/3 Waste Rock Stockpile	147	147	81	17	150	150	80	20	274	274	152	39	407	407	231	56	407	407	217	56	407	407	221	55	340	340	198	55	0	0	17	10
Category 4 Waste Rock Stockpile	72	72	38	8	70	70	36	9	126	126	68	18	126	126	72	17	126	126	57	17	0	0	0	0	0	0	0	0	0	0	0	0
Ore Surge Pile	72	72	37	8	70	70	37	9	72	72	37	9	72	72	38	9	72	72	36	9	72	72	37	9	70	70	36	9	72	72	36	9
Total(5)	**2,227**	**1,165**	**963**	**230**	**3,444**	**1,974**	**1152**	**474**	**4,325**	**2,362**	**1,771**	**661**	**6,829**	**3,654**	**2,714**	**1,308**	**4,520**	**2,305**	**2,146**	**1,337**	**4,503**	**2,290**	**2,666**	**1,319**	***5,897***	***2,717***	**2,429**	**1,291**	**3,074**	**1,079**	**873**	**243**

(1) All averaged data is reported as the P90 values.
(2) Source: Conventional Hydrology Modeling dated March 3, 2015
(3) P90 total mine water flow to WWTS shown; column values do not sum to total value due to probabilistic modeling.
(4) Category 1 Stockpile Groundwater Containment System flow estimates are based on modeling performed January 25, 2013.
(5) Column values do not sum to total value due to probabilistic modeling.

Large Table 2 Low Concentration Equalization Basin Water Quality Statistics

Mine Year	Ag Summary, mg/L			Al Summary, mg/L			Alk Summary, mg/L as HCO3$^-$		
	Annual Average			Annual Average			Annual Average		
	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc
1	9.03E-05	1.27E-04	1.09E-04	9.53E-04	1.54E-03	1.26E-03	3.14E+01	4.01E+01	3.58E+01
4	1.29E-04	1.86E-04	1.39E-04	1.03E-03	1.68E-03	1.33E-03	3.37E+01	4.34E+01	3.73E+01
5	1.31E-04	1.87E-04	1.43E-04	1.01E-03	1.66E-03	1.31E-03	3.36E+01	4.34E+01	3.77E+01
10	1.44E-04	1.88E-04	1.53E-04	9.23E-04	1.65E-03	1.27E-03	3.18E+01	4.24E+01	3.55E+01
14	1.48E-04	1.88E-04	1.63E-04	9.14E-04	1.66E-03	1.24E-03	3.11E+01	4.18E+01	3.51E+01
15	1.53E-04	1.88E-04	1.66E-04	9.15E-04	1.66E-03	1.30E-03	3.07E+01	4.18E+01	3.51E+01
20	1.09E-04	1.60E-04	1.25E-04	1.41E-03	2.13E-03	1.73E-03	3.36E+01	4.29E+01	3.70E+01

Mine Year	As Summary, mg/L			B Summary, mg/L			Ba Summary, mg/L		
	Annual Average			Annual Average			Annual Average		
	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc
1	3.40E-02	6.16E-02	4.51E-02	7.18E-02	8.49E-02	7.14E-02	3.17E-02	3.65E-02	3.13E-02
4	4.88E-02	7.82E-02	5.83E-02	8.05E-02	9.00E-02	8.04E-02	2.33E-02	2.63E-02	2.55E-02
5	4.71E-02	7.58E-02	5.49E-02	7.71E-02	8.73E-02	7.84E-02	2.35E-02	2.70E-02	2.54E-02
10	3.65E-02	5.43E-02	4.20E-02	6.47E-02	7.63E-02	6.72E-02	2.62E-02	2.95E-02	2.63E-02
14	8.22E-02	8.62E-02	8.19E-02	8.81E-02	9.37E-02	8.95E-02	1.48E-02	1.74E-02	1.75E-02
15	8.18E-02	8.59E-02	8.29E-02	8.76E-02	9.32E-02	9.06E-02	1.51E-02	1.78E-02	1.76E-02
20	4.59E-02	5.92E-02	3.81E-02	6.82E-02	8.35E-02	7.49E-02	2.30E-02	2.62E-02	2.58E-02

Mine Year	Be Summary, mg/L			Ca Summary, mg/L			Cd Summary, mg/L		
	Annual Average			Annual Average			Annual Average		
	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc
1	2.56E-04	3.66E-04	3.13E-04	1.39E+02	2.18E+02	1.36E+02	3.37E-03	7.75E-03	5.71E-03
4	3.73E-04	3.95E-04	3.56E-04	2.52E+02	3.05E+02	2.80E+02	4.01E-03	7.65E-03	5.15E-03
5	3.75E-04	3.94E-04	3.62E-04	2.55E+02	2.97E+02	2.90E+02	3.63E-03	6.86E-03	4.74E-03
10	3.74E-04	3.88E-04	3.54E-04	1.93E+02	2.25E+02	2.22E+02	2.79E-03	4.78E-03	3.92E-03
14	3.72E-04	3.85E-04	3.74E-04	5.34E+02	5.82E+02	5.20E+02	7.07E-03	2.51E-02	1.70E-02
15	3.72E-04	3.85E-04	3.70E-04	5.18E+02	5.81E+02	5.01E+02	7.29E-03	2.59E-02	1.80E-02
20	3.04E-04	3.60E-04	3.13E-04	2.54E+02	3.17E+02	2.01E+02	2.55E-03	4.75E-03	3.04E-03

Mine Year	Cl Summary, mg/L			Co Summary, mg/L			Cr Summary, mg/L		
	Annual Average			Annual Average			Annual Average		
	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc
1	2.11E+01	1.57E+02	8.38E+01	2.22E-01	3.72E-01	2.51E-01	4.39E-03	5.90E-03	4.68E-03
4	1.09E+01	5.42E+01	2.76E+01	1.72E-01	3.09E-01	2.08E-01	4.43E-03	5.11E-03	4.81E-03
5	7.25E+00	5.23E+01	2.99E+01	1.52E-01	2.60E-01	1.90E-01	4.28E-03	4.95E-03	4.82E-03
10	5.01E+00	2.30E+01	1.35E+01	1.05E-01	1.83E-01	1.41E-01	3.25E-03	3.70E-03	3.67E-03
14	5.98E+00	2.61E+01	1.66E+01	8.92E-01	1.60E+00	1.10E+00	8.13E-03	8.52E-03	7.70E-03
15	5.17E+00	2.54E+01	1.62E+01	8.91E-01	1.58E+00	1.11E+00	7.89E-03	8.39E-03	7.27E-03
20	8.17E-01	4.66E+00	1.47E+00	1.16E-01	2.39E-01	1.48E-01	4.64E-03	5.67E-03	3.81E-03

Mine Year	Cu Summary, mg/L			F Summary, mg/L			Fe Summary, mg/L		
	Annual Average			Annual Average			Annual Average		
	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc
1	1.41E+00	2.61E+00	1.93E+00	1.44E+00	1.92E+00	1.44E+00	8.01E-02	1.68E-01	1.32E-01
4	1.25E+00	2.25E+00	1.43E+00	8.87E-01	1.24E+00	1.03E+00	8.98E-02	1.82E-01	1.34E-01
5	1.17E+00	2.07E+00	1.41E+00	8.15E-01	1.04E+00	9.60E-01	9.05E-02	1.80E-01	1.29E-01
10	7.55E-01	1.46E+00	1.03E+00	6.11E-01	7.01E-01	6.91E-01	9.30E-02	1.86E-01	1.35E-01
14	3.29E+00	7.14E+00	4.88E+00	1.25E+00	1.58E+00	1.37E+00	9.31E-02	1.84E-01	1.37E-01
15	3.31E+00	7.68E+00	5.00E+00	1.27E+00	1.86E+00	1.44E+00	9.28E-02	1.85E-01	1.36E-01
20	2.61E-01	6.28E-01	3.99E-01	1.07E+00	1.26E+00	9.62E-01	5.92E-02	1.73E-01	1.16E-01

Mine Year	K Summary, mg/L			Mg Summary mg/L			Mn Summary, mg/L		
	Annual Average			Annual Average			Annual Average		
	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc
1	1.86E+01	2.75E+01	2.05E+01	3.38E+01	7.72E+01	4.56E+01	3.79E-01	5.26E-01	3.73E-01
4	2.23E+01	2.64E+01	2.44E+01	5.65E+01	1.30E+02	9.20E+01	3.31E-01	4.50E-01	3.66E-01
5	2.11E+01	2.49E+01	2.37E+01	5.56E+01	1.28E+02	1.02E+02	3.12E-01	4.18E-01	3.32E-01
10	1.58E+01	1.90E+01	1.85E+01	4.56E+01	9.55E+01	7.94E+01	2.65E-01	3.47E-01	2.77E-01
14	4.14E+01	4.65E+01	4.25E+01	1.16E+02	2.20E+02	1.68E+02	1.37E+00	2.17E+00	1.66E+00
15	4.12E+01	4.66E+01	4.23E+01	1.03E+02	1.92E+02	1.46E+02	1.29E+00	2.16E+00	1.62E+00
20	2.47E+01	2.97E+01	2.10E+01	5.86E+01	1.24E+02	7.28E+01	2.14E-01	3.53E-01	2.36E-01

Mine Year	Na Summary, mg/L			Ni Summary, mg/L			Pb Summary, mg/L		
	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc
	Mean	P90		Mean	P90		Mean	P90	
1	3.40E+01	9.16E+01	5.39E+01	2.76E+00	4.05E+00	2.68E+00	1.28E-03	2.33E-03	1.56E-03
4	6.74E+01	1.04E+02	8.70E+01	2.42E+00	3.96E+00	3.00E+00	2.37E-03	5.87E-03	3.47E-03
5	7.17E+01	1.05E+02	8.97E+01	2.13E+00	3.54E+00	2.72E+00	2.62E-03	6.46E-03	3.78E-03
10	5.91E+01	8.40E+01	7.40E+01	1.55E+00	2.63E+00	2.12E+00	2.47E-03	6.93E-03	4.16E-03
14	1.27E+02	1.94E+02	1.47E+02	1.31E+01	2.35E+01	1.61E+01	2.89E-03	5.66E-03	4.09E-03
15	1.01E+02	1.77E+02	1.31E+02	8.96E+00	1.90E+01	1.30E+01	2.89E-03	6.26E-03	4.21E-03
20	7.74E+01	1.08E+02	7.02E+01	2.08E+00	4.15E+00	2.50E+00	4.42E-03	1.05E-02	5.43E-03

Mine Year	Sb Summary, mg/L			Se Summary, mg/L			SO4 , mg/LSummary		
	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc
	Mean	P90		Mean	P90		Mean	P90	
1	2.25E-02	4.16E-02	3.11E-02	3.37E-03	6.37E-03	4.20E-03	2.35E+02	3.36E+02	2.12E+02
4	2.55E-02	4.01E-02	3.35E-02	3.01E-03	9.23E-03	6.27E-03	3.39E+02	6.05E+02	3.93E+02
5	2.35E-02	3.78E-02	3.27E-02	2.67E-03	1.03E-02	5.96E-03	3.55E+02	6.09E+02	4.09E+02
10	1.78E-02	2.71E-02	2.38E-02	2.03E-03	6.86E-03	4.90E-03	2.88E+02	5.49E+02	3.74E+02
14	4.50E-02	6.60E-02	5.24E-02	2.50E-02	5.48E-02	3.68E-02	1.77E+03	2.38E+03	1.94E+03
15	4.45E-02	6.61E-02	5.04E-02	1.68E-02	4.29E-02	3.00E-02	1.63E+03	2.29E+03	1.80E+03
20	2.65E-02	4.19E-02	2.58E-02	2.51E-03	1.50E-02	6.21E-03	5.01E+02	7.79E+02	5.37E+02

Mine Year	Tl Summary, mg/L			V Summary, mg/L			Zn Summary, mg/L		
	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc
	Mean	P90		Mean	P90		Mean	P90	
1	7.07E-05	1.44E-04	9.46E-05	8.55E-03	9.19E-03	8.98E-03	3.56E-01	6.85E-01	5.44E-01
4	1.25E-04	1.82E-04	1.45E-04	9.52E-03	9.91E-03	9.51E-03	3.78E-01	6.94E-01	4.78E-01
5	1.34E-04	1.86E-04	1.52E-04	9.56E-03	9.92E-03	9.64E-03	3.38E-01	6.91E-01	4.60E-01
10	1.41E-04	1.79E-04	1.55E-04	9.48E-03	9.79E-03	9.39E-03	2.41E-01	4.94E-01	3.22E-01
14	1.44E-04	1.72E-04	1.57E-04	9.56E-03	9.75E-03	9.70E-03	7.36E-01	1.17E+00	8.53E-01
15	1.46E-04	1.72E-04	1.60E-04	9.54E-03	9.72E-03	9.65E-03	7.68E-01	1.25E+00	8.95E-01
20	7.18E-05	1.28E-04	9.26E-05	8.89E-03	9.26E-03	9.13E-03	1.47E-01	2.53E-01	1.71E-01

Green Highlighted values denote where load calculation was used

Large Table 3 High Concentration Equalization Basin Water Quality Statistics, units in mg/L

Mine Year	Ag Summary, mg/L			Al Summary, mg/L			Alk Summary, mg/L		
	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc
	Mean	P90		Mean	P90		Mean	P90	
1	5.62E-03	1.62E-02	1.01E-02	6.68E+01	1.44E+02	1.11E+02	1.96E+01	3.00E+01	2.58E+01
4	7.91E-03	3.10E-02	1.82E-02	9.94E+01	2.10E+02	1.46E+02	2.06E+01	3.14E+01	2.52E+01
5	7.97E-03	3.29E-02	1.93E-02	9.94E+01	2.12E+02	1.50E+02	2.06E+01	3.14E+01	2.53E+01
10	2.07E-02	4.25E-02	2.94E-02	2.28E+02	3.73E+02	2.71E+02	1.36E+01	2.13E+01	1.66E+01
14	2.70E-02	3.26E-02	2.77E-02	2.42E+02	5.26E+02	3.80E+02	9.65E+00	1.56E+01	1.19E+01
15	3.02E-02	3.69E-02	3.12E-02	2.73E+02	5.90E+02	4.32E+02	7.35E+00	1.25E+01	9.59E+00
20	2.63E-02	3.06E-02	2.65E-02	2.26E+02	4.93E+02	3.49E+02	1.01E-01	3.48E-01	2.17E-01

Mine Year	As Summary, mg/L			B Summary, mg/L			Ba Summary, mg/L		
	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc
	Mean	P90		Mean	P90		Mean	P90	
1	9.96E-02	3.27E-01	2.33E-01	2.24E-01	4.00E-01	2.76E-01	4.18E-02	1.48E-01	9.64E-02
4	1.13E-01	4.03E-01	2.54E-01	3.56E-01	7.13E-01	4.78E-01	3.34E-02	2.01E-01	1.12E-01
5	1.13E-01	4.03E-01	2.42E-01	3.72E-01	7.32E-01	5.08E-01	3.32E-02	2.05E-01	1.11E-01
10	1.10E-01	3.32E-01	1.94E-01	3.53E-01	6.76E-01	4.80E-01	2.64E-02	1.62E-01	8.26E-02
14	9.98E-02	9.98E-02	9.99E-02	1.64E-01	2.60E-01	1.94E-01	9.62E-03	1.33E-02	1.12E-02
15	9.99E-02	9.99E-02	1.00E-01	1.72E-01	2.78E-01	2.13E-01	9.54E-03	1.37E-02	1.13E-02
20	6.37E-02	6.41E-02	6.13E-02	1.27E-01	2.26E-01	1.65E-01	8.34E-03	1.48E-02	1.01E-02

Mine Year	Be Summary, mg/L			Ca Summary, mg/L			Cd Summary, mg/L		
	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc
	Mean	P90		Mean	P90		Mean	P90	
1	3.24E-03	2.44E-02	1.53E-02	2.10E+02	4.13E+02	2.62E+02	2.66E-02	6.11E-02	4.74E-02
4	4.06E-03	3.70E-02	1.93E-02	5.88E+02	6.46E+02	5.57E+02	4.12E-02	8.56E-02	6.09E-02
5	4.06E-03	3.70E-02	1.88E-02	6.01E+02	6.48E+02	5.81E+02	4.18E-02	8.64E-02	5.96E-02
10	9.03E-03	3.53E-02	1.73E-02	5.39E+02	5.75E+02	5.26E+02	6.74E-02	1.19E-01	7.87E-02
14	1.08E-02	1.42E-02	1.16E-02	5.00E+02	5.42E+02	4.91E+02	5.95E-02	1.43E-01	8.96E-02
15	1.21E-02	1.58E-02	1.30E-02	4.76E+02	5.23E+02	4.70E+02	6.27E-02	1.56E-01	9.58E-02
20	8.53E-03	1.30E-02	9.67E-03	2.50E+02	2.86E+02	2.54E+02	1.27E-02	6.65E-02	4.23E-02

Mine Year	Cl Summary, mg/L			Co Summary, mg/L			Cr Summary, mg/L		
	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc
	Mean	P90		Mean	P90		Mean	P90	
1	2.85E+01	2.23E+02	8.78E+01	2.10E+00	3.53E+00	2.40E+00	6.84E-03	1.03E-02	7.43E-03
4	1.03E+01	6.80E+01	2.93E+01	4.08E+00	6.99E+00	4.59E+00	1.10E-02	2.00E-02	1.24E-02
5	6.56E+00	4.69E+01	1.91E+01	4.27E+00	7.25E+00	5.22E+00	1.12E-02	2.26E-02	1.34E-02
10	6.41E+00	4.32E+01	1.86E+01	9.23E+00	1.44E+01	1.01E+01	1.33E-02	2.59E-02	1.63E-02
14	2.85E-21	7.55E-21	4.91E-21	8.87E+00	2.05E+01	1.13E+01	1.38E-02	1.45E-02	1.41E-02
15	2.85E-21	7.55E-21	4.87E-21	9.03E+00	2.23E+01	1.20E+01	1.43E-02	1.51E-02	1.42E-02
20	2.85E-21	7.55E-21	4.67E-21	3.95E+00	2.25E+01	1.47E+01	9.94E-03	1.05E-02	9.54E-03

Mine Year	Cu Summary, mg/L			F Summary, mg/L			Fe Summary, mg/L		
	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc
	Mean	P90		Mean	P90		Mean	P90	
1	4.26E+00	9.27E+00	6.91E+00	1.81E+00	2.38E+00	1.78E+00	5.21E+01	2.03E+02	1.25E+02
4	5.47E+00	1.08E+01	7.47E+00	1.53E+00	2.10E+00	1.75E+00	7.66E+01	4.74E+02	2.55E+02
5	5.55E+00	1.09E+01	7.71E+00	1.50E+00	2.02E+00	1.68E+00	7.86E+01	5.12E+02	2.70E+02
10	5.11E+01	6.15E+01	5.31E+01	1.59E+00	1.79E+00	1.66E+00	9.25E+01	5.11E+02	2.87E+02
14	9.97E+01	1.11E+02	9.99E+01	1.64E+00	1.88E+00	1.70E+00	5.73E+01	1.11E+02	8.07E+01
15	1.11E+02	1.24E+02	1.10E+02	1.68E+00	1.90E+00	1.74E+00	6.47E+01	1.24E+02	8.79E+01
20	9.40E+01	1.05E+02	9.42E+01	1.14E+00	2.20E+00	1.22E+00	5.44E+01	1.09E+02	7.66E+01

Mine Year	K Summary, mg/L			Mg Summary, mg/L			Mn Summary, mg/L		
	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc	Annual Average		P90 Load Calc
	Mean	P90		Mean	P90		Mean	P90	
1	2.54E+01	3.45E+01	2.76E+01	1.11E+02	1.96E+02	1.19E+02	3.31E+00	5.51E+00	3.45E+00
4	4.05E+01	4.66E+01	4.02E+01	3.01E+02	5.72E+02	3.20E+02	9.72E+00	1.73E+01	8.99E+00
5	4.07E+01	4.67E+01	4.24E+01	3.23E+02	6.07E+02	3.62E+02	1.14E+01	1.98E+01	1.04E+01
10	3.67E+01	4.17E+01	3.75E+01	5.63E+02	9.04E+02	6.24E+02	2.38E+01	4.08E+01	2.47E+01
14	3.64E+01	4.57E+01	3.76E+01	4.64E+02	9.89E+02	6.55E+02	1.76E+01	3.85E+01	2.32E+01
15	3.44E+01	4.44E+01	3.63E+01	4.92E+02	1.07E+03	7.15E+02	1.85E+01	4.18E+01	2.51E+01
20	1.76E+01	2.66E+01	1.96E+01	1.35E+02	6.96E+02	4.18E+02	1.24E+01	4.46E+01	2.87E+01

Mine Year	Na Summary, mg/L			Ni Summary, mg/L			Pb Summary, mg/L		
	Annual Average			Annual Average			Annual Average		
	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc
1	4.09E+01	7.80E+01	4.73E+01	7.61E+00	1.30E+01	8.99E+00	7.55E-02	1.16E-01	1.04E-01
4	1.28E+02	2.27E+02	1.47E+02	1.87E+01	3.03E+01	1.90E+01	9.87E-02	1.46E-01	1.12E-01
5	1.38E+02	2.28E+02	1.54E+02	2.02E+01	3.38E+01	2.09E+01	9.88E-02	1.46E-01	1.17E-01
10	1.24E+02	2.18E+02	1.44E+02	1.13E+02	2.20E+02	1.37E+02	1.90E-01	2.59E-01	2.12E-01
14	1.12E+02	2.14E+02	1.35E+02	1.58E+02	3.93E+02	2.09E+02	2.33E-01	3.60E-01	2.77E-01
15	9.80E+01	1.91E+02	1.25E+02	1.61E+02	4.03E+02	2.17E+02	2.60E-01	4.07E-01	3.19E-01
20	3.76E+01	1.02E+02	6.60E+01	7.70E+01	4.85E+02	3.19E+02	2.23E-01	3.44E-01	2.73E-01

Mine Year	Sb Summary, mg/L			Se Summary, mg/L			SO4 Summary, mg/L		
	Annual Average			Annual Average			Annual Average		
	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc
1	1.45E-01	2.43E-01	1.56E-01	2.22E-02	3.97E-02	2.29E-02	1.44E+03	2.81E+03	1.70E+03
4	3.35E-01	6.42E-01	3.56E-01	6.89E-02	1.17E-01	6.77E-02	3.69E+03	8.06E+03	4.43E+03
5	3.67E-01	7.50E-01	4.22E-01	7.39E-02	1.31E-01	7.78E-02	4.01E+03	8.67E+03	4.98E+03
10	9.23E-01	1.43E+00	1.03E+00	9.16E-02	1.40E-01	9.64E-02	5.99E+03	1.10E+04	6.81E+03
14	9.74E-01	1.72E+00	1.20E+00	8.59E-02	1.10E-01	8.65E-02	5.00E+03	8.93E+03	5.92E+03
15	1.06E+00	1.82E+00	1.34E+00	8.77E-02	1.06E-01	8.53E-02	5.00E+03	9.63E+03	6.62E+03
20	1.69E-01	1.14E+00	6.88E-01	6.26E-02	6.37E-02	6.01E-02	1.56E+03	6.93E+03	4.68E+03

Mine Year	Tl Summary, mg/L			V Summary, mg/L			Zn Summary, mg/L		
	Annual Average			Annual Average			Annual Average		
	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc	Mean	P90	P90 Load Calc
1	3.84E-04	5.81E-04	4.01E-04	9.54E-03	4.80E-02	2.92E-02	2.51E+00	6.99E+00	5.03E+00
4	7.16E-04	1.47E-03	7.44E-04	1.09E-02	5.85E-02	3.06E-02	3.38E+00	9.01E+00	5.46E+00
5	7.31E-04	1.77E-03	8.28E-04	1.09E-02	5.85E-02	3.08E-02	3.40E+00	9.02E+00	5.75E+00
10	1.94E-03	7.25E-03	3.32E-03	2.61E-02	6.24E-02	3.72E-02	5.90E+00	1.38E+01	8.80E+00
14	1.53E-03	7.70E-03	3.34E-03	3.93E-02	4.24E-02	3.94E-02	4.86E+00	1.57E+01	8.30E+00
15	1.69E-03	7.11E-03	3.34E-03	4.29E-02	4.66E-02	4.33E-02	5.24E+00	1.71E+01	8.61E+00
20	1.26E-03	1.90E-03	1.29E-03	3.50E-02	3.75E-02	3.45E-02	2.11E+00	6.75E+00	4.42E+00

Green Highlighted values denote where load calculation was used

Large Table 4 Projected Construction Mine Water Quality

Parameter	Units	Construction Phase	Mine Year 2	Mine Year 3	Mine Year 4	Mine Year 5	Mine Year 6	Mine Year 8	Mine Year 10	Mine Year 11
Alkalinity	µg/L	59,809.90	58,228.25	158,814.80	63,625.28	62,106.06	63,975.02	59,680.34	60,253.77	60,871.59
Aluminum (Al)	µg/L	93.35	92.76	150.90	59.93	69.29	64.81	83.93	80.44	79.07
Arsenic (As)	µg/L	0.95	0.98	1.82	0.76	0.82	0.74	0.92	0.90	0.88
Barium (Ba)	µg/L	31.60	32.48	77.75	31.57	31.82	31.45	32.24	32.14	31.88
Beryllium (Be)	µg/L	0.13	0.12	0.30	0.12	0.12	0.12	0.12	0.12	0.12
Boron (B)	µg/L	29.61	27.71	67.21	27.11	27.28	27.27	27.54	27.48	27.95
Cadmium (Cd)	µg/L	0.40	0.37	0.30	0.14	0.21	0.13	0.31	0.29	0.28
Calcium (Ca)	µg/L	16,061.77	15,935.64	38,277.51	15,481.94	15,610.40	15,514.72	15,813.57	15,765.37	15,779.08
Chloride	µg/L	1,075.61	1,230.33	1,801.76	740.47	879.63	769.58	1,098.53	1,046.48	984.75
Chromium (Cr)	µg/L	0.94	0.94	2.33	0.93	0.94	0.94	0.94	0.94	0.94
Cobalt (Co)	µg/L	15.19	14.42	4.44	2.93	6.16	2.35	11.32	10.10	9.87
Copper (Cu)	µg/L	24.59	18.15	9.66	4.89	8.62	4.74	14.58	13.18	14.35
Fluoride	µg/L	681.33	661.43	1787.43	716.12	700.74	720.62	676.14	681.96	689.20
Iron (Fe)	µg/L	1,536.27	1,427.62	3,546.31	1,429.64	1,428.98	1,436.08	1,428.17	1,428.38	1,456.86
Lead (Pb)	µg/L	0.63	0.65	1.52	0.61	0.62	0.62	0.64	0.63	0.63
Magnesium (Mg)	µg/L	7,999.45	7,979.27	17,412.29	7,107.45	7,353.09	7,089.45	7,744.71	7,652.07	7,623.36
Manganese (Mn)	µg/L	589.97	601.39	1369.66	558.71	570.71	555.21	589.91	585.37	580.81
Nickel (Ni)	µg/L	103.41	62.12	19.51	11.21	25.50	11.44	48.42	43.01	51.87
Potassium (K)	µg/L	2,322.33	2,635.14	4,320.78	1,834.58	2,060.00	1,778.20	2,419.75	2,334.69	2,222.60
Selenium (Se)	µg/L	0.82	0.87	1.35	0.58	0.66	0.56	0.79	0.76	0.73
Silver (Ag)	µg/L	0.10	0.10	0.27	0.11	0.11	0.11	0.10	0.10	0.10

Parameter	Units	Construction Phase	Mine Year 2	Mine Year 3	Mine Year 4	Mine Year 5	Mine Year 6	Mine Year 8	Mine Year 10	Mine Year 11
Sodium (Na)	µg/L	6,125.25	6,201.29	13,366.77	5,471.76	5,677.14	5,439.59	6,005.00	5,927.49	5,879.68
Sulfate	µg/L	28,853.28	29,634.43	27,454.38	12,647.82	17,429.49	11,966.84	25,064.12	23,259.30	22,404.35
Thallium (Tl)	µg/L	0.12	0.12	0.31	0.12	0.12	0.12	0.12	0.12	0.12
Vanadium (V)	µg/L	3.37	3.29	8.91	3.57	3.49	3.59	3.37	3.40	3.43
Zinc (Zn)	µg/L	44.97	31.16	16.64	8.44	14.82	8.16	25.04	22.63	25.38

Exhibits

Exhibit 1

Calculation Detail for Construction Mine Water Quantities and Sources

Exhibit 1: Calculation Detail for Construction Mine Water Quantities and Sources More detailed calculations available upon request

Source	Groundwater ac-ft/wk	Excavation RO ac-ft/wk	Liner RO ac-ft/wk	Weeks of Construction	Construction gpm	ac-ft	gallons	MG
Year -1								
Cat 4 Stockpile	12.94	0.22	1.39	1.72	470	24.94	8,127,535	8.1
Cat 1 Stockpile	65.65	0.72		0.65	2,145	43.30	14,108,256	14.1
OSP	2.28	0.05	1.49	1.75	124	6.71	2,185,726	2.2
Cat 2/3 Stockpile	18.14	0.33	2.42	3.66	675	76.54	24,940,059	24.9
Pre-Stripping East Pit-GW	31.11			19.83	1,006	616.98	201,042,043	201.0
Pre-Stripping East Pit-RO		5.00		19.83	162	99.19	32,321,389	32.3
Process Water Ponds	2.74	0.08	0.48	12.65	107	41.84	13,634,793	13.6
Stormwater Ponds	13.55	0.32	0.17	4.17	454	58.50	19,063,514	19.1
Cat 1 GCS	1.11	0.04		15.00	37	17.11	5,576,511	5.6
WWTS - Splitter Building	0.91	0.02	0.03	2.16	31	2.08	678,378	0.7
				Total	5,179	985.11	320,999,825	321.0
Year 2								
Pre-Stripping West Pit-GW	22.50			11.58	727	260.51	84,888,302	84.9
Pre-Stripping West Pit-RO		2.90		11.58	94	33.55	10,931,966	10.9
Process Water Ponds	2.80	0.09	0.07	1.74	96	5.15	1,677,992	1.7
				Total	917	299.21	97,498,260	97.5
Year 3								
Cat 4 Stockpile	15.32	0.26	1.22	1.45	543	24.31	7,920,554	7.9
Cat 1 Stockpile	63.03	0.21		0.19	2,044	11.77	3,835,787	3.8
Cat 2/3 Stockpile	27.98	0.49	2.18	3.23	991	99.12	32,298,307	32.3
Process Water Ponds	2.84	0.05	0.05	1.31	95	3.87	1,260,609	1.3
Cat 1 GCS	1.12	0.03		6.87	37	7.93	2,582,956	2.6
				Total	3,710	146.99	47,898,214	47.9
Year 4								
Pre-Stripping West Pit-GW	17.98			0.65	581	11.76	3,830,429	3.8
Pre-Stripping West Pit-RO		0.31		0.65	10	0.21	66,906	0.1
				Total	591	11.96	3,897,334	3.9
Year 5								
Cat 1 Stockpile	57.91	0.15		0.14	1,877	8.07	2,630,186	2.6
Pre-Stripping West Pit-GW	21.38			4.49	691	95.92	31,256,661	31.3
Pre-Stripping West Pit-RO		1.18		4.49	38	5.31	1,731,662	1.7
Stormwater Ponds	8.91	0.32		0.81	298	7.52	2,449,979	2.4
Cat 1 GCS	1.42	0.03		3.34	47	4.85	1,579,830	1.6
				Total	2,952	121.68	39,648,318	39.6
Year 6								
Cat 1 Stockpile	62.19	0.26		0.24	2,019	14.81	4,824,278	4.8
Cat 2/3 Stockpile	20.70	0.38	2.24	3.16	754	73.61	23,985,750	24.0
Process Water Ponds	3.20	0.08	0.08	2.00	109	6.71	2,185,032	2.2
Cat 1 GCS	1.05	0.04		5.33	35	5.79	1,887,631	1.9
				Total	2,917	100.91	32,882,691	32.9
Year 8								
Pre-Stripping West Pit-GW	22.62			8.46	731	191.38	62,361,891	62.4
Pre-Stripping West Pit-RO		2.15		8.46	69	18.16	5,916,047	5.9
				Total	801	209.54	68,277,938	68.3
Year 10								
Pre-Stripping West Pit-GW	25.92			8.05	838	208.71	68,007,363	68.0
Pre-Stripping West Pit-RO		2.15		8.05	69	17.30	5,637,277	5.6
				Total	907	226.01	73,644,640	73.6
Year 11								
Pre-Stripping West Pit-GW	24.02			7.86	777	188.81	61,524,422	61.5
Pre-Stripping West Pit-RO		2.07		7.86	67	16.23	5,289,453	5.3
Pre-Stripping Central Pit-GW	23.26			6.65	752	154.78	50,436,702	50.4
Pre-Stripping Central Pit-RO		1.51		6.65	49	10.06	3,277,678	3.3
				Total	1,644	369.89	120,528,255	120.5

Attachment D

Reverse Osmosis Pilot-Test Report – SD033 Active Treatment Evaluation

Reverse Osmosis Pilot Test Report

SD033 Active Treatment Evaluation

Prepared for
Cliffs Erie LLC and PolyMet Mining Inc.

September 2013

Reverse Osmosis Pilot Test Report

SD033 Active Treatment Evaluation

Prepared for
Cliffs Erie LLC and PolyMet Mining Inc.

September 2013

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Reverse Osmosis Pilot Test Report

SD033 Active Treatment Evaluation

September 2013

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1.0 Introduction

The northern portion of the former LTV Steel Mining Company (LTVSMC) Mining Area 5 (Area 5 North) discharges water to the Embarrass River watershed. Area 5 North contains a number of mine pit lakes, as shown on the general site layout provided as Figure 1. Discharge from Area 5 North forms the headwaters of Spring Mine Creek, which flows north (via surface discharge station SD033) to the Embarrass River.

The discharge at the headwaters of Spring Mine Creek is administered under Minnesota Pollution Control Agency (MPCA) National Pollutant Discharge Elimination System (NPDES) / State Disposal System (SDS) Permit MN0042536 (Permit). In the Permit, this discharge is designated SD033 and is routinely monitored at a culvert that passes beneath a former railway northeast of the former Area 5 North pit load-out pocket. The Permit is currently held by Cliffs Erie LLC (CE), but Poly Met Mining Inc. (PolyMet) is collaborating with CE on the reissuance of the Permit.

A key aspect of the Permit renewal process is the development of a plan to address sulfate and parameters of concern that have had elevated concentrations in the discharge. The ‘parameters of concern’ (as defined in the April 6, 2010 Consent Decree between MPCA and CE) are total dissolved solids (TDS), bicarbonates, total hardness, and specific conductivity. Although multiple options were identified as potential solutions to address and mitigate or treat the elevated concentrations of sulfate and parameters of concern at SD033, none were found to be implementable as short-term mitigation options in the *Short-Term Mitigation Evaluation and Implementation Plan for SD033,* which was submitted to the MPCA in June 2010. The potential mitigation options were not implementable in the short term primarily because of the significant time required for bench testing, pilot testing, and full-scale design of the options.

A *Long-Term Mitigation Evaluation and Implementation Plan for SD033* (*Long-Term Plan*) was submitted to the MPCA in April 2012. The *Long-Term Plan* recommended the continued evaluation of source isolation methods (to limit the contact of rainwater with stockpiles influencing the discharge water quality) and passive treatment technologies (for reducing the concentrations of the parameters of concern in the SD033 discharge). As part of their review of the *Long-Term Plan*, the MPCA indicated that testing of active treatment technologies would also be required.

In September 2012, a work plan to investigate the feasibility and cost of using reverse osmosis (RO) to reduce the concentrations of sulfate and parameters of concern (*Work Plan for Investigation of*

Membrane Treatment at SD033) was submitted to the MPCA. The primary objectives of the testing proposed in the work plan were to collect sufficient information to (1) determine the requirements for successful implementation of RO treatment to meet the water quality goals, including pretreatment, permeate stabilization, and concentrate management; and (2) collect sufficient information to refine the estimated capital and operating costs for treatment systems necessary to meet the water quality goals. The work plan was accepted by the MPCA in a letter dated October 31, 2012.

This report presents the data collected during the testing program, evaluates its applicability to the discharge at SD033, evaluates concentrate management approaches, and provides preliminary estimates of costs to implement the evaluated technologies. The report is structured as follows:

1. A presentation of the project background (Section 1.0)
2. An overview of the testing program structure (Section 2.0)
3. A review of the historical, tested, and target water qualities (Section 3.0)
4. A presentation and evaluation of the RO pilot testing results (Section 4.0)
5. A presentation and evaluation of the concentrate management testing results (Section 5.0)
6. A presentation and evaluation of the permeate stabilization testing results (Section 6.0)
7. A presentation of the preliminary cost estimates for the evaluated treatment approaches (Section 7.0)
8. A discussion of final conclusions from the testing program (Section 8.0).

2.0 Testing Overview

In order to meet the pilot testing objectives and allow for an adequate period of testing conditions, the pilot testing program was conducted in phases. These phases provided periods of time for investigation, optimization, and for collection of data required to assess the longer term performance of the processes under investigation. Each of the testing phases and its objectives are briefly described in the following sections.

2.1 Phase 1 – Startup and Commissioning

Phase 1 consisted of the startup and commissioning of the greensand filter and RO pilot units around January 25, 2013, and lasted for approximately two weeks. The greensand filter and RO pilot testing units were manufactured and supplied by General Electric (GE). Operators were familiar with the pilot test system due to previous testing on other source waters (tailings basin water), but the system did require the installation of new membranes for this pilot source water and some startup time. During this period, operators completed pilot unit installation and assembly, tuning of control systems, implementation of the data collection procedures, and the initiation of the process of determining operating conditions.

2.2 Phase 2 – Membrane Selection, Pretreatment Investigations, and System Optimization

The purpose of Phase 2 was to identify pretreatment requirements and RO operating conditions that optimize the treatment train (balancing capital costs, operating costs, and reliability). Phase 2 lasted from February 11 to March 18, 2013. During this phase, greensand filter operation as well as flow rate and flux of the RO system were set and adjusted (if needed) to determine an operating approach for use in Phase 3. Due to operational issues, replacement of a few system components, including the concentrate orifice valve and RO unit flowmeter, was required during this phase to achieve flow rates that resulted in target RO system recovery. For this pilot test, a recovery of 80% was set as the target during Phase 2 and established as the steady-state condition for Phase 3.

2.3 Phase 3 – Steady-State Operation

The treatment train and operating conditions optimized during the Phase 2 investigations were used during Phase 3. The treatment system was operated, largely unaltered, for the duration of Phase 3 under steady-state conditions. The purposes of this test were to gain longer-term operating data on the proposed system to evaluate system reliability, system performance with respect to water quality targets, life cycle cost, and the ability to effectively clean the membranes. The pilot test was also used to generate permeate and concentrate for use in the effluent stabilization and concentrate management investigations. Steady-state operation occurred from March 19 through July 2, 2013.

2.4 Effluent Stabilization Investigation

Were RO to be implemented for the treatment of the discharge from SD033, the future treatment plant effluent would be a blend of membrane permeates and other distillates with very low dissolved solids content. An effluent blend of these streams would be void of alkalinity and hardness, making the water corrosive to piping and materials near the outfall and likely toxic to aquatic organisms. The objective of the effluent stabilization investigation was to identify a stabilization method (e.g., addition of minerals) that will reduce the corrosiveness of the blended effluent, while maintaining compliance with the effluent water quality targets (listed in Section 3.3).

2.5 Concentrate Management Investigation

Mechanical evaporation and crystallization of the RO concentrate was the concentrate management method paired with RO treatment and determined to be potentially feasible at SD033 in the *Short-Term Mitigation Evaluation and Implementation Plan for SD033.* The primary objectives of this concentrate management investigation were to verify the technical feasibility of this approach to concentrate management and to better quantify the associated costs. For this investigation, three "pretreatment" approaches for the evaporator and crystallizer were evaluated:

1. Greensand filtration followed by RO, with the RO concentrate being sent to the evaporator without further treatment, and
2. Greensand filtration followed by RO, with the RO concentrate being further reduced in volume by a specialty RO membrane (vibratory sheer enhanced processing, or VSEP), with the VSEP concentrate routed to the evaporator, and
3. Greensand filtration followed by RO, with the RO concentrate being further reduced in volume by intermediate concentrate chemical precipitation (ICCP) and a secondary RO system, and with the secondary concentrate routed to the evaporator.

For testing with reduced concentrate volume per option 2 above, the RO pilot system concentrate was routed through the VSEP system, manufactured by New Logic Research, once steady-state operation of the RO pilot was established. The objective of this investigation was to evaluate the recovery, fluxes, and operational requirements for the VSEP equipment, and to characterize the resulting concentrate and permeate quality. VSEP operation occurred from April 10 through July 2, 2013.

To investigate the ICCP process, bench testing of lime soda-ash softening of the pilot test RO concentrate was conducted in a laboratory setting. Bench testing was followed by an evaluation of a secondary RO system by GE, which included modeling of the secondary RO system performance, preliminary equipment sizing, and assessing pretreatment requirements.

For all of the three pretreatment options listed above, data was provided to GE for their evaluation of the use of evaporation and crystallization in this application. Results of the testing detailed above, along with the evaluations completed by GE, are discussed in Section 5.0 of this report.

3.0 Water Quality

3.1 Historical Water Quality

The quality of the water being discharged via the outfall at SD033 has been monitored regularly over the past several years. Table 1 includes a statistical summary of the water quality data from SD033 from January 2005 through December 2011. These data are based on the analytical results from the monthly Discharge Monitoring Reports (DMRs) as reported by CE in accordance with the Permit. For parameters that had concentrations below their corresponding reporting limit values, concentrations were reported as the reporting limit values. These reporting limit values, along with the actual analytical data results, were used to calculate the average concentrations.

3.2 Pit Water Used in Pilot Testing

The Area 5NW pit lake was proposed as an alternate collection location for the RO pilot testing source water. The water collection point at Area 5NW was considerably safer and easier to access than SD033 and was more amenable to collection in winter due to the potential for freezing conditions near the SD033 discharge. Further, this alternative water source was believed to be suitable for the pilot testing because the Area 5NW pit lake is the primary contributor to the discharge and has similar observed water qualities to SD033. The use of Area 5NW water for the SD033 pilot was proposed in the work plan and accepted by the MPCA in the October 2012 letter of approval.

Water quality data for the Area 5NW water collected during the pilot test are presented in Table 2. Overall, the data set compares fairly well to the historical data collected from the SD033 discharge. A comparison of historical TDS, alkalinity, and sulfate data for the discharge from SD033 and the pilot feed water from Area 5NW is shown on Figure 2. Both Table 2 and Figure 2 show that there was a nearly one-month long period where the water pumped from the Area 5NW pit was considerably diluted compared to historical averages. This period was attributed to runoff and dilution from the substantial snow melt (created by heavy snowfalls and a long winter) that narrowed the melting period in 2013. Based on the analytical data, the period of impact to the pilot testing program was part limited to the weeks of Monday, April 29th through Monday, May 13th. In response to the run-off dilution observed near the surface of the pit lake, the collection pump intake was lowered at the Area 5NW sampling location to access water having more representative water quality for testing. Where differences in the quality of pilot feed water may have affected treatment considerations, and/or when the data are excluded from calculations, these conditions are identified and described within the evaluations presented in Sections 4.0 through 6.0.

3.3 Treated Water Quality Goals

The allowable concentrations of parameters in permitted discharges are derived from the beneficial use classification(s) of the receiving water. The receiving water for SD033 is Spring Mine Creek, which is an unlisted water with default beneficial use classifications of 2B, 3C, 4A, 4B, 5, and 6, as described in Minnesota Rule Chapter 7050.0430. However, because a detailed evaluation of actual uses of the receiving water has not yet been completed, the potentially applicable Minnesota water quality standards were used as a guide in the selection of RO treatment for testing and in the development of the pilot testing work plan.

3.3.1 Sulfate

The primary use classifications pertaining to sulfate are the Class 1, Class 4A, and Class 4B water quality standards, as described in Minnesota Rules Chapters 7050.0221 and 7050.0224. Waters with a beneficial use classification of 1 are used for drinking water consumption and, as noted above, are not applicable to Spring Mine Creek. Class 1 waters must meet the U.S. EPA primary and secondary drinking water standards. The secondary drinking water standard for sulfate is 250 milligrams per liter (mg/L). For waters with a beneficial use classification of 4A (irrigation), the sulfate concentration in those waters can be no greater than 10 mg/L for waters where wild rice is produced "during periods when the rice may be susceptible to damage by high sulfate levels." For waters with a beneficial use classification of 4B (livestock and wildlife consumption), while no numeric standard is given, it has been interpreted by the MPCA to mean that the sulfate concentration in those waters cannot be greater than 1,000 mg/L. Given the potentially wide range of applicable water quality targets for sulfate discharge to Spring Mine Creek, a conservative value of 10 mg/L was used as a treatment target when evaluating the data collected during the pilot testing program.

3.3.2 Other Parameters of Concern

For the parameters of concern, the following in-stream water quality standards, from Minnesota Rules Chapter 7050.0222 through 7050.02, were used as a guide for setting treatment goals for the pilot test:

- Class 2B (fishing and aquatic life): no specific requirements for the parameters of concern
- Class 3C (industrial cooling and materials transport): Hardness – 500 mg/L

- Class 4A (irrigation): Bicarbonates – 5 millequivalents per liter (meq/L) (250 mg/L as $CaCO_3$), specific conductance – 1,000 micromhos per centimeter (µmhos/cm), total dissolved salts – 700 mg/L
- Class 4B (livestock and wildlife consumption): Total salinity – 1,000 mg/L
- Class 5 (aesthetic enjoyment and navigation): no specific requirements for the parameters of concern
- Class 6 (other uses): no specific requirements for the parameters of concern

4.0 Reverse Osmosis Pilot Test Results

4.1 Pretreatment

4.1.1 Greensand Filtration

The greensand filter pilot unit for the pilot test was a pressure filter (see Figure 3). This filter is a 30-inch diameter unit filled with coarse gravel (5 inches), greensand filter media (30 inches), and anthracite (12 inches). The greensand media is silica sand coated with manganese oxide. Technical information on the greensand used during the pilot test and information on the pilot unit systems can be found in Appendix A.

For the pilot test, the influent was dosed continuously with potassium permanganate in order to (1) oxidize iron and manganese for removal by filtration and (2) regenerate the greensand media.

4.1.1.1 Filter Loading

Over the duration of the testing program, the influent flow rate ranged from around 15 to 22 gpm. The resultant range of hydraulic loading to the filter was 3.1 to 4.5 gpm per square foot (gpm/ft^2) of filter bed area.

4.1.1.2 Filter Removal Rates

The greensand filter removal rates for total suspended solids (TSS), iron, and manganese are presented in Table 3. During the complete period of testing (including startup and optimization phases), the TSS removal across the filter averaged > 41.9%. However, 15 of the 21 sampling events had TSS concentrations in both the influent and effluent from the greensand filter below the method reporting limit. Similarly, the removal of TSS was > 45% on average during Phase 3, but again the low observed removal may be related to the frequent influent concentrations below method reporting limits. Iron removal through the filter averaged > 73.1% over the course of the entire testing period. The concentration of iron in the filter effluent was never detected above the method reporting limit.

Greensand filter manganese removal averaged 86.0% over the course of the entire test. The greensand filter demonstrated the lowest manganese removal when the influent concentration dropped significantly during the three-week snow melt period. If those data points are removed from the average, manganese removal performance increases to 89.9% for the remainder of the testing period. Breakthrough of manganese to levels that could be problematic for operation of the RO membrane was not observed during the pilot test. Some variability in the effluent manganese was apparent, but effluent concentrations never exceeded 58 micrograms per liter (ug/L), a value similar to the alert level of 50 ug/L recommended by some membrane system vendors (Hydranautics, 2006). The variability in effluent manganese observed during the test can likely be attributed to varied uptake of the potassium permanganate across different regions of the filter media. Potassium permanganate dosing was held constant at 2.5 mg/L for the duration of the pilot test. Concentrations of manganese, iron, TSS, and all other parameters measured in the greensand filter effluent are displayed in Table 4.

4.1.1.3 Residuals

Periodically, accumulated solids must be removed from the greensand filter bed to maintain hydraulic capacity and performance. A filter backwash can be triggered based on filter run time, or more commonly, an increase in pressure drop across the filter. For the pilot unit, pressure drop was used to trigger backwash events. When the pressure drop across the unit reached approximately 10 psi, feed water was pumped up through the filter bed at a rate of 60 to 70 gpm (12 gpm/ft^2) to remove solids from the bed. During Phase 3 operations, the filter backwash frequency was approximately once every two days. Samples of the spent backwash water were collected and analyzed periodically. Greensand filter backwash water quality results are summarized in Table 5. In addition to containing elevated concentrations of TSS, iron, and manganese (the targeted constituents), the spent backwash water also contained elevated concentrations of organic material (as chemical oxygen demand), silica, and a few other trace metals.

4.1.1.4 Discussion

The primary purpose of the greensand filter was to protect the RO membranes by removing particulate matter, iron, and manganese upstream. The filter generally removed TSS and iron to concentrations below the method reporting limits and significantly reduced manganese concentrations. Although the RO membranes did exhibit signs of fouling during the seven-month pilot test, the reasons for this observed fouling were not likely due to the concentrations of iron, manganese, or other potential scalants or foulants in the RO feed water. The minimal fouling observed was due to the presence of microorganisms that result in biofouling, as discussed in more detail in Section 4.2. The greensand filter was a simple-to-operate, effective means of pretreatment for the feed water from Area 5NW.

In a full-scale application, one of the primary design criteria for greensand filters is the hydraulic loading rate. The loading rate for greensand filters has the potential to affect the manganese removal efficiency, the backwash frequency, and the number of filters required for filtration. For this pilot testing unit, the hydraulic loading rate was fixed by the unit supplier and was higher than typical hydraulic loadings for this type of filter (up to 4.5 gpm/ft^2 for the pilot compared to 3 gpm/ft^2 as a typical value). Influent concentrations of TSS, iron, and manganese for the Area 5 NW pit water were generally low compared to other greensand filter applications. Higher-than-typical loading rates can also be acceptable if demonstration testing shows acceptable treatment performance and backwash frequency, as was case during this pilot testing program.

4.1.2 Chemical Pretreatment

At the recommendation of the unit supplier, 3.9 ppm of Hypersperse MDC150, a scale inhibitor, was added to the process upstream of the RO membranes. As can be seen in Figure 2, the water at SD033 has generally contained slightly higher concentrations of bicarbonate alkalinity than was observed in the feed water from Area 5NW during the pilot testing program. For implementation of RO for the treatment of water from SD033, additional pretreatment of the water with a mineral acid may be required to mitigate scaling from calcium carbonate.

4.2 Reverse Osmosis

The RO pilot unit, as installed for this pilot testing application, is shown in the photograph on Figure 4. Manufacturer's information on the pilot unit can be found in Appendix A. The pilot used 18, 4-inch-diameter RO modules housed in six vessels, with the vessels oriented in a 4-stage (2-2-1-1) array. The 2-2-1-1 pattern provides treatment with two housings in parallel, two more housings in parallel, and the final two housings in series. Membranes employed in the pilot test were low-pressure RO membranes (GE model AG90). The pilot unit was operated continuously for approximately 8 hours per day, typically 5 days per week. At the end of each 8-hour shift, the RO system was flushed with permeate and shut down.

4.2.1 Flux and Recovery

Key operating variables for membrane treatment are recovery, the percentage of feed water volume that becomes permeate, and flux, or the flow rate through the system per unit area of membrane in service. In general, the higher the membrane flux, the lower the membrane area required for a given treatment capacity. However, operation at higher flux rates has the potential to increases the fouling rate of the membranes. For this application, the pilot flux and recovery targets were chosen during the initial period of testing and not changed during Phase 2 of testing. However, a substantial period of time during Phase 2 was dedicated to installing new mechanical components to allow the system to reach the target recovery and flux. Components changed included the pilot RO unit's flowmeter and concentrate orifice valve, which helps regulate concentrate flow and therefore recovery.

By the end of Phase 2, the following target operating parameters were set:

- Recovery of 80%
- Flux of 15 gallons per square foot per day (gfd)

During Phase 3, the RO pilot unit operated continuously at these target operating parameters. The flux of the system was within the limits of what is generally used in the design of RO groundwater treatment systems (US EPA, 2005). The feed-to-concentrate pressure drop across the RO system was stable at approximately 21 to 27 psi during much of Phase 3, and remained well below the threshold to initiate membrane cleaning (> 50 psi per stage) for the entire testing period. A slight decrease in pressure drop related to a drop in the feed pressure occurred later in Phase 3. This period occurred after the period of diluted feed water that resulted from the snow melt condition of the Area 5NW pit, which resulted in a lower osmotic pressure (from feed water with a lower TDS concentration). Decreasing feed pressures over the course of the test can be attributed to the change in temperature experienced during the spring thaw and into the summer. The water temperature through the unit went from about 10 degrees Celsius (°C) to nearly 22 °C by the end of testing in early July. The feed-to-concentrate pressure drop and the feed pressures experienced over the course of pilot testing are shown on Figures 5 and 6, respectively.

4.2.2 Field Performance Monitoring

Operators of the pilot testing unit collected field parameters from the RO membrane unit feed, permeate, and concentrate daily during operation. Readings were taken from each flow stream for at least one of the following parameters: flow rate, temperature, pH, conductivity, oxidation-reduction potential (ORP), turbidity and TDS. These data were collected in addition to the online data collection system of the pilot testing unit to give the operators a real-time indication of performance and allow them to troubleshoot problems with the unit if necessary.

During the month of June, operators began taking conductivity readings of the permeates from each membrane vessel when higher permeate conductivity and sulfate concentrations began to be observed. These inter-stage conductivity readings helped narrow the source of potential operational issues with the pilot RO membrane unit. Readings of inter-stage conductivities collected by the operators are shown with a depiction of the membrane layout in Figure 7.

Readings taken on June 7, 2013 before any troubleshooting of the system indicated that the increased conductivity in the permeate was likely resulting from the lower salt rejection in the tail elements (relative to the modeled predictions by GE). The second set of readings was taken on June 14th, after an inspection of vessel housing #6 suggested that a loose o-ring may have been allowing feed water to leak through into the permeate tube and after the subsequent replacement of the o-ring. As can be seen from Figure 7, the conductivity in the last housing dropped after that event, but only slightly. GE indicated at that time that the increase in permeate conductivity was partially due to temperature increases through the system, but that the conductivities, particularly in housing #6, were higher than the model had suggested. During the replacement of the o-ring, the operators observed a fishy odor and film on the membrane units, which then prompted a cleaning event for the system (as discussed further in section 4.2.4). The final readings shown in Figure 7 from July 1st were collected after chemical cleaning and suggest that performance was actually lower after the chemical clean-in-place (CIP) event.

4.2.3 Permeate Water Quality

The RO feed ("pretreated effluent"), permeate, and concentrate water quality data collected during Phases 2 and 3 are summarized in Table 4, Table 6, and Table 7, respectively.

4.2.3.1 Removal Rates

Average removal rates were estimated for those parameters with detectable concentrations in the greensand filter effluent (RO feed) and are displayed in Table 8. Excluding the data from the melt-water period (which would artificially skew the apparent performance of the membranes), the average sulfate removal was 99.6% during the pilot test (Figure 8) and the average sulfate concentration in the RO permeate was 4.2 mg/L. The highest permeate sulfate concentration observed during the test was 12 mg/L. As can be seen on Figure 8, sulfate rejection decreased over the course of the pilot test. This was, in part, due to increased feed water temperatures over the pilot testing program. However, the performance decline is not fully explained by temperature. Further, the last three samples collected, two of which were taken on June 24th shortly after each of the two CIP events and a third that was collected a week later, showed the worst sulfate removal performance. These analytical results confirm that chemical cleaning actually worsened performance of the membranes (as was suggested by the inter-stage conductivity readings). A discussion of the probable reasons for the drop in removal rates can be found in Section 4.2.5.

During Phase 3 of the testing, the average salt passage through the membranes (as represented by the percentage of TDS in the feed that passed through the membrane as permeate) was < 0.3%, with no reported TDS in the permeate at a laboratory reporting limit of 10 mg/l (see Figure 9). Calculated removal excludes the melt period and samples collected on June 24th, which were affected by cleaning solutions applied just prior to sampling. Many other parameters, particularly the major anions and cations, were reduced by greater than 95%. However, in many instances the upper limit of removals were not determined in the routine testing because (1) the concentrations measured in the permeate were less than the method reporting limit and/or (2) the concentrations in the influent were low and close to the method reporting limit.

For some constituents, removal by RO membranes is highly pH-dependent. Examples of this are ammonia and boron, which are present as un-ionized species over a range of pH values. The un-ionized species are not well-removed by membranes. For this pilot test, the following observations were noted:

- Ammonia: At pH values below 7, most of the ammonia is present as the ammonium ion and can be removed by the RO process. The pH of the feed water to the pilot RO system was approximately 8.2, meaning that a lower amount of ammonia could be removed. However, the concentration of ammonia in the influent was relatively low, and therefore the ability to accurately estimate the ammonia removal by the RO system was inhibited.
- Boron: It is known that boron removal at pH values below the pKa (pH = 9.2) of boric acid is limited due to the lack of charge on the species. The boron removal during the pilot-testing program, while limited compared to other parameters, was sufficient to remove boron to below the detection limit of 0.05 mg/L. Specialty membranes or pH adjustment are typically required for greater boron removal.

Total organic carbon and fluoride do not appear to be well removed by the RO system. However, the upper limits of removal could not be determined because the concentrations of these two parameters were low in the RO system influent and below the method reporting limits for essentially every sample in the permeate.

4.2.3.2 Comparison to Equipment Supplier Models

The suppliers of RO membranes commonly use models in their system design and to estimate the permeate water quality. Each supplier typically has developed its own models for its membranes, and each supplier has significant operating data collected over many years for validation of the model output. The model water quality input and output is generally limited to the major anions and cations, pH, boron, and certain constituents of concern with respect to membrane fouling or scaling (e.g., aluminum, barium, silica, and strontium). Preliminary modeling was completed with both Area 5NW pit water and SD033 discharge as feed waters. Two types of membranes were also used as inputs into the model. GE’s RO model results for the selected membrane type and the pilot test feed water (from the Area 5NW pit) are presented in Table 9. Modeling of treatment of pilot test water by RO resulted in:

- 80% recovery across the RO system
- A requirement of pretreatment with anti-scalant
- Permeate water quality very similar to that demonstrated during the early portion of the pilot test for sulfate and parameters of concern before sulfate and other selected parameters began increasing due to membrane condition issues (see Section 4.2.5).

4.2.4 Cleaning Requirements

Inorganic and organic scale and foulants build up on RO membranes over time and reduce performance. Membranes undergo CIP events to remove the foulants and restore performance. CIP events are triggered at one of the following conditions: when the system pressure drop reaches a predetermined value or increases by a certain percentage, if salt passage increases beyond a certain percentage, or on a regular time interval if other parameters have not triggered a CIP event. GE generally recommends that membranes be cleaned every 3-4 months (of continuous operation) if a CIP has not been initiated for other reasons. Significant increases in pressure drop from the RO feed to the concentrate were not seen in any phase of the pilot testing.

However, an orange to brown, slimy material was observed on the RO membranes during the check of the inter-stage conductivities in mid-June. Based on the color and odor (a fishy smell), this was thought by the membrane vendor to be biofouling resulting from a common microorganism found in RO systems (pseudomonas). While the material did not seem to hinder membrane operation and did not result in an increase in pressure drop, its presence, along with the high inter-stage conductivities, was the impetus for initiating a CIP event for the system.

A CIP was conducted on July 23-24, 2013 following the cleaning procedures recommended by GE. A low pH cleaner (citric acid) was used on July 23rd, and a proprietary high pH cleaner from GE was used on July 24th to clean the membranes. The cleaning solutions were recirculated through the membranes in a two-step cleaning process and samples of the spent cleaning wastes were collected for analysis (see Table 10).

The analytical results from the chemical cleaning wastes can provide insight into the fouling or scaling constituents on the membranes and which cleaner removes them. The following parameters were elevated following treatment of each cleaner:

- Low pH cleaner: chemical oxygen demand (COD, from the cleaner), TDS, aluminum, arsenic, barium, calcium, iron, magnesium, manganese, sodium, and strontium
- High pH cleaner: sodium and COD (both from cleaner) and magnesium

The presence of increased concentrations of parameters such as barium and strontium suggest that some accumulation of these constituents did occur on the membrane, even though increased pressure drop was not observed.

4.2.5 Discussion

The selection of RO for pilot testing of mechanical treatment of SD033 water was driven primarily by its potential to produce treated water containing less than 10 mg/L of sulfate. Early during the testing (Phase 2 and early phase 3), the RO membranes consistently produced water with sulfate concentrations less than the water quality targets listed in Section 3. As Phase 3 progressed, the sulfate removal achieved by the membranes gradually decreased. Although the RO permeate sulfate concentration remained below the 10 mg/L target until the last two samples, the quality produced would not allow blending of other permeate streams (from concentrate management) without exceeding the water quality target. Further, the samples collected after the completion of the CIP event showed sulfate concentrations greater than the water quality target.

To investigate the possible reasons for the downward trend in performance during the RO membrane pilot test, Separation Processes, Inc. (SPI) completed both a membrane autopsy and a review of the operation data collected by the unit. Reports detailing their findings can be found as Appendix B (autopsy) and Appendix C (data performance). SPI first performed the flow and rejection testing portion of the membrane autopsy on two lead elements and two of the tail elements of the system. The two lead elements were operated in parallel and were essentially exposed to water from the Area 5NW pit, while the tail elements were operated in series at the end of the unit (i.e. these membranes were exposed to higher conductivity water similar to RO concentrate). The tail membrane elements showed significant loss of salt rejection in the testing, and were therefore further analyzed through a physical and chemical evaluation.

Both tail elements underwent an external inspection that yielded no areas of concern regarding damage or the potential for a loss in salt rejection. SPI next completed an internal inspection on the lag elements that included dye testing, Scanning Electron Microscopy inspection, and other testing. Upon completing the internal examination of the membrane element, SPI determined that there were two potential reasons for the decreased measured performance of the RO pilot: possible issues in the manufacturing process and the exposure of the elements to excess permeate backpressure during the pilot test that resulted in damage to the membranes.

Regarding potential manufacturing issues, an important finding of the testing was the uneven distribution of dye concentrations across a membrane element (element 6-3) that underwent dye testing. An irregular distribution of foulant was also observed on the other element (element 6-2) that did not undergo dye testing. Inconsistent tensioning during the rolling of the individual membrane element is a common cause of this patterning of dye variable rejection. Further, the autopsy also revealed very poor adhesion of the composite membrane sheets and weak glue line adhesion in the elements.

Secondly, SPI determined that permeate backpressure damage likely occurred during the pilot test because the patterns in membrane dye passage mirrored the feed/brine spacer construction, suggesting that the feed/brine spacer burrowed into the membrane surface. This action would have likely caused the increased salt passage by scratching and making holes in the polyamide layer. According to SPI, backpressure often results in a single event of membrane failure (i.e. membrane delamination). These membranes did not experience a failure event, but rather experienced membrane “pouching”, the term applied to the driving of the feed/brine spacer into the membrane during conditions of permeate backpressure. SPI also concluded that it was rather surprising that the backpressure issue did not result in membrane delamination because of the weak adhesion it observed during the internal inspection.

Based on its review of the operating data recorded by the pilot unit throughout the pilot test (see Appendix C), SPI concluded that the performance data corroborated the observations made during the membrane autopsy. The primary basis for this conclusion is the increase in salt passage measured over the course of Phase 3 of testing. SPI also cited in its review that the data collected during phases 1 and 2 of the test (prior to March 18), would not provide an accurate indication of membrane performance. As noted above, the early phases included an optimization period and were marred by flow control issues, parts replacement, and an inaccurate flow meter on the unit. The best estimate of membrane rejection properties can only be gathered from the most representative period of membrane performance, which is March 18th through April 23rd.

Once the operational parameters were set by phase 3 of the pilot testing program, no significant operational or maintenance problems were encountered. A scale inhibitor (a phosphoric acid salt solution) was used to manage the formation of scale and silica on the membranes. As mentioned above, the membrane system did not experience a significant increase in pressure drop from the RO feed to the concentrate. This stability suggests that chemical scaling and fouling were not significant during the pilot test and that the pretreatment systems in place were effective. It also indicates that the possible biofouling of the membranes observed during testing did not result in significant increases in pressure drop. Other means of monitoring for this type of foulant would need to be instituted in a full-scale operation to prevent excessive buildup that may cause throughput limitations or pressure drop increases.

5.0 Concentrate Management Evaluation

Concentrate management is a key component that must be considered for successful implementation of membrane treatment for any application. Concentrate management options for the use of RO at SD033 were reviewed in *Short-Term Mitigation Evaluation and Implementation Plan for SD033* in 2010. That report concluded that evaporation and crystallization of the RO concentrate, followed by disposal of the solid salts, was the most feasible option technically and practically. The objectives of the concentrate management evaluation discussed below were to examine these technologies in more detail and to determine if other complementary volume-reducing technologies could reduce the cost of producing a solid salt waste product for disposal.

Bench testing, pilot testing, and the receipt of input from GE, a manufacturer of evaporation and crystallization equipment, comprised this evaluation. The sections below describe the results of the technical evaluations that were completed. Updated estimates of implementation costs are provided in Section 7.0 for each of the three management options included in the evaluation.

5.1 Evaporation and Crystallization

The use of evaporation (brine concentration) and crystallization immediately after the RO system, as shown in Figure 10, is the approach that was reviewed originally in the *Short-Term Mitigation Evaluation and Implementation Plan for SD033*. Based on the damage to the membranes observed during pilot testing, the pilot RO concentrate was not used for the evaluation. Rather, the complete data set of Area 5NW water collected during the pilot test was provided to GE for their use in modeling RO to treat the water from SD033. With the RO process model and using the same membrane that was employed during the pilot testing program, GE produced a resulting RO concentrate water quality. The modeling results are presented in Table 11. The resulting modeled RO concentrate was then used as the theoretical feed source for evaluation of the mechanical brine concentrator and crystallizer systems.

For this application, GE suggested the following equipment:

- Falling-film, mechanical vapor recompression evaporator with seed slurry, followed by a
- Mixed-salt, calandria crystallizer
- Further dewatering of the salt solids using a filter press

Some pretreatment of the RO concentrate prior to the evaporator is necessary. The recommended pretreatment consists of pH adjustment to reduce carbonate scaling followed by deaeration to remove the resulting carbon dioxide. The feed to the evaporator is heated, in part, by the waste heat from the system distillate (via a heat exchanger). During the evaporator cycle, concentrated brine slurry is continuously withdrawn and sent to the crystallizer. In the crystallizer, the brine slurry becomes supersaturated and salt crystals will precipitate. The precipitates are separated from solution by a filter press.

The water from SD033, if similar to the pilot feed water from the Area 5NW pit, may contain some naturally occurring organic matter (as total organic carbon, TOC). The TOC may impact the performance of the evaporator and crystallizer units in two specific ways: foaming, and decreased solids separation efficiency in the dewatering process. To manage foaming, antifoaming agent would be continuously added to the crystallizer body. To manage the effects of the TOC on the solids separation process, a purge may be necessary from the crystallizer. This concentrated, liquid purge stream would require detailed evaluation of disposal options. Alternatively, additional pretreatment may be required upstream of the RO process to remove or mineralize the TOC prior to treatment. Additional treatment processes could include options such as adsorption with granular activated carbon, or advanced oxidation processes such as ozone/peroxide.

The distillates generated by the evaporator and crystallizer units will be low in TDS (< 50 mg/L). These distillates would be blended with the RO permeate for stabilization and discharge. The distillate may contain some volatile components such as ammonia or organic compounds that have been cycled up throughout the treatment train. However, their dilution by the primary RO system permeate will likely result in only minor increases compared to the feed water concentrations.

5.2 Concentrate Volume Reduction using VSEP

The capital and operating costs of evaporators and crystallizers can be a significant percentage of overall project costs. The VSEP process was evaluated as a possible method to reduce the capacity of or eliminate the evaporator and reduce overall operating costs of the concentrate management train. The VSEP configuration evaluated is illustrated in Figure 11.

5.2.1 VSEP Pilot Test Operation and Results

A picture of the pilot test unit that was used in the pilot testing program is shown on Figure 12. Manufacturer’s information on the pilot unit can be found in Appendix A. The unit can be operated in batch mode or single-pass (continuous) mode, and RO membranes (ESPA series manufactured by Hydranautics) were utilized in the pilot test.

5.2.1.1 Operational Mode

As part of previous pilot testing, a New Logic Research field engineer led startup and optimization of the VSEP unit with assistance provided by PolyMet staff. Through operation of the unit in both batch and single-pass mode, it was determined that greater flux stability could be achieved by operating the unit in batch mode. This mode was used for all SD033 pilot testing activities.

In batch mode, the VSEP system uses a constant cross flow along with vibration to reduce fouling and polarization at the membrane surface. For the batch process, a fixed volume of concentrate from the RO system is fed to the VSEP system. The concentrate from the VSEP unit is returned to the VSEP feed tank and the VSEP permeate is discharged (as illustrated on Figure 11). As a result, the concentration of total dissolved solids in the feed tank increases over the duration of batch processing. This process continues until the target recovery has been achieved or until the flow through the membrane falls below a predetermined threshold, which occurs along with an increase in the osmotic pressure as scalants and foulants accumulate on the membrane. When the terminal flow is reached, the membranes must be cleaned. It is possible to process more than one batch of concentrate before a cleaning is required.

5.2.1.2 Recovery

In general, higher recovery results in less final VSEP concentrate volume, which has the advantage of minimizing the volume of VSEP concentrate that must be processed by an evaporator and/or crystallizer. Higher recoveries also have the potential to require more frequent chemical cleanings and have a greater potential for scaling and fouling issues. A target recovery of 80% was used for the pilot testing of the system and this evaluation.

5.2.1.3 Chemical Pretreatment

Due to the results observed during the initial startup that occurred during previous testing, only one test was completed without the addition of chemical additives to the feed. This test showed only about a 50% recovery. Three additional tests were completed with the addition of an anti-scalant (NRL 759) at 10 ppm and without pH adjustment, but these tests also failed to reach the target recovery of 80% (ending at roughly 70-75% recovery). Therefore, the subsequent batches were tested with the addition of the anti-scalant and with pH adjustment to between 6 and 7 standard pH units (SU).

Adjustment of the VSEP pilot unit feed pH was achieved in one of two ways for each subsequent batch: the addition of 40% sulfuric acid to the feed tank, or the dosing of carbon dioxide (CO_2) gas to the VSEP feed stream. Carbon dioxide was used in an attempt to reduce the sulfate load to the membranes and improve the VSEP permeate water quality with respect to sulfate. All pH adjustment scenarios involved lowering the pH throughout the duration of the batch test. A comparison of the batches run with the two different forms of pH adjustment indicated that similar flux curves and final fluxes at the target recovery of 80% were obtained (see Figure 13). The addition of CO_2 resulted in a rougher flux curve due to a less stable pH, which was attributed to the extent of pH control available when using the regulators available with the CO_2 gas cylinder. However, the noise induced by the fluctuating pH did not produce a significant difference in flux from similar batches completed with acid addition.

Acid addition to the feed water improves operation of the membrane system because the scaling potential of calcium carbonate is reduced at pH levels of 6 to 7 compared to the initial pH of about 8.2. Both methods of pH adjustment were tested at target feed pH values of 6, 6.5, and 7 SU. Little to no additional improvement in flux at the target recovery was achieved by lowering the pH below 7, with resulting fluxes routinely around 20 to 25 gfd. Figure 14 illustrates the results of changing the target feed water pH to the VSEP pilot unit when feeding with sulfuric acid.

5.2.1.4 Cleaning

The VSEP membranes must be cleaned on a regular basis during continuous operation. As part of the pilot testing evaluation, several different cleaning strategies were employed between the testing batches. Typical cleaning procedures for membranes, including standard RO membranes, involve a two-step process: an acid clean and a basic clean. The acid clean removes scale and foulants such as carbonate minerals and some metals, while the basic cleaning step removes organic materials, silica, and biofilms. For the VSEP, three types of cleanings were tested:

- Hot water flush – no chemicals
- Acid clean – using a proprietary cleaning solution from New Logic Research, NLR 404
- Basic clean – using a proprietary cleaning solution from New Logic Research, NLR 505

For the three batches in which only anti-scalant was used for chemical pretreatment, neither of the two cleaners distinctly restored flux more effectively than the other. When both anti-scalant and acid were used for pretreatment of the batch feed solution, a cleaning regimen of applying NLR 404 followed by NLR 505 was effective in restoring membrane flux. In some cases though, the cleaning materials provided little increase in flux compared to the hot water flush. With some improvement in flux gained from the application of each solution, different components likely contributed to the recovery limitations observed during each batch, including acid-soluble minerals and those foulants removed by basic solutions (organic compounds or silica). A few cleaning events involved a second clean with the NLR 505 basic solution, but no (or limited) additional flux was gained with this repeated application.

Samples of spent cleaning solutions were collected and analyzed during pilot testing, as summarized in Table 12. One spent solution from the application of the NLR 404 and one solution from the application of NLR 505, applied on the same day in that order, were analyzed. For all cleanings, the spent cleaning solution contained elevated concentrations of chemical oxygen demand (COD). Both the NLR 404 (an organic acid) and the NLR 505 (an organic surfactant) could be expected to exhibit some COD, although a relatively small amount of the COD could be from possible accumulation of organic material on the membranes. The NLR 404 spent solution also showed elevated levels of orthophosphate, sodium, and aluminum relative to the VSEP feed water. These parameters, particularly the orthophosphate, are likely part of the formulation of the proprietary NLR 404 cleaner. The same can be said for the high levels of alkalinity and sodium measured in the spent cleaning waste from the application of the NLR 505.

Three critical observations can be made about the VSEP membrane cleaning process:

- The original flux of the new membrane prior to any treatment or cleanings was 100 gfd. However, the achievable flux with membranes often decreases to a lower value after the membrane is conditioned via the introduction of the site-specific water. After multiple batches and cleanings, the decreased flux stabilizes at a new level considered the baseline flux for this application. For this pilot testing application, the flux stabilized near 60 gfd after about the eighth batch of treatment and cleaning. Subsequent cleanings were able to restore the membrane flux to between about 58 and 70 gfd, or to within about 17% of the baseline flux (of about 60 gfd). Although the original flux was not again achieved, the established baseline flux for this application was restored. This suggests that irreversible fouling, which reduces membrane life, was not observed during the operation of the pilot test.
- Cleaning temperature is an important variable for effective cleanings. New Logic Research recommended that the chemical cleaning solutions be 50°C for the cleaning process. Based on the results of the hot water flush, cleanings at higher temperatures were more effective at restoring membrane flux.

- Pretreatment with acid and anti-scalant may reduce the cleaning frequency required. A hot water flush alone was applied only to the new membrane, and chemicals will likely be required between all batches unless further testing can demonstrate that how water flushes alone are sufficient to restore the flux.

5.2.1.5 Removal Rates

A summary of the VSEP permeate water quality is presented in Table 13. Batches of RO concentrate treated from May 1st through May 14th had diluted RO concentrate due to the run-off event and are not considered representative (and were not included in computed removal rates). A preliminary estimate of average removal rates is shown in Table 14 and Table 15 (concentration and mass-based, respectively). Removal rates were estimated for those parameters with detectable concentrations in the RO concentrate (VSEP feed). Many parameters are reduced by greater than 90% on average. Similar to the primary RO unit, in many instances the upper limit of removals were not determined in the routine testing because (1) the concentrations measured in the permeate were less than the method reporting limit and/or (2) the concentrations in the influent were low and close to the method reporting limit (e.g. arsenic and fluoride).

With the exception of sulfate, the VSEP permeate met the treatment targets listed in Section 3.3. Although the VSEP permeate will be blended with the RO permeate and distillate prior to discharge, as shown on Figure 11, the extent of sulfate removal by the VSEP was insufficient to produce a blended permeate stream below 10 mg/L if all VSEP permeate were routed to the effluent stream. Excluding additional dilution with the distillates, blending of the pilot permeates would have a combined sulfate concentration of approximately 24.5 mg/L, based on 80% recovery across the primary RO system, 80% recovery across the VSEP, a primary RO permeate sulfate concentration of 4.2 mg/L, and an overall average VSEP permeate sulfate concentration of 126 mg/L. If the modeled primary RO permeate of 2.62 mg/L were used (instead of the pilot average of 4.2 mg/L), the resulting combined permeate concentration would be 23.1 mg/L.

In order to accommodate the VSEP permeate sulfate concentrations above the water quality targets, a portion of the VSEP permeate will need to be routed back to the primary RO system for additional treatment through the entire train. This return stream will, in effect, dilute the feed stream to the primary RO unit. For this alternative, the same modeling results of the primary RO unit, which saw undiluted feed water from Area 5NW, were used in order to provide a conservative estimate of the residuals in the concentrate. The return stream of VSEP permeate is shown as a blue line on Figure

11. Based on these results, approximately 75% of the VSEP permeate will require re-treatment in the primary RO system.

The VSEP concentrate and permeate quality was analyzed during the pilot test for a considerable number of the batches tested. Resulting concentrate from batches tested with both CO_2 and sulfuric acid were analyzed. Those results are presented in Table 16. For the events shown in the table that occurred after the run-off period (i.e., after May 14th), batches conducted on May 20th-21st and June 20th-27th used CO_2 for pH adjustment, while batches from June 11th-18th used sulfuric acid. Use of CO_2 did result in a slight increase in the alkalinity of both the permeate and the concentrate streams. In the permeate, the additional alkalinity may be beneficial to the effluent stabilization process where alkalinity is reintroduced to the water, but the increase measured is likely not enough to drastically change the stabilization method. For the concentrate stream, the increase in alkalinity would have to be considered in the selection of evaporator and crystallizer systems but would likely not have implementation concerns commensurate with the addition of other pH adjustment methods. Sulfate concentrations and pH levels in the VSEP permeate were not found to be considerably different for the two pH adjustment methods.

5.2.2 Crystallization of the VSEP Concentrate

New Logic Research utilized the pilot data collected from the VSEP system and information on the full-size RO systems to estimate the size and performance of a VSEP system to treat the water from SD033. The estimated recovery for a full-scale system for SD033 would be 80%, similar to what was observed on the pilot scale. Based on the full-scale system and the results of the pilot test, New Logic Research indicated that a VSEP system for SD033 would consist of:

- Four i84 (84 inch) modules containing RO membranes (Hydranautics ESPA flat sheet membranes)
- Pretreatment with anti-scalant and pH adjustment (CO_2 or mineral acid)
- Feed tanks
- CIP system

The concentrate from the VSEP unit would be further treated using crystallization to produce a solid salt product for disposal. Using the projected VSEP rejection rates observed during pilot testing and the RO concentrate from the final primary RO unit modeling done by GE, a projected VSEP concentrate chemistry for SD033 was provided to GE for their assessment of the crystallization process. For this alternative, GE recommended that a steam-driven, mixed-salt crystallizer with a thermocompressor should be installed for handling of the VSEP concentrate. Also included in GE's recommendation was the upgrading of materials of construction of the crystallizer because of the potential for the use of hydrochloric acid in adjusting the pH prior to the VSEP system (which produces elevated concentrations of magnesium chloride in the concentrate sent to the crystallizer). These upgraded materials are reflected in the capital costs presented in Section 7.0. If CO_2 gas or a different acid were used for VSEP pretreatment, this materials upgrade may not be necessary and the capital costs of the crystallizer will be reduced.

Similar to the considerations discussed in Section 5.1, foam control and management of TOC in the system will also apply to this concentrate management configuration.

5.3 Intermediate Concentrate Chemical Precipitation

Another method to reduce RO concentrate volume (and thereby also reduce the size of downstream concentrate management processes) is the use of intermediate concentrate chemical precipitation (ICCP). ICCP involves treatment of the RO concentrate by processes including lime softening to remove certain constituents such as calcium and silica that contribute to RO fouling. After treatment by ICCP, the treated concentrate can be passed through a secondary RO system to reduce the concentrate volume further and maximize permeate production. The process is illustrated conceptually in Figure 15. Both the pilot test feed water and SD033 contain concentrations of calcium carbonate high enough to limit the recovery of an RO system. For this reason, calcium carbonate and other potential foulants such as silica, were targeted for removal by the ICCP process.

Silica and silicates are generic names given to compounds derived from the polymerization of silicic acid ($Si(OH)_4$). In neutral pH waters (pH of 6-8), silicic acid is common and has a propensity to polymerize, eventually forming colloidal polymers of many silicon dioxide molecules linked together. Metal hydroxides, if available, can be incorporated into the polymers to form more complex silicates (Ning, 2002).

In RO systems, the polymers of silicon dioxide and silicates coagulate with themselves and other organic matter and foul membranes, reducing recovery (Ning, 2002). To remove silica from feed water, lime-soda ash softening is commonly applied. This process increases the pH to 10-11, allowing magnesium hydroxide and calcium carbonate to precipitate. Silica is removed during this process by adsorption onto the surface of magnesium precipitates and by precipitation of the mineral forsterite (Mg_2SiO_4) (Sheikholeslami and Bright, 2002 and Parks and Edwards, 2007).

The rate of silica polymerization decreases at a pH above 9.5 and below 5.5. At a pH of 9.5, silicic acid mostly ionizes, preventing polymerization and minimizing fouling potential. Ionized silicic acid (present at pH of 9.5) in the presence of cations like magnesium and calcium could cause particulate fouling of a membrane, but a majority of the cations should be removed during the softening process (Sheikholeslami, Al-Mutaz, and Young, 2001). The amount of silica removal via lime-soda ash softening reportedly ranges from 70% to 90% (Sheikholeslami, Al-Mutaz, and Young, 2001, Sheikholeslami and Bright, 2002, and Parks and Edwards, 2007).

5.3.1 Bench Test Results

As introduced in Section 2.0, bench testing of the ICCP process was conducted to verify that scalants such as silica and calcium carbonate could be removed from the RO concentrate to allow for additional volume reduction by a second stage of RO membranes. The protocols followed can be found in Appendix A. Three lime doses, based on the optimal dose determined through chemical speciation modeling and doses at plus and minus ten percent of optimal, were applied to RO concentrate during bench testing.

Table 17 presents a summary of the ICCP bench test analytical results. Table 18 displays the percent removal rates for the three final samples, those collected after the settling period and dosed with soda ash, compared with the untreated RO concentrate water quality. All three final samples demonstrated removal rates at or near the maximum silica removal rate recorded in the literature (up to 90%).

All three dosages resulted in similar final silica concentrations, with the optimal -10% lime dosage, resulting in the lowest final silica concentration (1.9 mg/L). Each of the three samples had the same silica concentration (1.7 mg/L) after the lime settling period and before the addition of soda ash. Figure 16 shows the silica concentrations measured during lime flocculation and the concentration following soda ash addition. Most of the silica that was removed during the lime addition occurred within the first 10 minutes of flocculation. Between 10 and 45 minutes of flocculation, only the Optimal +10% sample had additional silica removal (compared to the untreated RO concentration).

Along with silica and calcium carbonate, barium sulfate, calcium fluoride, calcium sulfate, and metal oxides are all known scalants or foulants that can reduce membrane recoveries. Significant removal of barium and strontium and some fluoride removal were observed from the ICCP bench testing (Table 18), which, along with silica removal, may improve RO recovery. As expected with lime softening, calcium and magnesium were also significantly reduced.

Some boron removal was also observed during the bench test. Boron removal has been reported during the formation of magnesium silicates during lime-soda ash softening. The removal mechanism is either co-precipitation or adsorption to the magnesium silicate solids. The optimal pH for boron removal has been reported to be 10.8 (Rahman, 2009).

5.3.2 Secondary Reverse Osmosis System

The ICCP bench test results for silica removal were provided to GE for their use in further evaluating lime-soda ash softening and the secondary RO system for concentrate volume reduction. Based on the available data, it is estimated that the recovery of the secondary RO system would be approximately 80%. The blended permeates are estimated to meet the water quality goals presented in Section 3.3, including 10 mg/L sulfate (based on a primary RO concentration of 4.2 mg/L and a secondary RO permeate concentration of 26.6 mg/L). Pretreatment with pH adjustment and anti-scalant would also be required after the softening process, prior to treatment by the secondary RO unit. As rejection of this membrane can change with seasonality (i.e. temperature) and over the age of the membrane, it is possible that a portion of the secondary RO permeate will require re-treatment by the primary RO system (similar to the VSEP permeate in the second concentrate management option).

5.3.3 Crystallization of the Secondary RO System Concentrate

The concentrate from the secondary RO system would be sent to a crystallizer to produce a solid salt product for disposal. GE evaluated crystallizers for this water based on their modeling conducted in support of the secondary membrane system (i.e. using modeled secondary RO concentrate as feed). For this flow and feed water chemistry, either a mechanical vapor recompression or steam-driven, mixed-salt crystallizer were recommended. The materials of construction recommended are different than the crystallizer proposed for the VSEP option, due to the removal of magnesium from the water in the ICCP process. As discussed in Section 5.1, pH adjustment and foam control would be required. Some removal of TOC is expected across the lime softening process, but a purge or other pretreatment may still be necessary to manage the effects of organic materials on the precipitation process.

5.4 Implementation Considerations

When evaporators and crystallizers are used for concentrate management, they are typically the most expensive pieces of equipment in the treatment train. Pretreatment to optimize the water they receive is an important consideration in the overall engineering of the treatment train. In the case of SD033, two important factors to be considered in the design of a full-scale treatment facility are: (1) selection of the pH adjustment methods used upstream of the evaporator and crystallizer and (2) managing the effects of the total organic carbon in the feed water on the crystallization process.

pH adjustment to manage scale will be necessary prior to the RO system and VSEP system. The chemical additive selected for this process will ultimately report to the evaporator and/or crystallizer and may impact the materials of construction required for this equipment. For example, if hydrochloric acid is selected for use (to minimize the sulfate concentration in discharged water), the chloride may dictate higher grade materials be used in the crystallizer. The cost of the acid, the cost of the materials of construction for the crystallizer, and the final effluent water quality must be balanced.

During their evaluation of SD033 treatment, GE indicated that a purge stream off the crystallizer may be necessary to remove TOC that has been cycled up in the treatment process and which may interfere with salt precipitation and dewatering. A purge stream, regardless of volume, may be difficult to dispose, given its high concentrations of salts. Strategies to manage the purge stream or alternatives to eliminate it (e.g., removal of the TOC upstream of the RO process by adsorption or use of an advanced oxidation process) should be considered prior to detailed engineering.

6.0 Permeate Stabilization

Because RO membrane treatment removes dissolved constituents from water, the permeate is virtually void of minerals, and contains low amounts of calcium and alkalinity. Additionally, RO permeate often contains elevated concentrations of dissolved carbon dioxide. The carbon dioxide is formed from the reaction of anti-scalant chemicals, which are added to RO feed water to prevent calcium carbonate scale formation on the membranes, and bicarbonate alkalinity already present in the feed water. The resulting permeate stream, with low buffering capacity and low pH, is corrosive and tends to be toxic to some aquatic organisms. Prior to discharge, RO permeate must be stabilized to meet the discharge water quality targets.

An effluent stabilization bench testing experiment was designed and executed with two main objectives: (1) identify a stabilization method (e.g., addition of minerals) that will reduce the corrosiveness of the blended RO and VSEP permeates and maintain compliance with the effluent water quality targets in Section 3.3, and (2) produce a non-toxic effluent. For the purposes of the bench test, “non-toxic” was defined as water that was neither acutely nor chronically toxic to *Ceriodaphnia dubia* (*C. dubia*). The measure of chronic toxicity used for this evaluation was the ability of the test organisms to produce at least 75% of the number of young as those organisms in the control water. Two known treatment technologies were tested to meet the above objectives:

- Carbon dioxide (CO_2) and hydrated lime ($Ca(OH)_2$) addition
- Limestone contactors (LC)

The permeate used for testing was a blend of RO and VSEP permeate generated by the RO and VSEP pilot units, blended at a 5:1 ratio (representing recoveries of 80% for the RO unit and 80% for the VSEP unit). The stabilization bench testing was conducted at Barr’s wastewater laboratory.

In addition to the final water quality targets for the stabilized water discussed in Section 3.3, the following additional targets were used in this evaluation to measure the corrosiveness and toxicity of the blended effluent:

- Langelier Saturation Index (LSI) ≥ 0
- Calcium carbonate saturation index (SI) > 0
- 7-day chronic whole effluent toxicity (WET) test young reproduction $\geq$ 75% young reproduction of the laboratory control water sample (moderately hard laboratory water)

- $6.5 < pH < 8.5$

LSI and SI are both indices used to measure the scaling potential of calcium carbonate. Positive values for both indices indicate scale forming water whereas negative values indicate corrosive water. The treatment targets for the stabilization tests were to obtain slightly positive values for each measure (i.e., near values of 0 to 0.1).

6.1 Lime Addition Bench Test

The carbon dioxide and lime stabilization process was first modeled using PHREEQC, an aquatic equilibrium model by the United States Geological Survey (USGS). The simulation was used to estimate the carbon dioxide and lime dosages that would be required to achieve the target SI and the resulting final pH. Table 19 displays the modeling results of the estimated optimal lime dose. While the approach was initially modeled with lime addition first (as indicated in Appendix A), insufficient acidity (as dissolved CO_2) in the blended permeate required that CO_2 addition occur prior to lime addition.

An experimental protocol was then developed using the PHREEQC model dose as a guide. The protocol included the addition of carbon dioxide to the blended effluent to increase the total alkalinity, followed by lime addition to the blended effluent to increase the total hardness concentration of the blended permeates and achieve the target SI value. Through this method, the carbon dioxide dose further lowers the pH and SI values of the blended effluent, and the lime dose raises the pH and SI values of the blended effluent to the target value. This approach results in water with minimal carbon dioxide fugacity, which lends stability to the effluent pH and provides stable water for WET testing.

Based on the modeling results shown in Table 19, all blended permeate samples were sparged with carbon dioxide to a pH of 5.25. Then a range of hydrated lime doses were added to the samples to reach a range of pH endpoints. For example, hydrated lime was added to the "Optimal" sample until a resulting pH of 7.8 was reached.

6.1.1 Experimental Setup

The carbon dioxide and lime addition tests were conducted in a 4-L Erlenmeyer flask using 3-L aliquot samples of the blended permeate. All samples were titrated to pH of 5.25 using a 5%:95% carbon dioxide and nitrogen gas mixture bubbled into the water. Next, a range of hydrated lime doses (see Table 20) were added to the 3-L aliquots and were mixed vigorously on a stir plate. Final blend samples were submitted to external laboratories for analytical and WET testing. The hydrated lime used in the bench testing experiments was 94.3% $Ca(OH)_2$.

6.1.2 Results

6.1.2.1 Stabilized Water Chemistry

Table 20 presents a summary of the stabilization bench test results. Doses 4, 5, and 6 all met the calcium carbonate scaling potential water quality targets described in Section 6.1. Dosages 1, 2, and 3 did not have enough hardness and alkalinity to result in a positive LSI or SI value, indicating the final samples were still corrosive. The following observations can be made about the results of lime addition:

- turbidity - dosages 5 and 6 may exceed potential future turbidity requirements
- TSS – dose 6 may exceed the potential future TSS requirements

The results for these three parameters were likely affected by the grade of hydrated lime, lime contact time, and dosing methods. Excess turbidity and TSS likely, in part, resulted from the experimental setup and can be mitigated. Section 6.1.3 contains additional discussion of these issues.

6.1.2.2 Whole Effluent Toxicity

Based on the results from the bench testing, Dose 4 would likely produce the most stable blended effluent for the system. The LSI and SI values indicate the water would not be corrosive, and the WET testing suggests that the stabilized blended effluent would meet the WET requirements.

Figure 17 displays the mean number of young produced per female for each dose compared to 75% of the control. Note that the raw, unstabilized blended permeate achieved a mean young production that was 40% of the control (i.e., an observable toxic effect). Doses 2-6 produced effluent that achieved a mean number of young produced per female of at least 75% of the control, suggesting that the stabilization approach reduced toxicity as intended. Dose 2 resulted in a mean young production higher than the control, but was not fully stabilized with respect to LSI or SI.

6.1.3 Implementation Considerations

Dose 4 was identified as the best dose for stabilization of the blend of permeates tested, as its LSI and SI were closest to the targets for those parameters and the water was not toxic in WET testing. Although doses 5 and 6 also showed positive LSI and SI values and no toxicity, these higher doses would result in more lime use and higher operating costs. Residual turbidity is a known operational challenge of using a lime addition to stabilize RO effluent (AWWA, 2007). As listed above in

Section 6.1.2.1, lime doses 4 through 6 all had elevated turbidities. If lime addition is the chosen method of effluent stabilization, turbidity could be managed using the following techniques:

- High quality lime – Using high quality lime reduces the amount of inert material present to contribute to TSS and turbidity. For project implementation, the lime product used should be greater than 94% hydrated lime (purity used for bench testing) if available. High quality lime also has a high specific surface area which helps to maximize reactivity and minimize grit (Hart, 2007).
- Liquid lime dosing – Dosing the lime as a liquid slurry rather than a solid provides minimal turbidity increases because less inert materials are present in liquid lime, and it avoids maintenance issues associated with dry lime (Lozier, et al., 2010).
- Lime contact chamber – Contact chambers provide the necessary turbulent mixing time for the lime to fully dissolve into the blended effluent. The mixing or contact time is a key design parameter and is typically between 5-10 minutes (AWWA, 2007)

When the lime is initially dosed to the blended effluent, some of the dissolved carbon dioxide reacts with the lime and calcium carbonate precipitates and turns the mixture cloudy. As additional mixing time is allowed in the lime contact chamber, the remaining carbon dioxide reacts and dissolves the newly formed calcium carbonate, thereby reducing the turbidity. Mixing time can be controlled as a design parameter of a full-scale application.

Along with turbidity, all treated water quality targets listed in Section 3.3 will need to be achieved in the final stabilized blended permeate. The final aluminum concentrations (Table 20) did not exceed the aluminum water quality target, but aluminum might become an issue if a lower quality lime is used. Using the measured aluminum and calcium concentrations it is estimated that the lime product used in bench testing contained approximately 0.06% aluminum by weight. In order to achieve the 125 µg/L effluent aluminum concentration using Dose 4, the lime product would have to contain less than 1670 mg aluminum/kg hydrated lime product (0.167% aluminum by weight). Availability of suppliers that can provide a lime product with aluminum consistently less than this amount within a reasonable shipping distance should be a consideration for this stabilization option.

6.2 Limestone Contactor Bench Test

The LC system is a semi-passive stabilization option that passes the blended effluent through a crushed limestone bed. As the blended effluent contacts the limestone media, it dissolves the limestone ($CaCO_3$), increasing both the hardness and alkalinity of the blended effluent. The rate of limestone dissolution is an important design parameter for an LC system. Three different hydraulic loading rates were tested on three identical LCs to identify the rate that would result in adequate introduction of hardness and alkalinity to the blended permeate.

Because the effluent from the LC columns was anticipated to still have a low LSI, due primarily to dissolved CO_2 added prior to contact with the $CaCO_3$, air stripping and caustic addition for final pH adjustment were also tested.

The objectives of this bench test were as follows:

- identify the maximum hydraulic loading rate that would achieve the treated water quality targets outlined in Section 6.1
- identify the best post-LC treatment to achieve the treated water quality targets outlined in Section 6.1

6.2.1 Experimental Setup

The LCs were constructed as 6-feet long, 2-inch diameter upflow columns (Figure 18). The limestone media used for testing was Columbia River Carbonates' Puri-Cal RO product with a particle size range of 2-3.4 mm. The media was backwashed for a minimum of 4-hours prior to packing into the column to remove fines.

The test program is illustrated in Figure 19. The blended permeate was sparged with 5%:95% carbon dioxide and nitrogen gas mix to a pH of 5.25 and then was pumped through the LC. The first 4-L of effluent from the LBC was discarded and the next 6-L of sample from each LC was collected for analysis. 2-L of the collected sample was sparged with compressed air, 2-L was dosed with caustic soda, and the final 2-L was left unamended. A minimum of 8-L of deionized water was flushed through the LC between tests. All samples were submitted for analytical and WET testing. Turbidity values were measured upon collection using a field turbidimeter.

6.2.2 Results

6.2.2.1 Stabilized Water Chemistry

Table 21 presents a summary of the results from the testing using the Puri-Cal RO product. The following observations can be made regarding the results of the LC bench tests:

- Turbidity – all of the samples were below the target turbidity and resulted in turbidity values less than 0.3 NTU.

- TSS – all of the samples were below the target TSS level.
- Total hardness – all of the samples were below the target TSS level.

6.2.2.2 Whole Effluent Toxicity

Figure 20 displays the mean number of young produced per female for the LC treatments, compared to 75% of the control sample's reproduction. As shown in the figure, the unstabilized blended permeate would not likely pass the IC25 criterion. All of the samples ran through a LC would likely achieve a mean number of young produced per female of at least 75% of the control.

6.2.3 Implementation Considerations

The LC bench test results suggest treatment consisting of acidity addition with CO_2 gas, feed through a LC at a hydraulic loading rate (HLR) of 1.1 gpm/sf (using the Puri-Cal RO product), and air sparging of the LC effluent, is able to produce a stabilized effluent that meets the treatment targets. However, in addition to HLR, there are other factors that will need to be considered for full-scale stabilization, such as residence time and bed depth.

For upflow contactors, HLRs ranging from 1.0-17.2 gpm/sf are typical (Shih, et al., 2012). The HLR is related to the flow rate of the LC system required for a given reactor diameter. The highest HLR that achieves the treated water quality targets minimizes the number of LCs required to stabilize the blended effluent flow. However, HLRs that are too high can cause media blowouts causing turbidity and TSS.

The residence time of the system is related to the dissolution rate of the limestone. Typical empty bed contact times range from 3.6 to 30 minutes for LC systems (Shih, et al., 2012). Required residence times are related to the limestone media size. Larger diameter media has lower specific surface area which requires longer residence times to allow for adequate dissolution of the media.

After the residence time and the HLR are defined, the volume and therefore the bed depth of the LC can be calculated. The calculated bed depth represents the minimum depth of media required to meet the treatment targets that must always be maintained. As mentioned above, LC systems are semi-passive. The limestone will need to be replaced periodically as it dissolves. If the blended permeate is applied at 1.1 gpm/sf to the LCs and the system is operated 24 hours/day, then 1.68 pounds of limestone per day per square feet of LC will need to be replaced. The frequency of media replacement would need to be considered in the amount of limestone that is provided beyond the minimum depth that must be maintained for stabilization.

The pre-LC CO_2 addition was introduced to increase the acidity of the blended permeate prior to the LC. CO_2 addition equipment will require additional capital and maintenance costs. Sparge systems are commonly added as a post treatment following LCs to strip any excess dissolved carbon dioxide remaining in the effluent. The dissolved carbon dioxide will likely off-gas at the discharge point if not removed at the treatment site. Off-gassing of excess CO_2 will cause a pH increase which is known to contribute to failed WET tests. Stripping the carbon dioxide before it reaches the final discharge point will produce a more pH-stable water.

Upflow contactors were constructed for this bench test and are the most common LC, but downflow contactors are also used. Upflow reactors typically result in a lower effluent turbidity and do not require backwashing, but an internal top screen does need to be used to prevent calcite from blowing out of the reactor. Downflow reactors provide calcite dissolution and sediment filtration. Disadvantages of downflow configurations include required backwashing, high turbidity waste streams, increased risk of TSS in the treated effluent from fines breakthrough, and higher capital and operational and maintenance costs (Shih, et al., 2012). The upflow configuration was selected for this application because of the typically lower turbidity effluent and no backwashing requirement.

7.0 Preliminary Estimates of Implementation Costs

7.1 Basis of Cost Estimates

The pilot and bench testing studies described above, along with the associated literature and modeling studies of concentrate management, were used to refine the RO treatment train originally presented in the *Short-Term Mitigation Evaluation and Implementation Plan for SD033*, and to update the estimated capital and operation and maintenance costs for a full-scale system. Cost estimates were developed for the three treatment train concepts discussed in Section 5.0 and shown in Figures 10, 11, and 15. Table 22 provides an overview of the basic treatment information used to develop the capital and operating costs for the systems.

The cost estimates provided in this report represent updates to the costs of treatment presented in the *Short-Term Mitigation Evaluation and Implementation Plan for SD033*. Costs associated with site work and utilities have not been updated. In determining the flow rates used as the basis of the cost estimates, it was assumed that the Area 5NW pit would be used for equalization of the flow at SD033 for a full-scale system. Implementing equalization reduces the peak flow to SD033, thereby reducing the size and cost of the required installed treatment system capacity. The flow data used for this evaluation are based upon the water balance presented in the *NPDES Field Studies Report – SD033* (Barr, 2011). Over the duration of the field studies, the average observed flow at SD033 was 401 gpm with a range of 158 to 1,115 gpm. This average value was used to estimate the annual operating costs for each of the options, as well as capital costs for options 1 and 3. The installed capacity for capital costs for option 2 assumes a peak influent flow rate of 454 gpm, which is the average flow number plus a slipstream of VSEP permeate routed back to the primary RO membrane for re-treatment. Costs developed as a part of the *Short-Term Mitigation Evaluation and Implementation Plan for SD033* were based on flow rates estimated for NPDES permit reporting requirements from about 2002 through 2011, which showed an average flow of 1,180 gpm. Thus, the cost estimates developed in this evaluation are based on a lower, more accurate flow rate requiring treatment. The cost of equalization is not included in the estimates, nor is the cost of supplying power to Area 5.

For the selected treatment options presented in this report, the capital, operation and maintenance (O&M), and present worth costs have been developed for the purpose of evaluating and comparing alternatives. The cost estimates developed for this report are considered conceptual level costs or Class 5 estimates, according to the Association for the Advancement of Cost Engineering International. The typical associated level of accuracy of Class 5 cost estimates is ±25 to 100%.

The capital and O&M costs were developed using the sources listed below, recent local pricing for similar equipment, and general resources:

- RO system and evaporator and crystallizer capital and operating costs were obtained from GE budgetary quotes
- VSEP capital and operating costs were obtained from New Logic Research budgetary quotes
- Lime costs were obtained from the USGS on-line mineral commodity summaries (http://minerals.usgs.gov/minerals/pubs/commodity/lime/)
- Acid prices were obtained from ICIS on-line (http://www.icis.com/)
- The cost of electricity used was $0.055/kW-h.
- Office of Management and Budget (1992), Guidelines and Discount Rates for Benefit Cost Analysis for Federal Programs, Circular A-94, Appendix C, updated December 2012.
- U. S. EPA (2000), A Guide to Developing and Documenting Cost Estimates During the Feasibility Study, U.S. EPA 540-R00-002.

The following assumptions were used in developing the opinion of probable cost:

- The capital costs assume a 20-year equipment life for mechanical equipment.
- No redundant capacity is included in the costs for the treatment equipment.
- A real discount rate of 0.8% and a time frame of 20 years were used in calculating the net present value of the operation and maintenance costs. Present value analyses are typically conducted for the duration of the project (U.S. EPA, 2000). In this case, the duration of the project has been assumed to be the life of the equipment, which is approximately 20 years. The conceptual treatment facilities presented in this report were developed with the assumption that they could be incorporated into a long-term treatment strategy, if necessary.
- A 30% contingency has been included in the capital and O&M costs to account for items not detailed in the estimate but known to be part of the project such as process pumps, piping and supports, painting and protective coatings, process ancillary equipment, spare parts, operation and maintenance consumables, contractor mobilization and demobilization, and demolition.

- A 10% contingency has been included for professional services and reflects the lesser degree to which changes in capital items impact the cost of required engineering services.
- As discussed earlier, the range of accuracy for the costs presented is ±25 to 100%. This reflects the uncertainties associated with the scope of the project at this time, including: site and subsurface conditions, costs of materials and services, and utility requirements. This degree of accuracy falls within the level of accuracy suggested for screening and conceptual development of alternatives by the U.S. EPA (U.S. EPA, 2000).

As noted, the preliminary cost estimates were made using a variety of references, along with professional experience from qualified professionals familiar with the project, and with the assistance of potential water treatment vendors. The estimates are based on project-related information, including the water quality as described in this report and the general characteristics of the site (based on field observations) and include a contingency factor to account for items that are unknown at this time. While the costs of some specific items for a specified set of conditions can be determined with precision, the factors controlling the design conditions, namely the actual water quality and site conditions, are still highly variable. The high potential for changes in these controlling values precludes a lower contingency in cost estimates at this stage of the project.

The potential actual costs for implementation of any technology selected based on the evaluation described in this plan would be expected to change as more detailed information (site survey, geotechnical testing, etc.) becomes available, further design is completed, or as the project needs change. PolyMet, CE, and Barr cannot and do not guarantee that proposals, bids, or actual construction costs will not vary from the preliminary cost estimates prepared in this report as any approved mitigation/treatment plan is implemented.

7.2 Preliminary Estimates

7.2.1 Reverse Osmosis with Evaporation and Crystallization

A summary of the required treatment equipment is provided below, and Table 23 provides a summary of the estimated capital and operating costs for this treatment option.

Major equipment required includes:

- Greensand filtration:
    - 3 filter units
    - Potassium or sodium permanganate storage and feed system

  - Filtrate tank and forwarding pumps
- RO system:
  - Acid storage feed system
  - Anti-scalant feed system
  - Sodium bisulfite feed system
  - RO skid with feed pumps, membrane housings, and membrane elements
  - CIP skid
  - Control system
- Evaporator system:
  - Evaporator feed tank and mixer
  - Evaporator feed pump
  - Heat exchangers
  - Feed deaerator
  - Evaporator vessel
  - Vapor compressor
  - Distillate tank
  - Distillate pump
  - Evaporator recirculation pump
  - Seed pump, tank, and mixer
  - Seed recycle system
  - Acid pumps
  - Caustic pumps
  - Anti-scalant and antifoam pumps
  - Control system
- Crystallizer system:
  - Calandria crystallizer with internal heater
  - Recirculation pump
  - Crystallizer feed tank, pump, and mixer
  - Dewatering feed pump
  - Filter press
  - Filtrate pump
  - Distillate tank and pump
  - Antifoam pump
  - Caustic pump

    - Control system
- Permeate stabilization system:
    - 3 LC units
    - 2 degassifiers and blowers

The estimated building area for this treatment equipment is approximately 6,200 sf. The revised preliminary capital cost estimate for this option is $14.9M, with an annual operation and maintenance cost of $1.4M. This treatment train is similar to that first evaluated in the *Short-Term Mitigation Evaluation and Implementation Plan for SD033* except that the flow rate on which the costs are based is significantly less for this estimate. Although the capital cost presented here is lower than the capital cost presented in that report ($20.7M), the revised cost estimate is considerably higher on a cost per gallon treated basis. This increase in the cost per gallon treated is driven largely by the higher cost of the evaporator and crystallizer equipment. The costs for that equipment were previously developed based on published cost curves (Mickley, 2006) and escalated using Engineering News Record (ENR) indices, while the current estimate is based on budgetary estimates from GE, obtained in August 2013. The cost of this type of equipment has increased at a rate significantly greater than the ENR Construction Cost Index (CCI).

7.2.2 Reverse Osmosis with VSEP and Crystallization

A summary of the required treatment equipment is provided below, and Table 24 provides a summary of the estimated capital and operating costs for this treatment option.

Major equipment required includes:

- Greensand filtration:
    - 3 filter units
    - Potassium or sodium permanganate storage and feed system
    - Filtrate tank
- RO system:
    - Acid storage feed system
    - Anti-scalant feed system
    - Sodium bisulfite feed system
    - RO skid with feed pumps, membrane housings, and membrane elements
    - CIP skid
    - Control System

- VSEP system:
    - 2 feed tanks
    - Anti-scalant pumps
    - CO_2 storage and feed system
    - Four i84 modules containing RO membranes
    - CIP skid
- Crystallizer system:
    - Steam-driven, mixed-salt crystallizer vapor body
    - External crystallizer heater
    - Recirculation pump
    - Crystallizer feed tank, pump, and mixer
    - Dewatering feed pump
    - Filter press
    - Filtrate pump
    - Distillate tank and pump
    - Antifoam pump
    - Caustic pump
    - Control system
- Permeate stabilization system:
    - 3 LC units
    - 2 degassifiers and blowers

The estimated building area for this treatment equipment is approximately 4,700 sf. The revised preliminary capital cost estimate for this option is $20M, with an annual operation and maintenance cost of $1.3M. For this treatment train configuration, the VSEP assembly acts as the brine concentrator, replacing the evaporator. However, a larger crystallizer is required because the VSEP does not reduce the volume of RO concentrate to the same degree as the evaporator.

7.2.3 Reverse Osmosis with ICCP, Secondary RO System, and Crystallization

A summary of the required treatment equipment is provided below, and Table 25 provides a summary of the estimated capital and operating costs for this treatment option.

Major equipment required includes:

- Greensand filtration:

  - 3 filter units
  - Potassium or sodium permanganate storage and feed system
  - Filtrate tank
- Primary RO system:
  - Acid storage feed system
  - Anti-scalant feed system
  - Sodium bisulfite feed system
  - RO skid with feed pumps, membrane housings, and membrane elements
  - CIP skid
  - Control System
- ICCP system:
  - Lime storage
  - Soda ash storage
  - Slurry tanks and pumps
  - Solids contact clarifier
  - Solids dewatering equipment
- Secondary RO system:
  - Feed tank
  - Acid feed pump
  - Anti-scalant feed pump
  - RO skid with pump, membrane housing, and membrane elements
- Crystallizer system:
  - Steam-driven, mixed-salt crystallizer vapor body
  - External crystallizer heater
  - Recirculation pump
  - Crystallizer feed tank, pump, and mixer
  - Dewatering feed pump
  - Filter press
  - Filtrate pump
  - Distillate tank and pump
  - Antifoam pump
  - Caustic pump
- Permeate stabilization system:
  - 3 LC units

- 2 degassifiers and blowers

The estimated building area for this treatment equipment is approximately 5,600 sf. The revised preliminary cost estimate for this option is $12.9M, with an annual operation and maintenance cost of $1.6M.

7.3 Discussion

The use of mechanical evaporation and/or crystallization for concentrate management is a capital-intensive approach; however, concentrate disposal options in the project area are limited. Therefore, other methods to reduce the capital, operating, or overall lifecycle cost were investigated for this project. The 20-year lifecycle costs for each option are presented in Table 26. The baseline concentrate management option – evaporation and crystallization of primary RO concentrate – relies largely on heat energy to reduce the concentrate volume for disposal. The use of the VSEP process replaces some of the heat energy required for volume reduction with mechanical energy, and the use of ICCP and secondary RO membranes replaces some of the heat energy with chemical and mechanical energy. One of the focuses of this investigation was to determine the relative efficiencies of each of these forms of energy for concentrate volume reduction.

From a capital cost perspective, the replacement of the evaporator with ICCP and secondary RO membranes is the most cost-effective of the three options. However, its operating costs are higher, largely due to the costs of the chemicals required and solids disposal. For all of the treatment options, it is important to note that the cost of chemicals is a significant component of the overall operation and maintenance cost. The unit prices for chemicals such as mineral acids can be volatile. Because of this volatility and because the annual operation costs for the options are of similar magnitude, the relative lifecycle costs can change, depending on the market pricing of these commodities at any given time. Were one of these treatment options to be selected for implementation, special consideration should be given to the selection of acids used for pH adjustment because their selection can have multiple implications, including:

- Final discharge water chemistry – The type of acid and the grade of acid selected can impact the discharged water quality.
- Operating costs – The pricing of certain mineral acids, such as hydrochloric acid, is volatile, and other acids may provide more stable and predictable pricing.
- Capital costs – The use of hydrochloric acid may necessitate higher grade materials of construction for concentrate management equipment to reduce chloride corrosion.

In examining option 2 and the utilization of the VSEP system for this application, the operating costs do not include the cost of retreatment of a portion of the VSEP permeate. Although the increased flow rate resulting from the retreatment of permeate can be handled by the system specified by the equipment vendor, the additional cost of chemical use and possible effects on membrane life are not accounted for in the comparison.

8.0 Conclusions

Through the operation of the pilot testing program and related modeling evaluations, a number of critical pieces of information regarding active treatment of the SD033 discharge have been recognized. Firstly, RO membranes can effectively reduce the concentration of sulfate and parameters of concern for the SD033 discharge to levels less than or equal to the water quality goals listed in Section 3.3. Secondly, proper materials construction and operation and maintenance measures are paramount to the application of the RO treatment system, because the pilot test membranes became damaged through the testing period, resulting in treated water that failed to meet the water quality goals. Quality assurances must be made regarding the products utilized in the installation of an RO treatment system as well as for concentrate management equipment. Lastly, in the event that very low sulfate concentrations are required in a full-scale system discharge (e.g., the 10 mg/L value used for this pilot test study), treated water from a secondary system may require re-treatment even when performing to specifications. This requirement is simply due to the high concentrations of sulfate present in the primary RO concentrate, which results in elevated sulfate concentrations in the secondary membrane system permeate.

Furthermore, based on pilot testing, the use of an RO system for treatment of the SD033 discharge would require pretreatment by the following (or equivalent) process:

- Greensand filtration for TSS, iron, and manganese removal,
- Anti-scalant to mitigate mineral scaling,
- pH adjustment with acid to reduce the formation of calcium carbonate scale.

The pilot testing program yielded several important results, including the following for the RO system:

- the RO system produced permeate with sulfate concentrations less than 10 mg/L, but could not consistently maintain permeate of that quality due to accumulated membrane damage;
- the pretreatment methods selected for the RO system—greensand filtration and anti-scalant addition— were effective in maintaining stable RO performance;
- while the RO system experienced some suspected biofouling on some membranes, it did not experience significant fouling or scaling that altered performance or triggered CIP precursors during the testing program;

- the RO system operated stably and effectively at 80% recovery on the pilot feed water, which is similar in quality to what is projected for water from SD033.

Concentrate management and permeate stabilization were assessed as part of the evaluation of active treatment options for SD033. The ability to manage RO concentrate is a critical component of the RO technology's feasibility for any project. Based on the initial evaluations conducted in the *Short-Term Mitigation Evaluation and Implementation Plan for SD033,* creation of a solid salt for disposal from the RO concentrate was selected for more detailed evaluation. In order to produce the solid salt, three volume-reduction approaches were investigated:

- Evaporation and crystallization,
- VSEP and crystallization,
- ICCP, secondary RO, and crystallization.

The VSEP product was pilot tested for over 2 months. The VSEP pilot test yielded the following results:

- The VSEP sulfate removal efficiency averaged 97.4%. Under the pilot test conditions, when the VSEP and RO permeates are blended, the sulfate concentration could not meet the target limit of 10 mg/L;
- Some VSEP permeate will require retreatment by the primary RO train to meet the water quality target for sulfate;
- The VSEP system consistently demonstrated performance at 80% recovery;
- No irreversible fouling was observed during the course of testing, and the membrane flux was restored to the established baseline flux for this application after each cleaning;
- No decline in sulfate removal was observed over time.

ICCP testing was conducted on the bench scale, and testing demonstrated silica removal similar to that which has been reported in the scientific literature. Other potential scalants (barium, calcium, fluoride, and strontium) were also removed during the lime-soda ash softening process. Modeling of the secondary RO process suggests that 80% recovery is achievable for the secondary RO system and that blended permeates would produce a final effluent that meets the water quality goals.

Evaluations of evaporation and crystallization were conducted with assistance from GE, a manufacturer of this equipment. Products capable of dewatering solutions of mixed salts were recommended by GE. Technical considerations for their implementation included selection of the materials of construction (based on the salts present), the need for pH control, foam management, and the need for a purge stream due to the presence of organic materials in the water. Organic materials, which are natural organic matter that would be cycled up in concentration, can interfere with the precipitation process. The management and disposal of a purge stream from the crystallizer may present significant technical obstacles. Additional treatment upstream of the RO system to remove or mineralize those materials prior to treatment may be necessary.

Effluent stabilization is also necessary after treatment to adjust the pH and reduce the corrosiveness of permeates and distillates prior to discharge. The permeate stabilization bench testing results produced the following conclusions:

- Lime addition
    - Lime addition was able to adjust the pH and meet most water quality targets, including measures of corrosiveness;
    - Two important factors were identified in the test that would need to be considered on a full-scale design:
        - Quality of lime used (to reduce turbidity from inert materials);
        - Method of lime addition and reaction to minimize residual turbidity.
- Limestone contactor
    - The LC was able to adjust the pH and meet all water quality targets, including measures of corrosiveness;
    - Additional treatment after a LC was needed to remove remaining carbon dioxide (e.g. air sparging).

Preliminary capital and operating costs were developed for the three treatment approaches evaluated. Capital costs ranged from $12.9M to $20M and operating costs ranged from $1.3M to $1.6M annually. These costs are higher than previously estimated for the *Short-Term Mitigation Evaluation and Implementation Plan for SD033* when consideration is given to the higher flow rate used in that previous estimate. The costs differences reflect: (1) the availability of more complete water quality data for SD033; (2) pilot and bench testing results, which informed not only the equipment requirements but also the chemical treatment needs for the processes; and (3) updated budgetary estimates from the major equipment suppliers. Total costs do not include actions like providing equalization in the pits and supplying power to Area 5.

Were any of the investigated approaches to be selected for implementation at SD033, the following additional tasks are recommended:

- Work with the manufacturer of the membranes installed for treatment to acquire product assurances and understand quality control procedures that are in place to guarantee performance of their products;
- Work with the evaporator and/or crystallizer supplier to select the chemicals used throughout the treatment train (and which report to this equipment) to optimize capital and operating costs, as well as to meet water quality objectives;
- Work with evaporator and/or crystallizer supplier to investigate alternatives for managing necessary purge streams, including addition of equipment upstream of the RO to remove organic compounds;
- Work with the evaporator and/or crystallizer supplier to optimize heating options for the equipment to minimize operating costs;
- Evaluate the level of equipment redundancy required to reliably treat the discharge;
- Evaluate regional disposal options for the solid, mixed salt that will be produced.

9.0 References

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Tables

Table 1
SD033 Historical Water Quality Summary (2005-2011)

Analyte	Units	Minimum	Maximum	Average
Alkalinity, Bicarbonate as CaCO3	mg/L	287	398	341
Alkalinity, Total as CaCO3	mg/L	287	367	332
Arsenic	ug/L	2	2	2
Bromide	mg/L	0.5	0.5	0.5
Calcium	mg/L	53.3	111	87.6
Chloride	mg/L	2.7	5.51	4.34
Cobalt	ug/L	0.27	2	0.89
Copper	ug/L	2	2	2
Flow	mgd	0	4.94	1.43
Fluoride	mg/L	0.16	0.2	0.18
Hardness, Carbonate	mg/L	287	367	332
Hardness, Total as CaCO3	mg/L	109	1420	1166
Iron	mg/L	0.05	0.11	0.07
Iron	ug/L	50	119	57
Magnesium	mg/L	172	280	247
Mercury, Low Level	ng/L	0.5	4	1.2
Nickel	ug/L	2	2	2
Nitrogen, Ammonia as N	mg/L	0.1	0.1	0.1
Nitrogen, Nitrate+Nitrite as N	mg/L	0.24	0.24	0.24
pH	Std Units	7.35	8.5	8.00
Phosphorous, Total as P	mg/L	0.009	0.009	0.009
Potassium	mg/L	57.4	57.4	57.4
Salinity	Std Units	0.9	1.4	1.2
Selenium	ug/L	2	2	2
Silver	ug/L	0.012	0.4	0.2
Sodium	mg/L	90.7	90.7	90.7
Solids, Filterable (TDS)	mg/L	1150	2140	1800
Solids, Total Suspended (TSS)	mg/L	1	7	3.2
Specific Conductance	umh/cm	507	3000	2178
Sulfate	mg/L	591	2520	1099
TOC	mg/L	4.4	4.4	4.4
Turbidity	NTU	0.05	2.4	0.74
Zinc	ug/L	239	23955	5173

When calculating the minimum, maximum, and average for analytes with only non-detect values, the absolute value of each non-detect was used.

Table 2
Area 5NW 2013 Water Quality Data

	Location	**Area 5NW**	**Area 5NW**	**Area 5NW**	**Area 5NW**	**Area 5NW**	**Area 5NW**	**Area 5NW**	**Area 5NW**
	Date	**2/5/2013**	**2/12/2013**	**2/19/2013**	**2/25/2013**	**3/4/2013**	**3/11/2013**	**3/19/2013**	**3/25/2013**
Parameter	Total or Dissolved								
General Parameters									
Alkalinity, bicarbonate, as CaCO3	NA	**300 mg/l**	**300 mg/l**	**310 mg/l**	**320 mg/l**	**310 mg/l**	**320 mg/l**	**290 mg/l**	**290 mg/l**
Alkalinity, total, as CaCO3	NA	**300 mg/l**	**300 mg/l**	**310 mg/l**	**320 mg/l**	**310 mg/l**	**320 mg/l**	**290 mg/l**	**290 mg/l**
Carbon, dissolved organic	NA	**2.1 mg/l**	**2.7 mg/l**	**2.3 mg/l**	**2.7 mg/l**	**2.7 mg/l**	**2.3 mg/l**	**2.1 mg/l**	**2.3 mg/l**
Carbon, total organic	NA	**2.0 mg/l**	**2.3 mg/l**	**2.2 mg/l**	**2.7 mg/l**	**2.6 mg/l**	**2.2 mg/l**	**2.2 mg/l**	**2.2 mg/l**
Chloride	NA	**4.5 mg/l**	**4.5 mg/l**	**4.1 mg/l**	**4.3 mg/l**	**4.1 mg/l**	**4.4 mg/l**	**4.1 mg/l**	**4.0 mg/l**
Fluoride	NA	**0.14 mg/l**	**0.15 mg/l**	**0.15 mg/l**	**0.14 mg/l**	**0.14 mg/l**	**0.12 mg/l**	**0.13 mg/l**	**0.13 mg/l**
Nitrogen, ammonia as N	NA	< 0.500 mg/l	< 0.470 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.490 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l
Nitrogen, Nitrate as N	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 mg/l	< 0.045 mg/l	< 0.20 mg/l	< 0.20 mg/l
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 mg/l
pH	NA	**8.2 pH units**	**8.1 h pH units**	**8.1 h pH units**	**8.1 h pH units**	**8.2 pH units**	**8.1 pH units**	**8.1 pH units**	**8.2 pH units**
Silicon dioxide	NA	**10.5 mg/l**	**10.5 mg/l**	**9.97 mg/l**	**10.1 mg/l**	**8.82 mg/l**	**8.96 mg/l**	**1.07 mg/l**	**1.06 mg/l**
Solids, total dissolved	NA	**1900 mg/l**	**1900 mg/l**	**1900 mg/l**	**2000 mg/l**	**1900 mg/l**	**2100 mg/l**	**2000 mg/l**	**1800 mg/l**
Solids, total suspended	NA	**4.4 mg/l**	< 4.0 mg/l	< 4.0 mg/l	**4.8 mg/l**	< 4.0 mg/l	**7.6 mg/l**	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25 ºC	NA	**2100 umhos/cm**	**2100 umhos/cm**	**2200 umhos/cm**	**2200 umhos/cm**	**2200 umhos/cm**	**2200 umhos/cm**	**2000 umhos/cm**	**2100 umhos/cm**
Sulfate, as SO4	NA	**1100 mg/l**	**1100 mg/l**	**1200 mg/l**	**1200 mg/l**	**1200 mg/l**	**1200 mg/l**	**1100 mg/l**	**1100 mg/l**
Metals									
Aluminum	Total	< 10 ug/l	< 10 ug/l	< 10 ug/l	**17 ug/l**	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l
Arsenic	Total	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l
Barium	Total	**6.5 ug/l**	**7.1 ug/l**	**6.6 ug/l**	**6.9 ug/l**	**6.6 ug/l**	**6.5 ug/l**	**6.3 ug/l**	**6.2 ug/l**
Boron	Total	**0.19 mg/l**	**0.17 mg/l**	**0.17 mg/l**	**0.18 mg/l**	**0.17 mg/l**	**0.17 mg/l**	**0.18 mg/l**	**0.17 mg/l**
Calcium	Total	**92 mg/l**	**88 mg/l**	**90 mg/l**	**92 mg/l**	**88 mg/l**	**88 mg/l**	**91 mg/l**	**89 mg/l**
Iron	Dissolved	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Iron	Total	< 0.050 mg/l	**0.050 mg/l**	< 0.050 mg/l	**0.46 mg/l**	< 0.050 mg/l	**0.21 mg/l**	< 0.050 mg/l	< 0.050 mg/l
Magnesium	Total	**240 mg/l**	**230 mg/l**	**230 mg/l**	**240 mg/l**	**220 mg/l**	**220 mg/l**	**240 mg/l**	**230 mg/l**
Manganese	Dissolved	**280 ug/l**	**270 ug/l**	**240 ug/l**	**260 ug/l**	**290 ug/l**	**280 ug/l**	**240 ug/l**	**290 ug/l**
Manganese	Total	**350 ug/l**	**300 ug/l**	**240 ug/l**	**380 ug/l**	**330 ug/l**	**300 ug/l**	**220 ug/l**	**280 ug/l**
Potassium	Total	**49 mg/l**	**52 mg/l**	**53 mg/l**	**52 mg/l**	**52 mg/l**	**49 mg/l**	**52 mg/l**	**52 mg/l**
Silicon	Total	**5.0 mg/l**	**4.7 mg/l**	**4.9 mg/l**	**5.0 mg/l**	**4.9 mg/l**	**5.0 mg/l**	**5.1 mg/l**	**4.7 mg/l**
Sodium	Total	**110 mg/l**	**100 mg/l**	**110 mg/l**	**110 mg/l**	**100 mg/l**	**99 mg/l**	**110 mg/l**	**100 mg/l**
Strontium	Total	**310 ug/l**	**330 ug/l**	**320 ug/l**	**350 ug/l**	**330 ug/l**	**330 ug/l**	**280 ug/l**	**310 ug/l**

Table 2
Area 5NW 2013 Water Quality Data

	Location	Area 5NW	Area 5NW	Area 5NW	Area 5NW	Area 5NW	Area 5NW	Area 5NW	Area 5NW
	Date	4/1/2013	4/8/2013	4/15/2013	4/22/2013	4/29/2013	5/6/2013	5/13/2013	5/20/2013
Parameter	Total or Dissolved								
General Parameters									
Alkalinity, bicarbonate, as CaCO3	NA	**290 mg/l**	**280 mg/l**	**270 mg/l**	**290 mg/l**	**72 mg/l**	**33 mg/l**	**68 mg/l**	**240 mg/l**
Alkalinity, total, as CaCO3	NA	**290 mg/l**	**280 mg/l**	**270 mg/l**	**290 mg/l**	**72 mg/l**	**33 mg/l**	**68 mg/l**	**240 mg/l**
Carbon, dissolved organic	NA	**2.3 mg/l**	**2.4 mg/l**	**2.1 mg/l**	**2.2 mg/l**	< 1.5 mg/l	< 1.5 mg/l	**1.7 mg/l**	**2.8 mg/l**
Carbon, total organic	NA	**2.4 mg/l**	**2.6 mg/l**	**2.2 mg/l**	**2.3 mg/l**	< 1.5 mg/l	< 1.5 mg/l	**1.7 mg/l**	**2.1 mg/l**
Chloride	NA	**4.6 mg/l**	**4.1 mg/l**	**3.9 mg/l**	**4.2 mg/l**	**0.96 mg/l**	**0.30 mg/l**	**0.60 mg/l**	**3.3 mg/l**
Fluoride	NA	**0.12 mg/l**	**0.12 mg/l**	**0.11 mg/l**	**0.14 mg/l**	< 0.050 mg/l	< 0.050 mg/l	**0.075 mg/l**	**0.10 mg/l**
Nitrogen, ammonia as N	NA	< 0.500 mg/l	< 0.470 mg/l	< 0.480 mg/l	< 0.480 mg/l	< 0.490 mg/l	< 0.460 * mg/l	< 0.450 mg/l	< 0.460 mg/l
Nitrogen, Nitrate as N	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.045 mg/l	**0.056 mg/l**	**0.14 mg/l**	< 0.045 mg/l	**0.26 mg/l**	**0.075 mg/l**
Orthophosphate, as PO4	NA	< 0.20 h mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l
pH	NA	**8.1 pH units**	**8.1 pH units**	**8.1 pH units**	**8.1 pH units**	**8.1 pH units**	**8.3 pH units**	**7.8 pH units**	**8.2 pH units**
Silicon dioxide	NA	**9.34 mg/l**	**8.66 mg/l**	**8.76 mg/l**	**9.59 mg/l**	**2.16 mg/l**	**0.912 mg/l**	**2.44 mg/l**	**7.50 mg/l**
Solids, total dissolved	NA	**1700 mg/l**	**1700 mg/l**	**1600 mg/l**	**1900 mg/l**	**310 mg/l**	**130 mg/l**	**300 mg/l**	**1500 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	**4.4 mg/l**
Specific Conductance @ 25 ºC	NA	**2200 umhos/cm**	**2100 umhos/cm**	**1900 umhos/cm**	**2100 umhos/cm**	**520 umhos/cm**	**240 umhos/cm**	**540 umhos/cm**	**1900 umhos/cm**
Sulfate, as SO4	NA	**1100 mg/l**	**1000 mg/l**	**990 mg/l**	**1100 mg/l**	**470 mg/l**	**83 mg/l**	**190 mg/l**	**1800 mg/l**
Metals									
Aluminum	Total	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	**12 ug/l**	**15 ug/l**	**16 ug/l**	**10 ug/l**
Arsenic	Total	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l
Barium	Total	**6.3 ug/l**	**6.1 ug/l**	**6.1 ug/l**	**7.1 ug/l**	**1.7 ug/l**	**1.5 ug/l**	**2.6 ug/l**	**5.6 ug/l**
Boron	Total	**0.16 mg/l**	**0.16 mg/l**	**0.16 mg/l**	**0.15 mg/l**	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	**0.14 mg/l**
Calcium	Total	**90 mg/l**	**83 mg/l**	**83 mg/l**	**86 mg/l**	**15 mg/l**	**9.7 mg/l**	**16 mg/l**	**70 mg/l**
Iron	Dissolved	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	**0.074 mg/l**	**0.088 mg/l**
Iron	Total	< 0.050 mg/l	**0.13 mg/l**	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	**0.057 mg/l**	< 0.050 mg/l	**0.088 mg/l**
Magnesium	Total	**230 mg/l**	**210 mg/l**	**210 mg/l**	**220 mg/l**	**35 mg/l**	**18 mg/l**	**51 mg/l**	**180 mg/l**
Manganese	Dissolved	**230 ug/l**	**340 ug/l**	**200 ug/l**	**270 ug/l**	**54 ug/l**	**43 ug/l**	**130 ug/l**	**220 ug/l**
Manganese	Total	**240 ug/l**	**340 ug/l**	**200 ug/l**	**280 ug/l**	**68 ug/l**	**50 ug/l**	**120 ug/l**	**230 ug/l**
Potassium	Total	**47 mg/l**	**48 mg/l**	**50 mg/l**	**45 mg/l**	**8.4 mg/l**	**4.7 mg/l**	**8.5 mg/l**	**41 mg/l**
Silicon	Total	**4.9 mg/l**	**4.6 mg/l**	**4.7 mg/l**	**4.6 mg/l**	**0.94 mg/l**	**0.54 mg/l**	**1.4 mg/l**	**3.9 mg/l**
Sodium	Total	**110 mg/l**	**94 mg/l**	**95 mg/l**	**96 mg/l**	**14 mg/l**	**6.7 mg/l**	**13 mg/l**	**79 mg/l**
Strontium	Total	**320 ug/l**	**310 ug/l**	**290 ug/l**	**340 ug/l**	**53 ug/l**	**33 ug/l**	**57 ug/l**	**250 ug/l**

Table 2
Area 5NW 2013 Water Quality Data

Location		Area 5NW	Area 5NW	Area 5NW	Area 5NW	Area 5NW
Date		6/3/2013	6/10/2013	6/18/2013	6/25/2013	7/2/2013
Parameter	Total or Dissolved					
General Parameters						
Alkalinity, bicarbonate, as CaCO3	NA	**260 mg/l**	**250 mg/l**	**260 mg/l**	**260 mg/l**	**260 mg/l**
Alkalinity, total, as CaCO3	NA	**260 mg/l**	**250 mg/l**	**260 mg/l**	**260 mg/l**	**260 mg/l**
Carbon, dissolved organic	NA	**2.20 mg/l**	**2.60 mg/l**	**2.34 mg/l**	**2.64 mg/l**	**2.69 mg/l**
Carbon, total organic	NA	**2.46 mg/l**	**2.61 mg/l**	**2.51 mg/l**	**2.60 mg/l**	**2.72 mg/l**
Chloride	NA	**3.7 mg/l**	**3.5 mg/l**	**17 mg/l**	**3.3 mg/l**	**3.1 mg/l**
Fluoride	NA	**0.14 mg/l**	**0.14 mg/l**	**0.61 mg/l**	< 0.25 mg/l	< 0.20 mg/l
Nitrogen, ammonia as N	NA	< 0.490 mg/l	< 0.480 mg/l	< 0.500 mg/l	< 0.460 mg/l	< 0.460 mg/l
Nitrogen, Nitrate as N	NA	< 0.045 mg/l	**0.092 mg/l**	**0.30 mg/l**	< 0.90 mg/l	< 0.18 mg/l
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 0.80 mg/l
pH	NA	**8.3 pH units**	**8.3 pH units**	**8.2 pH units**	**8.2 pH units**	**8.2 pH units**
Silicon dioxide	NA	**7.75 mg/l**	**7.75 mg/l**	**7.86 mg/l**	**8.17 mg/l**	**8.06 mg/l**
Solids, total dissolved	NA	**1600 mg/l**	**1600 mg/l**	**1800 mg/l**	**1800 mg/l**	**1700 mg/l**
Solids, total suspended	NA	**4.8 mg/l**	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25 ºC	NA	**2000 umhos/cm**	**2000 umhos/cm**	**2000 umhos/cm**	**1900 umhos/cm**	**2000 umhos/cm**
Sulfate, as SO4	NA	**1000 mg/l**	**1000 mg/l**	**940 mg/l**	**950 mg/l**	**950 mg/l**
Metals						
Aluminum	Total	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l
Arsenic	Total	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l
Barium	Total	**5.4 ug/l**	**5.8 ug/l**	**5.8 ug/l**	**5.7 ug/l**	**5.8 ug/l**
Boron	Total	**0.21 mg/l**	**0.40 mg/l**	**0.35 mg/l**	**0.36 mg/l**	**0.37 mg/l**
Calcium	Total	**76 mg/l**	**76 mg/l**	**75 mg/l**	**71 mg/l**	**75 mg/l**
Iron	Dissolved	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	**0.056 mg/l**
Iron	Total	< 0.050 mg/l	**0.055 mg/l**	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Magnesium	Total	**190 mg/l**	**210 mg/l**	**210 mg/l**	**210 mg/l**	**210 mg/l**
Manganese	Dissolved	**160 ug/l**	**120 ug/l**	**100 ug/l**	**96 ug/l**	**87 ug/l**
Manganese	Total	**200 ug/l**	**160 ug/l**	**130 ug/l**	**100 ug/l**	**98 ug/l**
Potassium	Total	**42 mg/l**	**44 mg/l**	**42 mg/l**	**42 mg/l**	**42 mg/l**
Silicon	Total	**4.1 mg/l**	**4.2 mg/l**	**4.0 mg/l**	**4.0 mg/l**	**4.2 mg/l**
Sodium	Total	**86 mg/l**	**86 mg/l**	**86 mg/l**	**84 mg/l**	**82 mg/l**
Strontium	Total	**260 ug/l**	**250 ug/l**	**250 ug/l**	**280 ug/l**	**270 ug/l**

Table 3
Greensand Filter Removal Rates

	TSS			Total Fe			Total Mn		
Sample Date	**Feed Tank Effluent (mg/l)**	**Pretreated Effluent (mg/l)**	**% Removal**	**Feed Tank Effluent (ug/l)**	**Pretreated Effluent (ug/l)**	**% Removal**	**Feed Tank Effluent (ug/l)**	**Pretreated Effluent (ug/l)**	**% Removal**
02/05/2013	6.0	5.2	13.3%	100	25	> 75.0%	340	10	97.1%
02/12/2013	2.0	2.0	ND	66	25	> 62.1%	290	11	96.2%
02/19/2013	2.0	2.0	ND	84	25	> 70.2%	340	8.1	97.6%
02/25/2013	2.0	2.0	ND	200	25	> 87.5%	400	5.9	98.5%
03/04/2013	2.0	2.0	ND	140	25	> 82.1%	490	28	94.3%
03/11/2013	4.8	2.0	> 58.3%	120	25	> 79.2%	320	16	95.0%
03/19/2013	2.0	2.0	ND	25	25	ND	240	17	92.9%
03/25/2013	2.0	2.0	ND	66	25	> 62.1%	300	51	83.0%
04/01/2013	4.0	2.0	> 50.0%	100	25	> 75.0%	260	31	88.1%
04/08/2013	2.0	2.0	ND	56	25	> 55.4%	350	41	88.3%
04/15/2013	2.0	2.0	ND	57	25	> 56.1%	240	33	86.3%
04/22/2013	2.0	10	> 80.0%	120	25	> 79.2%	300	58	80.7%
04/29/2013	2.0	2.0	ND	85	25	> 70.6%	130	47	63.8%
05/06/2013	2.0	2.0	ND	90	25	> 72.2%	57	27	52.6%
05/13/2013	2.0	2.0	ND	25	25	ND	110	31	71.8%
05/20/2013	2.0	2.0	ND	170	25	> 85.3%	240	18	92.5%
06/03/2013	4.0	2.0	> 50.0%	79	25	> 68.4%	200	17	91.5%
06/10/2013	2.0	2.0	ND	290	25	> 91.4%	230	24	89.6%
06/18/2013	4.4	4.4	0.0%	110	25	> 77.3%	130	23	82.3%
06/24/2013	2.0	2.0	ND	67	25	> 62.7%	110	19	82.7%
07/02/2013	2.0	2.0	ND	110	25	> 77.3%	99	18	81.8%

Notes:

1. Where ">" (greater than) is indicated, the permeate concentration was often less than the method reporting limit. Half of the method reporting limit was used to calculate the percent removal in those cases.
2. ND = Parameter not detected.

Table 4
Greensand Filter Treated Water Quality

	Location	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**
	Date	**2/5/2013**	**2/12/2013**	**2/19/2013**	**2/25/2013**	**3/4/2013**	**3/11/2013**	**3/19/2013**	**3/25/2013**
Parameter	Total or Dissolved								
General Parameters									
Alkalinity, bicarbonate, as CaCO3	NA	**300 mg/l**	**300 mg/l**	**300 mg/l**	**310 mg/l**	**300 mg/l**	**300 mg/l**	**290 mg/l**	**290 mg/l**
Alkalinity, total, as CaCO3	NA	**300 mg/l**	**300 mg/l**	**300 mg/l**	**310 mg/l**	**300 mg/l**	**300 mg/l**	**290 mg/l**	**290 mg/l**
Carbon, dissolved organic	NA	**1.9 mg/l**	**2.4 mg/l**	**2.2 mg/l**	**2.0 mg/l**	**2.5 mg/l**	**2.1 mg/l**	**2.1 mg/l**	**2.3 mg/l**
Carbon, total organic	NA	**1.9 mg/l**	**2.1 mg/l**	**2.2 mg/l**	**2.1 mg/l**	**2.4 mg/l**	**2.1 mg/l**	**2.1 mg/l**	**2.3 mg/l**
Chloride	NA	**4.1 mg/l**	**4.1 mg/l**	**4.8 mg/l**	**4.1 mg/l**	**4.1 mg/l**	**4.1 mg/l**	**4.0 mg/l**	**4.5 mg/l**
Fluoride	NA	**0.13 mg/l**	**0.14 mg/l**	**0.15 mg/l**	**0.14 mg/l**	**0.14 mg/l**	**0.12 mg/l**	**0.12 mg/l**	**0.13 mg/l**
Nitrogen, ammonia as N	NA	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l
Nitrogen, Nitrate as N	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 mg/l	**0.083 mg/l**	< 0.20 mg/l	< 0.20 mg/l
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 mg/l
pH	NA	**8.2 pH units**	**8.1 h pH units**	**8.2 h pH units**	**8.2 h pH units**	**8.2 pH units**	**8.2 pH units**	**8.1 pH units**	**8.2 pH units**
Silicon dioxide	NA	**10.4 mg/l**	**10.2 mg/l**	**10.1 mg/l**	**10.1 mg/l**	**8.40 mg/l**	**8.73 mg/l**	**1.07 mg/l**	**1.04 mg/l**
Solids, total dissolved	NA	**1800 mg/l**	**1900 mg/l**	**1800 mg/l**	**1900 mg/l**	**1900 mg/l**	**1900 mg/l**	**1900 mg/l**	**1900 mg/l**
Solids, total suspended	NA	**5.2 mg/l**	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25 ºC	NA	**2100 umhos/cm**	**2100 umhos/cm**	**2200 umhos/cm**	**2100 umhos/cm**	**2100 umhos/cm**	**2100 umhos/cm**	**2100 umhos/cm**	**2100 umhos/cm**
Sulfate, as SO4	NA	**1100 mg/l**	**1100 mg/l**	**1100 mg/l**	**1100 mg/l**	**1200 mg/l**	**1100 mg/l**	**1200 mg/l**	**1100 mg/l**
Metals									
Aluminum	Total	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l
Arsenic	Total	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l
Barium	Total	**13 ug/l**	**13 ug/l**	**11 ug/l**	**12 ug/l**	**8.9 ug/l**	**8.6 ug/l**	**8.6 ug/l**	**7.5 ug/l**
Boron	Total	**0.18 mg/l**	**0.17 mg/l**	**0.17 mg/l**	**0.18 mg/l**	**0.18 mg/l**	**0.17 mg/l**	**0.17 mg/l**	**0.17 mg/l**
Calcium	Total	**91 mg/l**	**87 mg/l**	**89 mg/l**	**85 mg/l**	**89 mg/l**	**86 mg/l**	**88 mg/l**	**89 mg/l**
Iron	Dissolved	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Magnesium	Total	**240 mg/l**	**230 mg/l**	**230 mg/l**	**240 mg/l**	**230 mg/l**	**220 mg/l**	**230 mg/l**	**230 mg/l**
Manganese	Dissolved	**6.6 ug/l**	**9.3 ug/l**	**7.2 ug/l**	**5.3 ug/l**	**23 ug/l**	**15 ug/l**	**7.0 ug/l**	**35 ug/l**
Manganese	Total	**10 ug/l**	**11 ug/l**	**8.1 ug/l**	**5.9 ug/l**	**28 ug/l**	**16 ug/l**	**17 ug/l**	**51 ug/l**
Potassium	Total	**49 mg/l**	**54 mg/l**	**57 mg/l**	**54 mg/l**	**53 mg/l**	**49 mg/l**	**51 mg/l**	**54 mg/l**
Silicon	Total	**4.9 mg/l**	**4.7 mg/l**	**4.9 mg/l**	**4.9 mg/l**	**4.9 mg/l**	**4.8 mg/l**	**4.9 mg/l**	**4.7 mg/l**
Sodium	Total	**110 mg/l**	**100 mg/l**	**110 mg/l**	**110 mg/l**	**100 mg/l**	**97 mg/l**	**110 mg/l**	**110 mg/l**
Strontium	Total	**310 ug/l**	**310 ug/l**	**330 ug/l**	**320 ug/l**	**320 ug/l**	**320 ug/l**	**290 ug/l**	**310 ug/l**

Table 4
Greensand Filter Treated Water Quality

	Location	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**
	Date	**4/1/2013**	**4/8/2013**	**4/10/2013**	**4/15/2013**	**4/22/2013**	**4/29/2013**	**5/6/2013**	**5/13/2013**
Parameter	Total or Dissolved								
General Parameters									
Alkalinity, bicarbonate, as CaCO3	NA	**290 mg/l**	**280 mg/l**	--	**290 mg/l**	**290 mg/l**	**90 mg/l**	**35 mg/l**	**63 mg/l**
Alkalinity, total, as CaCO3	NA	**290 mg/l**	**280 mg/l**	--	**290 mg/l**	**290 mg/l**	**90 mg/l**	**35 mg/l**	**63 mg/l**
Carbon, dissolved organic	NA	**2.2 mg/l**	**2.4 mg/l**	--	**2.0 mg/l**	**2.2 mg/l**	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l
Carbon, total organic	NA	**2.2 mg/l**	**2.4 mg/l**	--	**2.1 mg/l**	**2.6 mg/l**	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l
Chloride	NA	**4.7 mg/l**	**4.0 mg/l**	--	**4.1 mg/l**	**4.1 mg/l**	**1.2 mg/l**	**0.30 mg/l**	**0.55 mg/l**
Fluoride	NA	**0.12 mg/l**	**0.12 mg/l**	--	**0.12 mg/l**	**0.12 mg/l**	**0.053 mg/l**	< 0.050 mg/l	< 0.050 mg/l
Nitrogen, ammonia as N	NA	< 0.490 mg/l	< 0.480 mg/l	--	< 0.470 mg/l	< 0.490 mg/l	< 0.500 mg/l	< 0.450 mg/l	< 0.470 mg/l
Nitrogen, Nitrate as N	NA	< 0.20 mg/l	< 0.20 mg/l	--	< 0.045 mg/l	< 0.045 mg/l	**0.19 mg/l**	< 0.045 mg/l	**0.22 mg/l**
Orthophosphate, as PO4	NA	< 0.20 h mg/l	< 0.20 mg/l	--	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l
pH	NA	**8.2 pH units**	**8.1 pH units**	--	**8.2 pH units**	**8.2 pH units**	**8.2 pH units**	**8.2 pH units**	**7.8 pH units**
Silicon dioxide	NA	**9.01 mg/l**	**9.10 mg/l**	--	**9.01 mg/l**	**9.24 mg/l**	**2.66 mg/l**	**0.874 mg/l**	**2.21 mg/l**
Solids, total dissolved	NA	**1800 mg/l**	**1700 mg/l**	--	**1600 mg/l**	**1800 mg/l**	**400 mg/l**	**180 mg/l**	**290 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	--	< 4.0 mg/l	**10 mg/l**	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25 ºC	NA	**2200 umhos/cm**	**2100 umhos/cm**	--	**2100 umhos/cm**	**2200 umhos/cm**	**680 umhos/cm**	**250 umhos/cm**	**510 umhos/cm**
Sulfate, as SO4	NA	**1100 mg/l**	**1200 mg/l**	--	**1000 mg/l**	**1100 mg/l**	**570 mg/l**	**83 mg/l**	**190 mg/l**
Metals									
Aluminum	Total	< 10 ug/l	< 10 ug/l	--	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l
Arsenic	Total	< 1.0 ug/l	< 1.0 ug/l	--	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l
Barium	Total	**7.8 ug/l**	**7.2 ug/l**	--	**7.7 ug/l**	**6.9 ug/l**	**2.7 ug/l**	**2.1 ug/l**	**3.3 ug/l**
Boron	Total	**0.16 mg/l**	**0.17 mg/l**	--	**0.17 mg/l**	**0.16 mg/l**	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l
Calcium	Total	**90 mg/l**	**84 mg/l**	--	**83 mg/l**	**81 mg/l**	**26 mg/l**	**10 mg/l**	**15 mg/l**
Iron	Dissolved	< 0.050 mg/l	< 0.050 mg/l	--	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	--	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Magnesium	Total	**220 mg/l**	**220 mg/l**	--	**220 mg/l**	**210 mg/l**	**64 mg/l**	**18 mg/l**	**44 mg/l**
Manganese	Dissolved	**28 ug/l**	**32 ug/l**	**25 ug/l**	**33 ug/l**	**48 ug/l**	**41 ug/l**	**26 ug/l**	**31 ug/l**
Manganese	Total	**31 ug/l**	**41 ug/l**	--	**33 ug/l**	**58 ug/l**	**47 ug/l**	**27 ug/l**	**31 ug/l**
Potassium	Total	**47 mg/l**	**51 mg/l**	--	**50 mg/l**	**49 mg/l**	**14 mg/l**	**4.9 mg/l**	**7.6 mg/l**
Silicon	Total	**4.8 mg/l**	**4.7 mg/l**	--	**4.6 mg/l**	**4.5 mg/l**	**1.6 mg/l**	**0.53 mg/l**	**1.1 mg/l**
Sodium	Total	**110 mg/l**	**99 mg/l**	--	**96 mg/l**	**93 mg/l**	**26 mg/l**	**6.8 mg/l**	**12 mg/l**
Strontium	Total	**320 ug/l**	**320 ug/l**	--	**310 ug/l**	**310 ug/l**	**92 ug/l**	**34 ug/l**	**58 ug/l**

Table 4
Greensand Filter Treated Water Quality

	Location	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**	**Pretreated Effluent**
	Date	**5/20/2013**	**6/3/2013**	**6/10/2013**	**6/18/2013**	**6/24/2013**	**7/2/2013**
Parameter	Total or Dissolved						
General Parameters							
Alkalinity, bicarbonate, as CaCO3	NA	**240 mg/l**	**270 mg/l**	**250 mg/l**	**260 mg/l**	**270 mg/l**	**260 mg/l**
Alkalinity, total, as CaCO3	NA	**240 mg/l**	**270 mg/l**	**250 mg/l**	**260 mg/l**	**270 mg/l**	**260 mg/l**
Carbon, dissolved organic	NA	**2.0 mg/l**	**2.13 mg/l**	**2.47 mg/l**	**2.18 mg/l**	**2.62 mg/l**	**2.58 mg/l**
Carbon, total organic	NA	**2.1 mg/l**	**2.33 mg/l**	**2.47 mg/l**	**2.19 mg/l**	**2.46 mg/l**	**2.66 mg/l**
Chloride	NA	**3.2 mg/l**	**3.6 mg/l**	**3.5 mg/l**	**17 mg/l**	**3.5 mg/l**	**3.1 mg/l**
Fluoride	NA	**0.10 mg/l**	**0.12 mg/l**	**0.12 mg/l**	**0.57 mg/l**	< 0.25 mg/l	< 0.20 mg/l
Nitrogen, ammonia as N	NA	< 0.490 mg/l	< 0.500 mg/l	< 0.480 mg/l	< 0.510 mg/l	< 0.490 mg/l	< 0.490 mg/l
Nitrogen, Nitrate as N	NA	**0.075 mg/l**	< 0.045 mg/l	**0.058 mg/l**	**0.27 mg/l**	< 0.22 mg/l	< 0.18 mg/l
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 0.80 mg/l
pH	NA	**8.2 pH units**	**8.3 pH units**	**8.3 pH units**	**8.3 pH units**	**8.3 pH units**	**8.2 pH units**
Silicon dioxide	NA	**7.68 mg/l**	**8.11 mg/l**	**7.50 mg/l**	**7.47 mg/l**	**7.85 mg/l**	**8.04 mg/l**
Solids, total dissolved	NA	**1400 mg/l**	**1600 mg/l**	**1600 mg/l**	**1500 mg/l**	**1700 mg/l**	**1700 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	**4.4 mg/l**	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25 ºC	NA	**1800 umhos/cm**	**2000 umhos/cm**	**2000 umhos/cm**	**2000 umhos/cm**	**1900 umhos/cm**	**1900 umhos/cm**
Sulfate, as SO4	NA	**1800 mg/l**	**1000 mg/l**	**1000 mg/l**	**1000 mg/l**	**960 mg/l**	**940 mg/l**
Metals							
Aluminum	Total	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l
Arsenic	Total	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l
Barium	Total	**5.5 ug/l**	**4.5 ug/l**	**4.8 ug/l**	**4.8 ug/l**	**4.9 ug/l**	**4.8 ug/l**
Boron	Total	**0.14 mg/l**	**0.16 mg/l**	**0.37 mg/l**	**0.34 mg/l**	**0.36 mg/l**	**0.36 mg/l**
Calcium	Total	**70 mg/l**	**76 mg/l**	**76 mg/l**	**72 mg/l**	**74 mg/l**	**75 mg/l**
Iron	Dissolved	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Magnesium	Total	**180 mg/l**	**200 mg/l**	**210 mg/l**	**200 mg/l**	**220 mg/l**	**220 mg/l**
Manganese	Dissolved	**16 ug/l**	**17 ug/l**	**19 ug/l**	**19 ug/l**	**17 ug/l**	**15 ug/l**
Manganese	Total	**18 ug/l**	**17 ug/l**	**24 ug/l**	**23 ug/l**	**19 ug/l**	**18 ug/l**
Potassium	Total	**40 mg/l**	**42 mg/l**	**43 mg/l**	**41 mg/l**	**43 mg/l**	**44 mg/l**
Silicon	Total	**3.8 mg/l**	**4.1 mg/l**	**4.3 mg/l**	**4.0 mg/l**	**4.2 mg/l**	**4.2 mg/l**
Sodium	Total	**77 mg/l**	**86 mg/l**	**86 mg/l**	**84 mg/l**	**84 mg/l**	**85 mg/l**
Strontium	Total	**260 ug/l**	**250 ug/l**	**260 ug/l**	**260 ug/l**	**270 ug/l**	**280 ug/l**

Table 5
Greensand Filter Backwash Water Quality

	Location **Date**	**Green Sand Filt** **2/11/2013**	**Green Sand Filt** **2/19/2013**	**Green Sand Filt** **3/25/2013**	**Green Sand Filt** **4/22/2013**	**Green Sand Filt** **7/2/2013**
Parameter	Total or Dissolved					
General Parameters						
Alkalinity, bicarbonate, as CaCO3	NA	**310 mg/l**	**310 mg/l**	**310 mg/l**	**300 mg/l**	**270 mg/l**
Alkalinity, total, as CaCO3	NA	**310 mg/l**	**310 mg/l**	**310 mg/l**	**300 mg/l**	**270 mg/l**
Carbon, total organic	NA	**5.7 mg/l**	**4.4 mg/l**	**6.6 mg/l**	**8.3 mg/l**	**6.18 mg/l**
Chemical Oxygen Demand	NA	**140 mg/l**	< 50 mg/l	**82 mg/l**	**61 mg/l**	**120 mg/l**
Chloride	NA	**4.1 mg/l**	**4.1 mg/l**	**4.4 mg/l**	**4.1 mg/l**	**3.4 mg/l**
Fluoride	NA	**0.14 mg/l**	**0.15 mg/l**	**0.12 mg/l**	**0.12 mg/l**	**0.11 mg/l**
Nitrogen, ammonia as N	NA	< 0.470 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.480 mg/l	< 0.460 mg/l
Nitrogen, Nitrate as N	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.045 mg/l	**0.10 mg/l**
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l
pH	NA	**8.1 h pH units**	**8.1 h pH units**	**8.2 pH units**	**8.1 pH units**	**8.1 pH units**
Solids, total dissolved	NA	**2000 mg/l**	**1800 mg/l**	**1800 mg/l**	**1900 mg/l**	**1600 mg/l**
Solids, total suspended	NA	**190 mg/l**	**62 mg/l**	**180 mg/l**	**160 mg/l**	**150 mg/l**
Specific Conductance @ 25 ºC	NA	**2100 umhos/cm**	**2200 umhos/cm**	**2100 umhos/cm**	**2100 umhos/cm**	**1900 umhos/cm**
Sulfate, as SO4	NA	**1100 mg/l**	**1200 mg/l**	**1100 mg/l**	**1100 mg/l**	**970 mg/l**
Metals						
Aluminum	Total	**950 ug/l**	**510 ug/l**	**650 ug/l**	< 1000 ug/l	**1100 ug/l**
Arsenic	Total	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	**3.8 ug/l**	< 10 ug/l
Barium	Total	**290 ug/l**	**150 ug/l**	**170 ug/l**	**190 ug/l**	**170 ug/l**
Boron	Total	**0.17 mg/l**	**0.17 mg/l**	< 1.0 mg/l	< 1.0 mg/l	**0.36 mg/l**
Calcium	Total	**92 mg/l**	**93 mg/l**	**92 mg/l**	**86 mg/l**	**78 mg/l**
Iron	Dissolved	< 0.050 mg/l	< 0.050 mg/l	< 0.50 mg/l	< 0.050 mg/l	< 0.050 mg/l
Iron	Total	**3.6 mg/l**	**1.9 mg/l**	**3.7 mg/l**	**5.5 mg/l**	**17 mg/l**
Magnesium	Total	**230 mg/l**	**230 mg/l**	**230 mg/l**	**240 mg/l**	**210 mg/l**
Manganese	Dissolved	**14 ug/l**	**34 ug/l**	**9.6 ug/l**	**32 ug/l**	**30 ug/l**
Manganese	Total	**22000 ug/l**	**13000 ug/l**	**26000 ug/l**	**27000 ug/l**	**33000 ug/l**
Potassium	Total	**55 mg/l**	**56 mg/l**	**49 mg/l**	**51 mg/l**	**43 mg/l**
Silicon	Total	**6.4 mg/l**	**5.7 mg/l**	**5.5 mg/l**	**6.6 mg/l**	**8.2 mg/l**
Sodium	Total	**100 mg/l**	**110 mg/l**	**94 mg/l**	**88 mg/l**	**81 mg/l**
Strontium	Total	**380 ug/l**	**360 ug/l**	**350 ug/l**	**390 ug/l**	**330 ug/l**

Table 6
RO Permeate Water Quality

Location Date		RO Permeate 2/5/2013	RO Permeate 2/12/2013	RO Permeate 2/19/2013	RO Permeate 2/25/2013	RO Permeate 3/4/2013	RO Permeate 3/11/2013	RO Permeate 3/19/2013	RO Permeate 3/25/2013	RO Permeate 4/1/2013	RO Permeate 4/8/2013	RO Permeate 4/15/2013	RO Permeate 4/22/2013	RO Permeate 4/29/2013
Parameter	Total or Dissolved													
General Parameters														
Alkalinity, bicarbonate, as CaCO3	NA	--	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l
Alkalinity, total, as CaCO3	NA	--	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l
Carbon, total organic	NA	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l
Chloride	NA	--	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l
Fluoride	NA	--	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Nitrogen, ammonia as N	NA	< 0.500 mg/l	< 0.500 mg/l	< 0.480 mg/l	< 0.480 mg/l	< 0.470 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.450 mg/l	< 0.480 mg/l	< 0.480 mg/l	< 0.490 mg/l
Nitrogen, Nitrate as N	NA	--	< 0.20 mg/l	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 mg/l	< 0.045 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l
Orthophosphate, as PO4	NA	--	< 0.20 mg/l	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l
pH	NA	--	**6.5 h pH units**	**7.0 h pH units**	**7.7 h pH units**	**6.7 pH units**	**7.2 h pH units**	**7.6 pH units**	**7.0 pH units**	**7.1 pH units**	**6.8 pH units**	**6.8 pH units**	**6.8 pH units**	**6.9 pH units**
Solids, total dissolved	NA	--	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l
Solids, total suspended	NA	--	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25 ºC	NA	--	< 10 umhos/cm	< 10 umhos/cm	< 10 umhos/cm	< 10 umhos/cm	< 10 umhos/cm	< 10 umhos/cm	**10 umhos/cm**	**11 umhos/cm**	**11 umhos/cm**	**14 umhos/cm**	**20 umhos/cm**	< 10 umhos/cm
Sulfate, as SO4	NA	--	**1.6 mg/l**	**1.5 mg/l**	**1.4 mg/l**	**1.1 mg/l**	**1.3 mg/l**	**1.5 mg/l**	**2.3 mg/l**	**2.3 mg/l**	**2.3 mg/l**	**3.4 mg/l**	**5.2 mg/l**	**1.4 mg/l**
Metals														
Aluminum	Total	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l
Arsenic	Total	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l
Barium	Total	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	**0.31 ug/l**	< 0.20 ug/l
Boron	Total	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l
Calcium	Total	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Magnesium	Total	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Manganese	Total	< 0.50 ug/l	**1.0 ug/l**	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	**0.54 ug/l**	< 0.50 ug/l
Potassium	Total	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Silicon	Total	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l
Sodium	Total	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Strontium	Total	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	**0.51 ug/l**	**0.53 ug/l**	**0.81 ug/l**	**1.5 ug/l**	< 0.50 ug/l

Table 6
RO Permeate Water Quality

	Location	RO Permeate	RO Permeate	RO Permeate	RO Permeate	RO Permeate	RO Permeate	RO Permeate	RO Permeate
	Date	5/6/2013	5/13/2013	5/20/2013	6/3/2013	6/10/2013	6/18/2013	6/24/2013	7/2/2013
Parameter	Total or Dissolved								
General Parameters									
Alkalinity, bicarbonate, as CaCO3	NA	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l < 20 mg/l	< 20 mg/l
Alkalinity, total, as CaCO3	NA	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l < 20 mg/l	< 20 mg/l
Carbon, total organic	NA	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.00 mg/l	< 1.00 mg/l	**11.2 mg/l**	< 1.00 mg/l < 1.00 mg/l	< 1.00 mg/l
Chloride	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l < 0.20 mg/l	< 0.20 mg/l
Fluoride	NA	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l < 0.050 mg/l	< 0.050 mg/l
Nitrogen, ammonia as N	NA	< 0.470 mg/l	< 0.460 mg/l	< 0.450 mg/l	< 0.500 mg/l	< 0.480 mg/l	< 0.490 mg/l	< 0.510 mg/l < 0.490 mg/l	< 0.480 mg/l
Nitrogen, Nitrate as N	NA	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l 0.045 mg/l	< 0.045 mg/l
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l < 0.20 mg/l	< 0.20 mg/l
pH	NA	**7.4 pH units**	**7.5 pH units**	**7.3 pH units**	**7.9 pH units**	**7.5 pH units**	**6.9 pH units**	**6.9 pH units** **6.8 pH units**	**6.6 pH units**
Solids, total dissolved	NA	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	< 10 mg/l	**190 mg/l** **510 mg/l**	< 10 mg/l
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l < 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25 ºC	NA	< 10 umhos/cm	**11 umhos/cm**	**21 umhos/cm**	**24 umhos/cm**	**23 umhos/cm**	**21 umhos/cm**	**40 umhos/cm** **27 umhos/cm**	**41 umhos/cm**
Sulfate, as SO4	NA	**0.99 mg/l**	**2.6 mg/l**	**5.4 mg/l**	**6.0 mg/l**	**5.5 mg/l**	**4.7 mg/l**	**7.3 mg/l** **11 mg/l**	**12 mg/l**
Metals									
Aluminum	Total	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l < 10 ug/l	< 10 ug/l
Arsenic	Total	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l < 1.0 ug/l	< 1.0 ug/l
Barium	Total	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l < 0.20 ug/l	< 0.20 ug/l
Boron	Total	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l < 0.10 mg/l	< 0.10 mg/l
Calcium	Total	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l < 1.0 mg/l	< 1.0 mg/l
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l < 0.050 mg/l	< 0.050 mg/l
Magnesium	Total	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	**1.0 mg/l**	< 1.0 mg/l	< 1.0 mg/l	**2.0 mg/l** **1.2 mg/l**	**2.2 mg/l**
Manganese	Total	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l	< 0.50 ug/l < 0.50 ug/l	< 0.50 ug/l
Potassium	Total	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	**1.4 mg/l** **1.1 mg/l**	**1.4 mg/l**
Silicon	Total	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l < 0.25 mg/l	< 0.25 mg/l
Sodium	Total	< 1.0 mg/l	< 1.0 mg/l	**1.2 mg/l**	**1.3 mg/l**	**1.6 mg/l**	**1.1 mg/l**	**2.3 mg/l** **1.8 mg/l**	**2.6 mg/l**
Strontium	Total	< 0.50 ug/l	**0.75 ug/l**	**1.2 ug/l**	**1.4 ug/l**	**1.2 ug/l**	**0.92 ug/l**	**2.6 ug/l** **1.5 ug/l**	**3.0 ug/l**

Table 7
RO Concentrate Water Quality

	Location Date	RO Concentrate 2/5/2013	RO Concentrate 2/12/2013	RO Concentrate 2/19/2013	RO Concentrate 2/25/2013	RO Concentrate 3/4/2013	RO Concentrate 3/11/2013	RO Concentrate 3/19/2013	RO Concentrate 3/25/2013	RO Concentrate 4/1/2013	RO Concentrate 4/8/2013
Parameter	Total or Dissolved										
General Parameters											
Alkalinity, bicarbonate, as CaCO3	NA	--	**1000 mg/l**	**970 mg/l**	**1300 mg/l**	**1300 mg/l**	**1200 mg/l**	**1300 mg/l**	**1300 mg/l**	**1200 mg/l**	**1300 mg/l**
Alkalinity, total, as CaCO3	NA	--	**1000 mg/l**	**970 mg/l**	**1300 mg/l**	**1300 mg/l**	**1200 mg/l**	**1300 mg/l**	**1300 mg/l**	**1200 mg/l**	**1300 mg/l**
Carbon, total organic	NA	**7.7 mg/l**	**8.1 mg/l**	**8.3 mg/l**	**11 mg/l**	**11 mg/l**	**10 mg/l**	**12 mg/l**	**12 mg/l**	**12 mg/l**	**13 mg/l**
Chloride	NA	--	**14 mg/l**	**13 mg/l**	**18 mg/l**	**18 mg/l**	**19 mg/l**	**19 mg/l**	**21 mg/l**	**23 mg/l**	**19 mg/l**
Fluoride	NA	--	**0.29 mg/l**	**0.14 mg/l**	**0.40 mg/l**	**0.35 mg/l**	**0.30 mg/l**	**0.32 mg/l**	**0.57 mg/l**	**0.56 mg/l**	**0.56 mg/l**
Nitrogen, ammonia as N	NA	< 0.500 mg/l	< 0.500 mg/l	< 0.490 mg/l	< 0.500 mg/l	< 0.470 mg/l	< 0.500 mg/l	< 0.510 mg/l	< 0.500 mg/l	< 0.460 mg/l	< 0.510 mg/l
Nitrogen, Nitrate as N	NA	--	< 0.20 mg/l	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 mg/l	< 0.045 mg/l	< 0.20 h mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l
Orthophosphate, as PO4	NA	--	< 1.0 mg/l	< 1.0 mg/l	< 1.0 h mg/l	< 0.20 mg/l	< 0.20 mg/l	< 1.0 h mg/l	< 1.0 mg/l	< 1.0 h mg/l	< 1.0 mg/l
pH	NA	--	**7.9 h pH units**	**7.6 h pH units**	**8.0 h pH units**	**7.9 pH units**	**8.0 pH units**	**8.0 pH units**	**8.0 pH units**	**7.9 pH units**	**8.0 pH units**
Solids, total dissolved	NA	--	**6400 mg/l**	**7200 mg/l**	**8900 mg/l**	**7500 mg/l**	**8200 mg/l**	**8600 mg/l**	**8200 mg/l**	**8200 mg/l**	**8500 mg/l**
Solids, total suspended	NA	--	**10 mg/l**	< 4.0 mg/l	**9.2 mg/l**	**7.2 mg/l**	**6.0 mg/l**	**11 mg/l**	**6.4 mg/l**	**10 mg/l**	**9.6 mg/l**
Specific Conductance @ 25 ºC	NA	--	**5900 umhos/cm**	**6200 umhos/cm**	**7300 umhos/cm**	**7600 umhos/cm**	**7300 umhos/cm**	**8000 umhos/cm**	**8000 umhos/cm**	**7800 umhos/cm**	**7900 umhos/cm**
Sulfate, as SO4	NA	--	**3700 mg/l**	**3800 mg/l**	**5000 mg/l**	**4600 mg/l**	**4900 mg/l**	**5500 mg/l**	**4700 mg/l**	**4900 mg/l**	**4700 mg/l**
Metals											
Aluminum	Total	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l
Arsenic	Total	**1.5 ug/l**	**1.5 ug/l**	**2.2 ug/l**	**1.7 ug/l**	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l
Barium	Total	**45 ug/l**	**36 ug/l**	**37 ug/l**	**45 ug/l**	**39 ug/l**	**38 ug/l**	**39 ug/l**	**34 ug/l**	**37 ug/l**	**34 ug/l**
Boron	Total	**0.52 mg/l**	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Calcium	Total	**320 mg/l**	**300 mg/l**	**300 mg/l**	**370 mg/l**	**380 mg/l**	**370 mg/l**	**410 mg/l**	**420 mg/l**	**410 mg/l**	**390 mg/l**
Iron	Total	< 0.050 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l
Magnesium	Total	**800 mg/l**	**810 mg/l**	**810 mg/l**	**970 mg/l**	**980 mg/l**	**970 mg/l**	**1100 mg/l**	**1100 mg/l**	**1000 mg/l**	**1000 mg/l**
Manganese	Total	**12 ug/l**	**14 ug/l**	**14 ug/l**	**12 ug/l**	**79 ug/l**	**38 ug/l**	**65 ug/l**	**100 ug/l**	**90 ug/l**	**140 ug/l**
Potassium	Total	**170 mg/l**	**190 mg/l**	**190 mg/l**	**210 mg/l**	**210 mg/l**	**210 mg/l**	**240 mg/l**	**230 mg/l**	**220 mg/l**	**220 mg/l**
Silicon	Total	**17 mg/l**	**16 mg/l**	**17 mg/l**	**20 mg/l**	**21 mg/l**	**21 mg/l**	**22 mg/l**	**22 mg/l**	**22 mg/l**	**21 mg/l**
Sodium	Total	**390 mg/l**	**330 mg/l**	**340 mg/l**	**410 mg/l**	**420 mg/l**	**410 mg/l**	**470 mg/l**	**470 mg/l**	**480 mg/l**	**430 mg/l**
Strontium	Total	**1200 ug/l**	**1100 ug/l**	**1200 ug/l**	**1500 ug/l**	**1400 ug/l**	**1300 ug/l**	**1300 ug/l**	**1400 ug/l**	**1700 ug/l**	**1500 ug/l**

Table 7
RO Concentrate Water Quality

Location Date		RO Concentrate 4/15/2013	RO Concentrate 4/22/2013	RO Concentrate 4/29/2013	RO Concentrate 5/6/2013	RO Concentrate 5/13/2013	RO Concentrate 5/20/2013	RO Concentrate 6/3/2013	RO Concentrate 6/10/2013	RO Concentrate 6/18/2013	RO Concentrate 6/24/2013	RO Concentrate 7/2/2013
Parameter	Total or Dissolved											
General Parameters												
Alkalinity, bicarbonate, as CaCO3	NA	**1300 mg/l**	**1200 mg/l**	**390 mg/l**	**150 mg/l**	**290 mg/l**	**1100 mg/l**	**1200 mg/l**	**1200 mg/l**	**1200 mg/l**	**1200 mg/l** **1200 mg/l**	**1200 mg/l**
Alkalinity, total, as CaCO3	NA	**1300 mg/l**	**1200 mg/l**	**390 mg/l**	**150 mg/l**	**290 mg/l**	**1100 mg/l**	**1200 mg/l**	**1200 mg/l**	**1200 mg/l**	**1200 mg/l** **1200 mg/l**	**1200 mg/l**
Carbon, total organic	NA	**12 mg/l**	**12 mg/l**	**5.4 mg/l**	**2.2 mg/l**	**6.3 mg/l**	**9.7 mg/l**	**12.3 mg/l**	**12.2 mg/l**	< 1.00 mg/l	**14.6 mg/l** **12.6 mg/l**	< 1.00 mg/l
Chloride	NA	**19 mg/l**	**19 mg/l**	**5.7 mg/l**	**1.6 mg/l**	**3.0 mg/l**	**15 mg/l**	**18 mg/l**	**17 mg/l**	**17 mg/l**	**17 mg/l** **16 mg/l**	**17 mg/l**
Fluoride	NA	**0.56 mg/l**	**0.56 mg/l**	**0.20 mg/l**	**0.13 mg/l**	**0.17 mg/l**	**0.54 mg/l**	**0.56 mg/l**	**0.61 mg/l**	**0.63 mg/l**	**0.56 mg/l** **0.59 mg/l**	**0.52 mg/l**
Nitrogen, ammonia as N	NA	< 0.500 mg/l	**0.541 mg/l**	**0.590 mg/l**	< 0.460 mg/l	< 0.480 mg/l	< 0.470 mg/l	< 0.500 mg/l	< 0.470 mg/l	< 0.500 mg/l	< 0.460 mg/l < 0.470 mg/l	< 0.470 mg/l
Nitrogen, Nitrate as N	NA	**0.15 mg/l**	**0.12 mg/l**	**0.53 mg/l**	**0.19 mg/l**	**1.0 mg/l**	**0.33 mg/l**	**0.20 mg/l**	**0.25 mg/l**	**0.28 mg/l**	**0.24 mg/l** **0.24 mg/l**	**0.33 mg/l**
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	**0.25 mg/l**	**0.21 mg/l**	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l < 1.0 mg/l	< 1.0 mg/l
pH	NA	**8.0 pH units**	**8.0 pH units**	**8.2 pH units**	**8.2 pH units**	**8.0 pH units**	**8.1 pH units**	**8.1 pH units**	**8.0 pH units**	**8.1 pH units**	**8.1 pH units** **8.1 pH units**	**8.1 pH units**
Solids, total dissolved	NA	**7200 mg/l**	**8500 mg/l**	**1500 mg/l**	**700 mg/l**	**1600 mg/l**	**7000 mg/l**	**7400 mg/l**	**8000 mg/l**	**7900 mg/l**	**8900 mg/l** **8700 mg/l**	**9200 mg/l**
Solids, total suspended	NA	**8.8 mg/l**	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	**9.6 mg/l**	**12 mg/l**	**5.2 mg/l**	**9.2 mg/l**	**11 mg/l** **10 mg/l**	< 4.0 mg/l
Specific Conductance @ 25 ºC	NA	**7700 umhos/cm**	**7600 umhos/cm**	**2600 umhos/cm**	**970 umhos/cm**	**1900 umhos/cm**	**7100 umhos/cm**	**7500 umhos/cm**	**7500 umhos/cm**	**7500 umhos/cm**	**7100 umhos/cm** **7200 umhos/cm**	**7400 umhos/cm**
Sulfate, as SO4	NA	**5100 mg/l**	**4800 mg/l**	**1300 mg/l**	**380 mg/l**	**890 mg/l**	**4300 mg/l**	**4900 mg/l**	**4900 mg/l**	**4800 mg/l**	**5000 mg/l** **4300 mg/l**	**4900 mg/l**
Metals												
Aluminum	Total	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l < 50 ug/l	< 10 ug/l
Arsenic	Total	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l < 5.0 ug/l	< 1.0 ug/l
Barium	Total	**35 ug/l**	**32 ug/l**	**11 ug/l**	**9.9 ug/l**	**15 ug/l**	**26 ug/l**	**22 ug/l**	**23 ug/l**	**23 ug/l**	**24 ug/l** **24 ug/l**	< 0.20 ug/l
Boron	Total	< 5.0 mg/l	< 1.0 mg/l	< 0.50 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	**0.50 mg/l**	**1.7 mg/l**	**1.4 mg/l**	**1.5 mg/l** **1.4 mg/l**	< 0.10 mg/l
Calcium	Total	**430 mg/l**	**360 mg/l**	**110 mg/l**	**46 mg/l**	**78 mg/l**	**340 mg/l**	**360 mg/l**	**380 mg/l**	**360 mg/l**	**360 mg/l** **340 mg/l**	< 1.0 mg/l
Iron	Total	< 2.5 mg/l	< 0.50 mg/l	< 0.050 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.25 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l < 0.50 mg/l	< 0.050 mg/l
Magnesium	Total	**1100 mg/l**	**1000 mg/l**	**290 mg/l**	**85 mg/l**	**220 mg/l**	**900 mg/l**	**920 mg/l**	**1000 mg/l**	**970 mg/l**	**1000 mg/l** **950 mg/l**	**2.3 mg/l**
Manganese	Total	**110 ug/l**	**89 ug/l**	**130 ug/l**	**100 ug/l**	**88 ug/l**	**53 ug/l**	**52 ug/l**	**62 ug/l**	**40 ug/l**	**43 ug/l** **37 ug/l**	< 0.50 ug/l
Potassium	Total	**250 mg/l**	**210 mg/l**	**62 mg/l**	**22 mg/l**	**39 mg/l**	**200 mg/l**	**200 mg/l**	**210 mg/l**	**190 mg/l**	**210 mg/l** **200 mg/l**	**1.4 mg/l**
Silicon	Total	**24 mg/l**	**21 mg/l**	**6.8 mg/l**	< 2.5 mg/l	**5.4 mg/l**	**18 mg/l**	**19 mg/l**	**19 mg/l**	**18 mg/l**	**19 mg/l** **18 mg/l**	< 0.25 mg/l
Sodium	Total	**450 mg/l**	**420 mg/l**	**120 mg/l**	**30 mg/l**	**57 mg/l**	**370 mg/l**	**400 mg/l**	**410 mg/l**	**400 mg/l**	**410 mg/l** **380 mg/l**	**2.6 mg/l**
Strontium	Total	**1500 ug/l**	**1400 ug/l**	**430 ug/l**	**160 ug/l**	**270 ug/l**	**1200 ug/l**	**1200 ug/l**	**1200 ug/l**	**1200 ug/l**	**1300 ug/l** **1300 ug/l**	**2.9 ug/l**

Table 8
Average RO Removal Rates

	Fraction	Percent Reduction
General Parameters		
Alkalinity, bicarbonate, as CaCO3	NA	> 96.4%
Alkalinity, total, as CaCO3	NA	> 96.4%
Carbon, total organic	NA	> 69.5%
Chloride	NA	> 97.6%
Fluoride	NA	> 80.6%
Nitrogen, ammonia as N	NA	> 1.7%
Solids, total dissolved	NA	> 99.7%
Specific Conductance @ 25 ºC	NA	> 99.2%
Sulfate, as SO4	NA	99.6%
Metals		
Arsenic	Total	ND
Barium	Total	> 98.3%
Boron	Total	> 73.7%
Calcium	Total	> 99.4%
Magnesium	Total	> 99.7%
Manganese	Total	> 98.1%
Potassium	Total	> 98.7%
Silicon	Total	> 97.2%
Sodium	Total	> 99.0%
Strontium	Total	> 99.7%

Notes:

1. Where ">" (greater than) is indicated, the permeate concentration was often less than the method reporting limit. Half of the method reporting limit was used to calculate the percent removal in those cases.

2. ND = Parameter not detected.

Table 9
Preliminary RO Model Results for SD033

GE Water

Winflows Version 3.1.2
DataBase Version 3.04

Streams Analytical Data

Ions, mg/l		**Total Feed**	**Predosed Feed**	**1st Pass Feed**	**Final Downstream Perm**
Calcium		81.00	81.00	81.00	0.14
Magnesium		230.00	230.00	230.00	0.30
Sodium		110.00	110.00	110.00	1.25
Potassium		57.00	57.00	57.00	1.39
Ammonia - N		0.00	0.00	0.00	0.00
Barium		0.01	0.01	0.01	0.00
Strontium		0.29	0.29	0.29	0.00
Iron		0.00	0.00	0.00	0.00
Manganese		0.03	0.03	0.03	0.00
Sulfate		1000.00	1005.58	1005.58	1.30
Chloride		105.84	105.84	105.84	0.56
Fluoride		0.21	0.21	0.21	0.00
Nitrate		0.40	0.40	0.40	0.01
Bromide		0.00	0.00	0.00	0.00
Phosphate		0.10	0.10	0.10	0.00
Boron		0.14	0.14	0.14	0.07
Silica		4.70	4.70	4.70	0.05
Hydrogen Sulfide		0.00	0.00	0.00	0.00
Bicarbonate		317.17	317.28	317.28	4.84
Carbon Dioxide		1.62	4.08	4.08	5.40
Carbonate		5.75	2.29	2.29	0.00
TDS, mg/l		1912.63	1914.86	1914.86	9.91
Flow	gpm	21.25	21.25	21.25	17.00
Temperature	F	50.00	50.00	50.00	50.00
Pressure	psi	0.00	0.00	204.29	0.00
Osm. Pressure	psi	10.15	10.16	10.16	0.12
pH		8.50	8.10	8.10	6.27
Conductivity at 25C	µS/cm	2397.00	2397.00	2397.00	14.00
Saturation Data					
BaSO4	%	82.13	82.59	82.59	0.04
CaF2	%	0.26	0.26	0.26	0.00
CaSO4	%	11.84	11.90	11.90	0.00
SiO2	%	4.25	4.30	4.30	0.04
SrSO4	%	2.43	2.45	2.45	0.00
Struvite	%	0.00	0.00	0.00	0.00
LSI		0.99	0.59	0.59	-5.38
S&DI		0.75	0.35	0.35	-5.96

Table 9
Preliminary RO Model Results for SD033

GE Water

Streams Analytical Data

Ions, mg/l		**Product**	**Concentrate**
Calcium		0.14	404.17
Magnesium		0.30	1148.11
Sodium		1.25	544.66
Potassium		1.39	279.26
Ammonia - N		0.00	0.00
Barium		0.00	0.03
Strontium		0.00	1.45
Iron		0.00	0.00
Manganese		0.00	0.14
Sulfate		1.30	5019.65
Chloride		0.56	526.63
Fluoride		0.00	1.03
Nitrate		0.01	1.97
Bromide		0.00	0.00
Phosphate		0.00	0.50
Boron		0.07	0.44
Silica		0.05	23.29
Hydrogen Sulfide		0.00	0.00
Bicarbonate		4.84	1537.07
Carbon Dioxide		5.40	9.30
Carbonate		0.00	25.73
TDS, mg/l		9.91	9514.11
Flow	gpm	17.00	4.25
Temperature	F	50.00	50.00
Pressure	psi	0.00	163.29
Osm. Pressure	psi	0.12	45.88
pH		6.27	8.29
Conductivity at 25C	µS/cm	14.00	9286.00
Saturation Data			
BaSO4	%	0.04	**515.18**
CaF2	%	0.00	16.07
CaSO4	%	0.00	87.24
SiO2	%	0.04	21.17
SrSO4	%	0.00	14.29
Struvite	%	0.00	0.00
LSI		-5.38	1.74
S&DI		-5.96	1.56

Table 10
RO CIP Waste Quality

	Location	**CIP High**	**CIP Low**
	Date	**6/24/2013**	**6/23/2013**
Parameter	Total or Dissolved		
General Parameters			
Alkalinity, bicarbonate, as CaCO3	NA	**230 mg/l**	< 20 mg/l
Alkalinity, total, as CaCO3	NA	**410 mg/l**	< 20 mg/l
Chemical Oxygen Demand	NA	**530 mg/l**	**8000 mg/l**
Chloride	NA	**2.7 mg/l**	< 2.0 mg/l
Fluoride	NA	< 0.50 mg/l	**1.0 mg/l**
Nitrogen, ammonia as N	NA	< 0.490 mg/l	< 0.450 mg/l
Nitrogen, Nitrate as N	NA	< 0.45 mg/l	< 0.45 mg/l
Orthophosphate, as PO4	NA	< 2.0 mg/l	< 2.0 mg/l
pH	NA	**9.8 pH units**	**2.8 e pH units**
Solids, total dissolved	NA	**2100 mg/l**	**16000 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	**6.4 mg/l**
Specific Conductance @ 25 ºC	NA	**2000 umhos/cm**	**2100 umhos/cm**
Sulfate, as SO4	NA	**630 mg/l**	**290 mg/l**
Metals			
Aluminum	Total	< 50 ug/l	**1000 ug/l**
Arsenic	Total	< 5.0 ug/l	**7.2 ug/l**
Barium	Total	**5.2 ug/l**	**100 ug/l**
Boron	Total	**0.25 mg/l**	**0.17 mg/l**
Calcium	Total	**22 mg/l**	**330 mg/l**
Iron	Total	**0.12 mg/l**	**9.7 mg/l**
Magnesium	Total	**59 mg/l**	**58 mg/l**
Manganese	Total	**24 ug/l**	**5100 ug/l**
Potassium	Total	**26 mg/l**	**15 mg/l**
Silicon	Total	**4.2 mg/l**	**2.2 mg/l**
Sodium	Total	**320 mg/l**	**23 mg/l**
Strontium	Total	**81 ug/l**	**1100 ug/l**

Table 11
Final RO Model Results for SD033

GE Water

Winflows Version 3.1.2
DataBase Version 3.04

Streams Analytical Data

Ions, mg/l		**Total Feed**	**Predosed Feed**	**1st Pass Feed**	**Final Downstream Perm**
Calcium		83.50	83.50	83.50	0.15
Magnesium		218.33	218.33	218.33	0.39
Sodium		152.64	152.64	152.64	1.75
Potassium		47.00	47.00	47.00	1.59
Ammonia - N		0.30	0.30	0.30	0.01
Barium		0.01	0.01	0.01	0.00
Strontium		0.30	0.30	0.30	0.00
Iron		0.07	0.07	0.07	0.00
Manganese		0.05	0.05	0.05	0.00
Sulfate		1160.24	1201.51	1201.51	2.62
Chloride		4.70	4.70	4.70	0.07
Fluoride		0.16	0.16	0.16	0.00
Nitrate		0.00	0.00	0.00	0.00
Bromide		0.00	0.00	0.00	0.00
Phosphate		0.16	0.16	0.16	0.00
Boron		0.21	0.21	0.21	0.13
Silica		4.58	4.58	4.58	0.07
Hydrogen Sulfide		0.00	0.00	0.00	0.00
Bicarbonate		338.64	295.05	295.05	6.36
Carbon Dioxide		2.69	37.17	37.17	37.41
Carbonate		4.38	0.24	0.24	0.00
TDS, mg/l		2015.26	2008.81	2008.81	13.15
Flow	gpm	300.00	300.00	300.00	239.94
Temperature	F	75.00	75.00	75.00	75.00
Pressure	psi	0.00	0.00	159.38	0.00
Osm. Pressure	psi	10.62	10.74	10.74	0.41
pH		8.20	7.00	7.00	5.44
Conductivity at 25C	µS/cm	2385.00	2397.00	2397.00	19.00
Saturation Data					
BaSO4	%	**158.60**	**163.29**	**163.29**	0.07
CaF2	%	0.15	0.15	0.15	0.00
CaSO4	%	13.72	14.14	14.14	0.00
SiO2	%	3.58	3.66	3.66	0.04
SrSO4	%	2.82	2.90	2.90	0.00
Struvite	%	0.00	0.00	0.00	0.00
LSI		0.93	-0.27	-0.27	-5.87
S&DI		0.77	-0.49	-0.49	-6.38

Table 11
Final RO Model Results for SD033

GE Water

Streams Analytical Data

Ions, mg/l		Dosed Final Permeate	Product	Concentrate
Calcium		13.77	13.77	416.45
Magnesium		0.39	0.39	1088.87
Sodium		1.75	1.75	755.36
Potassium		1.59	1.59	228.39
Ammonia - N		0.01	0.01	1.44
Barium		0.00	0.00	0.05
Strontium		0.00	0.00	1.50
Iron		0.00	0.00	0.35
Manganese		0.00	0.00	0.25
Sulfate		2.62	2.62	5990.45
Chloride		0.07	0.07	23.20
Fluoride		0.00	0.00	0.78
Nitrate		0.00	0.00	0.00
Bromide		0.00	0.00	0.00
Phosphate		0.00	0.00	0.79
Boron		0.13	0.13	0.51
Silica		0.07	0.07	22.60
Hydrogen Sulfide		0.00	0.00	0.00
Bicarbonate		47.56	47.56	1439.20
Carbon Dioxide		7.68	7.68	39.24
Carbonate		0.02	0.02	5.88
TDS, mg/l		67.99	67.99	9976.08
Flow	gpm	239.94	239.94	60.07
Temperature	F	75.00	75.00	75.00
Pressure	psi	0.00	0.00	116.28
Osm. Pressure	psi	0.52	0.52	47.01
pH		7.00	7.00	7.53
Conductivity at 25C	µS/cm	85.00	85.00	9112.00
Saturation Data				
BaSO4	%	0.02	0.02	**1018.66**
CaF2	%	0.00	0.00	9.30
CaSO4	%	0.09	0.09	**103.57**
SiO2	%	0.05	0.05	17.98
SrSO4	%	0.00	0.00	16.92
Struvite	%	0.00	0.00	0.01
LSI		-1.44	-1.44	1.15
S&DI		-1.98	-1.98	1.03

Table 12
VSEP CIP Waste Quality

	Location	**VSEP Cleaning 404**	**VSEP Cleaning 505**
	Date	**7/2/2013**	**7/2/2013**
Parameter	Total or Dissolved		
General Parameters			
Alkalinity, bicarbonate, as CaCO3	NA	< 20 mg/l	**380 mg/l**
Alkalinity, total, as CaCO3	NA	< 20 mg/l	**950 mg/l**
Chemical Oxygen Demand	NA	**9700 mg/l**	**2900 mg/l**
Chloride	NA	< 2.0 mg/l	< 2.0 mg/l
Fluoride	NA	< 0.50 mg/l	**0.55 mg/l**
Nitrogen, ammonia as N	NA	< 0.460 mg/l	< 0.470 mg/l
Nitrogen, Nitrate as N	NA	< 0.45 mg/l	< 0.45 mg/l
Orthophosphate, as PO4	NA	**510 mg/l**	**17 mg/l**
pH	NA	**2.3 pH units**	**10 pH units**
Solids, total dissolved	NA	**8100 mg/l**	**5200 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25 ºC	NA	**2900 umhos/cm**	**3100 umhos/cm**
Sulfate, as SO4	NA	**39 mg/l**	**62 mg/l**
Metals			
Aluminum	Total	**350 ug/l**	< 50 ug/l
Arsenic	Total	< 5.0 ug/l	< 5.0 ug/l
Barium	Total	**2.7 ug/l**	**6.2 ug/l**
Boron	Total	**0.13 mg/l**	**0.25 mg/l**
Calcium	Total	**5.7 mg/l**	**3.6 mg/l**
Iron	Total	**0.097 mg/l**	< 0.050 mg/l
Magnesium	Total	**8.4 mg/l**	**8.2 mg/l**
Manganese	Total	**3.9 ug/l**	< 2.5 ug/l
Potassium	Total	**10 mg/l**	**24 mg/l**
Silicon	Total	**0.38 mg/l**	**0.46 mg/l**
Sodium	Total	**210 mg/l**	**800 mg/l**
Strontium	Total	**17 ug/l**	**14 ug/l**

Table 13
VSEP Permeate Water Quality

	Location **Date**	**VSEP Permeate** **5/1/2013**	**VSEP Permeate** **5/2/2013**	**VSEP Permeate** **5/6/2013**	**VSEP Permeate** **5/7/2013**	**VSEP Permeate** **5/9/2013**	**VSEP Permeate** **5/13/2013**	**VSEP Permeate** **5/14/2013**	**VSEP Permeate** **5/20/2013**
Parameter	Total or Dissolved								
General Parameters									
Alkalinity, bicarbonate, as CaCO3	NA	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	**21 mg/l**	**90 mg/l**
Alkalinity, total, as CaCO3	NA	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l	**21 mg/l**	**90 mg/l**
Carbon, total organic	NA	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	< 1.5 mg/l	**2.6 mg/l**	< 1.5 mg/l
Chloride	NA	**0.50 mg/l**	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	**0.21 mg/l**	< 0.20 mg/l	**1.5 mg/l**
Fluoride	NA	**0.13 mg/l**	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Hydroxide, as CaCO3	NA	--	--	--	--	--	--	--	--
Nitrogen, ammonia as N	NA	< 0.460 mg/l	**1.96 mg/l**	< 0.480 mg/l	< 0.470 mg/l	< 0.450 mg/l	< 0.450 mg/l	< 0.500 mg/l	< 0.480 mg/l
Nitrogen, Nitrate as N	NA	**0.046 mg/l**	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.18 mg/l	< 0.18 mg/l
Orthophosphate, as PO4	NA	< 0.20 mg/l	< 0.20 h mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l
pH	NA	**6.0 pH units**	**5.9 pH units**	**5.6 pH units**	**5.8 pH units**	**5.5 pH units**	**5.5 pH units**	**5.0 pH units**	**6.4 pH units**
Solids, total dissolved	NA	**37 mg/l**	< 10 mg/l	**14 mg/l**	**39 mg/l**	< 10 mg/l	< 10 mg/l	**80 mg/l**	**460 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25 ºC	NA	**77 umhos/cm**	**31 umhos/cm**	**37 umhos/cm**	**64 umhos/cm**	**42 umhos/cm**	**48 umhos/cm**	**110 umhos/cm**	**600 umhos/cm**
Sulfate, as SO4	NA	**20 mg/l**	**7.6 mg/l**	**9.7 mg/l**	**15 mg/l**	**12 mg/l**	**15 mg/l**	**22 mg/l**	**220 mg/l**
Metals									
Aluminum	Total	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l
Arsenic	Total	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l
Barium	Total	**0.36 ug/l**	**0.29 ug/l**	**0.20 ug/l**	**0.27 ug/l**	< 0.20 ug/l	< 0.20 ug/l	**0.43 ug/l**	**0.72 ug/l**
Boron	Total	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	< 0.10 mg/l	**0.16 mg/l**
Calcium	Total	**1.4 mg/l**	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	**1.9 mg/l**	**7.5 mg/l**
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Magnesium	Total	**3.4 mg/l**	**1.2 mg/l**	**1.2 mg/l**	**1.7 mg/l**	**1.5 mg/l**	**2.1 mg/l**	**6.5 mg/l**	**22 mg/l**
Manganese	Total	**4.0 ug/l**	**2.8 ug/l**	**2.8 ug/l**	**2.5 ug/l**	**1.8 ug/l**	**1.9 ug/l**	**2.6 ug/l**	**1.1 ug/l**
Potassium	Total	**3.2 mg/l**	< 1.0 mg/l	**1.3 mg/l**	**1.6 mg/l**	**1.6 mg/l**	**1.8 mg/l**	**4.4 mg/l**	**17 mg/l**
Silicon	Total	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	**0.29 mg/l**	**0.99 mg/l**
Sodium	Total	**4.6 mg/l**	**1.5 mg/l**	**2.2 mg/l**	**2.0 mg/l**	**2.0 mg/l**	**1.9 mg/l**	**3.7 mg/l**	**23 mg/l**
Strontium	Total	**5.4 ug/l**	**2.5 ug/l**	**2.3 ug/l**	**3.0 ug/l**	**2.5 ug/l**	**3.3 ug/l**	**7.5 ug/l**	**27 ug/l**

Table 13
VSEP Permeate Water Quality

	Location	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate	VSEP Permeate
	Date	5/21/2013	6/11/2013	6/13/2013	6/18/2013	6/20/2013	6/25/2013	6/27/2013
Parameter	Total or Dissolved							
General Parameters								
Alkalinity, bicarbonate, as CaCO3	NA	**62 mg/l**	**30 mg/l**	**50 mg/l**	< 20 mg/l	**72 mg/l**	**74 mg/l**	**71 mg/l**
Alkalinity, total, as CaCO3	NA	**62 mg/l**	**30 mg/l**	**50 mg/l**	< 20 mg/l	**72 mg/l**	**74 mg/l**	**71 mg/l**
Carbon, total organic	NA	**2.2 mg/l**	< 1.00 mg/l	< 1.00 mg/l	< 1.00 mg/l	**1.25 mg/l**	< 1.00 mg/l	< 1.00 mg/l
Chloride	NA	**1.2 mg/l**	**1.4 mg/l**	**1.4 mg/l**	**1.4 mg/l**	**1.3 mg/l**	**1.3 mg/l**	**1.3 mg/l**
Fluoride	NA	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Hydroxide, as CaCO3	NA	--	--	--	--	--	--	--
Nitrogen, ammonia as N	NA	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.510 mg/l	< 0.470 mg/l	< 0.500 mg/l
Nitrogen, Nitrate as N	NA	< 0.18 mg/l	< 0.18 mg/l	< 0.045 mg/l	< 0.045 mg/l	< 0.18 mg/l	< 0.045 mg/l	< 0.18 mg/l
Orthophosphate, as PO4	NA	< 0.20 * mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l
pH	NA	**5.4 pH units**	**5.5 pH units**	**6.3 pH units**	**5.1 pH units**	**5.4 pH units**	**5.6 pH units**	**5.6 pH units**
Solids, total dissolved	NA	**210 mg/l**	**250 mg/l**	**290 mg/l**	**260 mg/l**	**290 mg/l**	**270 mg/l**	**190 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25 ºC	NA	**340 umhos/cm**	**350 umhos/cm**	**370 umhos/cm**	**340 umhos/cm**	**380 umhos/cm**	**470 umhos/cm**	**390 umhos/cm**
Sulfate, as SO4	NA	**90 mg/l**	**110 mg/l**	**110 mg/l**	**120 mg/l**	**99 mg/l**	**110 mg/l**	**110 mg/l**
Metals								
Aluminum	Total	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l
Arsenic	Total	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l
Barium	Total	**0.56 ug/l**	**0.47 ug/l**	**0.45 ug/l**	**0.40 ug/l**	**0.51 ug/l**	**0.52 ug/l**	**0.55 ug/l**
Boron	Total	**0.17 mg/l**	**0.18 mg/l**	**0.20 mg/l**	**0.21 mg/l**	**0.20 mg/l**	**0.20 mg/l**	**0.21 mg/l**
Calcium	Total	**6.0 mg/l**	**6.1 mg/l**	**5.7 mg/l**	**5.2 mg/l**	**7.0 mg/l**	**7.0 mg/l**	**7.4 mg/l**
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Magnesium	Total	**18 mg/l**	**19 mg/l**	**17 mg/l**	**15 mg/l**	**20 mg/l**	**21 mg/l**	**23 mg/l**
Manganese	Total	**1.2 ug/l**	**1.2 ug/l**	< 0.50 ug/l	**0.99 ug/l**	**3.1 ug/l**	**1.3 ug/l**	**1.4 ug/l**
Potassium	Total	**18 mg/l**	**19 mg/l**	**19 mg/l**	**14 mg/l**	**18 mg/l**	**19 mg/l**	**17 mg/l**
Silicon	Total	**0.93 mg/l**	**1.0 mg/l**	**0.97 mg/l**	**0.92 mg/l**	**0.93 mg/l**	**0.86 mg/l**	**0.95 mg/l**
Sodium	Total	**23 mg/l**	**28 mg/l**	**26 mg/l**	**21 mg/l**	**27 mg/l**	**28 mg/l**	**26 mg/l**
Strontium	Total	**23 ug/l**	**19 ug/l**	**21 ug/l**	**19 ug/l**	**25 ug/l**	**27 ug/l**	**27 ug/l**

Table 14
Average VSEP Removal Rates (Concentration-Based)

	Fraction	Percent Reduction
General Parameters		
Alkalinity, bicarbonate, as CaCO3	NA	93.9%
Alkalinity, total, as CaCO3	NA	93.9%
Carbon, total organic	NA	> 92.7%
Chloride	NA	91.5%
Fluoride	NA	> 93.7%
Nitrogen, ammonia as N	NA	ND
Solids, total dissolved	NA	96.4%
Specific Conductance @ 25 ºC	NA	94.4%
Sulfate, as SO4	NA	97.4%
Metals		
Arsenic	Total	> 77.6%
Barium	Total	97.8%
Boron	Total	77.8%
Calcium	Total	98.0%
Magnesium	Total	97.8%
Manganese	Total	> 98.0%
Potassium	Total	91.1%
Silicon	Total	94.9%
Sodium	Total	93.4%
Strontium	Total	98.1%

Notes:

1. Where ">" (greater than) is indicated, the permeate concentration was often less than the method reporting limit. Half of the method reporting limit was used to calculate the percent removal in those cases.

Table 15
Average VSEP Removal Rates (Mass-Based)

	Fraction	Percent Reduction
General Parameters		
Alkalinity, bicarbonate, as CaCO3	NA	95.1%
Alkalinity, total, as CaCO3	NA	95.1%
Carbon, total organic	NA	> 94.2%
Chloride	NA	93.2%
Fluoride	NA	> 95.0%
Nitrogen, ammonia as N	NA	ND
Solids, total dissolved	NA	97.2%
Specific Conductance @ 25 ºC	NA	95.6%
Sulfate, as SO4	NA	97.9%
Metals		
Arsenic	Total	> 82.1%
Barium	Total	98.3%
Boron	Total	82.2%
Calcium	Total	98.4%
Magnesium	Total	98.2%
Manganese	Total	> 98.4%
Potassium	Total	92.9%
Silicon	Total	95.9%
Sodium	Total	94.7%
Strontium	Total	98.5%

Notes:

1. Where ">" (greater than) is indicated, the permeate concentration was often less than the method reporting limit. Half of the method reporting limit was used to calculate the percent removal in those cases.

Table 16
VSEP Concentrate Water Quality

	Location	VSEP Concentrate	VSEP Concentrate	VSEP Concentrate	VSEP Concentrate	VSEP Concentrate	VSEP Concentrate	VSEP Concentrate
	Date	**5/1/2013**	**5/2/2013**	**5/6/2013**	**5/7/2013**	**5/9/2013**	**5/13/2013**	**5/14/2013**
Parameter	Total or Dissolved							
General Parameters								
Alkalinity, bicarbonate, as $CaCO_3$	NA	**470 mg/l**	**67 mg/l**	**140 mg/l**	**190 mg/l**	**26 mg/l**	**65 mg/l**	**1200 mg/l**
Alkalinity, total, as $CaCO_3$	NA	**470 mg/l**	**67 mg/l**	**140 mg/l**	**190 mg/l**	**26 mg/l**	**65 mg/l**	**1200 mg/l**
Carbon, total organic	NA	**14 mg/l**	**9.0 mg/l**	**18 mg/l**	**11 mg/l**	**16 mg/l**	**9.9 mg/l**	**24 mg/l**
Chloride	NA	**15 mg/l**	**5.8 mg/l**	**6.4 mg/l**	**7.5 mg/l**	**8.6 mg/l**	**6.9 mg/l**	**13 mg/l**
Fluoride	NA	**0.70 mg/l**	**0.48 mg/l**	**0.55 mg/l**	**0.59 mg/l**	**0.79 mg/l**	**0.53 mg/l**	**0.81 mg/l**
Nitrogen, ammonia as N	NA	**1.64 mg/l**	< 0.470 mg/l	**1.60 mg/l**	**1.26 mg/l**	**0.876 mg/l**	< 0.450 mg/l	**0.910 mg/l**
Nitrogen, Nitrate as N	NA	**1.8 mg/l**	**0.86 mg/l**	**0.73 mg/l**	**0.88 mg/l**	**0.84 mg/l**	**0.68 mg/l**	**4.0 mg/l**
Orthophosphate, as PO_4	NA	< 2.0 mg/l	**2.2 h mg/l**	**2.0 mg/l**	**6.8 mg/l**	< 1.0 mg/l	**1.4 mg/l**	**1.7 mg/l**
pH	NA	**7.0 pH units**	**6.5 pH units**	**6.5 pH units**	**6.6 pH units**	**5.9 pH units**	**6.5 pH units**	**6.1 pH units**
Solids, total dissolved	NA	**6400 mg/l**	**2200 mg/l**	**2700 mg/l**	**3500 mg/l**	**4400 mg/l**	**3300 mg/l**	**7000 mg/l**
Solids, total suspended	NA	**4.4 mg/l**	**5.2 mg/l**	< 4.0 mg/l	< 4.0 mg/l	**7.6 mg/l**	**5.2 mg/l**	**10 mg/l**
Specific Conductance @ 25 ºC	NA	**5900 umhos/cm**	**2400 umhos/cm**	**3200 umhos/cm**	**3600 umhos/cm**	**4200 umhos/cm**	**3500 umhos/cm**	**6700 umhos/cm**
Sulfate, as SO_4	NA	**3700 mg/l**	**1500 mg/l**	**1900 mg/l**	**2200 mg/l**	**2900 mg/l**	**2200 mg/l**	**4000 mg/l**
Metals								
Aluminum	Total	**51 ug/l**	**98 ug/l**	**92 ug/l**	**63 ug/l**	**76 ug/l**	**57 ug/l**	< 50 ug/l
Arsenic	Total	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l	< 5.0 ug/l
Barium	Total	**55 ug/l**	**46 ug/l**	**61 ug/l**	**40 ug/l**	**48 ug/l**	**36 ug/l**	**67 ug/l**
Boron	Total	< 1.0 mg/l	**0.14 mg/l**	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 0.50 mg/l	< 0.50 mg/l
Calcium	Total	**330 mg/l**	**130 mg/l**	**210 mg/l**	**180 mg/l**	**270 mg/l**	**180 mg/l**	**290 mg/l**
Iron	Total	< 0.50 mg/l	**0.088 mg/l**	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.25 mg/l	< 0.25 mg/l
Magnesium	Total	**700 mg/l**	**200 mg/l**	**330 mg/l**	**320 mg/l**	**520 mg/l**	**360 mg/l**	**790 mg/l**
Manganese	Total	**600 ug/l**	**410 ug/l**	**720 ug/l**	**410 ug/l**	**540 ug/l**	**350 ug/l**	**370 ug/l**
Potassium	Total	**160 mg/l**	**54 mg/l**	**75 mg/l**	**81 mg/l**	**130 mg/l**	**83 mg/l**	**140 mg/l**
Silicon	Total	**18 mg/l**	**6.9 mg/l**	**11 mg/l**	**8.5 mg/l**	**12 mg/l**	**8.2 mg/l**	**20 mg/l**
Sodium	Total	**280 mg/l**	**88 mg/l**	**120 mg/l**	**120 mg/l**	**180 mg/l**	**120 mg/l**	**220 mg/l**
Strontium	Total	**1100 ug/l**	**440 ug/l**	**690 ug/l**	**690 ug/l**	**920 ug/l**	**680 ug/l**	**1200 ug/l**

Table 16
VSEP Concentrate Water Quality

	Location **Date**	**VSEP Concentrate** **5/20/2013**	**VSEP Concentrate** **5/21/2013**	**VSEP Concentrate** **6/11/2013**	**VSEP Concentrate** **6/13/2013**	**VSEP Concentrate** **6/18/2013**	**VSEP Concentrate** **6/20/2013**
Parameter	Total or Dissolved						
General Parameters							
Alkalinity, bicarbonate, as CaCO3	NA	**4200 mg/l**	**870 mg/l**	**1500 mg/l**	**3500 mg/l**	**840 mg/l**	**5200 mg/l**
Alkalinity, total, as CaCO3	NA	**4200 mg/l**	**870 mg/l**	**1500 mg/l**	**3500 mg/l**	**840 mg/l**	**5200 mg/l**
Carbon, total organic	NA	**59 * mg/l**	**61 mg/l**	**58.4 mg/l**	**48.5 mg/l**	**53.9 mg/l**	**63.8 mg/l**
Chloride	NA	**59 mg/l**	**66 mg/l**	**73 mg/l**	**62 mg/l**	**74 mg/l**	**70 mg/l**
Fluoride	NA	**1.9 mg/l**	**2.2 mg/l**	**2.8 mg/l**	**1.5 mg/l**	**2.9 mg/l**	**2.4 mg/l**
Nitrogen, ammonia as N	NA	**0.569 mg/l**	**0.526 mg/l**	< 0.500 mg/l	< 0.500 mg/l	< 0.530 mg/l	< 0.510 mg/l
Nitrogen, Nitrate as N	NA	**1.6 mg/l**	**1.3 mg/l**	**1.2 mg/l**	**0.96 mg/l**	**0.90 mg/l**	**1.1 mg/l**
Orthophosphate, as PO4	NA	< 2.0 mg/l	< 2.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
pH	NA	**6.8 pH units**	**6.6 pH units**	**6.6 pH units**	**7.1 pH units**	**6.4 pH units**	**6.7 pH units**
Solids, total dissolved	NA	**30000 mg/l**	**30000 mg/l**	**35000 mg/l**	**32000 mg/l**	**40000 mg/l**	**36000 mg/l**
Solids, total suspended	NA	**32 mg/l**	**32 mg/l**	**34 mg/l**	**52 mg/l**	**48 mg/l**	**54 mg/l**
Specific Conductance @ 25 ºC	NA	**20000 e umhos/cm**	**21000 e umhos/cm**	**24000 e umhos/cm**	**22000 e umhos/cm**	**24000 e umhos/cm**	**23000 e umhos/cm**
Sulfate, as SO4	NA	**17000 mg/l**	**19000 mg/l**	**29000 mg/l**	**19000 mg/l**	**26000 mg/l**	**21000 mg/l**
Metals							
Aluminum	Total	< 50 ug/l	< 50 ug/l	**51 ug/l**	< 50 ug/l	**69 ug/l**	< 50 ug/l
Arsenic	Total	**7.5 ug/l**	**7.2 ug/l**	**13 ug/l**	**11 ug/l**	**13 ug/l**	**11 ug/l**
Barium	Total	**120 ug/l**	**110 ug/l**	**110 ug/l**	**89 ug/l**	**100 ug/l**	**110 ug/l**
Boron	Total	**1.2 mg/l**	**1.4 mg/l**	**4.6 mg/l**	**5.2 mg/l**	**5.5 mg/l**	**4.5 mg/l**
Calcium	Total	**960 mg/l**	**980 mg/l**	**700 mg/l**	**580 mg/l**	**1100 mg/l**	**660 mg/l**
Iron	Total	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	**0.64 mg/l**	< 0.50 mg/l	< 0.50 mg/l
Magnesium	Total	**3200 mg/l**	**3500 mg/l**	**4400 mg/l**	**4800 mg/l**	**4300 mg/l**	**4200 mg/l**
Manganese	Total	**150 ug/l**	**220 ug/l**	**260 ug/l**	**95 ug/l**	**210 ug/l**	**560 ug/l**
Potassium	Total	**670 mg/l**	**710 mg/l**	**850 mg/l**	**950 mg/l**	**850 mg/l**	**790 mg/l**
Silicon	Total	**66 mg/l**	**71 mg/l**	**81 mg/l**	**88 mg/l**	**86 mg/l**	**82 mg/l**
Sodium	Total	**1400 mg/l**	**1400 mg/l**	**1700 mg/l**	**1900 mg/l**	**1700 mg/l**	**1700 mg/l**
Strontium	Total	**4500 ug/l**	**4900 ug/l**	**3800 ug/l**	**3900 ug/l**	**3900 ug/l**	**4200 ug/l**

Table 16
VSEP Concentrate Water Quality

	Location	**VSEP Concentrate**	**VSEP Concentrate**
	Date	**6/25/2013**	**6/27/2013**
Parameter	Total or Dissolved		
General Parameters			
Alkalinity, bicarbonate, as CaCO3	NA	**4600 mg/l**	**4800 mg/l**
Alkalinity, total, as CaCO3	NA	**4600 mg/l**	**4800 mg/l**
Carbon, total organic	NA	**52.7 mg/l**	**53.1 mg/l**
Chloride	NA	**68 mg/l**	**67 mg/l**
Fluoride	NA	**2.4 mg/l**	**2.7 mg/l**
Nitrogen, ammonia as N	NA	< 0.460 mg/l	< 0.480 mg/l
Nitrogen, Nitrate as N	NA	**1.0 mg/l**	**1.2 mg/l**
Orthophosphate, as PO4	NA	< 4.0 mg/l	< 4.0 mg/l
pH	NA	**6.7 pH units**	**6.7 pH units**
Solids, total dissolved	NA	**35000 mg/l**	**31000 mg/l**
Solids, total suspended	NA	**34 mg/l**	**27 mg/l**
Specific Conductance @ 25 ºC	NA	**21000 umhos/cm**	**22000 e umhos/cm**
Sulfate, as SO4	NA	**20000 mg/l**	**19000 mg/l**
Metals			
Aluminum	Total	< 50 ug/l	< 50 ug/l
Arsenic	Total	**10 ug/l**	**9.3 ug/l**
Barium	Total	**94 ug/l**	**94 ug/l**
Boron	Total	**4.5 mg/l**	**4.2 mg/l**
Calcium	Total	**900 mg/l**	**630 mg/l**
Iron	Total	< 0.50 mg/l	< 0.50 mg/l
Magnesium	Total	**4000 mg/l**	**3100 mg/l**
Manganese	Total	**190 ug/l**	**220 ug/l**
Potassium	Total	**760 mg/l**	**780 mg/l**
Silicon	Total	**78 mg/l**	**82 mg/l**
Sodium	Total	**1600 mg/l**	**1500 mg/l**
Strontium	Total	**5000 ug/l**	**3600 ug/l**

Table 17
ICCP Bench Test Analytical Results

Sample ID - Date 06/25/2013	Chloride	Fluoride	Sulfate	pH	Total Alkalinity	Bicarb Alkalinity	Barium	Boron	Calcium	Magnesium	Potassium	Silicon	Sodium	Strontium
	mg/l	mg/l	mg/l as SO4	SU	mg/l as CaCO3	mg/l as CaCO3	ug/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	ug/l
Untreated RO Concentrate	17	0.68	4700	8.1	1200	1200	23	1.1	350	990	210	19	440	1400
Opt-10% 10 min	--	--	--	--	--	--	--	--	--	220	--	1.6	--	--
Opt-10% 30 min	--	--	--	--	--	--	--	--	--	270	--	1.6	--	--
Opt-10% 45 min	--	--	--	--	--	--	--	--	--	310	--	1.7	--	--
Opt-10% Final	16	<.50	4900	10	180	41	0.67	0.71	110	200	240	1.9	1700	250
Opt 10 min	--	--	--	--	--	--	--	--	--	64	--	1.7	--	--
Opt 30 min	--	--	--	--	--	--	--	--	--	130	--	1.8	--	--
Opt 45 min	--	--	--	--	--	--	--	--	--	120	--	1.7	--	--
Opt Final	16	<.50	4900	11	410	48	0.51	0.85	23	61	230	2.6	2000	99
Opt+10% 10 min	--	--	--	--	--	--	--	--	--	32	--	2.1	--	--
Opt+10% 30 min	--	--	--	--	--	--	--	--	--	51	--	1.6	--	--
Opt+10% 45 min	--	--	--	--	--	--	--	--	--	44	--	1.7	--	--
Opt+10% Final	18	<.50	4800	11	310	<20	0.64	1	14	18	240	3.1	2100	70

Table 18
ICCP Removal Rates

		Percent Reduction		
Parameter	**Unit**	**Optimal Dose -10%**	**Optimal Dose**	**Optimal Dose +10%**
Barium	*ug/L*	97%	98%	97%
Boron	*mg/L*	35%	23%	9%
Calcium	*mg/L*	69%	93%	96%
Magnesium	*mg/L*	80%	94%	98%
Potassium	*mg/L*	-14%	-10%	-14%
Sodium	*mg/L*	-286%	-355%	-377%
Strontium	*ug/L*	82%	93%	95%
Bicarbonate Alkalinity	*mg/L as* $CaCO_3$	97%	96%	>98%
Chloride	*mg/L*	6%	6%	-6%
Fluoride	*mg/L*	>26%	>26%	>26%
Sulfate	*mg/L*	-4%	-4%	-2%
Silicon	*mg/L*	90%	86%	84%

Notes:

1. Where ">" (greater than) is indicated, the resulting concentration was often less than the method reporting limit. Half of the method reporting limit was used to calculate the percent removal in those cases.

Table 19
Modeled Lime Dose for Effluent Stabilization

Addition	Chemical	Optimal Dose (mg/L)	Optimal Final pH	$CaCO_3$ SI Final
Carbon Dioxide	CO_2	55	5.3	--
Lime	$Ca(OH)_2$	75	7.8	0.10

Table 20
Summary of Lime Addition Bench Test Results

Parameter	Total or Dissolved	Units	Control	Raw	Dose 1	Dose 2	Dose 3	Dose 4	Dose 5	Dose 6
Hydrated Lime Dose, as $Ca(OH)_2$	NA	mg/L			0	37	56	75	94	112
Alkalinity, total	NA	mg/L	NA	<20	<20	58	86	110	100	77
Aluminum	Total	µg/L	NA	<10	<10	20	31	44	52	61
Arsenic	Total	µg/L	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Calcium	Total	mg/L	NA	1.4	1.3	21	32	44	51	59
Copper	Total	µg/L	NA	0.94	11	3.2	1.9	0.89	0.99	0.74
Iron	Total	mg/L	NA	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lead	Total	µg/L	NA	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Manganese	Total	µg/L	NA	<0.50	2.2	4.7	2.9	3.4	4.2	3.9
pH	NA	SU	NA	6.2	5.6	6.8	7.8	8.0	8.3	8.4
Silicon	Total	mg/L	NA	<0.25	<0.25	0.34	0.39	0.46	0.49	0.56
Solids, total dissolved	NA	mg/L	NA	24	54	90	120	140	110	100
Solids, total suspended	NA	mg/L	NA	<4.0	<4.0	<4.0	<4.0	<4.0	9.6	30
Sulfate	NA	mg/L	NA	23	23	23	23	23	23	23
Turbidity	NA	NTU	NA	0.28	0.2	1.9	6.6	12.8	34.7	98.6
WET Test Results										
Survival	NA	%	100%	50%	60%	100%	100%	100%	100%	100%
Reproduction	NA	#/female	15.9	6.4	8.5	16.8	15.1	15.6	15.2	13.9
Calculated Indices										
LSI	NA	NA	NA	-4.16	-4.83	-1.68	-0.34	0.10	0.44	0.49
SI	NA	NA	NA	-3.97	-4.60	-1.48	-0.15	0.27	0.57	0.61

Table 21
Summary of Limestone Contactor Bench Test Results

				Rate 1			**Rate 2**			**Rate 3**			**Raw**
Parameter	Total or Dissolved	**Units**	**Control**	No Treatment	Sparge	Soda	No Treatment	Sparge	Soda	No Treatment	Sparge	Soda	Untreated Permeate
General Parameters													
Hydraulic Loading Rate	NA	gpm/sf	NA	2.6	2.6	2.6	1.1	1.1	1.1	0.7	0.7	0.7	NA
Alkalinity, bicaronate, as CaCO3	NA	mg/l	NA	88	89	120	140	140	150	140	140	140	<20
pH	NA	pH units	NA	7.2	8.1	7.7	7.5	8.2	7.7	7.7	8.1	7.8	5.8
Solids, total dissolved	NA	mg/l	NA	220	160	170	240	200	200	360	320	370	160
Solids, total suspended	NA	mg/l	NA	<10	<10	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Final Turbidity	NA	NTU	NA	0.05	0.12	0.1	0.08	0.05	0.05	0.11	0.29	0.12	0.01
Metals													
Aluminum	Total	ug/l	NA	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Antimony	Total	ug/l	NA	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40
Arsenic	Total	ug/l	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cadmium	Total	ug/l	NA	<0.20	0.21	<0.20	0.26	0.23	0.28	0.23	0.25	0.21	<0.20
Calcium	Total	mg/l	NA	31	30	31	50	51	47	53	51	50	1.4
Chromium, hexavalent	NA	mg/l	NA	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020
Cobalt	Total	ug/l	NA	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Copper	Total	ug/l	NA	7.5	7	6.7	8.6	7.8	7.9	7.9	7.9	9.1	16
Iron	Total	mg/l	NA	<0.50	<0.50	<0.50	<0.50	<0.050	<0.050	<0.050	<0.050	<0.050	<0.50
Lead	Total	ug/l	NA	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Manganese	Total	ug/l	NA	11	11	11	17	18	17	17	17	17	1.7
Molydenum	Total	ug/l	NA	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40
Nickel	Total	ug/l	NA	1.4	1.3	1.3	1.9	2	2	2.3	2.2	2.2	1.5
Selenium	Total	ug/l	NA	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Silicon	Total	mg/l	NA	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Tallium	Total	ug/l	NA	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Zinc	Total	ug/l	NA	12	11	11	15	12	13	12	11	12	<10
WET Test Results													
Survival	NA	%	100	100	100	100	100	100	100	100	100	100	10
Reproduction	NA	#/female	15.9	14.6	13.9	14.6	16.8	15.2	15.8	16	16	15.3	1.1
Calculated Indices													
LSI	NA	NA	NA	-0.97	-0.06	-0.32	-0.26	0.46	-0.05	-0.05	0.34	0.02	-4.64
SI	NA	NA	NA	-0.73	0.15	-0.11	-0.06	0.63	0.14	0.16	0.54	0.24	-4.32

Table 22
Summary of Cost Basis Information

				Option 1		Option 2		Option 3	
				Capital	**O&M**	**Capital**	**O&M**	**Capital**	**O&M**
Base Treatment		RO Feed Flow	gpm	401	401	454	401	401	401
		RO Recovery	%	80	80	80	80	80	80
		RO Concentrate Flow	gpm	80.2	80.2	90.8	80.2	80.2	80.2
		RO Permeate Flow	gpm	320.8	320.8	363.2	320.8	320.8	320.8
Concentrate Mgmt. Options	**Option 1**	Evaporator Feed Flow	gpm	80.2	80.2	--	--	--	--
		Crystallizer Feed Flow	gpm	2.6	2.6	--	--	--	--
	Option 2	VSEP Feed Flow	gpm	--	--	80.2	80.2	--	--
		VSEP Recovery	%	--	--	80	80	--	--
		VSEP Concentrate Flow	gpm	--	--	18.2	16	--	--
		VSEP Permeate Flow	gpm	--	--	62	64.2	--	--
		Crystallizer Feed Flow	gpm	--	--	18.2	16	--	--
	Option 3	ICCP Feed Flow	gpm	--	--	--	--	80.2	80.2
		Secondary RO Feed Flow	gpm	--	--	--	--	80.2	80.2
		Secondary RO Recovery	%	--	--	--	--	80	80
		Secondary RO Concentrate Flow	gpm	--	--	--	--	16	16
		Secondary RO Permeate Flow	gpm	--	--	--	--	64.2	64.2
		Crystallizer Feed Flow	gpm	--	--	--	--	16	16

Table 23
Revised Preliminary Cost Estimate for Evaporation and Crystallization

Item	Unit	Unit Cost	Qty	Cost
Construction and Equipment Costs				
Feed pumps and pump house	LS	$ 148,000	1	$ 148,000
Process building	SF	$ 100	6200	$ 620,000
Liquid chemical storage and feed systems	EA	$ 10,000	3	$ 30,000
MMF and reverse osmosis systems	LS	$ 1,053,000	1	$ 1,053,000
Evaporator and crystallizer	LS	$ 5,600,000	1	$ 5,600,000
Limestone contactor, carbon dioxide and degassifier	LS	$ 322,700	1	$ 322,700
Process equipment installation @30%	LS	$ 2,150,000	1	$ 2,150,000
Mechanical (HVAC & small mechanical) @15%	LS	$ 1,050,000	1	$ 1,050,000
Electrical and control systems @25%	LS	$ 1,790,000	1	$ 1,790,000
Construction and Equipment Subtotal				$ 12,763,700
Construction and Equipment Allowance	30%			
Construction and Equipment Cost Subtotal				*$ 12,763,700*
Professional Services				
Design and procurement	10%	$ 1,276,000	1	$ 1,276,000
Construction services	5%	$ 638,000	1	$ 638,000
Professional Services Subtotal				$ 1,914,000
Professional Services Allowance	10%			$ 191,000
Professional Services Subtotal				*$ 2,105,000*
Capital Cost Total				***$ 14,868,700***
Annual Operation and Maintenance				
RO O&M	LS	$ 199,100	1	$ 199,100
Evaporator and crystallizer O&M	LS	$ 441,800	1	$ 441,800
Limestone	LS	$ 48,000	1	$ 48,000
Sludge hauling and disposal (non-hazardous)	WT	$ 30	1897	$ 56,900
Labor	FTE	$ 60,000	5	$ 300,000
O&M Subtotal				$ 1,045,800
Operation and Maintenance Cost Allowance	30%			$ 313,700
Operation and Maintenance Cost Total				***$ 1,359,500***

Table 24
Preliminary Cost Estimate for VSEP and Crystallization

Item	Unit	Unit Cost	Qty	Cost
Construction and Equipment Costs				
Feed pumps and pump house	LS	$ 148,000	1	$ 148,000
Process building	SF	$ 100	4700	$ 470,000
Liquid chemical storage and feed systems	EA	$ 10,000	3	$ 30,000
MMF and reverse osmosis system	LS	$ 1,053,000	1	$ 1,053,000
VSEP system	LS	$ 1,199,000	1	$ 1,199,000
Crystallizer	LS	$ 4,750,000	1	$ 4,750,000
Limestone contactor, carbon dioxide and degassifier	LS	$ 322,700	1	$ 322,700
Process equipment installation @30%	LS	$ 2,250,000	1	$ 2,250,000
Mechanical (HVAC & small mechanical) @15%	LS	$ 1,100,000	1	$ 1,100,000
Electrical and control systems @25%	LS	$ 1,880,000	1	$ 1,880,000
Construction and Equipment Cost Subtotal				$ 13,202,700
Operation and Maintenance Cost Allowance	30%			$ 3,961,000
Construction and Equipment Cost Subtotal				*$ 17,163,700*
Professional Services				
Design and procurement	10%	$ 1,716,000	1	$ 1,716,000
Construction services	5%	$ 858,000	1	$ 858,000
Professional Services Subtotal				$ 2,574,000
Professional Services Cost Allowance	10%			$ 257,000
Professional Services Subtotal				*$ 2,831,000*
Capital Cost Total				***$ 19,994,700***
Annual Operation and Maintenance				
RO O&M	LS	$ 199,100	1	$ 199,100
VSEP O&M	LS	$ 188,300	1	$ 188,300
Crystallizer O&M	LS	$ 207,600	1	$ 207,600
Limestone	LS	$ 48,000	1	$ 48,000
Sludge hauling and disposal (non-hazardous)	WT	$ 30	2107	$ 63,200
Labor	FTE	$ 60,000	5	$ 300,000
Operation and Maintenance Subtotal				$ 1,006,200
Operation and Maintenance Cost Allowance	30%			$ 301,900
Operation and Maintenance Cost Total				***$ 1,308,100***

Table 25
Preliminary Cost Estimate for ICCP, Secondary RO, and Crystallization

Item	Unit	Unit Cost	Qty	Cost
Construction and Equipment Costs				
Feed pumps and pump house	LS	$ 148,000	1	$ 148,000
Process building	SF	$ 100	5600	$ 560,000
Liquid chemical storage and feed systems	EA	$ 10,000	3	$ 30,000
Primary and secondary RO systems	LS	$ 1,680,000	1	$ 1,680,000
Crystallizer	LS	$ 3,700,000	1	$ 3,700,000
Concentrate storage tank	LS	$ 20,000	1	$ 20,000
Lime storage silo and feed system	EA	$ 300,000	1	$ 300,000
Soda ash storage silo and feed system	EA	$ 200,000	1	$ 200,000
Solids contact clarifiers	EA	$ 100,000	1	$ 100,000
Dewatering equipment	EA	$ 150,000	2	$ 300,000
Limestone contactor, carbon dioxide and degassifier	LS	$ 322,700	1	$ 322,700
Process equipment installation @30%	LS	$ 2,040,000	1	$ 2,040,000
Mechanical (HVAC & small mechanical) @15%	LS	$ 1,000,000	1	
Electrical and control systems @25%	LS	$ 1,700,000	1	$ 1,700,000
Construction and Equipment Cost Subtotal				$ 11,100,700
Operation and Maintenance Cost Allowance	30%			$ 3,330,000
Construction and Equipment Cost Subtotal				*$ 11,100,700*
Professional Services				
Design and procurement	10%	$ 1,110,000	1	$ 1,110,000
Construction services	5%	$ 555,000	1	$ 555,000
Professional Services Subtotal				$ 1,665,000
Professional Services Cost Allowance	10%			$ 167,000
Professional Services Subtotal				*$ 1,832,000*
Capital Cost Total				***$ 12,932,700***
Annual Operation and Maintenance				
Reverse Osmosis O&M	LS	$ 261,500	1	$ 261,500
Crystallizer O&M	LS	$ 151,900	1	$ 151,900
Lime softening chemicals	LS	$ 300,000	1	$ 300,000
Limestone	LS	$ 48,000	1	$ 48,000
Solids disposal	WT	$ 30	4390	$ 131,700
Labor	FTE	$ 60,000	5	$ 300,000
Operation and Maintenance Cost Subtotal				$ 1,193,100
Operation and Maintenance Cost Allowance	30%			$ 357,900
Operation and Maintenance Cost Total				***$ 1,551,000***

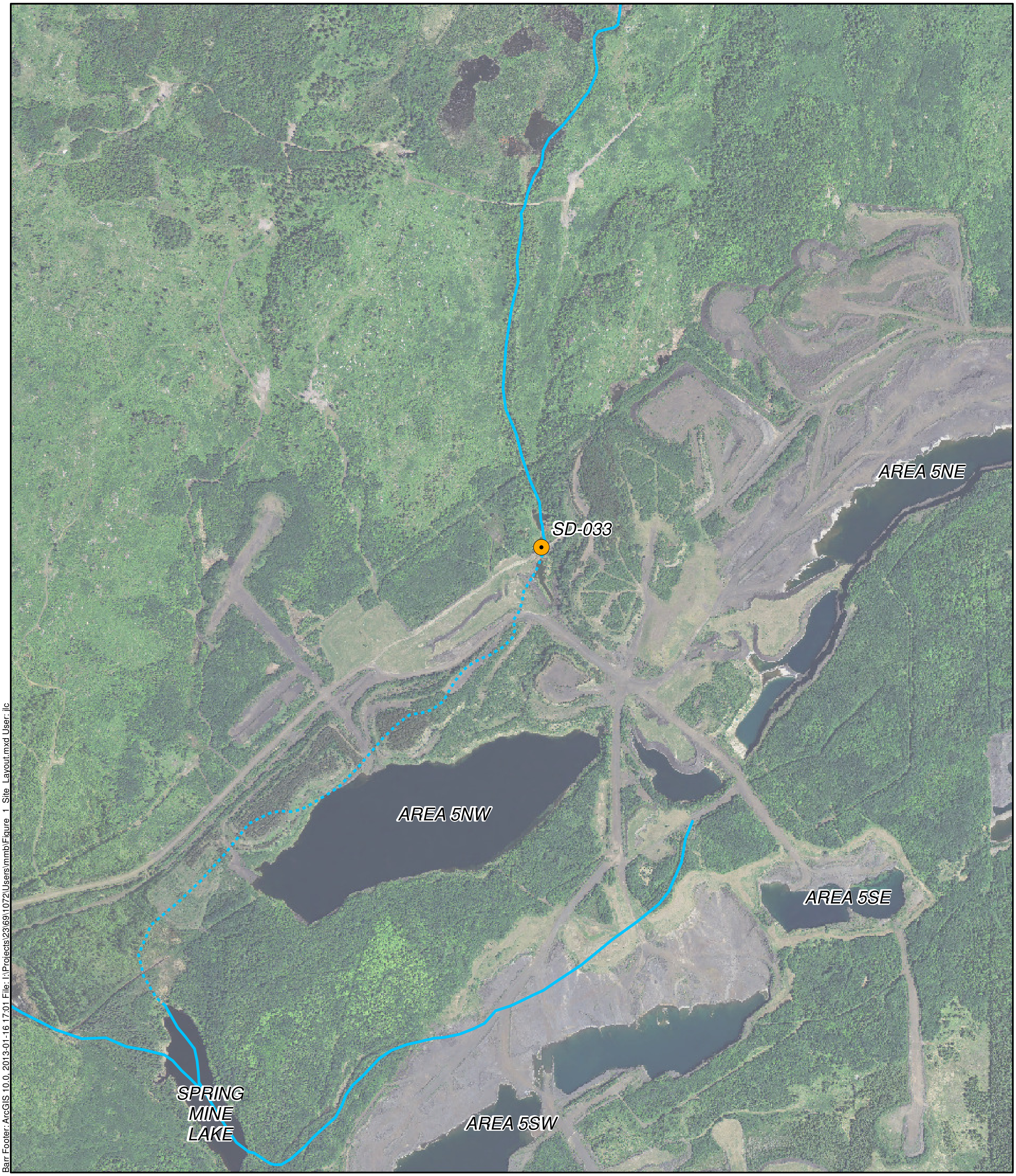
Table 26
Summary of Preliminary Costs Estimates

Primary Treatment (RO)/Concentrate Management Option	Capital Cost	Annual O&M Cost	20-yr NPV
Evaporator and crystallizer	$ 14,900,000	$ 1,360,000	$ 39,900,000
Volume reduction by VSEP with crystallizer	$ 20,000,000	$ 1,310,000	$ 44,100,000
ICCP, secondary RO, and crystallizer	$ 12,900,000	$ 1,550,000	$ 41,400,000

Table 27
Analytical Data Notes and Qualifiers

Data Qualifiers/Footnotes	
Qualifier	**Definition**
--	Not analyzed/not available.
a	Estimated value, calculated using some or all values that are estimates.
b	Potential false positive value based on blank data validation procedures.
c	Coeluting compound.
e	Estimated value, exceeded the instrument calibration range.
f	Sample was collected at a flowrate exceeding the recommended rate of 200 mL/minute.
h	EPA recommended sample preservation, extraction or analysis holding time was exceeded.
i	Indeterminate value based on failure of blind duplicate data to meet quality assurance criteria.
j	Reported value is less than the stated laboratory quantitation limit and is considered an estimated value.
p	Relative percent difference is >40% (25% CLP pesticides) between primary and confirmation GC columns.
pp	Small peak in chromatogram below method detection limit.
r	The presence of the compound is suspect based on the ID criteria of the retention time and relative retention time obtained from the examination of the chromatograms.
s	Potential false positive value based on statistical analysis of blank sample data.
t	Sample positive for total coliforms but negative for *E. coli.*
v	Sample was collected under a vacuum of greater than XX inches of mercury.
*	Estimated value, QA/QC criteria not met.
**	Unusable value, QA/QC criteria not met.
N	Sample Type: Normal
FD	Sample Type: Field Duplicate
AT	Sample chromatogram is noted to be atypical of a petroleum product.
DLND	Not detected, detection limit not determined.
DF	Did not flash
EMPC	Estimated maximum possible concentration.
NA – (Not applicable)	NA indicates that a fractional portion of the sample is not part of the analytical testing or field collection procedures.
ND	Not detected.
TIC	Tentatively identified compound
BQA	Barr-applied project specific qualifier: extraction and/or analyses conducted using an alternative method and/or procedure.
BQC	Barr-applied project specific qualifier: plant shut down.
BQD	Barr-applied project specific qualifier: equipment malfunction.
BQE	Barr-applied project specific qualifier: equipment adjustment.
BQM	Barr-applied project specific qualifier: manual measurement.
BQN	Barr-applied project specific qualifier: unable to be sampled or measured due to various reasons.
BQP	Barr-applied project specific qualifier: atypical chromatographic pattern.
BQQ	Barr-applied project specific qualifier: some aspect of QA/QC was not met.
BQR	Barr-applied project specific qualifier: location was re-sampled.
BQS	Barr-applied project specific qualifier: data is considered suspect.
BQT	Barr-applied project specific qualifier: summed value not displayed due to insufficient field length.
BQU	Barr-applied project specific qualifier: historical qualifier - definition unknown.
BQV	Barr-applied project specific qualifier: estimated value.
BQX	Barr-applied project specific qualifier: see notes for qualifier definition.
BQZ	Barr-applied project specific qualifier: data is considered unusable.
Validated	Laboratory data has been evaluated following Barr QA/QC procedures and/or project-specific data review requirements. Field data has been verified for transcription errors, consistency and completeness. Data transferred from the previous database (9/2009) were categorized as validated, but may be comprised of any one of the following data status categories: Validated, SSource, No QC or Legacy.
No QC	Laboratory data has been excluded from Barr QA/QC procedures.
SSource	Laboratory and/or field data obtained from a secondary source external to Barr. Second source QA/QC evaluation procedures may or may not have been performed beyond the original data generator.
Legacy	Historical laboratory data (internal at Barr). QA/QC evaluation procedures may or may not have been performed beyond the original data generator

Figures



Data Sources:
Photo: FSA 2010
Spring Mine Creek:
Department of Natural Resources
Monitoring Well: Barr Engineering

Figure 1
AREA 5 SITE LAYOUT
PolyMet Mining Inc.
Cliffs Erie L.L.C.
Hoyt Lakes, MN

Figure 2: Historical Data Comparison to Pilot

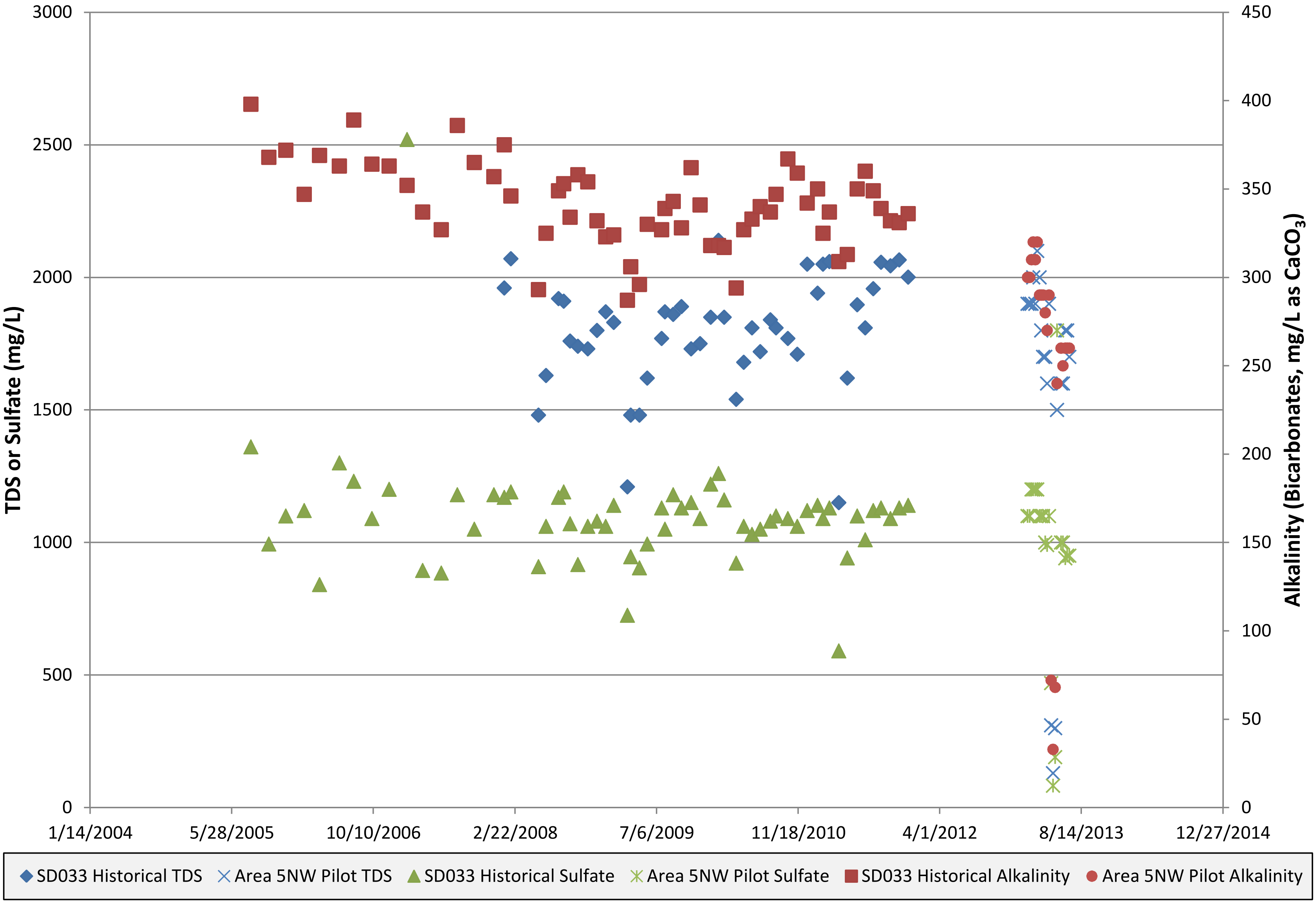


Figure 3: Greensand Filter Pilot Unit

Figure 4: RO Pilot Unit

Figure 5: RO Feed to Concentrate Pressure Drop

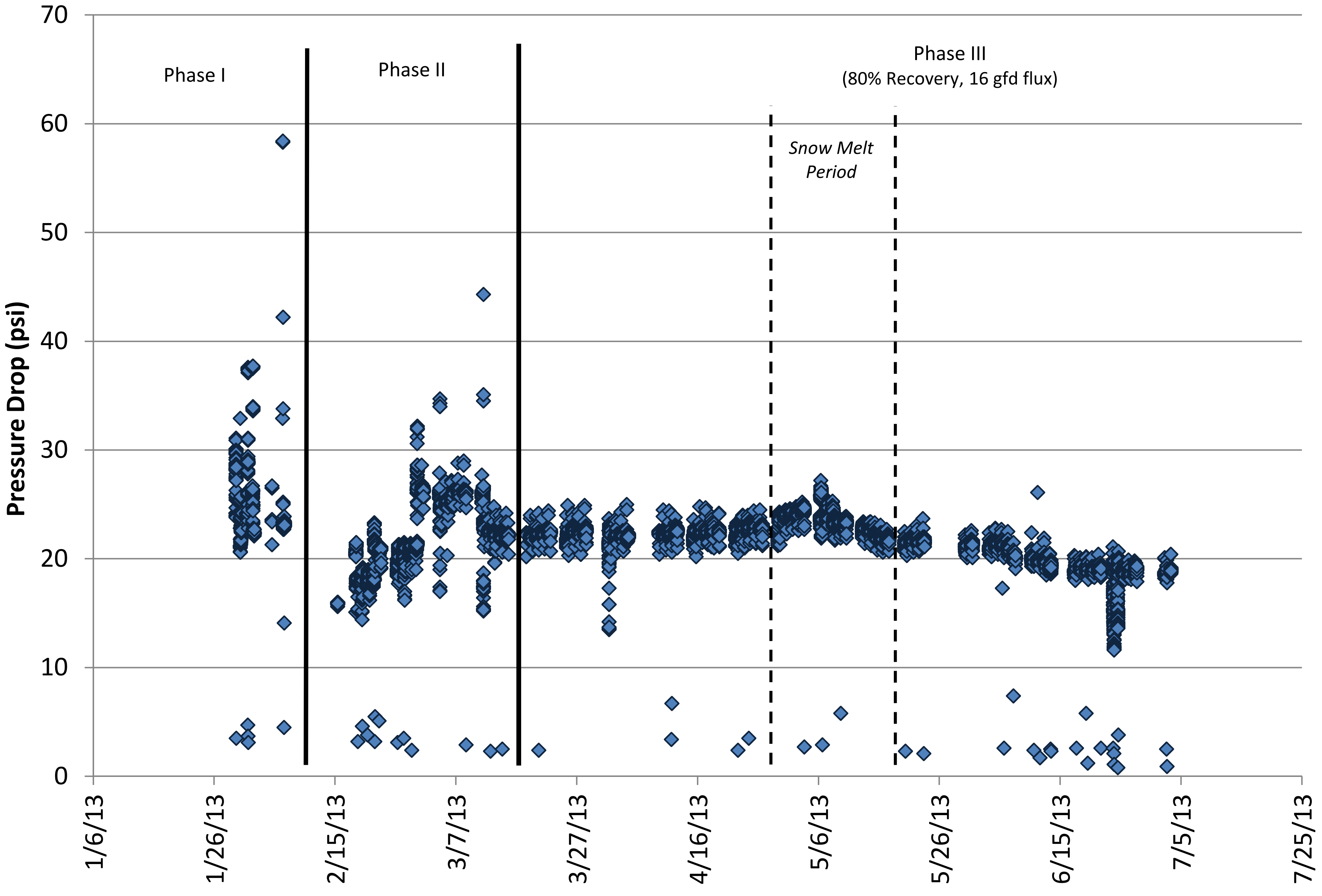


Figure 6: RO Feed Pressure

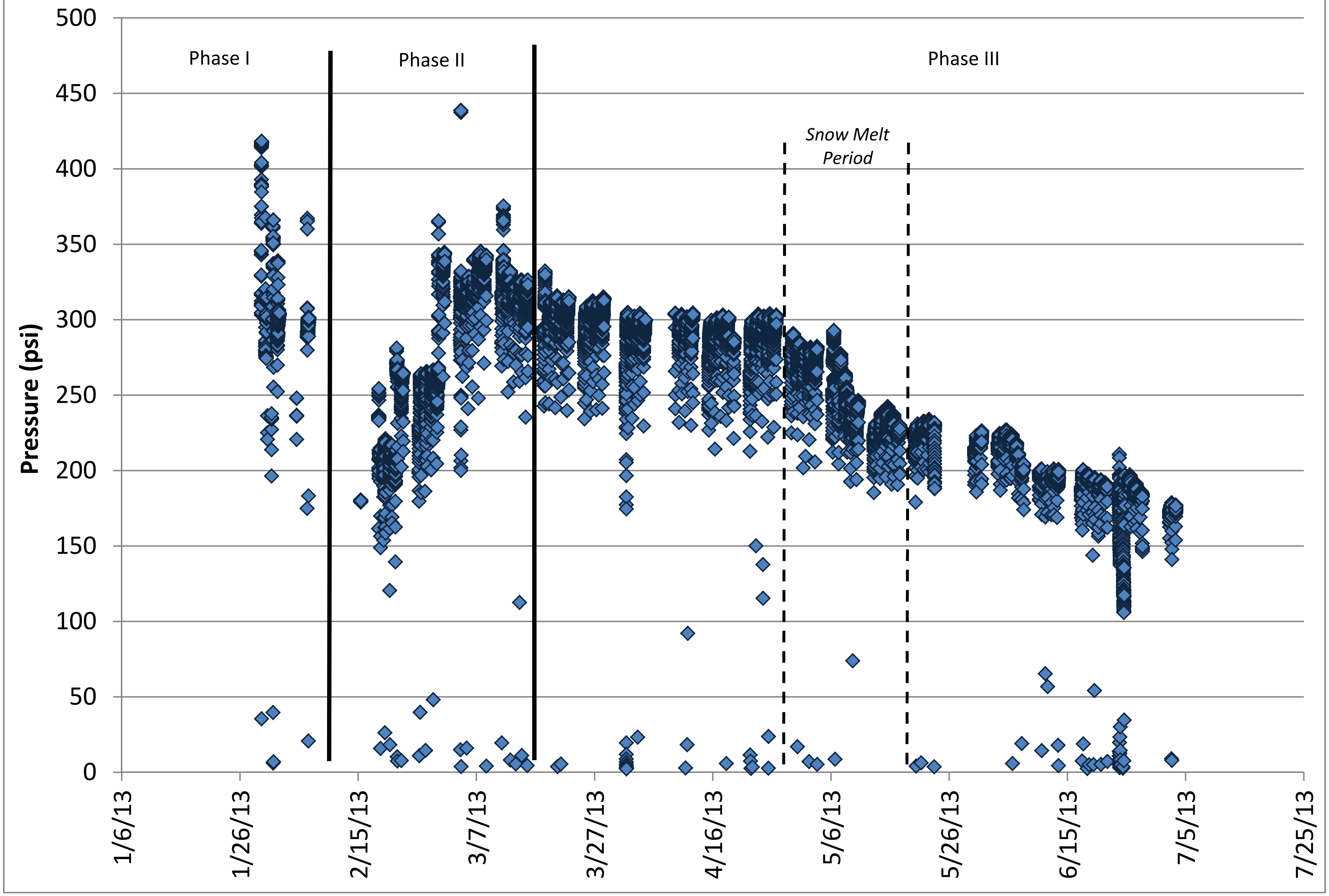
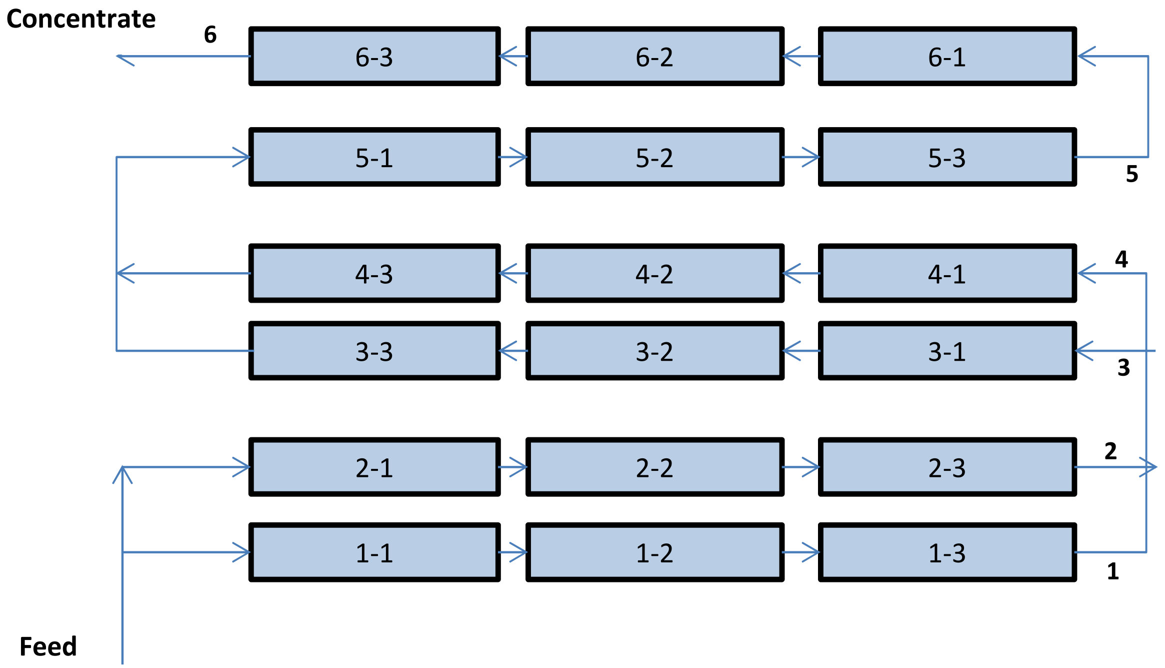


Figure 7: Inter-stage Conductivity Readings



	Date	6/7/2013	6/7/2013	6/7/2013	6/14/2013	6/14/2013	7/1/2013	7/1/2013
	Time	7:45	9:30	11:00	7:10	8:45	9:30	11:00
Housing Number	1	11.44	9.27	8.24	12.86	15.23	22.64	18.7
	2	9.86	8.15	7.28	10.55	9.46	15.28	14.9
	3	13.43	11.03	9.87	12.31	11.13	22.46	21.39
	4	13.02	11.14	9.97	13.03	11.69	23.57	21.45
	5	19.69	17.40	15.77	18.26	16.79	33.95	34.76
	6	91.74	85.85	80.13	77.28	72.95	188.7	182.0

Figure 8: Sulfate Removal by the RO Process

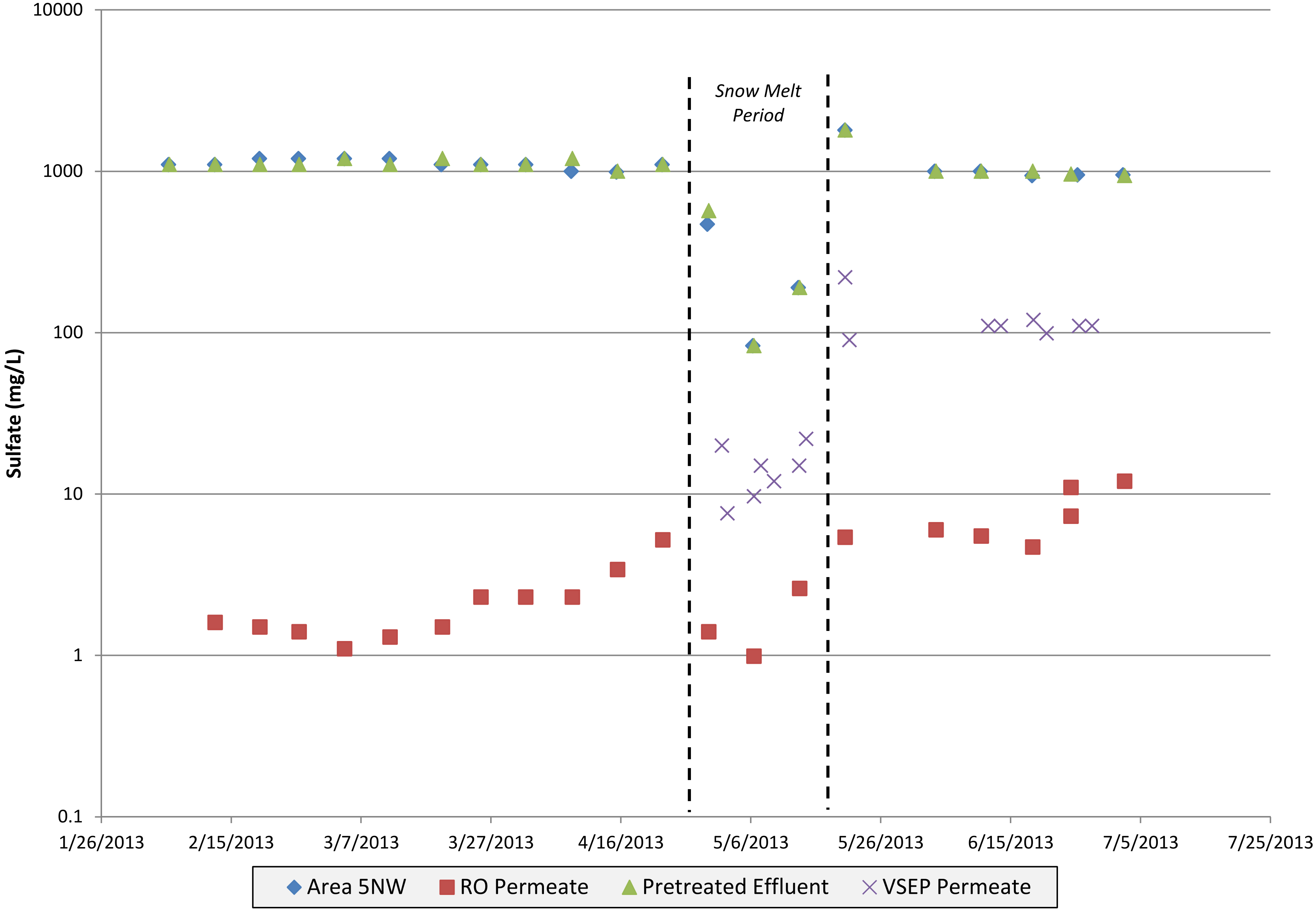


Figure 9: Total Dissolved Solids Removal by the RO Process

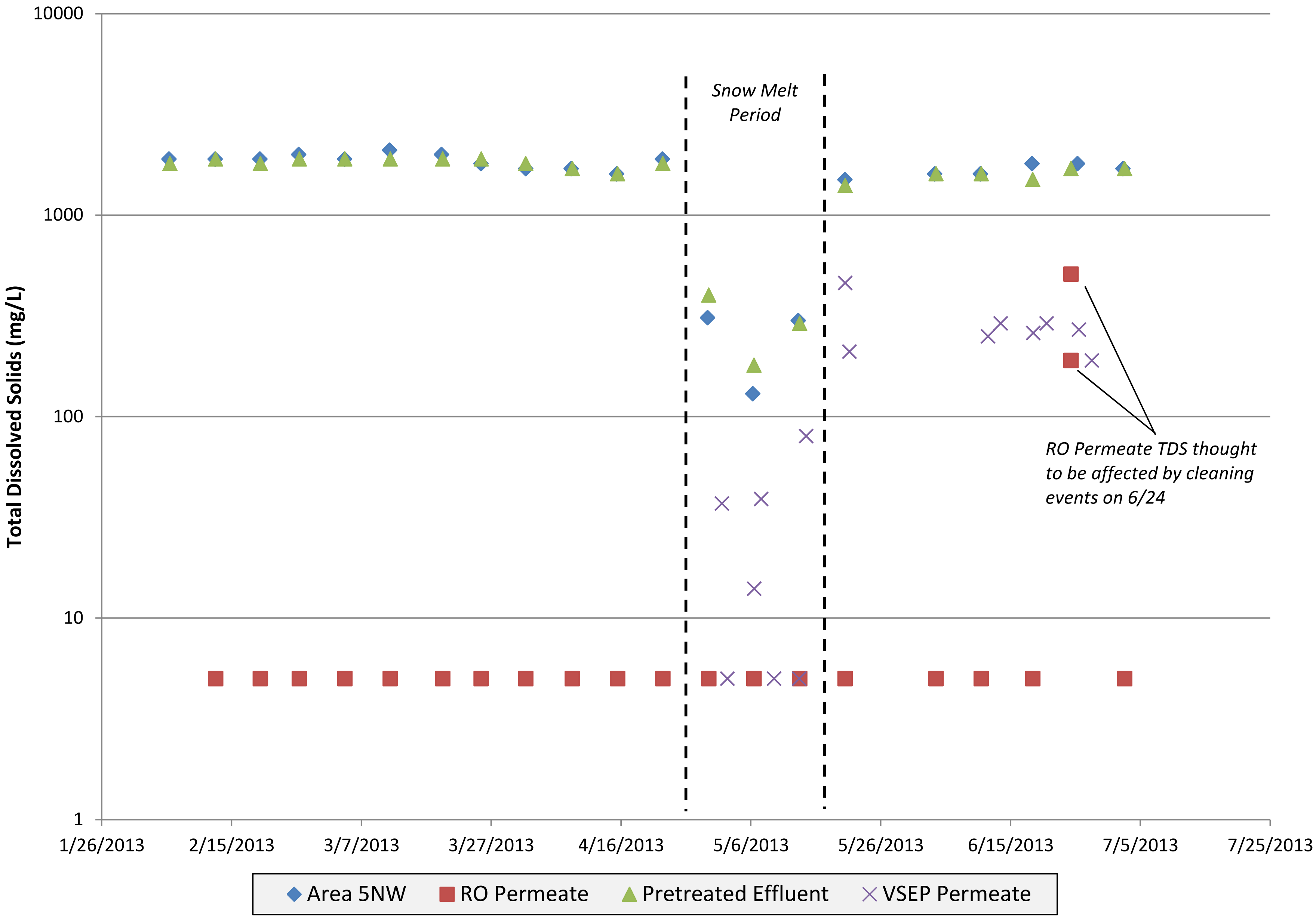


Figure 10: Simplified Process Schematic – Evaporation and Crystallization

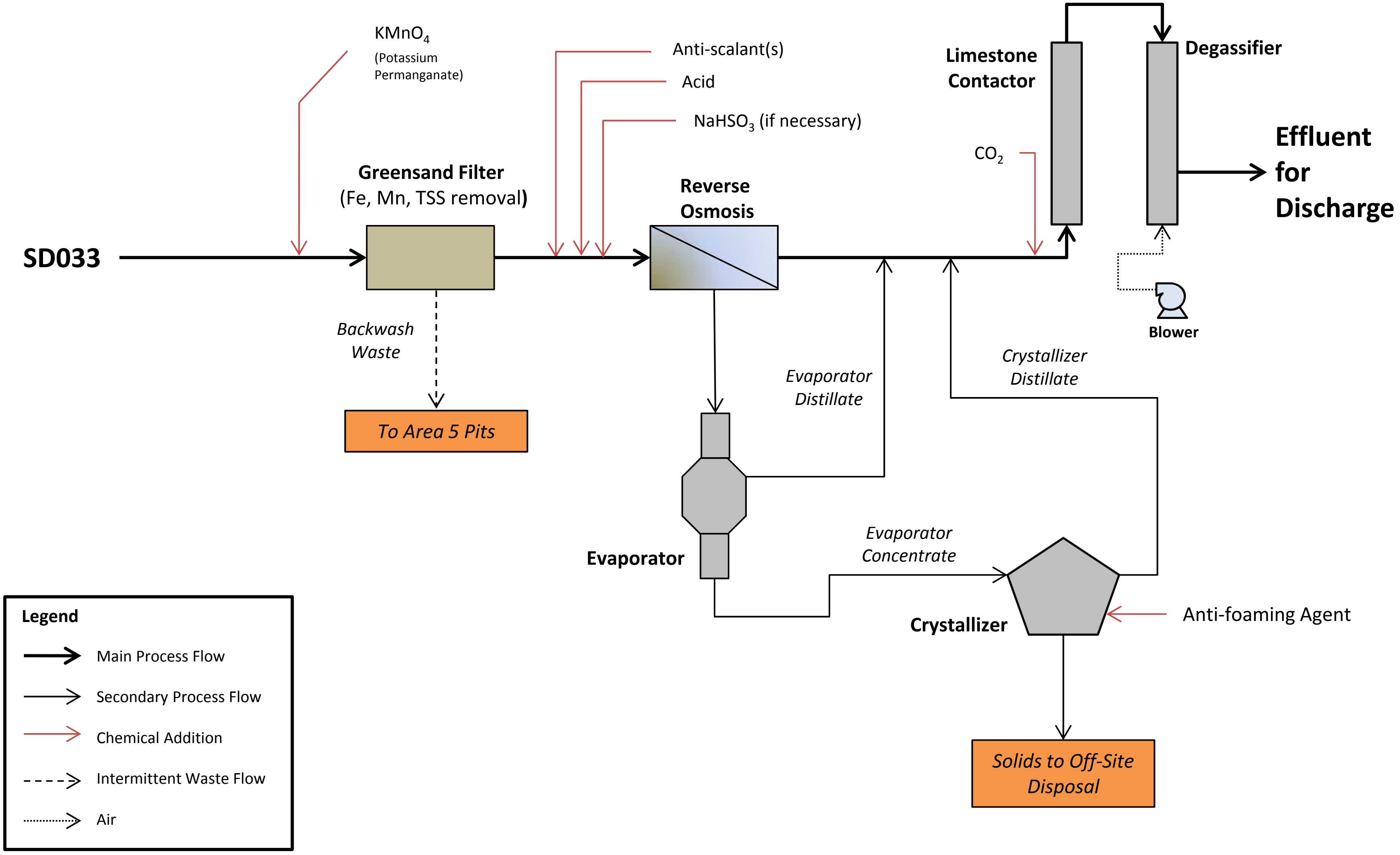


Figure 11: Simplified Process Schematic – VSEP and Crystallization

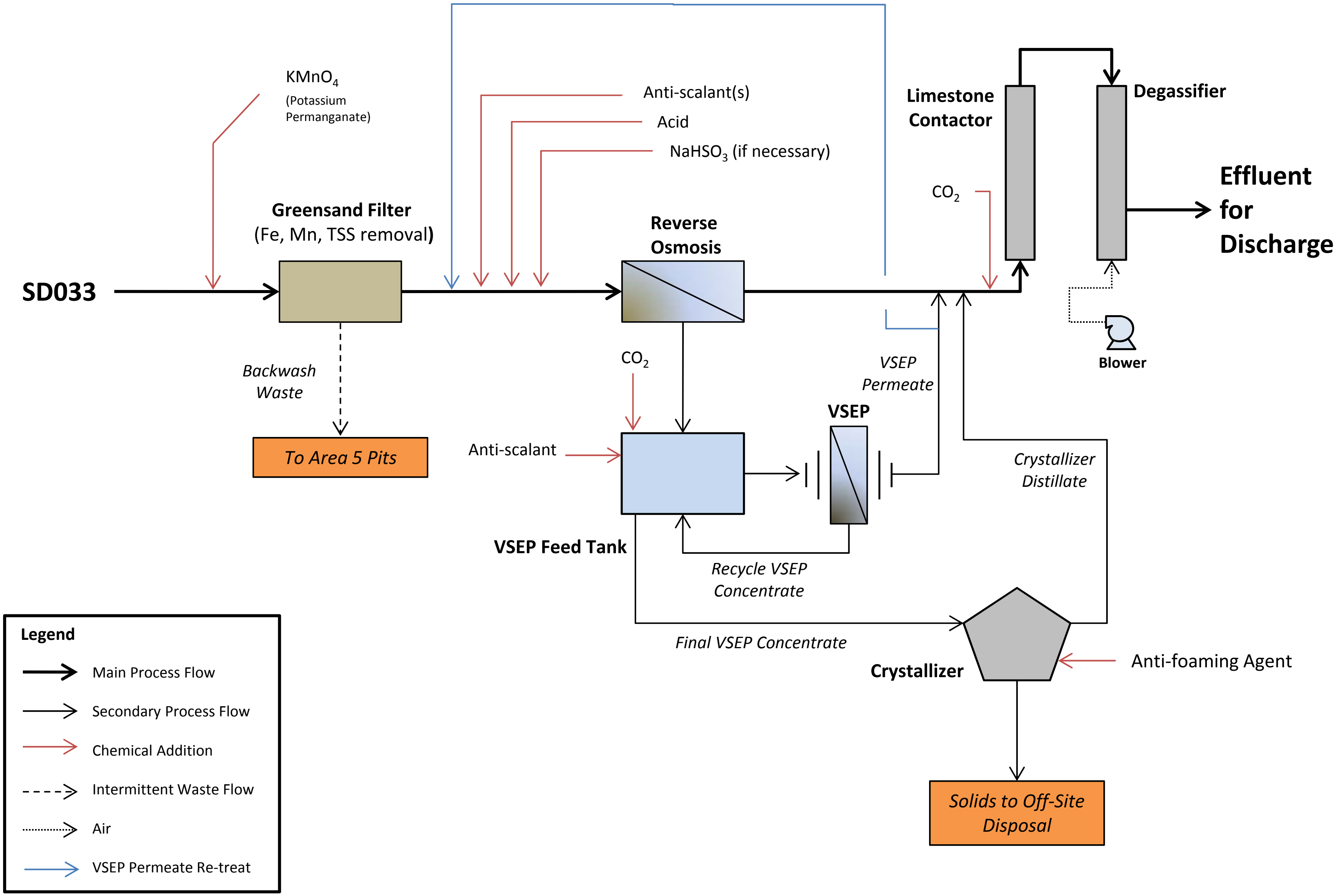


Figure 12: VSEP Pilot Unit

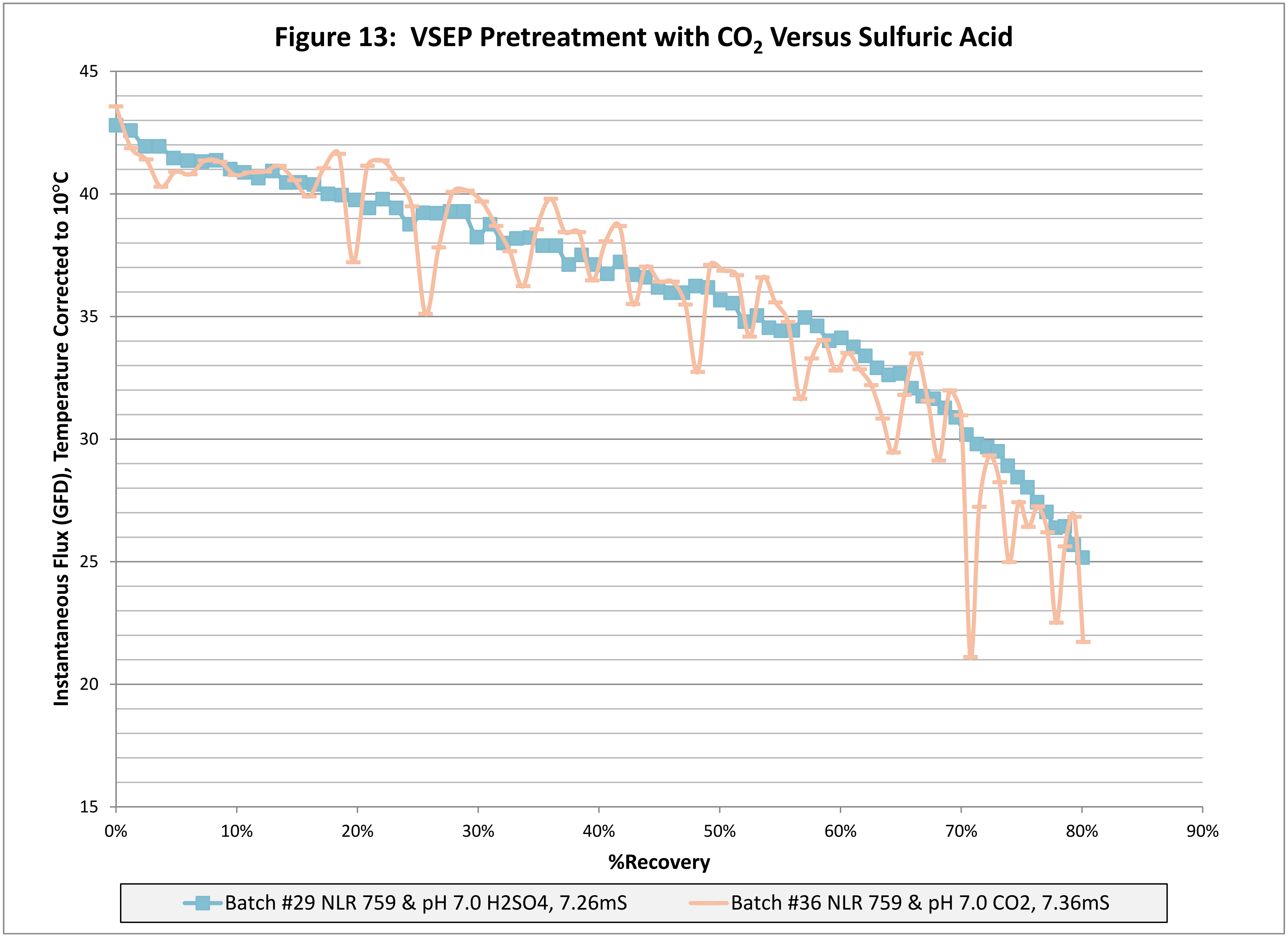


Figure 13: VSEP Pretreatment with CO_2 Versus Sulfuric Acid
Instantaneous Flux (GFD), Temperature Corrected to 10°C
45
40
35
30
25
20
15
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
%Recovery
Batch #29 NLR 759 & pH 7.0 H2SO4, 7.26mS
Batch #36 NLR 759 & pH 7.0 CO2, 7.36mS

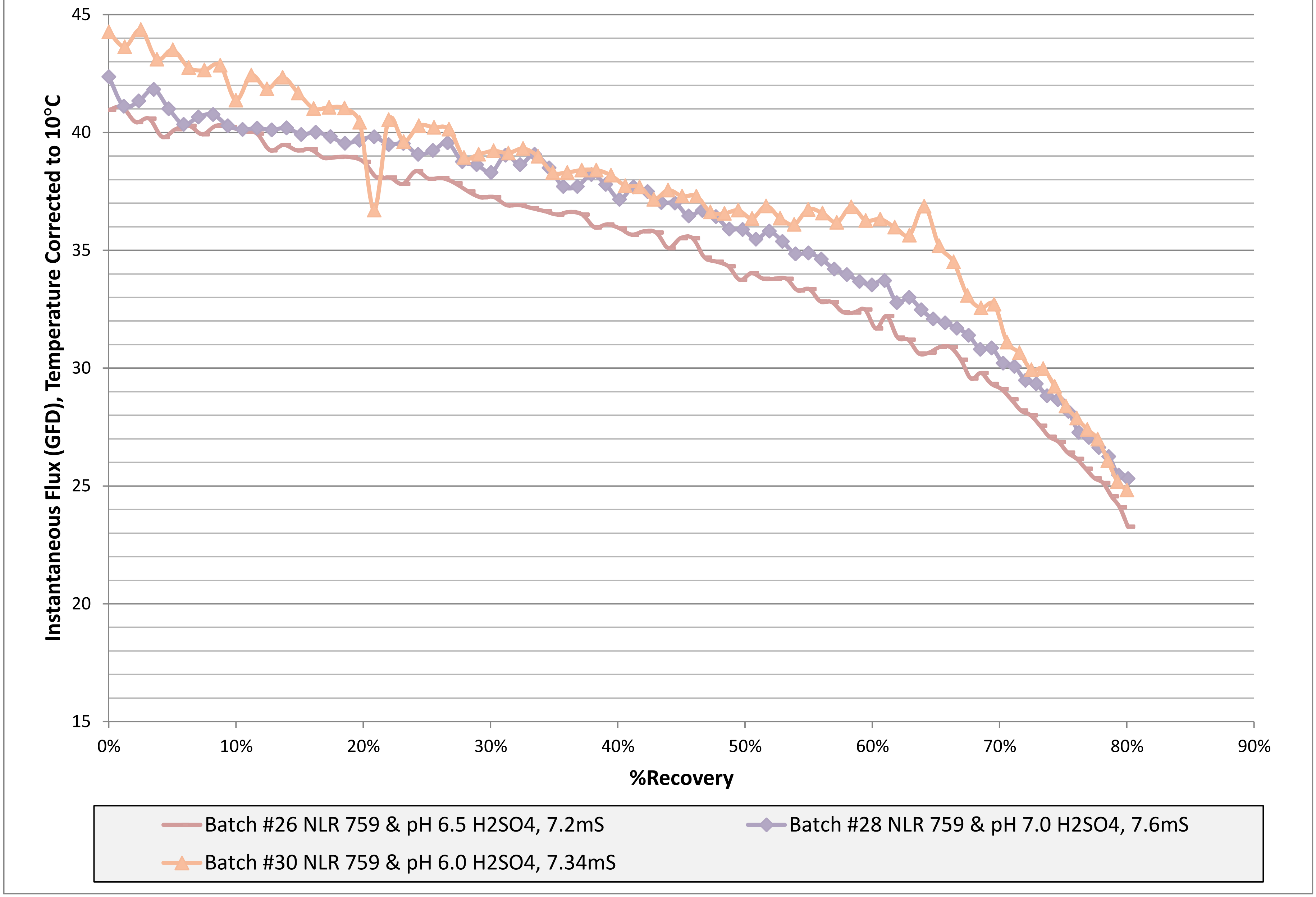


Figure 14: VSEP Pretreatment with Sulfuric Acid at Varying Target pH Values

Figure 15: Simplified Process Schematic – ICCP, Secondary RO, and Crystallization

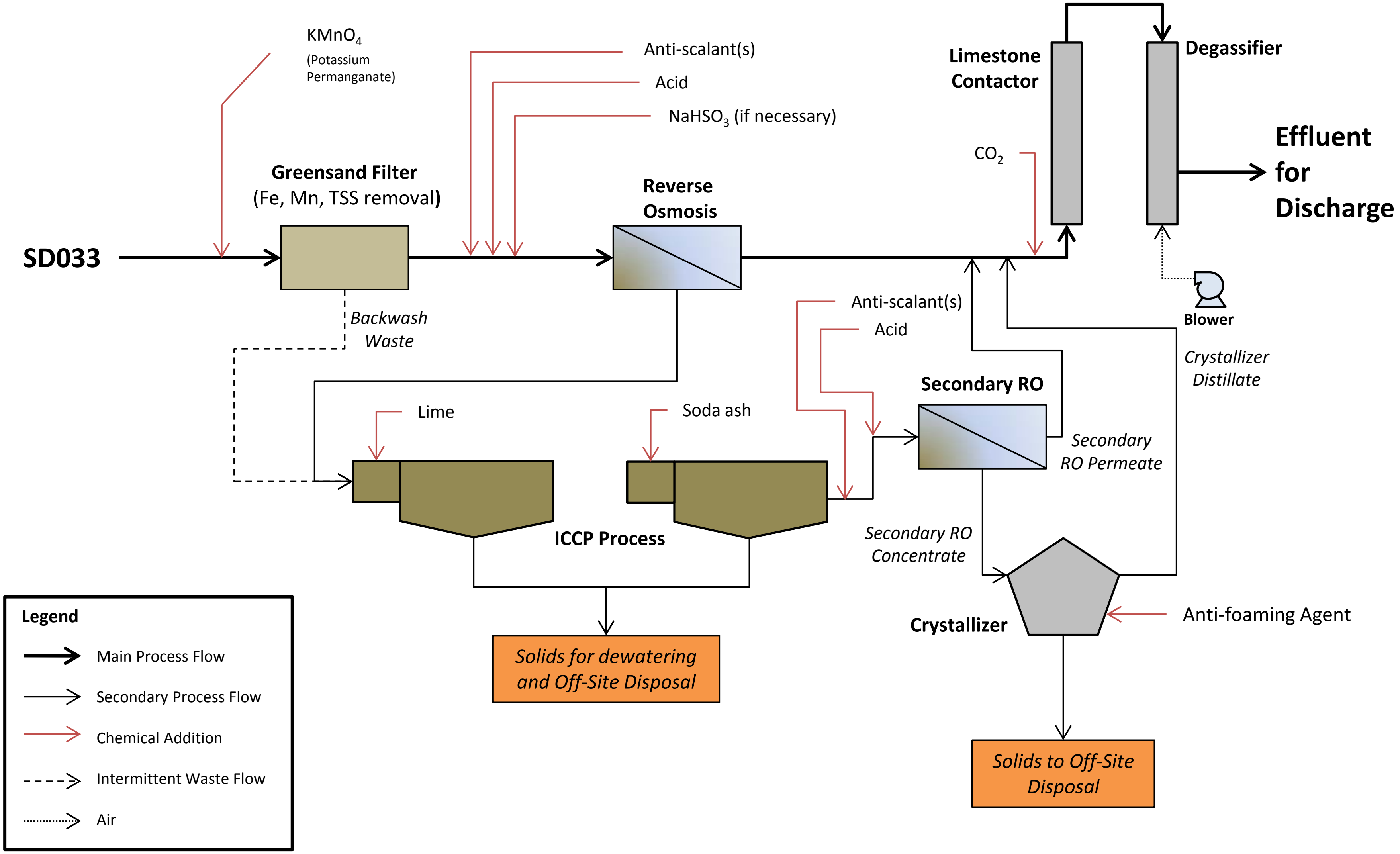
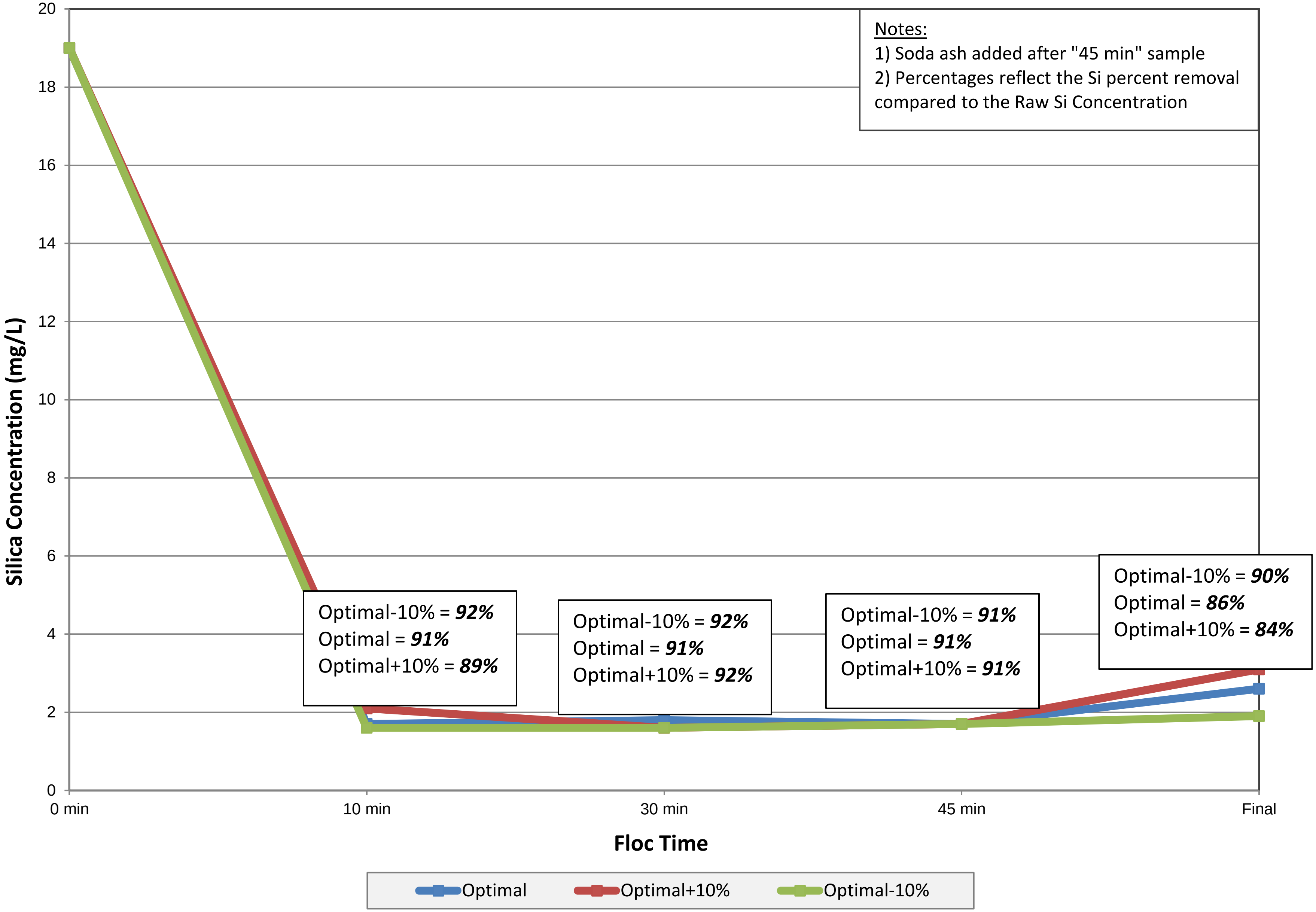


Figure 16: Silica Removal by ICCP



Notes:
1) Soda ash added after "45 min" sample
2) Percentages reflect the Si percent removal compared to the Raw Si Concentration

Optimal-10% = ***92%***
Optimal = ***91%***
Optimal+10% = ***89%***

Optimal-10% = ***92%***
Optimal = ***91%***
Optimal+10% = ***92%***

Optimal-10% = ***91%***
Optimal = ***91%***
Optimal+10% = ***91%***

Optimal-10% = ***90%***
Optimal = ***86%***
Optimal+10% = ***84%***

Figure 17: Lime Addition WET Test Results

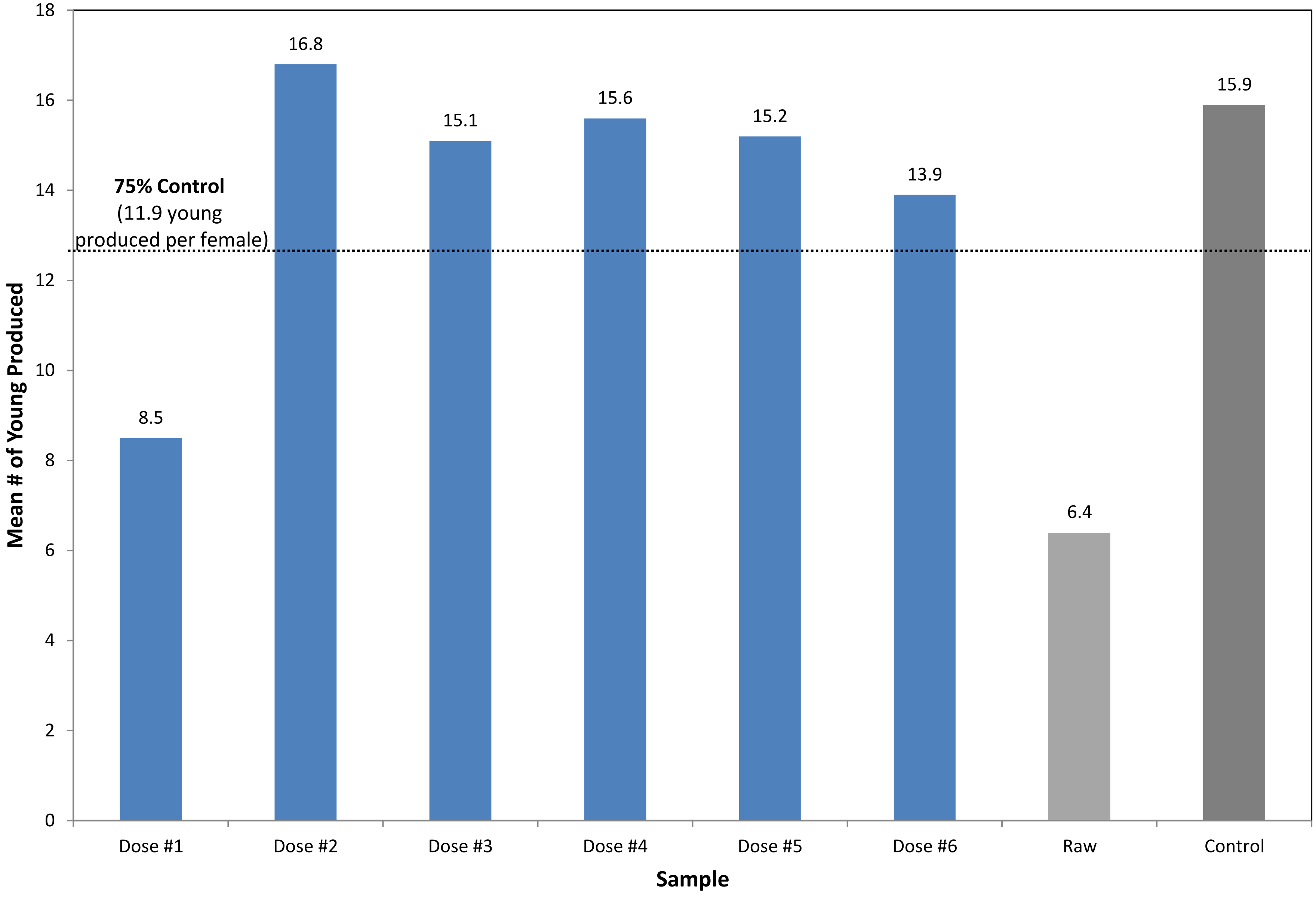


Figure 18: Limestone Contactor Columns

Upflow LC Columns

Puri-Cal RO media

Figure 19: Limestone Contactor Bench Test Illustration

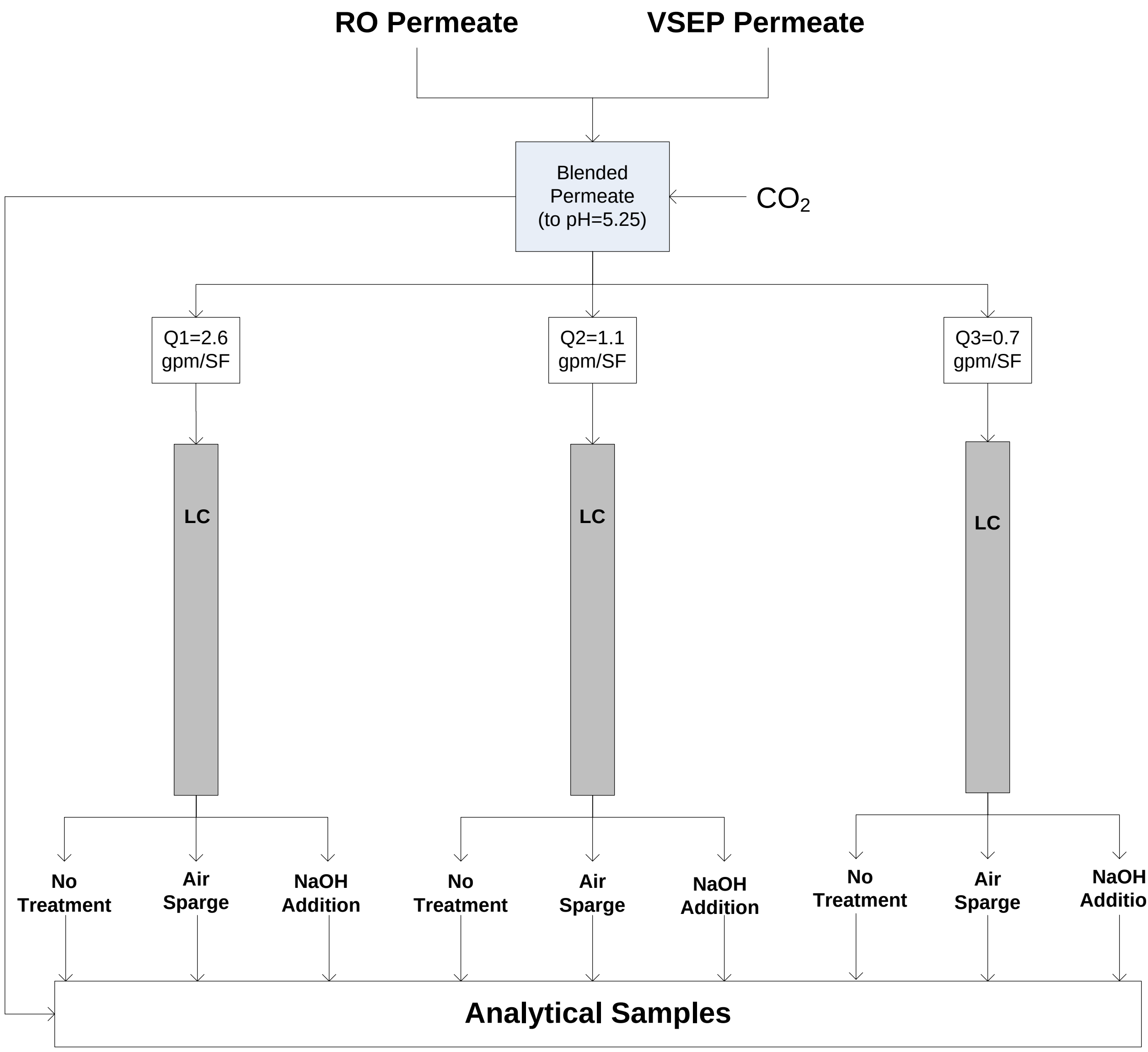
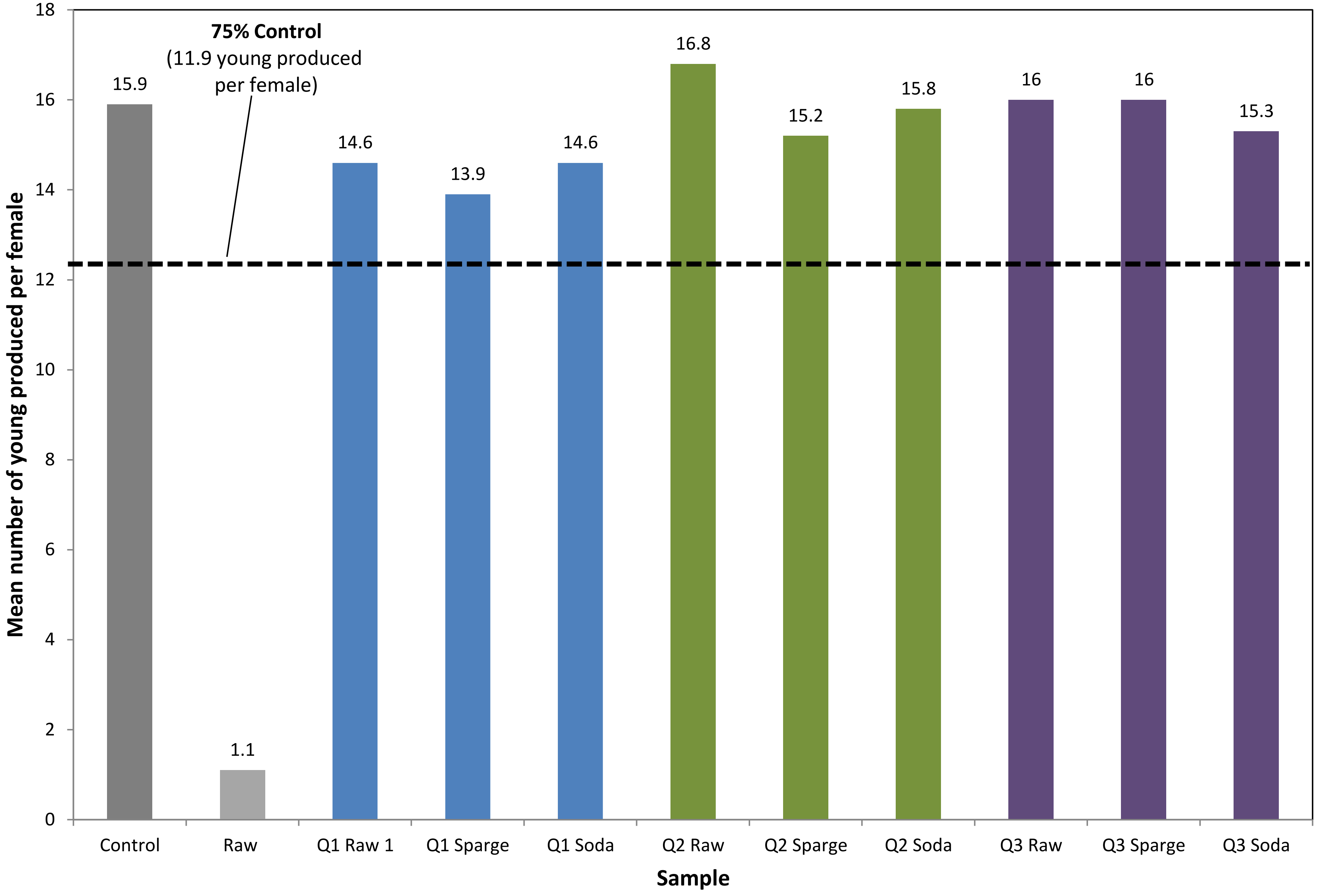


Figure 20: Limestone Contactor WET Test Results



Appendix A

Work Plan for Investigation of Membrane Treatment at SD033

Work Plan for Investigation of Membrane Treatment at SD033

NPDES/SDS Permit No. MN 0042536

Prepared for
Cliffs Erie LLC and PolyMet Mining Inc.

September 2012

Work Plan for Investigation of Membrane Treatment at SD033

NPDES/SDS Permit No. MN 0042536

Prepared for
Cliffs Erie LLC and PolyMet Mining Inc.

September 2012

BARR

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Work Plan for Investigation of Membrane Treatment at SD033

NPDES/SDS Permit No. MN 0042536

Prepared for
Cliffs Erie LLC and PolyMet Mining Inc.

September 2012

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1.0 Introduction

1.1 Background

The northern portion of the former LTV Steel Mining Company (LTVSMC) Mining Area 5 (Area 5 North) discharges water to the Embarrass River watershed. The general site layout is shown on Figure 1. Discharge from Area 5 North forms the headwaters of Spring Mine Creek, which flows north (via surface discharge station SD033) to the Embarrass River.

The discharge is administered under Minnesota Pollution Control Agency (MPCA) National Pollutant Discharge Elimination System (NPDES)/State Disposal System (SDS) Permit MN0042536 (Permit) as surface discharge station SD033. The Permit is currently held by Cliffs Erie LLC (CE). However, PolyMet Mining Inc. (PolyMet) is collaborating with CE on the reissuance of the Permit.

A key aspect of the Permit renewal process is the development of this Long-Term Mitigation Evaluation and Implementation Plan (Plan) to address sulfate and parameters of concern that have elevated concentrations in the discharge. The ‘parameters of concern’ (as defined in the April 6, 2010 Consent Decree between MPCA and CE) are total dissolved solids (TDS), bicarbonates (which contribute to alkalinity), total hardness (Ca^{2+} + Mg^{2+}), and specific conductivity (which is a function of TDS). Although sulfate is not a defined parameter of concern, it is a significant contributor to the TDS and specific conductivity in these waters.

A *Long-Term Mitigation Evaluation and Implementation Plan for SD033* was submitted to the MPCA in April 2012. The *Long-Term Mitigation Evaluation and Implementation Plan for SD033* proposed the investigation of a number of methods to reduce the concentrations of sulfate and the parameters of concern, including source isolation and passive treatment options - natural attenuation, enhanced natural attenuation, floating wetland, and lagoon/surface-flow wetland. As part of their review of the *Long-Term Mitigation Evaluation and Implementation Plan for SD033*, the MPCA indicated that testing of active treatment technologies would also be required.

The purpose of this work plan is to present a testing plan for evaluation of an active treatment technology - reverse osmosis (RO). Because a critical component of the technical and economic feasibility of reverse osmosis is concentrate (brine) management, this work plan also includes testing of concentrate management approaches, including mechanical evaporation and crystallization, and the use of concentrate volume reduction technologies prior to mechanical evaporation and crystallization.

Components of this Plan include:

1. A presentation of the detailed technical objectives to be accomplished by the testing described in this work plan (Section 1);
2. A summary of the historical water quality at SD033, the rationale for selection of the feed water to be used for the testing, and a review of the treatment objectives (Section 1);
3. A description of the infrastructure required for the testing plan and the associated parties who will be conducting the testing and providing technical support (Section 2);
4. Detailed descriptions of testing plans to be implemented as part of this work plan and the testing schedule (Section 3);
5. Description of the analytical and data management procedures to be followed during the pilot and bench tests (Section 4); and
6. Description of how the data collected will be used and evaluated (Section 5).

1.2 Selection of Reverse Osmosis as Active Treatment Technology and Testing Approach

Three technologies were screened in detail for removal of sulfate and the parameters of concern in the *Short-Term Mitigation Evaluation and Implementation Plan for SD033*: floating wetland treatment, ion-exchange, and reverse osmosis treatment (Barr, 2010). In addition, permeable reactive barrier (PRB) technology was evaluated in a December 2010 addendum to the *Short-Term Mitigation Evaluation and Implementation Plan for SD033.* Of the treatment technologies that were reviewed, membrane separation (reverse osmosis or nanofiltration) is the most established process. The *Short-Term Mitigation Evaluation and Implementation Plan for SD033* concluded that the reverse osmosis would likely be effective in meeting the treatment goals, but that two technical challenges remained: management of the concentrate and stabilization of the permeate (Barr, 2010). Initial evaluation of concentrate management options revealed no cost-effective options for disposal of the concentrate. The only viable solution, evaporation/crystallization, is a capital and power-intensive method. In contrast, stabilization is a technical issue that results from the treatment of the water with reverse osmosis to very low concentrations of dissolved constituents. Water that is too low in TDS will require stabilization treatment or augmentation prior to discharge to prevent toxicity.

This work plan describes testing protocols to evaluate RO as the primary treatment technology, to evaluate permeate stabilization requirements, and to evaluate evaporation and crystallization for concentrate management. The testing will consist of the following major components (which are described in greater detail in Section 3 and associated appendices, and are illustrated in Figure 2):

- RO pilot test
- Permeate stabilization bench testing
- Concentrate management evaluations
    - Vibratory Shear Enhanced Processing (VSEP™) pilot test
    - Intermediate concentrate chemical precipitation (ICCP) bench testing and RO modeling
    - Evaporator and crystallizer evaluations

The information collected during the pilot testing program will be used to assess the technical and economic feasibility of the treatment system (including concentrate management) required to meet the water quality standards at SD033.

1.3 Water Quality and Treatment Goals

1.3.1 Feed Water

The quality of the water being discharged via the outfall at SD033 has been monitored regularly over the past several years. Table 1 includes a statistical summary of the water quality data from SD033 from January 2005 through December 2011. These data are based on the analytical results from the monthly Discharge Monitoring Reports (DMRs) as reported by CE in accordance with NPDES/SDS Permit No. MN0042536. For parameters that had concentrations below their corresponding reporting limit values, concentrations were reported as the reporting limit values. These reporting limit values, along with the actual analytical data results, were used to calculate the average concentrations. This methodology for using non-detected sample results in the statistical analysis was deemed most appropriate for the data used in development of this work plan, as it is the most conservative.

Table 2 presents the water quality data from recent samples for the Area 5NW Pit and SD033. The parameters of concern are highlighted in yellow. The locations of these water sources are shown on Figure 1. For logistical reasons and safety reasons (i.e., truck access for collection of test water, climbing steep rocky areas for access to water), this work plan proposes to use Area 5NW Pit water as the feed water for the investigations described herein. Previous investigations have examined the water balance at SD033 and determined that Area 5NW Pit contributes the majority of the flow to SD033 (Barr, 2011 and Barr, 2012). The water quality of Area 5NW, as shown in Table 2, is quite similar to SD033 and within the historical variations observed for the parameters of concern (Table 1). Because of the large contribution of Area 5NW Pit outflow to the SD033 discharge and because of the similarity in quality between the two sites, the use of Area 5NW Pit water for the active treatment testing is reasonable.

With respect to reverse osmosis treatment, both water sources have similar potential foulants and scalants – suspended solids, manganese, calcium carbonate, calcium sulfate, and silica. Other potential scale-forming compounds such as barium sulfate are also present in Area 5NW Pit and SD033, but calcium carbonate, calcium sulfate, and silica are the three of greatest concern with respect to their potential to limit the recovery of the RO system. The required pretreatment for Area 5NW Pit and SD033 is similar – particulate removal and some manganese removal, and antiscalant addition.

1.3.2 Treatment Goals

The allowable concentrations of parameters in permitted discharges are derived from the beneficial use classification(s) of the receiving water. The receiving water for SD033 is Spring Mine Creek, which is an unlisted water with default beneficial use classifications of 2B, 3C, 4A, 4B, 5, and 6, as described in Minnesota Rule Chapter 7050.0430. However, because a detailed evaluation of actual uses of the receiving water has not yet been completed, the potentially applicable Minnesota water quality standards were used as a guide in the selection of reverse osmosis for testing and for development of this work plan.

1.3.2.1 Sulfate

The primary use classifications pertaining to sulfate are the Class 1, Class 4A, and Class 4B water quality standards, as described in Minnesota Rules Chapters 7050.0221 and 7050.0224. Waters with a beneficial use classification of 1 are used for drinking water consumption and, as noted above, are not applicable to Spring Mine Creek. Class 1 waters must meet the U.S. EPA primary and secondary drinking water standards. The secondary drinking water standard for sulfate is 250 milligrams per liter (mg/L). For waters with a beneficial use classification of 4A (irrigation), the sulfate concentration in those waters can be no greater than 10 mg/L for waters where wild rice is produced "during periods when the rice may be susceptible to damage by high sulfate levels." For waters with a beneficial use classification of 4B (livestock and wildlife consumption), while no numeric standard is given, it has been interpreted by the MPCA to mean that the sulfate concentration in those waters cannot be greater than 1,000 mg/L. Given the potentially wide range of applicable water quality targets for sulfate discharge to Spring Mine Creek, a conservative value of 10 mg/L was used for development of the testing protocol described in this work plan.

1.3.2.2 Other Parameters of Concern

For the parameters of concern, the following in-stream water quality standards, from Minnesota Rules Chapter 7050.0222 through 7050.02, were used as a guide for setting treatment goals for the pilot test:

- Class 2B (fishing and aquatic life): no specific requirements for the parameters of concern
- Class 3C (industrial cooling and materials transport): Hardness - 500 mg/L
- Class 4A (irrigation): Bicarbonates – 5 millequivalents per liter (meq/L) (250 mg/L as $CaCO_3$), specific conductance – 1,000 micromhos per centimeter (µmhos/cm), total dissolved salts – 700 mg/L, sulfate – 10 mg/L (where wild rice is produced during periods when the rice may be susceptible to damage by high sulfate levels)
- Class 4B (livestock and wildlife consumption): Total salinity – 1,000 mg/L
- Class 5 (aesthetic enjoyment and navigation): no specific requirements for the parameters of concern
- Class 6 (other uses): no specific requirements for the parameters of concern

1.4 Testing Objectives

The primary objectives of the testing proposed in this work plan are to collect sufficient information to (1) determine the requirements for successful implementation of reverse osmosis to meet the water quality goals, including permeate stabilization and concentrate management, and (2) collect sufficient information to refine the capital and operating costs for treatment systems necessary to meet the water quality goals. In order to meet the testing objectives, the following tasks are anticipated:

1. Selection of a membrane for use in the RO system that meets the permeate water quality goals while minimizing fouling and operating costs;
2. Determination of the optimal pretreatment for the RO system to minimize membrane fouling;
3. Establish the design flux for the RO system, balancing capital and operating costs and reliability;
4. Establish the design recovery for the RO system, balancing the cost of concentrate management with consistent and reliable RO operation;
5. Determine the operating conditions for the RO system, including:
    a. Operating pressures
    b. Chemical cleaning regime(s) and frequency
    c. Membrane replacement frequency
6. Confirm that permeate water quality goals can be met reliably by the proposed system;

7. Determine what post-treatment chemical stabilization is required to reduce corrosiveness and potential toxicity of the RO permeate;
8. Generate RO concentrate for use in VSEP™ pilot testing and ICCP bench testing;
9. Conduct volume reduction pilot testing to determine:
    a. Operating pressures
    b. Recovery
    c. Flux
    d. Chemical cleaning regime(s) and frequency
    e. Membrane replacement frequency
    f. Reliability
10. Conduct ICCP bench tests to determine silica removal and evaluate secondary RO recovery and resulting concentrate quality;
11. Collect concentrate water quality data for use by equipment suppliers in a detailed evaluation of mechanical evaporation and crystallization.

An overview of the proposed testing is provided in Figure 2.

2.0 Testing Roles, Responsibilities, and Infrastructure

2.1 Roles and Responsibilities

Note that some of the activities listed below, such as the establishment of the testing infrastructure and contracting have been completed or are in progress for the ongoing testing being conducted by PolyMet and will not need to be repeated for the SD033 testing described in this work plan. The technical tasks (pilot and bench testing) described below are unique to SD033 and are not yet underway.

2.1.1 PolyMet / CE

PolyMet is the lead organization in the pilot testing effort, in consultation with CE. PolyMet activities include:

- Contract development for the pilot testing equipment, laboratories, and consultants.
- Management of the pilot testing, Equipment Suppliers, laboratories, and consultants.
- Supplying location, utilities, non-proprietary chemicals, and laboratory services for the pilot testing.
- Provide feed, waste, and interconnecting piping outside of the selected Equipment Supplier’s skids.
- Provide a raw water feed tank with level sensors (high and low) and a high-level overflow.
- Provide wiring to the pilot unit skids for power, instrumentation, and communications.
- Operation of the pilot units, including regular monitoring, assistance with process troubleshooting, and conducting clean-in-place (CIP) procedures for the pilots when required.
- Management and disposal of wastes generated during the pilot testing program.
- Evaluation of the pilot units’ performance.

2.1.2 Barr Engineering

Barr Engineering Company staff will be providing the following services:

- Development of pilot unit plans, specifications, and testing protocols.
- Provide QA/QC of analytical data as described in Section 4.

- Provide on-going water quality data for those parameters described in Section 4 to PolyMet and to the Equipment Suppliers on a regular basis, as results are available from the laboratories.
- Participate in meetings and conference calls with PolyMet and the Equipment Suppliers.
- Conduct bench testing for the ICCP and effluent stabilization investigations.
- Provide technical support for process troubleshooting, data evaluations and interpretation, and performance evaluation.
- Assist with the development of the refined construction and O&M costs based on pilot testing results.

2.1.3 Equipment Suppliers

Equipment Supplier activities include:

- Provide pilot test equipment in accordance with their contracts. Coordinate arrival and installation with PolyMet.
- Provide on-site supervision of installation and startup.
- Conduct membrane selection and pretreatment investigations.
- Provide training such that PolyMet staff have sufficient knowledge to support the pilot testing program.
- Respond to requests for technical assistance within 24 hours.
- Correct any mechanical and control problems with the membrane pilot equipment within 1 to 3 business days of notification.
- Provide written documentation to PolyMet of adjustments to the pilot system operating conditions, controls, or equipment.
- Provide raw data collected by the pilot unit PLC to PolyMet. Provide weekly summaries of pilot unit performance to PolyMet and Barr. The weekly summary graphs and tables must include at a minimum: Permeability (specific flux), flux, operating pressures, feed water temperature, feed water specific conductivity, recovery, and permeate specific conductivity.
- Participate in conference calls and meetings.
- Provide a final report summarizing the pilot testing results.
- Provide equipment capital costs and updated annual O&M costs for supplied equipment to support the development of a refined project cost estimate.

2.1.4 Analytical Laboratories

Two analytical laboratories are proposed to provide analytical services during pilot testing. Legend Technical Services Inc. will provide analytical services for routine sampling and testing during the pilot testing program. Pace Analytical will provide analytical services for special or non-routine samples that require very short turn-around time.

2.2 Pilot Testing Facility

2.2.1 Description

The pilot test facility is located at the Wayne Transports facility in Virginia, MN. This facility has ample space for the pilot unit equipment and has overhead doors to facilitate equipment delivery. There are two 3,000 gallon feed water tanks at the pilot test facility. Appendix A provides drawings of the testing facility and associated infrastructure. Water from Area 5NW Pit will be hauled daily to the pilot test facility for use as feed water for the RO pilot test.

The utilities that will be provided at the pilot testing facility include:

- Power: 3-phase, 480V, 100A.
- Communications: The facility has cellular phone reception.
- Water: Potable water is available for use.
- Compressed air: A small compressor will be provided for the selected equipment supplier. Compressed air requirements for the pilot unit will be coordinated with the Equipment Supplier.
- HVAC: Basic building heat for freeze protection will be supplied.
- Plumbing: There will be drains to collect waste from the pilot unit.

2.2.2 Waste Management

The pilot testing program will generate a variety of residuals, including filter backwash, spent membrane cleaning solutions, and RO concentrate. These waste streams will be managed selectively:

- Greensand filter backwash waste will be discharged to the City of Virginia sewer system.
- RO concentrate will be blended with RO permeate and discharged to the City of Virginia sewer system.
- RO clean-in-place wastewater will be neutralized and discharged to the City of Virginia sewer system.

3.0 Testing Plan

3.1 Reverse Osmosis Treatment

Greensand filtration (GSF) and RO pilot testing units have been leased from GE for the ongoing testing being conducted by PolyMet. It is anticipated that the same equipment will be used for the SD033 testing. Information about the pilot units provided by GE can be found in Appendix B.

3.1.1 Phase 1 – Installation and Start-Up

The Phase 1 period is for preparing the RO pilot unit and associated infrastructure for testing with Area 5NW water. This period will provide an opportunity for pilot unit maintenance, instrument calibration and verification, membrane change-out, and other test preparations.

The duration of Phase 1will be approximately 2 weeks.

3.1.2 Phase 2 – Optimization

The purpose of Phase 2 is to allow the PolyMet and Equipment Supplier to test pretreatment strategies and operating conditions in order to optimize the treatment train (balancing capital costs, operating costs, and reliability).

Based on the evaluation of the data collected during Phase 2, the Equipment Supplier will propose a membrane, pretreatment strategy, and operating approach that will be carried into Phase 3 for demonstration over a longer period.

It is expected that equipment and operational adjustments made during Phase 2 will be developed collaboratively between PolyMet (in consultation with CE), Barr, and the Equipment Supplier in order to develop an equipment and operational strategy that balances capital and operating costs and reliability. To facilitate this process, weekly conference calls will be held with PolyMet, Barr Engineering, and the Equipment Supplier.

The duration of Phase 2 will be approximately 4 weeks.

3.1.2.1 Measurement Criteria

During Phase 2, the collected operating data will be reviewed and evaluated to assess:

- RO permeate water quality, particularly with respect to sulfate (less than 10 mg/L).
- RO system operating pressures.

- RO system fouling rates – For the RO system, the target RO CIP interval is 6 months.
- RO system recovery – 85% is the initial target recovery.
- RO system flux.
- Operational reliability of the pilot testing equipment and of the pretreatment and operational strategies under investigation.
- Overall chemical usage.

3.1.3 Phase 3 – Steady-State Operation

During Phase 3, the treatment train and operating conditions proposed based on the Phase 2 investigations will be used. The treatment system will run, unaltered, for the duration of Phase 3 under steady-state conditions. The purpose of this test is to gain longer-term operating data on the proposed system to evaluate system reliability, system performance with respect to water quality goals, life cycle cost, ability to effectively clean the membranes, and to generate permeate and concentrate for use in related bench and pilot tests.

At the end of Phase 3, a CIP will be conducted on the RO system. This CIP will likely be a two-step cleaning process, with each step using different chemicals to remove different foulants and scaling compounds ("CIP1" and "CIP2" in Table 4). The ability of the proposed CIP strategy to effectively restore permeability will be assessed.

Throughout Phase 3, biweekly conference calls will be held with PolyMet, Barr, and the Equipment Supplier to review operating data and to address any pilot testing issues that have arisen. At the end of Phase 3, the Equipment Supplier will provide a final report on the pilot test. The final report will contain the following minimum information:

- Summary of pretreatment investigations, results, and conclusions.
- Summary of steady-state operational data from Phase 3 including pretreatment and RO system performances (water quality and operational).
- Discussion of any recommended treatment (equipment or operational) modifications for a full-scale system, based on Phase 3 results.
- Estimated capital and O&M costs for a full-scale treatment system.

The duration of Phase 3 will be approximately 3 months.

3.1.3.1 Measurement Criteria

A description of performance evaluation criteria are provided in Section 5. In general, the data from Phase 3 will be evaluated to assess:

- The longer-term effectiveness of the pretreatment system on the RO system performance.
- The sustainability of the RO system operating conditions.
- The permeate water quality.
- The quality and quantity of residuals from the system.
- The value of critical design parameters:
    - Design and maximum flux
    - Design and maximum pressures
    - Design and maximum recovery rates
- CIP effectiveness at restoring membrane permeability.
- The system lifecycle cost.

3.2 Effluent Stabilization

The effluent stabilization investigation will consist of modeling using PHREEQC, an aquatic chemistry software package developed by the United States Geological Survey, and focused bench testing to evaluate methods to stabilize the RO permeate to reduce its corrosiveness to piping and materials near the outfall, and to achieve compliance with effluent water quality targets.

The objective of the effluent stabilization investigation will be to identify a stabilization method (e.g. addition of minerals) that will adequately address corrosiveness of the treated water and comply with the effluent water quality targets, including whole effluent toxicity.

This testing will involve stabilization of a blend of VSEP™ and RO permeate in a ratio to reflect the full-scale system. The waters will be sampled for water quality, subjected to a variety of stabilization treatments, and then sampled again to document the resulting changes in water quality. The detailed effluent stabilization bench testing protocol is provided in Appendix C.

The effluent stabilization investigation will occur during the concentrate management investigation, as it will require permeate from both the RO and VSEP™ unit. The PHREEQC modeling portion of the investigation will be conducted upon receipt of the first water quality data from concentrate management investigations described in Section 3.3. Following the PHREEQC modeling, the bench testing portion of the stabilization study will be initiated.

3.3 Concentrate Management

Mechanical evaporation and crystallization of the RO concentrate is the concentrate management method determined to be potentially feasible at SD033 in the *Short-Term Mitigation Evaluation and Implementation Plan for SD033.* The primary objectives of this concentrate management investigation are to verify the technical feasibility of this approach to concentrate management, and to better quantify the costs associated with it. When evaporators and crystallizers are used for concentrate management, the primary treatment process (RO) essentially acts as pretreatment for the evaporator and crystallizer, which are much larger and more expensive pieces of equipment. The capital and O&M costs associated with evaporation and crystallization are sensitive to flow rate, and in some applications, concentrate volume reduction can reduce the cost of the evaporator and crystallizer systems. For this investigation, we will evaluate three “pretreatment” approaches for the evaporator and crystallizer:

1. Greensand filtration followed by reverse osmosis (with the RO concentrate being sent to the evaporator without further treatment), and
2. Greensand filtration followed by reverse osmosis, with the RO concentrate being further reduced in volume by a specialty RO membrane (VSEP, see Section 3.3.1).
3. Greensand filtration followed by reverse osmosis, with the RO concentrate being further reduced in volume by ICCP and RO (see Section 3.3.2).

In addition to assessing technical feasibility, a comparison of these three approaches will be used to assess whether the additional capital and O&M costs associated with the specialty RO membrane and ICCP+RO are offset by the savings in evaporator and crystallizer capital and O&M costs.

3.3.1 Vibratory Sheer Enhanced Processing (VSEP™)

Once steady-state operation of the RO pilot has been established, a study of further reduction of the concentrate volume will be initiated via routing the RO concentrate through a specialty RO membrane system, Vibratory Sheer Enhanced Processing (VSEP™) by New Logic Research. The objective of this investigation will be to evaluate the recovery, fluxes, and operational requirements for the VSEP™ equipment, and to characterize the resulting concentrate and permeate quality. Information on the VSEP™ pilot unit can be found in Appendix D.

It is anticipated that the VSEP™ pilot will be operated in a batch mode, being fed from a concentrate storage tank that will receive concentrate from the RO pilot equipment. Permeate and concentrate from the VSEP™ pilot will be routed to collection tanks during sampling.

The VSEP™ pilot will run concurrently with Phase 3. A startup period of approximately one week is assumed for the VSEP™ pilot. Following startup, the duration of the concentrate volume reduction investigation is anticipated to be approximately two months.

In general, for each batch of RO reject processed by the VSEP™ pilot during the test, the following operational parameters will be logged during the run:

- VSEP™ flux
- VSEP™ recovery
- Permeate flow rate
- Permeate temperature, conductivity
- VSEP™ vibrational setting

A log of cleaning/maintenance activities conducted during VSEP pilot operation will also be maintained, noting types and quantities of cleaning reagents/antiscalants used, as well as a description of each maintenance procedure performed.

3.3.2.1 Measurement Criteria

VSEP™ pilot test performance/operational goals include:

- Flux
- Recovery
- Permeate quality, particularly with regards to sulfate
- Concentrate quality
- Uptime/Downtime
- Average recovery achieved over the course of each batch run

3.3.2 ICCP and Secondary RO

One method of maximizing recovery in RO systems is the use of intermediate concentrate chemical precipitation (ICCP). A general illustration of the ICCP process is shown in Figure 3. ICCP involves treatment of the primary RO reject to remove certain constituents such as calcium and silica that contribute to fouling and low recovery for the secondary RO system. After treatment by ICCP, the treated concentrate can be passed through a second RO system to reduce the concentrate volume further and maximize permeate production.

The protocol described in Appendix E has been developed to test the use of ICCP for silica removal from RO concentrate. Silica and silicates are generic names given to compounds derived from the polymerization of silicic acid $Si(OH)_4$. In neutral pH waters (pH of 6-8), silicic acid is common and has a propensity to polymerize, eventually forming colloidal polymers of many silicon dioxide molecules linked together. Metal hydroxides, if available, can be incorporated into the polymers to form more complex silicates (Ning, 2002).

In RO systems, the polymers of silicon dioxide and silicates coagulate with themselves and other organic matter and foul membranes, reducing recovery (Ning, 2002). To remove silica from RO feed water, lime-soda ash softening is commonly used which increases the pH to 10-11 allowing magnesium hydroxide and calcium carbonate to precipitate. Silica is removed during this process by adsorption onto the surface of magnesium precipitates and by precipitation of the mineral forsterite (Mg_2SiO_4) (Sheikholeslami and Bright, 2002 and Parks and Edwards, 2007). The amount of silica removal observed in lime-soda ash softening typically ranges from 70% to 90% (Sheikholeslami, Al-Mutaz, and Young, 2001, Sheikholeslami and Bright, 2002, and Parks and Edwards, 2007).

Lime-soda ash softening to remove silica will be tested on the RO pilot concentrate water. Following the bench testing, the resulting treated concentrate chemistry will be used in an RO modeling exercise to determine the potential recovery and concentrate chemistry of a secondary RO system. The chemistry of the secondary RO concentrate will be supplied to the evaporator and crystallizer manufacturer for use in their evaluation (as described in Section 3.3.3).

3.3.3 Evaporation and Crystallization

The technical evaluations of mechanical evaporation and crystallization will be conducted with the assistance of one of the two primary suppliers of this equipment in the United States – GE (formerly RCC) or Veolia (formerly HPD). The selected supplier will be provided with the detailed concentrate water quality from the RO and the VSEP™ pilot tests and from the RO model used in the ICCP evaluation. The following information will be provided by them:

- Identification of any additional modifications to the concentrate chemistry recommended prior to evaporation.
- Selection of specific type of evaporator and crystallizer for this application, along with materials of construction.
- Energy consumption required for each process.
- Quality and quantity of waste streams that will be generated (e.g. distillate, salt solids).
- Estimated capital costs for the systems.
- Estimated footprint of the systems.

- Estimated O&M costs for the systems.

The expected duration for this evaluation by the evaporation and crystallization supplier is 2 months, depending on their availability.

It should be noted that neither GE nor Veolia believe that bench or pilot testing of these processes is necessary in order to provide an assessment of technical feasibility and cost for this application, given the number and wide variety of operating installations that both suppliers have.

3.4 Testing Schedule

The proposed overall project schedule is shown below. The exact durations of each activity are estimates only and could be subject to change, depending on testing results. Estimated start date for the SD033 pilot test is December 2012 or January 2013.

	Time (Week)																															
Item	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
Phase 1																																
Pilot unit preparation and start-up	▨	▨																														
Phase 2 - Optimization																																
Pretreatment and RO optimization testing			▨	▨	▨	▨																										
Phase 3 - Steady State Operation																																
Steady state pilot unit operation and data collection							▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨														
Concentrate Management Testing																																
VSEP pilot unit preparation											▨	▨																				
VSEP optimization													▨	▨																		
VSEP steady state operation															▨	▨	▨	▨														
ICCP bench testing											▨	▨	▨																			
Evaporation and crystallization evaluation (by others)																			▨	▨	▨	▨	▨	▨	▨	▨						
Effluent Stabilization Bench Testing																																
Effluent stabilization bench testing																▨	▨															
Analytical results																		▨	▨													
WET results																		▨														
Reporting																																
Data evaluation																											▨	▨	▨	▨		
Report to MCPA																															▨	▨

This conceptual milestone schedule is subject to modification depending on the results of the pilot-scale testing.

4.0 Standard Procedures

4.1 Sampling and Analytical Methods

To ensure the accuracy of all collected data, consistent sampling methods with respect to location, timing, and the analytical methods must be maintained. The analytical methods to be used during testing are presented in Table 3.

The preliminary sampling and analytical schedule to be followed during testing is presented in Tables 4 and 5. Specific parameters and frequency may be revised during testing, depending on the initial results.

4.2 Data Management

There will be a significant amount of data generated from numerous sources during pilot testing. This section outlines the major classes of data and how they will be managed throughout piloting.

4.2.1 Pilot Unit Data / PLC Data

Operational data from the pilot units will be collected by each pilot unit's programmable logic controller (PLC) on a regular basis (at least every 5 minutes). These data will include the fundamental system operating parameters such as feed flow and pressure, concentrate flow and pressure, permeate flow and pressure, recovery, and water quality (e.g. pH, temperature, conductivity, turbidity).

4.2.2 Pilot Unit Monitoring and Maintenance Logs

Throughout the pilot test, PolyMet staff will be supporting the piloting efforts and manually collecting data. This data will be used for "at-a-glance" assessment of performance trends, to identify operational problems or issues in a timely manner, and to confirm instrumentation and chemical dosing pumps are operating properly. Operating logs to be completed during testing for the RO and VSEP™ systems are provided in Appendix F.

4.3 Quality Control and Quality Assurance

Laboratory data obtained during the course of piloting will be reviewed by Barr Engineering Co. chemists for quality assurance purposes and entered into a central database (the Barr EQuIS system) for use by the project.

5.0 Data Evaluation

Upon completion of testing, modeling, and equipment supplier evaluations, the collected data and information will be reviewed and evaluated to:

- Verify that the treated water quality goals can be met reliably.
- Identify what unit processes are necessary to meet the water quality objectives, including management of all residuals generated.
- Identify the quality and quantity of residuals generated.
- Identify any fundamental technical impediments to the use of reverse osmosis to achieve the water quality objectives and to the management of the reverse osmosis concentrate.
- Estimate the capital and O&M costs for the three treatment trains examined in this work plan:
    - Train 1
        - Greensand filter
        - RO
        - Effluent stabilization
        - Evaporation
        - Crystallization
    - Train 2
        - Greensand filter
        - RO
        - Effluent stabilization
        - VSEP™
        - Evaporation
        - Crystallization
    - Train 3
        - Greensand filter
        - RO
        - Effluent stabilization
        - ICCP+RO
        - Evaporation
        - Crystallization

6.0 References

Barr Engineering Company (Barr), 2012. Long-Term Mitigation Evaluation and Implementation Plan for SD033, NPDES/SDS Permit No. MN 0042536. Prepared for Cliffs Erie, LLC and PolyMet Mining Inc. April 2012.

Barr Engineering Company (Barr), 2011. NPDES Field Studies Report – SD033. Prepared for Cliffs Erie, L.L.C. and PolyMet Mining Inc. September 2011.

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Parks J.L. and Edwards M., 2007. Boron Removal via Formation of Magnesium Silicate Solids during Precipitative Softening. Journal of Environmental Engineering.

Sheikholeslami, R., and Bright, J., 2002. Silica and metals removal by pretreatment to prevent fouling of reverse osmosis membranes. Desalination 143: 255-267.

Sheikholeslami, R., Al-Mutaz, I.S., Koo, T., Young, A., 2001. Pretreatment and the effect of cations and anions on prevention of silica fouling. Desalination 139:83-95.

Tables

Table 1. SD033 Historical Water Quality (2005-2011)

	Parameter	Units	# of Samples	Minimum	Maximum	Average
Required Monitoring Parameters	**Bicarbonates (Alkalinity as CaCO3)**	mg/L	61	287	398	341
	Chloride	mg/L	46	2.7	5.51	4.34
	Flow	mgd	57	0	4.94	1.43
	Hardness, Carbonate (as CaCO3)	mg/L	37	287	367	332
	Iron, Dissolved	mg/L	40	<0.05	0.119	0.0020
	Mercury, Low Level	ng/L	56	<.5	4	1.1
	pH	Std Units	57	7.35	8.5	8.00
	Silver	ug/L	25	0.012 or <.4	0.012 or <.4	0.00048
	Solids, Total Dissolved (TDS)	mg/L	46	1150	2140	1800
	Solids, Total Suspended (TSS)	mg/L	37	<1	7	3.1
	Specific Conductance	umh/cm	69	507	3000	2178
	Sulfate	mg/L	61	591	2520	1099
	Turbidity	NTU	38	<0.05	2.4	0.74
Non-Required Monitoring Parameters	**Arsenic**	ug/L	2	<2	<2	<2
	Bromide	mg/L	1	<.5	<.5	<.5
	Calcium	mg/L	53	53.3	111	87.8
	Cobalt	ug/L	2	0.27 or <2	0.27 or <2	0.33
	Copper	ug/L	0	<2	<2	<2
	Fluoride	mg/L	2	0.16	0.2	0.18
	Hardness, Total as CaCO3	mg/L	61	109	1420	1166
	Magnesium	mg/L	53	172	280	247
	Nickel	ug/L	1	<2	<2	<2
	Nitrogen, Ammonia as N	mg/L	1	<.1	<.1	<.1
	Nitrogen, Nitrate+Nitrite as N	mg/L	1	0.24	0.24	0.24
	Phosphorous, Total as P	mg/L	1	0.009	0.009	0.009
	Potassium	mg/L	1	57.4	57.4	57.4
	Salinity	Std Units	15	0.9	1.4	1.2
	Selenium	ug/L	1	<2	<2	<2
	Sodium	mg/L	1	90.7	90.7	90.7
	Total Organic Carbon	mg/L	1	4.4	4.4	4.4
	Zinc	ug/L	1	<25	<25	<25

Table 2. Comparison of Area 5NW and SD033 Water Qualities

	Location	**Area 5 NW**	**SD033**
	Date	**8/16/2012**	**8/16/2012**
	Sample Type	**N**	**N**
	Fraction		
General Parameters			
Alkalinity, bicarbonate, as CaCO3	NA	**260 mg/l**	**400 mg/l**
Alkalinity, total	NA	**270 mg/l**	**400 mg/l**
Carbon, dissolved organic	NA	**2.9 mg/l**	**3.2 mg/l**
Carbon, total organic	NA	**3.0 mg/l**	**2.9 mg/l**
Chloride	NA	**3.6 mg/l**	**4.0 mg/l**
Fluoride	NA	**0.21 mg/l**	**0.17 mg/l**
Nitrogen, ammonia (NH3), as N	NA	< 0.200 mg/l	< 0.200 mg/l
Nitrogen, Nitrate as N	NA	< 0.40 mg/l	< 1.0 mg/l
pH	NA	**8.5 pH units**	**8.1 pH units**
Phosphorus, total	NA	< 0.100 mg/l	< 0.100 mg/l
Silicon dioxide	NA	**8.08 mg/l**	**8.93 mg/l**
Solids, total dissolved	NA	**1700 mg/l**	**2100 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l
Specific Conductance @ 25oC	NA	**2000 umhos/cm**	**2500 umhos/cm**
Sulfate	NA	**1000 mg/l**	**1200 mg/l**
Metals			
Aluminum	Total	< 10 ug/l	< 10 ug/l
Arsenic	Total	< 1.0 ug/l	**1.5 ug/l**
Barium	Total	**5.8 ug/l**	**4.1 ug/l**
Boron	Total	**0.14 mg/l**	**0.17 mg/l**
Calcium	Total	**81 mg/l**	**95 mg/l**
Cobalt	Total	< 0.20 ug/l	< 0.20 ug/l
Copper	Total	**2.6 ug/l**	**2.9 ug/l**
Iron	Dissolved	< 0.050 mg/l	< 0.050 mg/l
Iron	Total	< 0.050 mg/l	< 0.050 mg/l
Lead	Total	< 0.20 ug/l	< 0.20 ug/l
Magnesium	Total	**230 mg/l**	**290 mg/l**
Manganese	Dissolved	**2.7 ug/l**	**200 ug/l**
Manganese	Total	**28 ug/l**	**210 ug/l**
Nickel	Total	< 0.50 ug/l	< 0.50 ug/l
Potassium	Total	**57 mg/l**	**69 mg/l**
Selenium	Total	< 1.0 ug/l	< 1.0 ug/l
Silicon	Total	**4.7 mg/l**	**5.4 mg/l**
Sodium	Total	**110 mg/l**	**120 mg/l**
Strontium	Total	**290 ug/l**	**350 ug/l**
Vanadium	Total	< 0.50 ug/l	< 0.50 ug/l
Zinc	Total	< 5.0 ug/l	**5.0 ug/l**

Table 3. Analytical Methods

Parameter	Method (or equal)
Alkalinity, bicarbonate	SM 2320 B-97
Alkalinity, carbonate	SM 2320 B-97
Alkalinity, total	SM 2320 B-97
Aluminum, total	EPA 6020
Ammonium	ASTM D6919
Barium, total	EPA 6020
Boron, total	EPA 6010B
Calcium, total	EPA 6010B
Carbon, dissolved organic	SM 5310C
Carbon, total organic	SM 5310C
Chemical oxygen demand	SM 5220 D-97
Chloride	EPA 9056A
Conductivity, specific	SM 2510 B-97
Fluoride	EPA 9056A
Iron, dissolved	EPA 6010B
Iron, total	EPA 6010B
Magnesium, total	EPA 6010B
Manganese, dissolved	EPA 6020
Manganese, total	EPA 6020
Nitrate	EPA 9056A
pH	SM 4500H-00
Phosphate, ortho	EPA 9056A
Phosphorus, total	EPA 6010B
Potassium, total	EPA 6010B
Silica, reactive	ASTM 859D-10
Silica, total	EPA 6010B
Sodium, total	EPA 6010B
Solids, total dissolved	SM 2540-C-97
Solids, total suspended	SM 2540-D-97
Strontium, total	EPA 6020
Sulfate	EPA 9056A

Table 4. Reverse Osmosis Sampling Schedule

	Location							
Parameter	Area 5NW	Feed Tank Effluent	Greensand Filter backwash	Pretreated Effluent	RO Permeate	RO Concentrate	RO CIP 1	RO CIP 2
Alkalinity, bicarbonate	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Alkalinity, total	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Aluminum, total	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Ammonia	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Arsenic, total	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Barium, total	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Boron, total	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Calcium, total	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Carbon, dissolved organic	Weekly	--	--	Weekly	--	--	--	--
Carbon, total organic	Weekly	--	Biweekly	Weekly	Weekly	Weekly	--	--
Chloride	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Chemical oxygen demand	--	--	Biweekly	--	--	--	Each	Each
Conductivity, specific	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Fluoride	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Iron, dissolved	Weekly	Weekly	Biweekly	Weekly	--	--	--	--
Iron, total	Weekly	Weekly	Biweekly	Weekly	Weekly	Weekly	Each	Each
Magnesium, total	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Manganese, dissolved	Weekly	Weekly	Biweekly	Weekly	--	--	--	--
Manganese, total	Weekly	Weekly	Biweekly	Weekly	Weekly	Weekly	Each	Each
Nitrate	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
pH	Weekly	Weekly	Biweekly	Weekly	Weekly	Weekly	Each	Each
Phosphorus, total	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Potassium, total	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Silica, reactive	Weekly	--	--	Weekly	--	--	--	--
Silica, total	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Sodium, total	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Solids, total dissolved	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Solids, total suspended	Weekly	Weekly	Biweekly	Weekly	Weekly	Weekly	Each	Each
Strontium, total	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each
Sulfate	Weekly	--	Biweekly	Weekly	Weekly	Weekly	Each	Each

Table 5. VSEP Sampling Schedule

	Extended Duration Testing						
	Batch Mode		Single-Pass Mode			Common to Both Modes of Operation	
Parameter	**VSEP Feed/Concentrate**	**VSEP Permeate**	**VSEP Feed***	**VSEP Concentrate**	**VSEP Permeate**	**VSEP CIP 1**	**VSEP CIP 2**
Alkalinity, bicarbonate	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Alkalinity, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Aluminum, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Ammonia	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Arsenic, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Barium, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Boron, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Calcium, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Carbon, total organic	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	--	--
Chloride	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Chemical oxygen demand	--	--	--	--	--	2/month	2/month
Conductivity, specific	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Fluoride	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Iron, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Magnesium, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Manganese, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Nitrate	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
pH	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Phosphorus, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Potassium, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Silica, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Sodium, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Solids, total dissolved	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Solids, total suspended	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Strontium, total	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month
Sulfate	Composite 1/week	Composite 1/week	Weekly grab	Weekly grab	Weekly grab	2/month	2/month

Notes:

**In Single-Pass Mode, the VSEP Feed sample is the same as RO concentrate (from the GE RO unit).*

Figures

- ● Existing Surface Discharges
- ⊙ Existing Groundwater Wells
- ▲ Pilot Test Well
- — Streams and Rivers
- - - Spring Mine Creek - Former Channel

N

0 2,000 4,000
Feet

Figure 1
SITE LAYOUT
Cliffs Erie/PolyMet Mining Inc.
Hoyt Lakes, MN

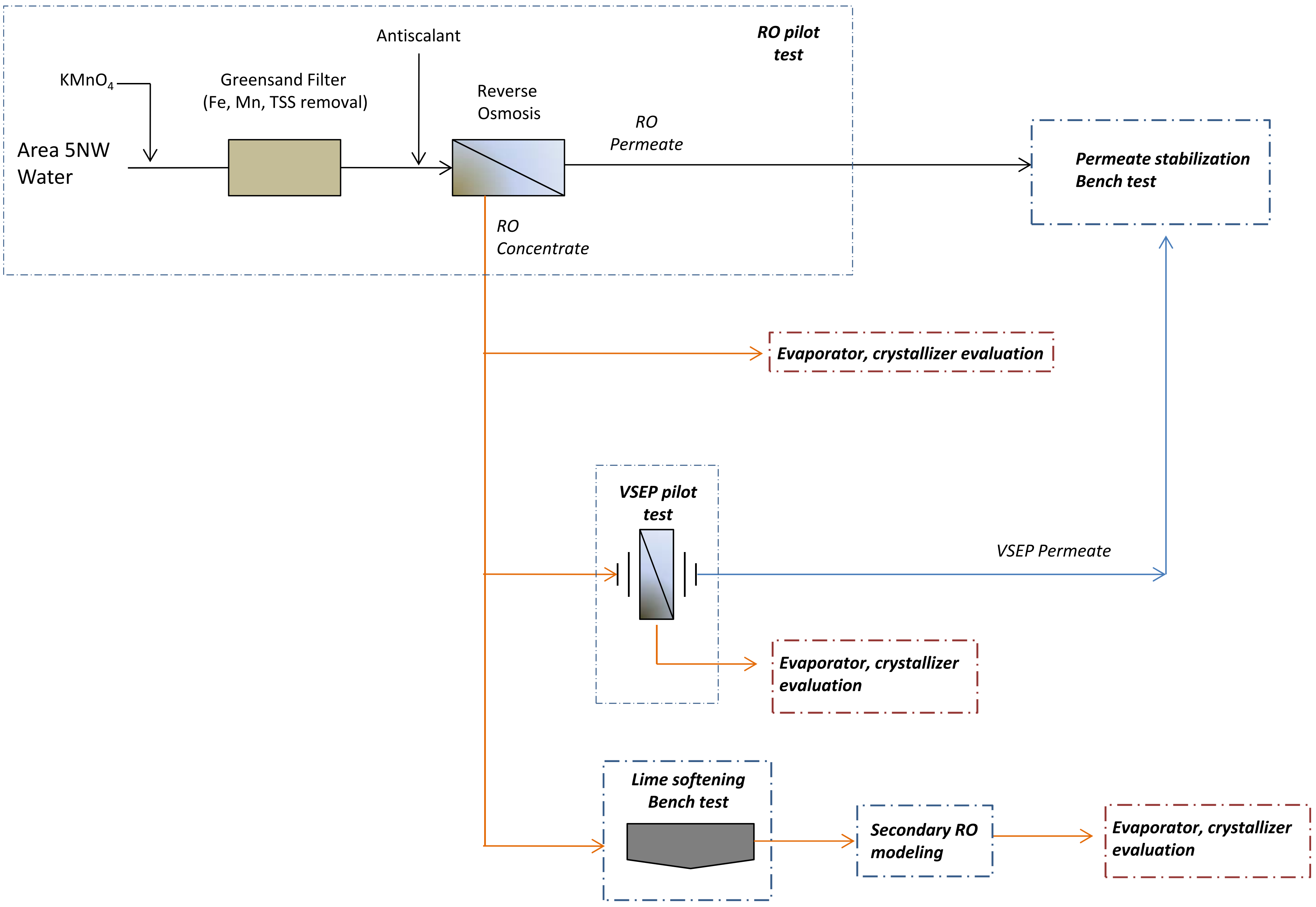


Figure 2. Proposed Testing Structure

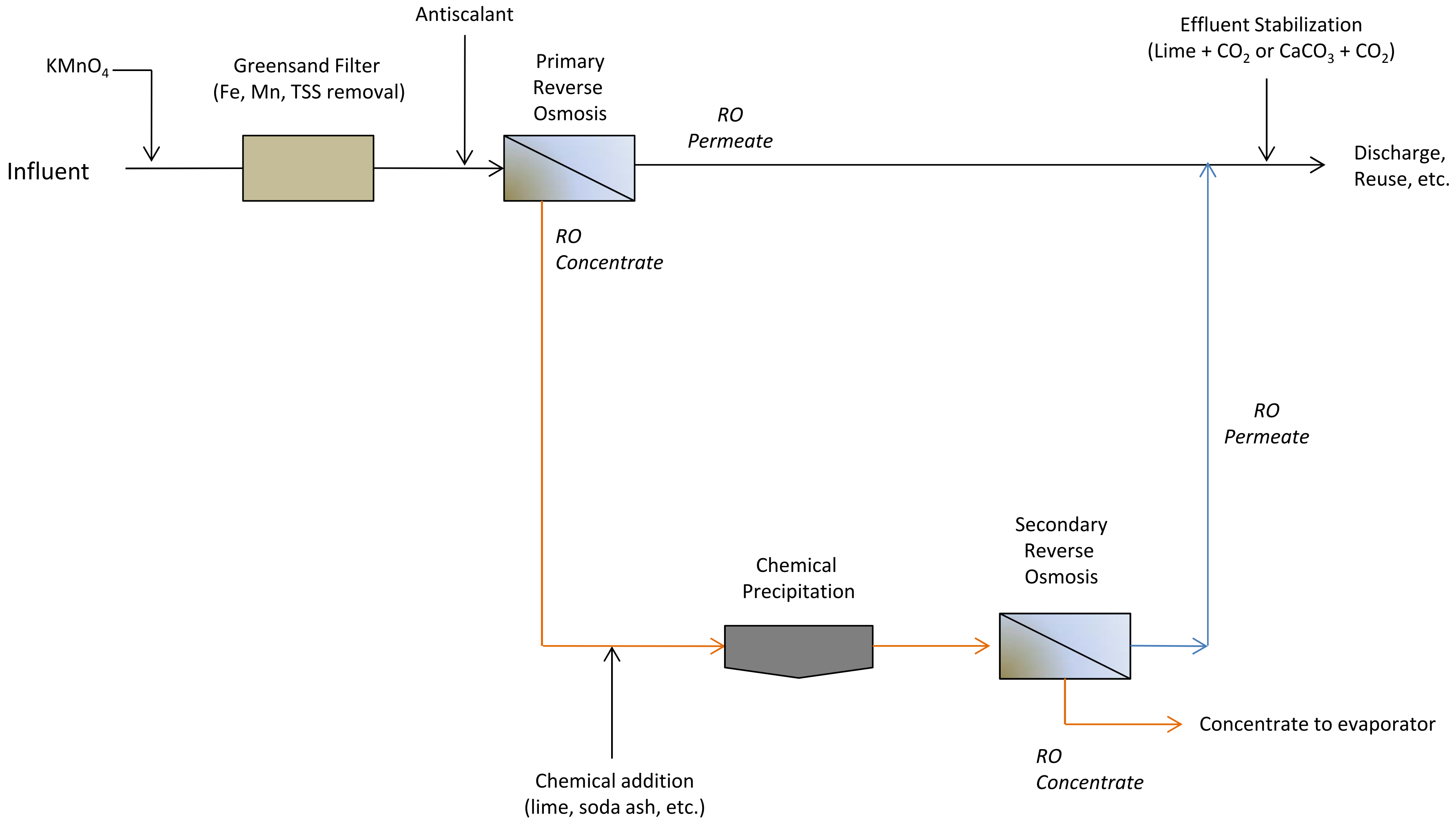


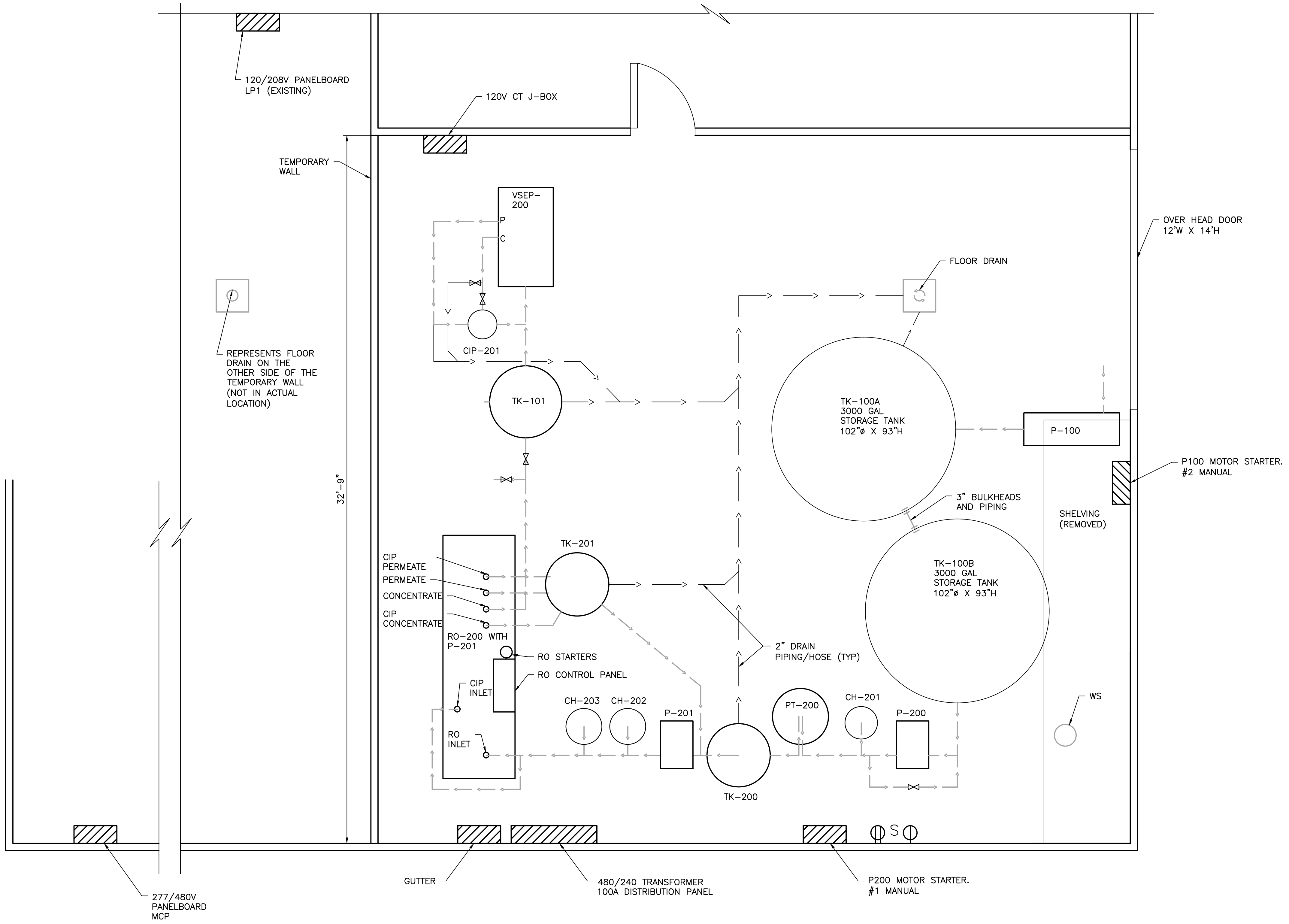
Figure 3. ICCP Illustrative Schematic

Appendices

Appendix A

Pilot Test Facility Drawings

CADD USER: Adeptuser FILE: \\ADEPTXPHIB\HIBBING PW IN\4CEA93E3-9A18-4478-A10E-84A13267474B\83ADFADB-31B9-418E-8B4F-D9A77022AC9A\23691302_NMPP002.DWG PLOT SCALE: 1:2 PLOT DATE: 4/13/2012 3:49 PM



LEGEND:
P – PIPING
TK – TANK
CH – CHEMICAL FEED
PT – PRETREATMENT
RO – RO PILOT SKID
CIP – CIP TANK
VSED – VSED PILOT SKID

NOTES:
1. SEE G.E. DRAWINGS FOR PIPING SIZES.
2. "100" ITEMS BY POLYMET. "200" ITEMS BY G.E./OTHERS.

PROPOSED FLOOR PLAN

0 1 2 3 4 5 6
SCALE

N

POLYMET DRAWING REVIEW
☒ APPROVED
☐ APPROVED AS NOTED
☐ REVISE AND RESUBMIT
BY: PAUL BRUNFELT DATE: 4/13/2012

REV NO	DATE	REVISIONS	BY	CHKR
0	4/13/12	ISSUED FOR CONSTRUCTION	TEG2	JSV
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DRAWN: KRM DATE: 3/16/12
CHECKED: – DATE: –
BARR PROJECT NO.: 23/69-1302
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

WAYNE SITE
WASTE WATER TREATMENT PILOT PLANT
GENERAL ARRANGEMENTS

POLYMET MINING

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING COMPANY
3128 14TH AVENUE EAST
HIBBING, MN.
55746
Ph: 1-800-225-1966
Fax: (218) 262-3460
www.barr.com

DWG. NO. NMPP-002
REV 0

INCHES
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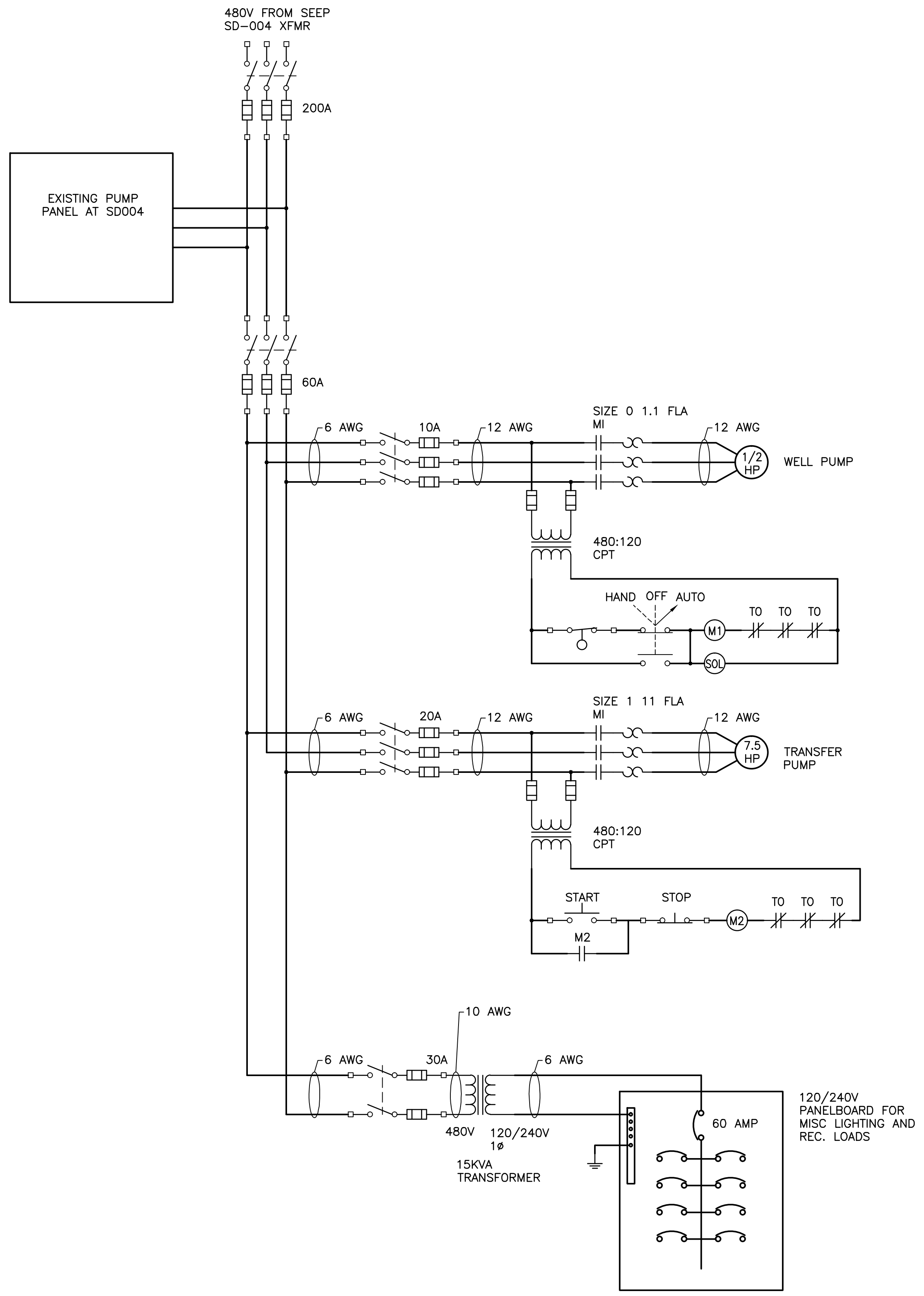

POLYMET DRAWING REVIEW

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☐ REVISE AND RESUBMIT

BY: PAUL BRUNFELT DATE: 4/13/2012

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APPROVED FOR CONSTRUCTION	0	4/13/12	–	–

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DATE ______ REG. NO. ______

DRAWN: KDS	DATE: 4/10/12
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BARR PROJECT NO.: 23/69-1302	
SCALE: AS SHOWN	

PLANT DRAWING NUMBER:

TAILINGS BASIN
PILOT PLANT ON SITE STORAGE
ELECTRICAL SCHEMATIC

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR ENGINEERING COMPANY
3128 14TH AVENUE EAST
HIBBING, MN.
55746
Ph: 1-800-225-1966
Fax: (218) 262-3460
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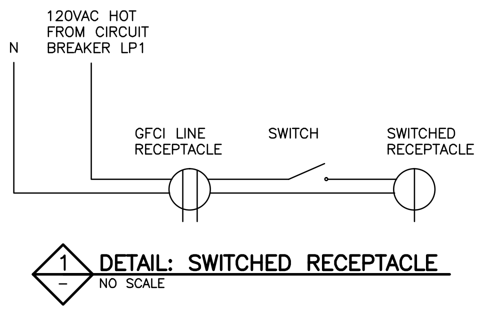
DWG. NO. NMPP-005

REV 0



DETAIL: SWITCHED RECEPTACLE
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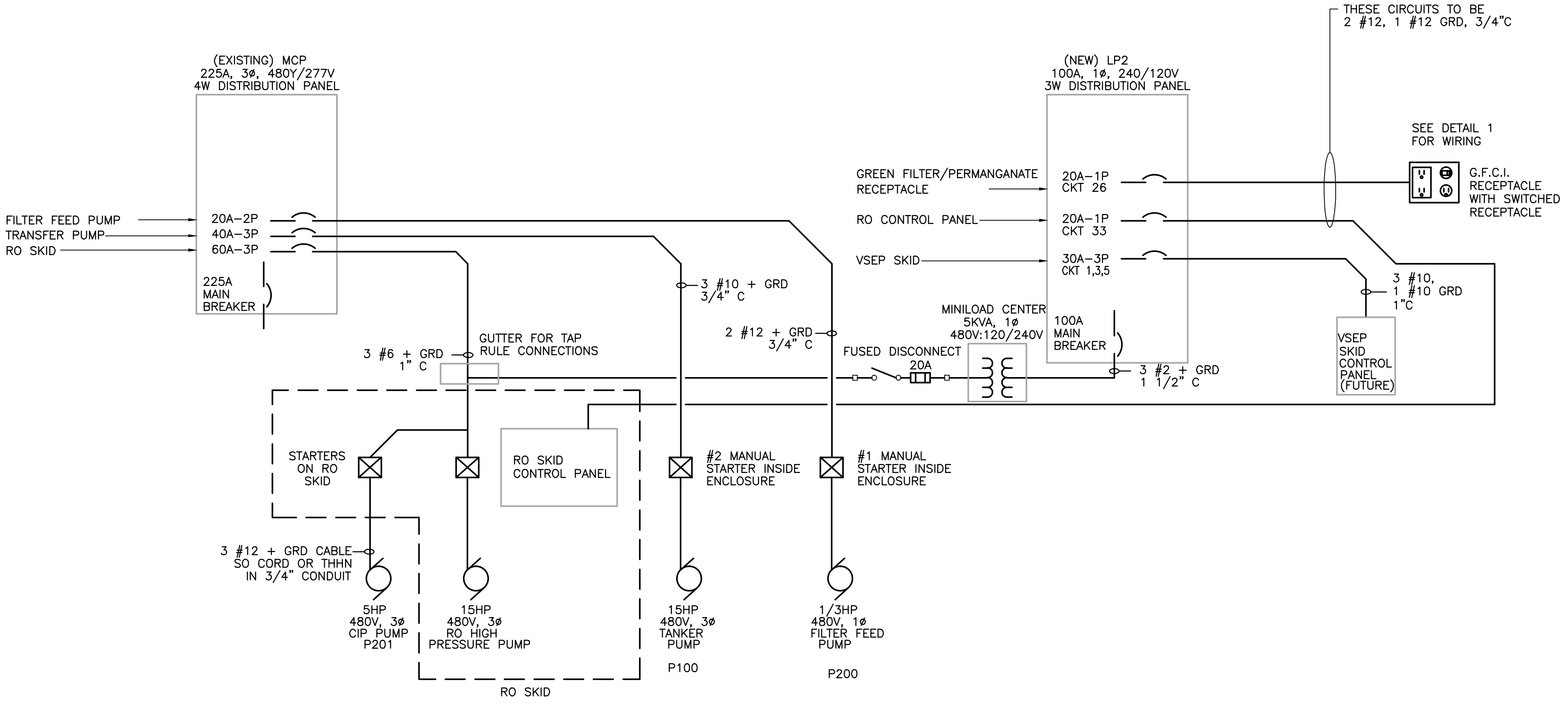

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NO SCALE

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POLYMET DRAWING REVIEW
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☐ APPROVED AS NOTED
☐ REVISE AND RESUBMIT
BY: PAUL BRUNFELT DATE: 4/13/2012

REV NO	DATE	REVISIONS	BY	CHKR
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DATE ________ REG. NO. ________

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CHECKED: –	DATE: –
BARR PROJECT NO.: 23/69–1302	
SCALE: AS SHOWN	

PLANT DRAWING NUMBER:

WAYNE SITE
WASTE WATER TREATMENT PILOT PLANT
ELECTRICAL SYSTEM DIAGRAM

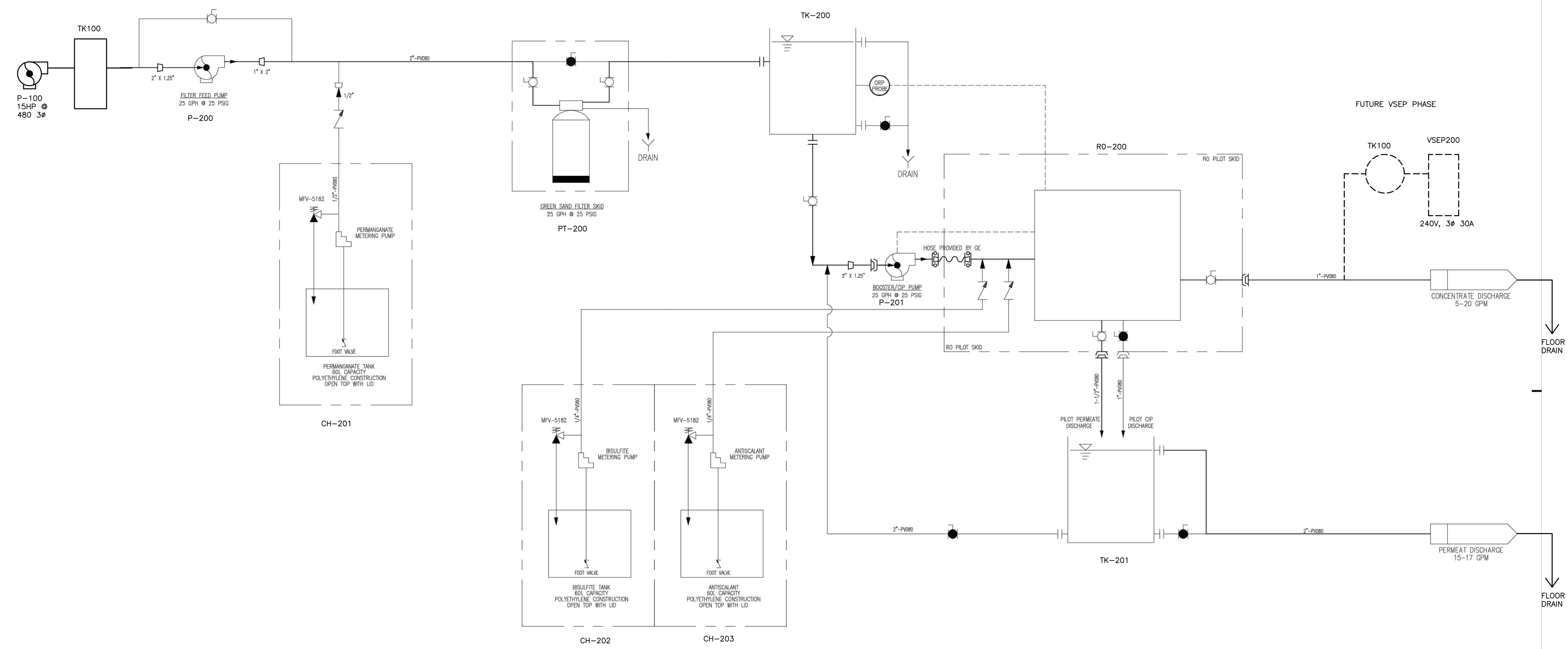
POLYMET MINING

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING COMPANY
3128 14TH AVENUE EAST
HIBBING, MN.
55746
Ph: 1–800–225–1966
Fax: (218) 262–3460
www.barr.com

DWG. NO. NMPP–006
REV 0

CADD USER: Adeptuser FILE: \\ADEPTXPHIB\HIBBING PW IN\565439ED-135B-4E7D-B3C2-447010DAB133\BCAA0E7B-D25F-4BDC-A7FB-E5FD2A7D32EB\23691302_NMPP007.DWG PLOT SCALE: 1:2 PLOT DATE: 4/13/2012 3:27 PM



FEED PUMP	PERMANGANTE PUMP	MEDIA FILTER	BISULFITE PUMP	ANTISCALANT PUMP	RO CONTROLS EQUIPMENT	RO PILOT PUMPS CONNECTION
208/440V / 4.25/1.95A / 1Ph / 60Hz	115V / 1A / 1Ph / 60Hz	115V / 15A / 1Ph / 60Hz	115V / 1A / 1Ph / 60Hz CAN BE PLUGGED INTO RO PILOT OR SEPARATE SUPPLY	115V / 1A / 1Ph / 60Hz CAN BE PLUGGED INTO RO PILOT OR SEPARATE SUPPLY	115V / 15A / 1Ph / 60Hz	460V / 60A / 3Ph / 60 Hz

POLYMET DRAWING REVIEW
☒ APPROVED
☐ APPROVED AS NOTED
☐ REVISE AND RESUBMIT
BY: PAUL BRUNFELT DATE: 4/13/2012

REV NO	DATE	REVISIONS	BY	CHKR
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DRAWING STATUS

ISSUED	REV	DATE	SDE	PEM
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DRAWN: KDS DATE: 3/28/12
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BARR PROJECT NO.: 23/69-1302
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

WAYNE SITE
WASTE WATER TREATMENT PLAN
PIPING AND INSTRUMENT DIAGRAM

POLYMET MINING

POLYMET MINING CORPORATION
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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3128 14TH AVENUE EAST
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REV 0

INCHES
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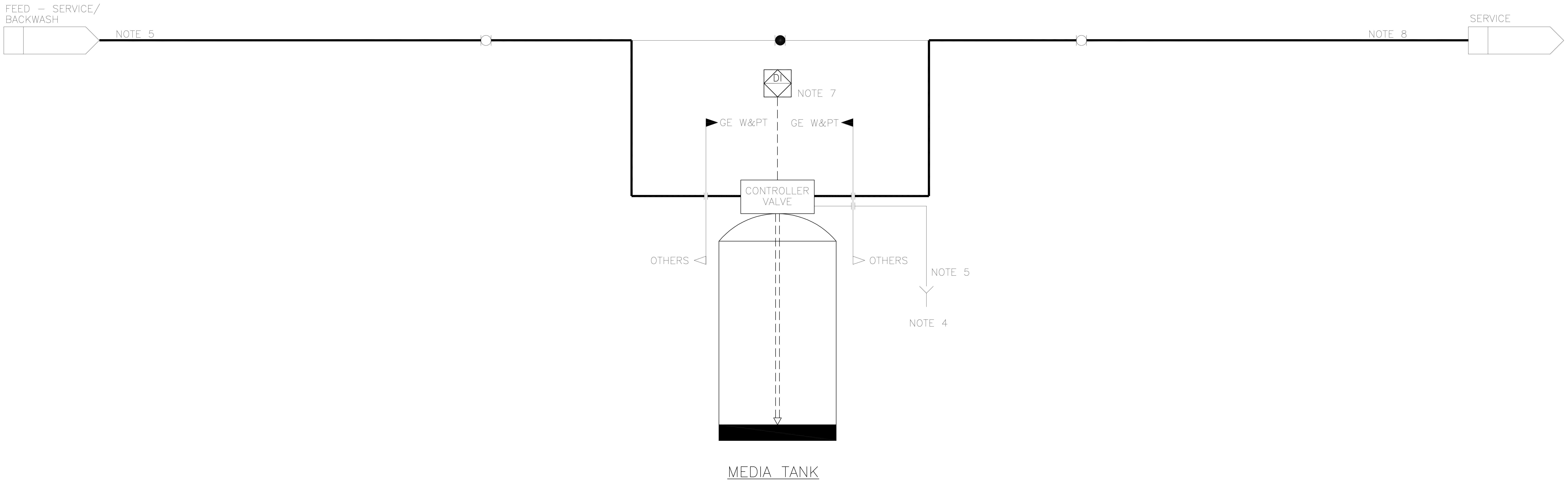
2

Appendix B

GE Pilot Test Information



SYSTEM INFORMATION (EACH)				
TANK SIZE (IN.);	SERVICE (GPM): NOTE 5	BACKWASH(GPM): NOTE 5	INLET/OUTLET CONNECTIONS SIZE (IN):	DRAIN CONNECTION SIZE (IN):
10	1.5–5	6	1.0 SPG	0.75 MPT
14	3–9	10	1.0 SPG	0.75 MPT
21	6–18	25	2.0 SPG	1.5 SPG
30	15–45	50	2.0 SPG	2.0 MPT
36	20–60	75	2.0 SPG	2.5 MPT

NOTE:

1. MANUAL VALVES AND PIPING IN CUSTOMER SCOPE OF SUPPLY.
2. WATER PRESSURE 25 PSI MINIMUM AND 125 PSI MAXIMUM.
3. A 120 VOLT ELECTRICAL OUTLET SHOULD BE PROVIDED WITHIN 10 FEET OF EQUIPMENT.
4. REFER TO INSTALLATION MANUAL FOR INSTALLATION INSTRUCTION. TO MEET SANITARY REQUIREMENTS, THE DRAIN LINE MUST BE PIPED TO AN OPEN DRAIN WHERE FLOW (DURING REGENERATION) CAN BE OBSERVED AND AN AIR GAP CAN BE MAINTAINED IN ACCORDANCE WITH LOCAL PLUMBING CODES.
5. FEED LINE AND DRAIN LINE SHALL BE SIZED FOR BACKWASH FLOW.
6. MEDIA SHIPPED LOOSE AND LOADED ON SITE BY CUSTOMER.
7. CONTROLLER IS PROVIDED WITH SWITCH FOR EQUIPMENT LOCKOUT DURING REGENERATION.
8. NO AUTOMATIC UNFILTERED WATER BYPASS DURING REGENERATION
9. REFERENCE P&ID LEGEND PAGE: 1301227

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	13308	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
.X ± ±
.XX ±
.XXX ±
FRAC
±

DRAWN BY	GRK	DATE 28Jun07
CHECKED BY	RLD	DATE 21Sep07
APPROVED BY	PWG	DATE 21Sep07
APPROVED BY		DATE

GE
Water & Process Technologies
GLOBAL HEADQUARTERS : TREVOSE, PA USA +1–215–355–3300 WWW.GEWATER.COM

CLIENT/JOB
FILE

DWG DESCRIPTION
PIPING & INSTRUMENTATION DIAGRAM
CARBON, FRP, SINGLE

MATERIAL/BOM NO.

SIZE D
DRAWING NO. 1303222
REV A
PROJECT
SCALE NONE
SHEET 1 OF 1

P/N 1161662–RGP01

REVISION HISTORY

REV	ZONE	DESCRIPTION	ECO	DWN	DATE	APVD
A	–	INITIAL RELEASE	–	–	–	–

LEGEND

1. INLET, 1.50" FLANGE
2. ELECTRICAL ASSEMBLY
3. PRE–FILTER PRESSURE GAUGE, 1–160 PSIG
4. POST–FILTER PRESSURE GAUGE, 1–160 PSIG
5. PRIMARY PRESSURE GAUGE/TRANSMITTER, 1–600 PSIG
6. FINAL PRESSURE GAUGE/TRANSMITTER, 1–600 PSIG
7. INLET ORP, THORNTON 770MAX
8. INLET pH, THORNTON 770MAX
9. INLET CONDUCTIVITY, THORNTON 770MAX
10. CONCENTRATE FLOWMETER, THORNTON 770MAX
11. PERMEATE FLOWMETER, THORNTON 770MAX
12. PERMEATE CONDUCTIVITY, THORNTON 770MAX
13. CONCENTRATE OUTLET, 1.00" FLANGE
14. CONCENTRATE OUTLET CIP, 1.00" HOSEBARB
15. PERMEATE OUTLET, 1.50" FLANGE
16. PERMEATE OUTLET CIP, 1.00" HOSEBARB
17. RO MOTOR STARTER ASSEMBLY
18. RO PUMP AND MOTOR, SS5512KZA W/ 15 HP, TEFC
19. CIP PUMP AND MOTOR, SS5503G W/ 5 HP, TEFC
20. CIP MOTOR STARTER ASSEMBLY
21. CIP INLET, 3.00" VICTAULIC

NOTICE ON REPRODUCTIONS

GE Osmonics
GE Water Technologies
5951 CLEARWATER DRIVE, MINNETONKA, MN 55343–8995 (952) 933–2277
WWW.GEWATER.COM

MATERIAL SEE BOM	TOLERANCES UNLESS NOTED FRAC ± DECIMALS .X ± .XX ± .50 .XXX ± ANGLES ± 1°		
FINISH			
ORDER NO.	DWN PDT	DATE 18Jan05	
CUSTOMER	CHKD BRB	DATE 19Jan05	
CUSTOMER LOC.	APVD JSS	DATE 17Jan05	
DO NOT SCALE	APVD	DATE	

TITLE
DWG, RO, PES–18
PALL PILOT SYSTEM

SIZE		DWG NO/PN	REV
D	THIRD ANGLE	2300026A–951	A
SCALE 3/32		FILE TYPE ACR2004	SHEET 1 OF 1

Appendix C

Effluent Stabilization Testing Procedure

Effluent Stabilization Bench Testing Protocol

Prepared for
Cliffs Erie LLC and PolyMet Mining, Inc.

September 2012

Effluent Stabilization Bench Testing Protocol

Prepared for
Cliffs Erie LLC and PolyMet Mining, Inc.

September 2012

BARR

4700 West 77th Street
Minneapolis, MN 55435-4803
Phone: (952) 832-2600
Fax: (952) 832-2601

Effluent Stabilization Bench Testing Protocol

September 2012

Table of Contents

List of Tables

List of Figures

1.0 Objectives

There are two objectives of this bench test: (1) Identify a stabilization method (e.g. addition of minerals) that will reduce the corrosiveness of the blended effluent and maintain compliance with the effluent water quality targets, and (2) produce a non-toxic effluent in the whole effluent toxicity (WET) test. There will be two series of bench tests conducted: (1) testing the ability of a combination of hydrated lime ($Ca(OH)_2$) and carbon dioxide (CO_2) to stabilize the blended effluent and (2) testing the ability of crushed limestone to stabilize the blended effluent. Samples of effluent stabilized by each method will undergo acute and chronic WET testing with *C. dubia*.

All of the chemical dosages contained in this plan are approximations based on software modeling and will be finalized as water chemistry data is produced and evaluated.

2.0 Chemical Modeling

The stabilization processes were modeled using PHREEQC, an aquatic equilibrium model developed by United States Geological Survey. Both series of bench tests were simulated to determine the optimal dosage of each chemical along with the corresponding optimal pH. The results of the modeling are summarized in Table 1. The optimal pH and dosage were defined as giving the equilibrium solution a calcite saturation index of about 0.1. The optimal CO_2 dose for the limestone addition was defined as doubling the reverse osmosis (RO) and Vibratory Shear Enhanced Processing (VSEP) blended effluent calcite saturation index. A CO_2 dosage should make the limestone/blended effluent reaction happen quicker, potentially reducing the size of the limestone bed needed.

Table 1. PHREEQC Modeling Results

Addition	Chemical	Optimal Dose (mg/L)	Optimal pH	$CaCO_3$ SI Index
Lime and CO_2	$Ca(OH)_2$	111	7.26	0.10
	CO_2	60	7.26	0.10
Limestone	$CaCO_3$	505	7.26	0.10

3.0 Experimental Procedures

3.1 Lime and Carbon Dioxide Addition

This procedure will involve adding six different doses of hydrated lime to separate beakers containing the blended effluent. CO_2 will then be bubbled through the solution until the solution reaches the optimal pH (7.3) as defined by PHREEQC. Samples will be collected and tested for compliance with the effluent water quality targets.

Materials:

- 6-clean 3-L beakers
- 18-liters of RO/VSEP blended effluent
- Pressurized CO_2
- CO_2 addition equipment
- $Ca(OH)_2$
- pH meter
- Bottles to collect samples to be tested for water quality tests

Procedure:

1. Add 3-L of blended effluent to separate clean beakers and label 1-6
2. Add each dose of hydrated lime from Table 2 to the corresponding beaker of blended effluent and mix
3. Insert a pH meter into beaker 1 and bubble a 5%:95% carbon dioxide/nitrogen gas mix through the solution until it reaches the optimal pH predicted by PHREEQC (7.3) as shown in Table 1
4. Collect a samples of solution in beaker 1
    a. Test pH at time of collection
    b. Collect analytical samples for compliance with the effluent water quality targets. The WET sample will be for 100% effluent only, thus will have a volume of approximately 1.5 L.
5. Repeat steps 3-4 with beakers 2-6.

Table 2. $Ca(OH)_2$ Dosages

Jar	1	2	3	4	5	6
$Ca(OH)_2$ dose (mg/L)	0	56	83	111	167	222

3.2 Calcium Carbonate Addition

The evaluation of the use of calcium carbonate for effluent stabilization will be a two-phase procedure. The first phase will test the kinetics of mixing blended effluent with limestone rock to estimate the required limestone bed residence time. The second phase will test the water quality of the blended effluent following the limestone addition and will evaluate if a pre-limestone carbon dioxide (CO_2) addition significantly decreases the limestone bed residence time required.

3.2.1 Phase I - Kinetics Test

Objective: The first phase of this procedure will be a kinetics test to determine the necessary residence time of the bed.

Method: An excess amount of crushed limestone will be added to jars and topped off with blended effluent. A pH meter will then be inserted into the beakers and the time it takes each solution to reach optimal pH (7.3) will be measured.

Materials:

- 3 clean beakers
- RO/VSEP blended effluent
- Crushed limestone
- pH meter
- Stopwatch

Procedure:

1. Add crushed limestone to 3 clean beakers to half full
2. Top off beaker 1 with blended effluent and begin stopwatch
3. Insert pH meter into beaker 1 and record time required to reach pH 7.3
4. Repeat steps 2 and 3 for beakers 2 and 3
5. Average the time required to reach pH 7.3 and use as the optimal residence time

3.2.2 Phase II - Water Quality and CO_2 Test

Objective:

1) Test the water quality of the effluent from the limestone bed process flow to confirm that water quality goals are met
2) Test whether CO_2 addition will significantly reduce the required residence time in the limestone bed

Method: The second phase involves setting up 6 columns with 1.5 feet of crushed limestone each. The blended effluent will then be run through the columns at a flow rate that will achieve a determined residence time. Samples will be collected and tested for compliance with the effluent water quality targets, including WET. The same procedure will be repeated with blended effluent that has been supersaturated with CO_2. The calcite saturation indices for each sample will be determined and the non-CO_2 addition and CO_2 addition samples (tested with the same residence time) will be compared to estimate residence time reductions.

Materials:

- 6-test columns
- 60-liters of RO/VSEP blended effluent
- 30-L Carboy with sealable cap
- CO_2 and compressed air gas tank
- Gas sparge stone
- Compressed air gas tank
- Crushed limestone
- pH meter
- Stopwatch
- 3-L Beakers for collecting composite samples
- Bottles to collect samples for water quality tests

Procedure:

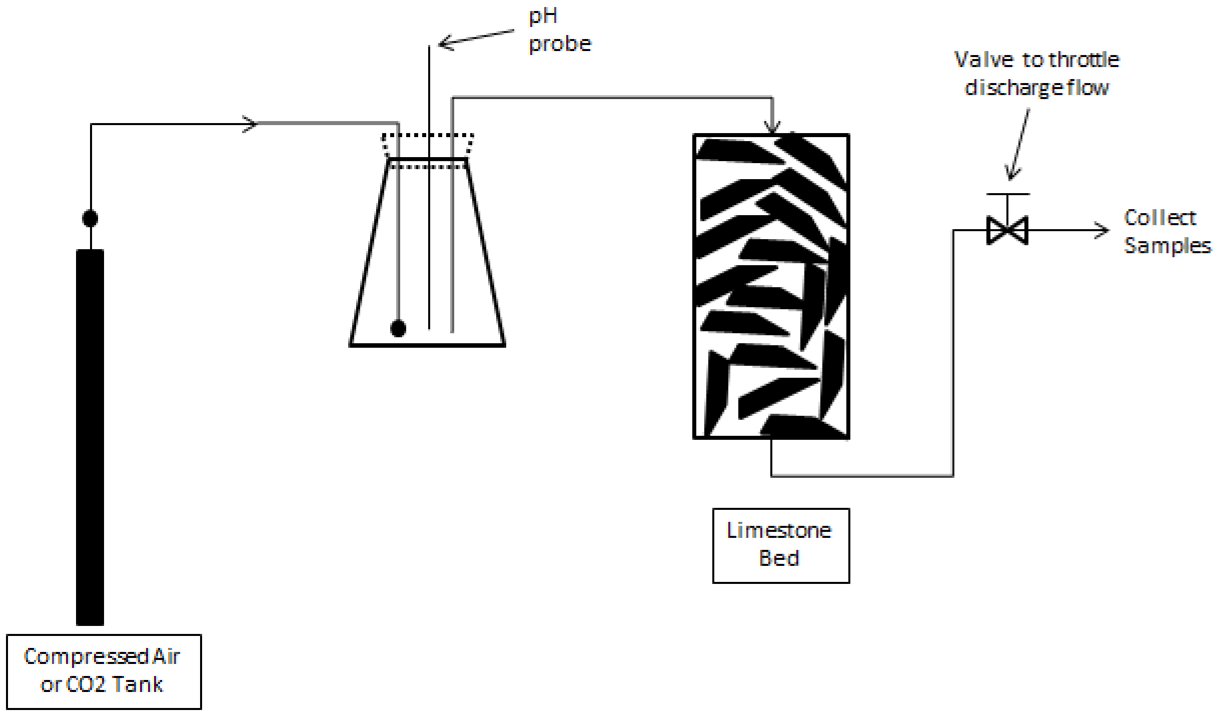
1. Calculate the 5 different effluent flows required based on the residence times shown in Table 3 and a set volume of 1.5 feet of crushed limestone in each column
2. Add 1.5 feet of crushed limestone to 3 test columns 2-6. Column 1 will be a control column that will contain no limestone.
3. Connect compressed air tank to process flow shown in Figure 1
4. Allow process in Figure 1 to deliver blended effluent to columns 1-6
5. Allow 2 limestone bed volumes of water to pass through system and discard
6. Collect samples from all 6 test columns (3-L composite samples from each)
    a. Test pH at time of collection
    b. Collect analytical samples for compliance with the effluent water quality targets. The WET sample will be for 100% effluent only, thus will require approximately 1.5 liters of sample.
7. Disconnect compressed air tank from process and connect CO_2 gas tank
8. Bubble CO_2 into blended effluent until optimal pH stabilizes
9. Repeat steps 4-6

Table 3. Required Residence Times

Column	1	2	3	4	5	6
Residence Time (s)	0.25*Optimal	0.5*Optimal	0.75*Optimal	Optimal	1.5*Optimal	2*Optimal

Optimal=Optimal residence time calculated in Phase I

Figure 1. $CaCO_3$ Addition Process Flow Diagram



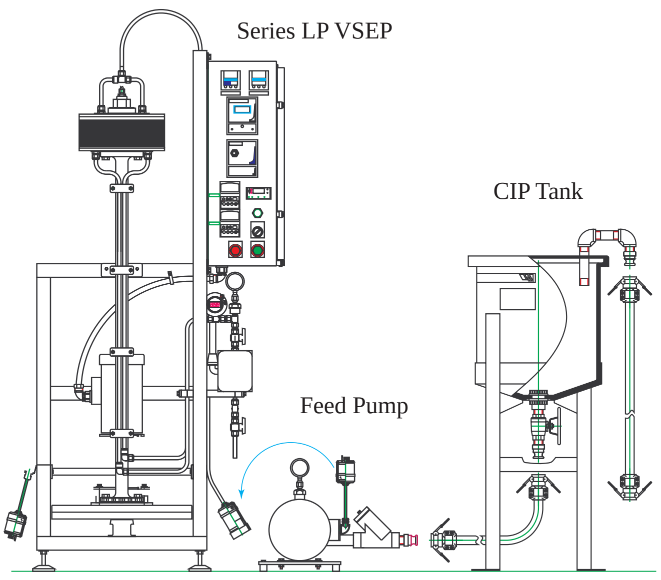
Appendix D

New Logic Research Pilot Test Information

VSEP - Vibratory Shear Enhanced Process

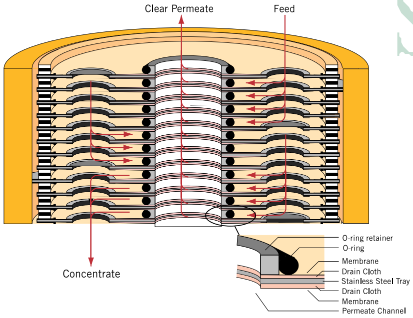
Description:

The V✧SEP Filtration System incorporates the patented Vibrating Membrane Filtration Technology. The key ingredient that comes from the vibrational oscillation is highly focused shear energy at the membrane surface. The combination of this plus pressure creates a non-fouling, high yielding, and efficient way of filtration for previously difficult separation applications. Throughputs of up to 225,000 GPD per module, (based on 150 GFD) are possible with a footprint of only 16 SF (1.5 m2). Torsional vibration created by an induced wobble in an opposing mass creates the necessary shear at the membrane.



Series LP V✧SEP Equipment Set Up

Filter Pack Cross Section



Series LP

The pilot scale VSEP unit is known as the *Series L/P*. This unit is inter-convertible between pilot (P), and laboratory modes (L). In the laboratory L mode, the system acts as a *Series L* with 0.4785 ft^2 of membrane area. However, in pilot P mode, with the addition of a small membrane stack, the membrane area is 16.44 ft^2. For most Microfiltration and Ultrafiltration applications, the Series L/P will filter between 62.5 and 125 gallons per hour (236-473 liters per hour). For Nanofiltration and RO applications, the system will filter approximately 25 to 94 gallons per hour (95-356 liters per hour). These ranges will vary according to feed material, pressure, temperature, and membrane selection.

Specifications:

1] Filter Pack

Membrane:	Reverse Osmosis-Microfiltration
Membrane Area:	16.8 square ft. (1.5 m2)
Max. Temperature:	up to 284 °F (140°C)
Allowable Ph Range:	1-14
Elastomers (O-rings):	EPDM,(Options for Buna, Viton)
Wetted Steel Trays:	304 .018 Gauge Stainless Steel

2] Piping

Maximum Pressure:	600 psi
Process Piping:	1/2” 316L Stainless Steel
Clean in Place Tank:	15 Gallon Polyethylene
Flow Control Valves:	Parker 12Z-PR4-VT-SS

3] Vibration System

Motor:	Baldor, 2HP, 3525 RPM
Speed Controller:	“ABB” ACS400501635
Maximum Decibels:	65

4] Electrical Specifications:

Power Supply Voltage:	240VAC 3 Phase 50/60Hz
Full Load Amp Rating:	30 Amps
Normal Load Amps:	9-26 Amps
Pressure Sensors:	Wika 0-600 Analog Gauge

5] Feed Pump Specifications:

Feed Pump Type:	Hydra-Cell M-10MRSEHHC
Power Supply Voltage:	240VAC 3 Phase 50/60Hz
Motor:	Baldor, 5HP, 1725 RPM, TEFC
Pressure Relief:	Wanner Bypass C22ADBESSEF

6] Pre-Screen Bag Filter:

Filter Housing Type:	316 SS Y-Strainer
Filter Size:	100 Mesh
Capacity:	10 GPM Each

7] Operating Site Conditions:

Equipment Rating:	NEMA 4, Indoor/Outdoor
Ambient Temperature:	5 - 37℃
Storage Temperature:	2 - 70℃ (Protect from Freezing)
Relative Humidity:	<95%, non-condensing
Elevation:	3300 ft max without derating

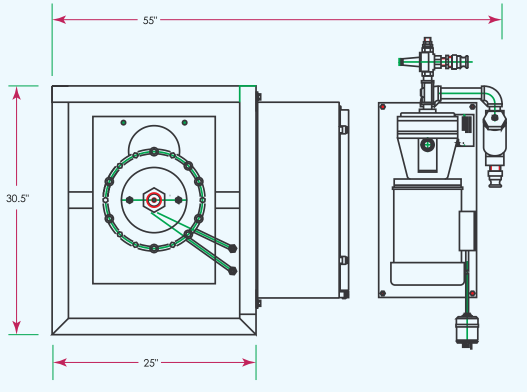
8] Instrumentation:

Temperature:	Ashcroft Digital Thermometer
pH:	Oakton Model EW-27011-11
Conductivity:	Myron L Company Model 758

VSEP Applications:

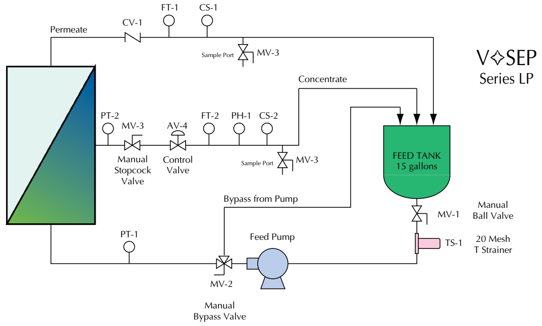
Ultrapure Water
Industrial Wastewater
Chemical Processing
Mineral Slurry Dewatering
Glycol Recovery
Waste Oil Recycling
Phosphate Clarification
Pulp & Paper Closed Loop
Water Recycling
Mining
Oil Production & Processing
Ethanol Production
Polymer & Pigment Diafiltration
Latex Concentration
Laundry Wastewater Recycling
Scrubber Blowdown

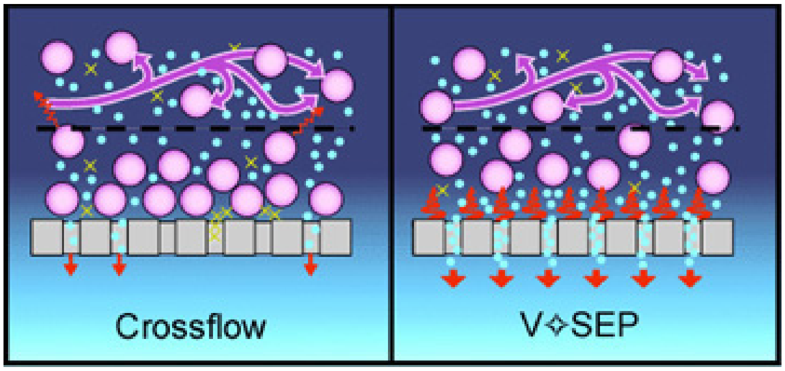
Footprint:



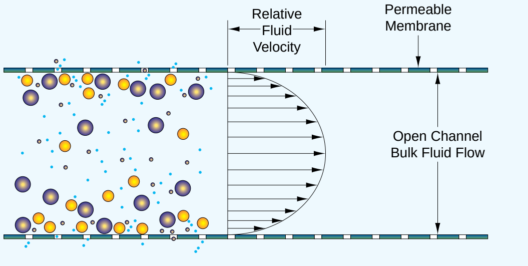
VSEP Series LP Footprint Drawing
(Tank not Shown)

Typical Simplified Flow Diagram:

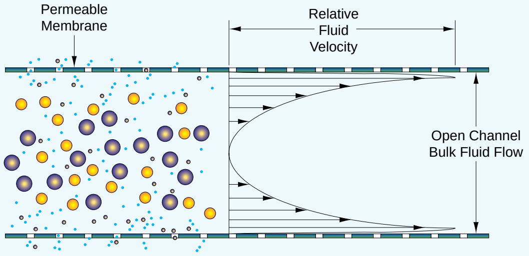




Tangential Flow Pattern in Crossflow Membrane Systems



Tangential Flow Pattern in Vibratory V✧SEP Membrane Systems



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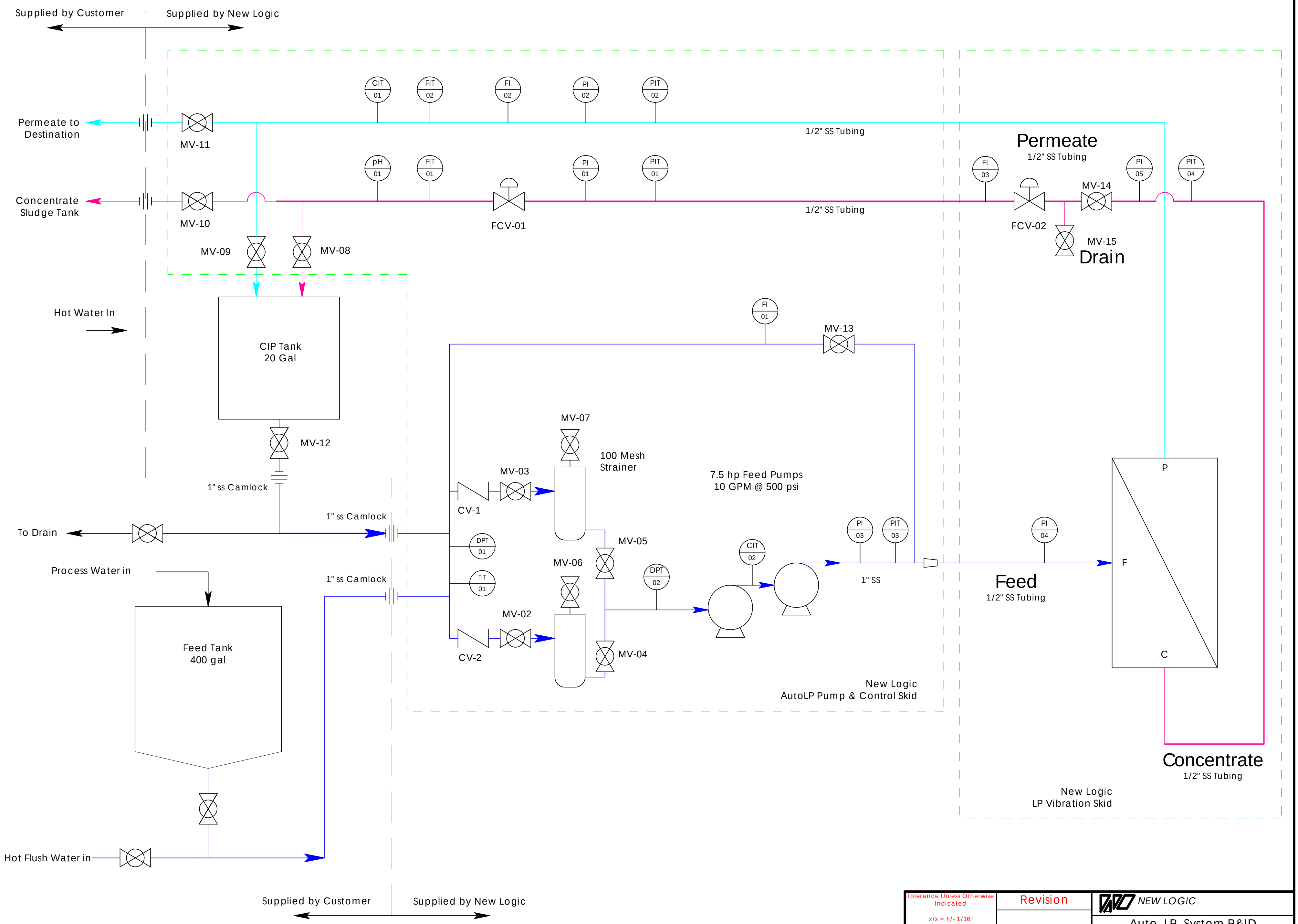

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Tolerance Unless Otherwise Indicated

x/x = +/- 1/16"
.x = +/- .100
.xx = +/- .030
.xxx = +/- .005
x¼ = +/- 30'

Revision

NEW LOGIC

Auto LP System P&ID

Sheet One

C
Scale: 1:18
LP-010

04/20/07
M Ayers

Appendix E

Bench Testing Protocol for Removal of Silica from Reverse Osmosis Concentrate by Chemical Precipitation

Bench Testing Protocol for Silica Removal from Reverse Osmosis Concentrate by Chemical Precipitation

Prepared for
Cliffs Erie LLC and PolyMet Mining Inc.

September 2012

Bench Testing Protocol for Silica Removal from Reverse Osmosis Concentrate by Chemical Precipitation

Prepared for
Cliffs Erie LLC and PolyMet Mining Inc.

September 2012

BARR

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Minneapolis, MN 55435-4803
Phone: (952) 832-2600
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Bench Testing Protocol for Silica Removal from Reverse Osmosis Concentrate by Chemical Precipitation

September 2012

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1.0 Objectives

One method of maximizing recovery (and reducing concentrate volume) in reverse osmosis (RO) systems is the use of intermediate concentrate chemical precipitation (ICCP). ICCP involves treatment of the RO reject to remove certain constituents such as calcium and silica that contribute to RO fouling. After treatment by ICCP, the treated concentrate can be passed through a secondary RO system to reduce the concentrate volume further and maximize permeate production.

This protocol has been developed to test the use of ICCP for silica removal from RO concentrate. Silica and silicates are generic names given to compounds derived from the polymerization of silicic acid ($Si(OH)_4$). In neutral pH waters (pH of 6-8), silicic acid is common and has a propensity to polymerize, eventually forming colloidal polymers of many silicon dioxide molecules linked together. Metal hydroxides, if available, can be incorporated into the polymers to form more complex silicates (Ning, 2002).

In RO systems, the polymers of silicon dioxide and silicates coagulate with themselves and other organic matter and foul membranes, reducing recovery (Ning, 2002). To remove silica from feed water, lime-soda ash softening is commonly used, which increases the pH to 10-11, allowing magnesium hydroxide and calcium carbonate to precipitate. Silica is removed during this process by adsorption onto the surface of magnesium precipitates and by precipitation of the mineral forsterite (Mg_2SiO_4) (Sheikholeslami and Bright, 2002 and Parks and Edwards, 2007).

The rate of silica polymerization drops at a pH above 9.5 and below 5.5. At a pH of 9.5, silicic acid mostly ionizes, preventing polymerization and minimizing fouling potential. Ionized silicic acid (present at pH of 9.5) in the presence of cations like magnesium and calcium causes particulate fouling, but a majority of the cations should be removed during the softening process (Sheikholeslami, Al-Mutaz, and Young, 2001).

Lime-soda ash softening will be tested between RO passes (Figure 1) to reduce silica fouling and increase recovery of the secondary RO system. There are two objectives of this bench test: (1) Identify a softening method (e.g. addition of lime and soda ash) that will minimize the silica concentration and fouling of the secondary RO membranes and (2) Identify the time required for the softening reactions to occur (in order to properly size equipment later).

The amount of silica removal via lime-soda ash softening reportedly ranges from 70% to 90% (Sheikholeslami, Al-Mutaz, and Young, 2001, Sheikholeslami and Bright, 2002, and Parks and Edwards, 2007).

2.0 Chemical Modeling

Table 1 shows the average feed water quality for the primary RO system in Figure 1. Hydranautics' IMSDesign membrane projection software version 2011 was used to predict the resulting concentrate chemistry, with the results then used for modeling of the ICCP process. The results are shown in Table 2.

A simulation of treatment of the concentrate by excess lime and soda ash softening was conducted using PHREEQC, an aquatic equilibrium model developed by United States Geological Survey. The optimal lime and soda ash dosage was defined as the dosage that reduced the magnesium concentration to approximately 5 mg/L, because one pathway of silica removal is by adsorption to magnesium hydroxide. As described in the Objectives section of this report, once the magnesium and calcium are removed, a pH of 9.5 or above reduces silica fouling. Hydrochloric acid (HCl) was then added to the solution to reduce the pH to about 9.5. The results of the PHREEQC modeling are shown in Table 3.

The PHREEQC modeling produced the theoretical lime and soda ash dosages required to reduce the fouling potential of the concentrate and to subsequently increase recovery in the second RO system. The theoretical dosages will be tested on the bench as discussed below.

3.0 Experimental Procedures

3.1 Lime and Soda Ash Addition

This procedure will involve adding three different doses of hydrated lime and soda ash to aliquots of the primary RO concentrate: the optimal dosage, 75% of the optimal dosage, and 125% of the optimal dosage. Following the lime and soda ash additions, samples will be taken from the jars at given time intervals to test the reaction kinetics. The kinetics testing and final samples will be sent to a lab for analytical testing.

Materials:

- 1-Phipps and Bird jar testers with 3 total B-KER^2 laboratory jars (jars)
- 10-L of RO concentrate
- Hydrated lime $Ca(OH)_2$
- Soda ash Na_2CO_3
- 1-stop watch
- 3-Filter manifolds
- 10-0.45 um filters to fit filter manifolds
- 12-Bottles to collect samples to be tested for water quality tests

Procedure:

1. Label jars 1-3
2. Add 2-L of RO concentrate to each clean jar (1-3)
3. Add hydrated lime ($Ca(OH)_2$) to each of the 3 jars according to Table 4 while rapidly stirring
4. Begin stopwatch
5. After 30 seconds turn mixing intensity to low setting
6. After 10 minutes, 30 minutes, and 45 minutes draw 100 mL out of each jar
    - **a.** Filter each of the 10, 30, and 45 samples through a 0.45 um filter immediately after collection and place in a 50 mL nitric acid preserved bottle and send for Si and Mg analysis at analytical lab
7. After 1 hour, add 80% of the theoretical soda ash dosage as shown in Table 4 for the corresponding jar at a high mixing intensity
8. Wait 2 minutes, using the Hach Total Hardness Test Kit and protocol (attached), test the hardness of each jar 1-3

   - **a.** If the hardness is below 37 mg/L as $CaCO_3$ then do not add final 20% of soda ash and move to step #9
   - **b.** If the hardness is > than 37 mg/L as $CaCO_3$ then add final 20% of soda ash and follow step (i)
      - **i.** If adding final 20% of soda ash, add the chemical at a high mixing intensity for 30 seconds and then wait 5 minutes with mixing at a low intensity

9. Turn off mixers
10. Start timer
11. Allow the three jars to settle for 2 minutes
12. Take a sample from each jar to take a turbidity reading
13. Sample each jar every 2 minutes until 3 turbidity measurements in a row from the same jar are within +/- 20% of each other, record time elapsed
14. Decant overflow from jars into sample bottles (1-50 mL nitric acid preserved for metals and 2-250 mL unpreserved bottles for alkalinity and anions for each jar) and send to analytical lab

4.0 References

Ning, R.Y. (2002). Discussion of silica speciation, fouling, control and maximum reduction. Desalination 151:67-73.

Sheikholeslami, R., and Bright, J. (2002). Silica and metals removal by pretreatment to prevent fouling of reverse osmosis membranes. Desalination 143: 255-267.

Parks J.L. and Edwards M. (2007). Boron Removal via Formation of Magnesium Silicate Solids during Precipitative Softening. Journal of Environmental Engineering.

Sheikholeslami, R., Al-Mutaz, I.S., Koo, T., Young, A. (2001). Pretreatment and the effect of cations and anions on prevention of silica fouling. Desalination 139:83-95.

Tables

Table 1

Influent Water Quality

	Location	Area 5 NW
	Date	8/16/2012
	Sample Type	N
	Fraction	
General Parameters		
Alkalinity, bicarbonate, as CaCO3	NA	**260 mg/l**
Alkalinity, total	NA	**270 mg/l**
Carbon, dissolved organic	NA	**2.9 mg/l**
Carbon, total organic	NA	**3.0 mg/l**
Chloride	NA	**3.6 mg/l**
Fluoride	NA	**0.21 mg/l**
Nitrogen, ammonia (NH3), as N	NA	< 0.200 mg/l
Nitrogen, Nitrate as N	NA	< 0.40 mg/l
pH	NA	**8.5 pH units**
Phosphorus, total	NA	< 0.100 mg/l
Silicon dioxide	NA	**8.08 mg/l**
Solids, total dissolved	NA	**1700 mg/l**
Solids, total suspended	NA	< 4.0 mg/l
Specific Conductance @ 25oC	NA	**2000 umhos/cm**
Sulfate	NA	**1000 mg/l**
Metals		
Aluminum	Total	< 10 ug/l
Arsenic	Total	< 1.0 ug/l
Barium	Total	**5.8 ug/l**
Boron	Total	**0.14 mg/l**
Calcium	Total	**81 mg/l**
Cobalt	Total	< 0.20 ug/l
Copper	Total	**2.6 ug/l**
Iron	Dissolved	< 0.050 mg/l
Iron	Total	< 0.050 mg/l
Lead	Total	< 0.20 ug/l
Magnesium	Total	**230 mg/l**
Manganese	Dissolved	**2.7 ug/l**
Manganese	Total	**28 ug/l**
Nickel	Total	< 0.50 ug/l
Potassium	Total	**57 mg/l**
Selenium	Total	< 1.0 ug/l
Silicon	Total	**4.7 mg/l**
Sodium	Total	**110 mg/l**
Strontium	Total	**290 ug/l**
Vanadium	Total	< 0.50 ug/l
Zinc	Total	< 5.0 ug/l

Table 2

RO Concentrate Chemistry as Estimated by IMSDesign

Parameter	Permeate (mg/L)	Concentrate (mg/L)
Ca^{+2}	0.3	672.4
Mg^{+2}	1.0	1909.4
Na^{+}	2.3	900.1
K^{+}	1.5	464.3
Ba^{+2}	0.0	0.1
Sr^{+2}	0.0	2.4
CO_3^{-2}	0.0	0.2
HCO_3^{-}	7.6	1822.9
SO_4^{-2}	5.2	9048.6
Cl^{-}	0.1	29.5
F^{-}	0.0	1.6
B	0.1	0.5
SiO2	0.1	83.1
CO2	158.0	158.0

Table 3

Chemical Dosages for Excess Lime Softening and Resulting Water Chemistry from PHREEQC

Chemical Dosages		
Chemical		
Lime, CaO (g/L)		5.43
Soda Ash, Na2CO3 (g/L)		8.79
Final Concentrations		
Parameter	**Unit**	**Value**
Ca	mg/L	4.9
Mg	mg/L	4.0
Na	mg/L	4733.4
K	mg/L	47.2
Ba	mg/L	0.1
Sr	mg/L	2.4
HCO3	mg/L	65.9
SO4	mg/L	919.0
Cl	mg/L	72.8
F	mg/L	1.6
SiO2	mg/L	23.1
pH	pH units	9.5

Table 4

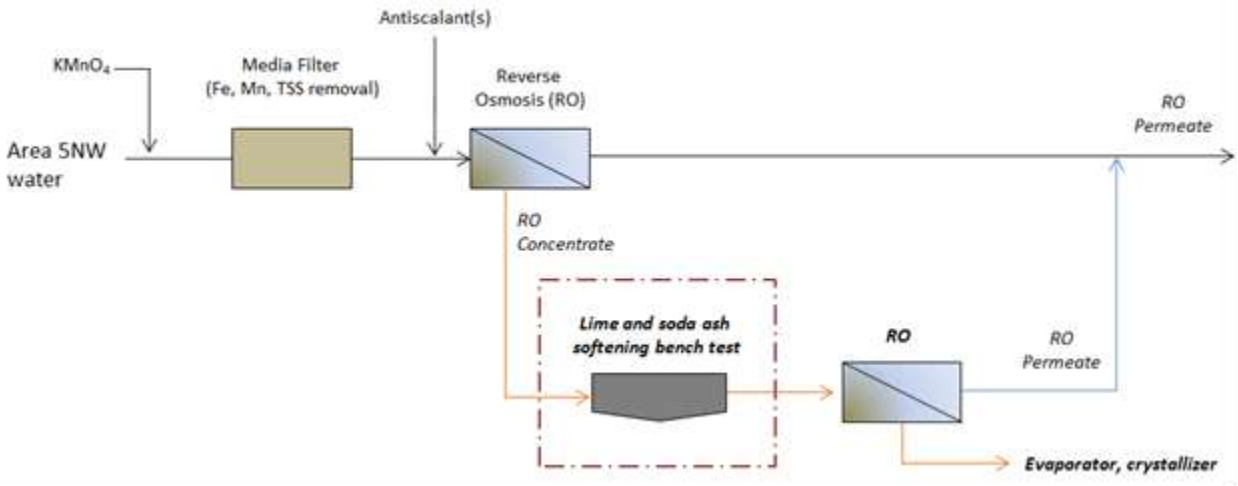
Chemical dosages for jar testing

B-KER^2 #	**Ca(OH)2 dosage (g/L)**	**Theoretical Na_2CO_3 dosage (g/L)**	**80% of Theoretical Na_2CO_3 (g/L)**
1	5.38	6.36	5.09
2	7.17	8.79	7.03
3	8.96	11.36	9.09

Figures

Figure 1

Treatment Process



Dashed line indicates the processes to be bench tested.

Appendix F

Operator Log Sheets

RO Unit Operator Log

	Date & Time of Sampling/Observation (e.g. 15-Sep-2010 14:30)										
	Entered By (Print Initials)										
Greensand Feed											
	Flow gpm										
	Pressure psi										
ULTRAMETER	Temp C										
ULTRAMETER	Cond uS										
ULTRAMETER	ORP mV										
ULTRAMETER	pH SU										
ULTRAMETER	TDS ppm										
Greensand Effluent											
	Pressure psi										
ULTRAMETER	Temp C										
ULTRAMETER	Cond uS										
ULTRAMETER	ORP mV										
ULTRAMETER	pH SU										
ULTRAMETER	TDS ppm										
Cartridge Filter											
	Filter Pressure (Cartridge Feed)										
	Filter Pressure (Cartridge Post)										
Membrane Filter											
	RO Concentrate Pressure After Adjustments psi										
	RO Feed Pressure After Adjustments psi										
Permeate Flow											
	Initial gpm										
	After Adjustments gpm										
Concentrate Flow											
	Initial gpm										
	After Adjustments gpm										
RO Data Logger											
	Pre MMF Turb NTU										
	Feed pH										
	Perm Conduct us/cm										
	Feed ORP										
	Conc Conductivity us/cm										
	Feed Conductivity us/cm										
	Post MMF Turb NTU										
	RO Perm pH										
	Feed TDS mg/L										
	Conc TDS mg/L										
	Perm TDS mg/L										
	Perm Temp C										
	SDI										
Antiscalant											
	Dosing Rate at Pump ml/hr										
	Antiscalant Tank Level inches										
Potassium Permanganate											
	Dosing Rate										
	Tank Level										

VSEP Unit Operator Log

Batch Number	Date & Time of Sampling/Observation						
7	Entered By						
Feed Tank	Feed Tank Level (L)						
VSEP							
Data Logger	Pressure In						
Data Logger	Pressure Out						
Data Logger	Temp C						
Data Logger	Permeate Flux (ml/min)						
Data Logger	Concentrate Flux (ml/min)						
Data Logger	Vibration						
Data Logger	Perm Conduct us/cm						
Concentrate							
ULTRAMETER	Temp C						
ULTRAMETER	Cond uS						
ULTRAMETER	ORP mV						
ULTRAMETER	pH SU						
ULTRAMETER	TDS ppm						
Permeate							
ULTRAMETER	Temp C						
ULTRAMETER	Cond uS						
ULTRAMETER	ORP mV						
ULTRAMETER	pH SU						
ULTRAMETER	TDS ppm						
Sulfate Test	Concentrate ppm						
	Permeate ppm						

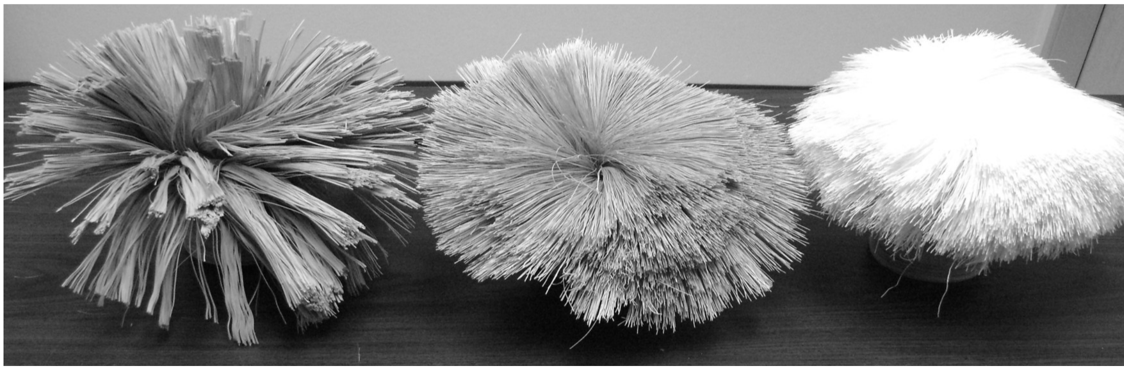
pH Adjustment		
1	Initial pH	
	Acid Addition (mL)	
	Time of acid addition	
	Final pH	
2	Initial pH	
	Acid Addition (mL)	
	Time of acid addition	
	Final pH	
3	Initial pH	
	Acid Addition (mL)	
	Time of acid addition	
	Final pH	
4	Initial pH	
	Acid Addition (mL)	
	Time of acid addition	
	Final pH	
5	Initial pH	
	Acid Addition (mL)	
	Time of acid addition	
	Final pH	
6	Initial pH	
	Acid Addition (mL)	
	Time of acid addition	
	Final pH	
7	Initial pH	
	Acid Addition (mL)	
	Time of acid addition	
	Final pH	

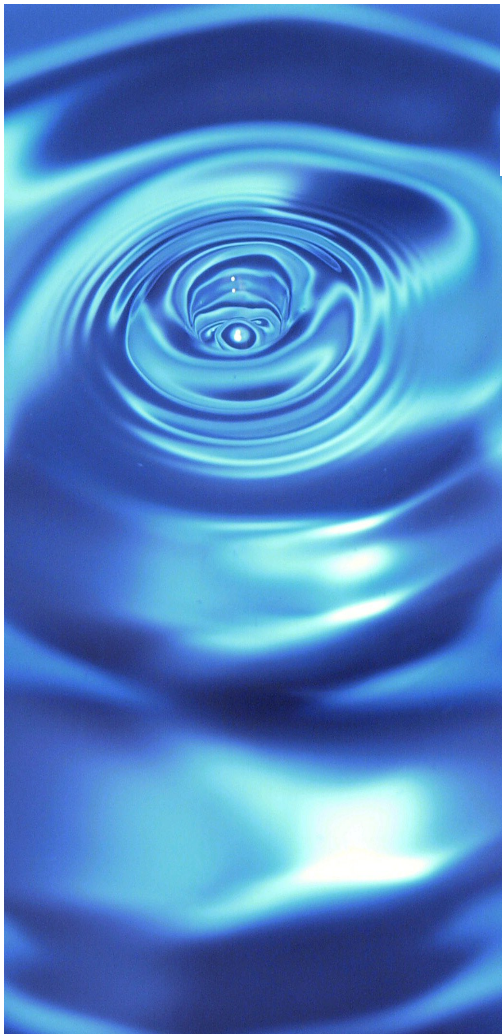
Start Time	**Stop Time**	**Comment**

Appendix B

Membrane Autopsy Report by Separation Processes, Inc.

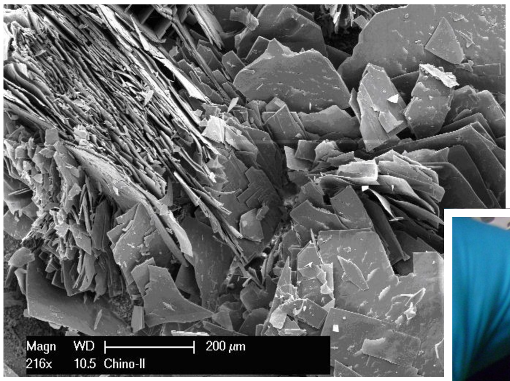
Membrane Autopsy Report

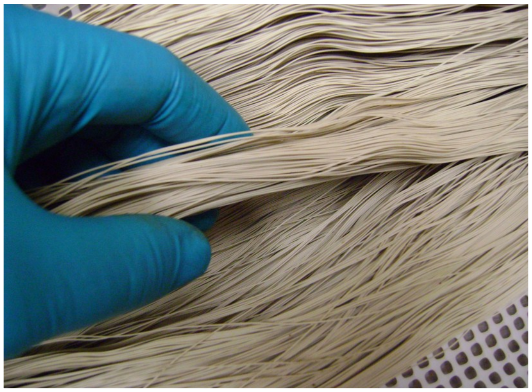




Prepared for: Barr Engineering—SD033

Distribution Date: August 2013





Separation Processes, Inc.
3156 Lionshead Ave., 2
Carlsbad, CA 92010

Phone: (760) 400-3660
Fax: (760) 400-3661

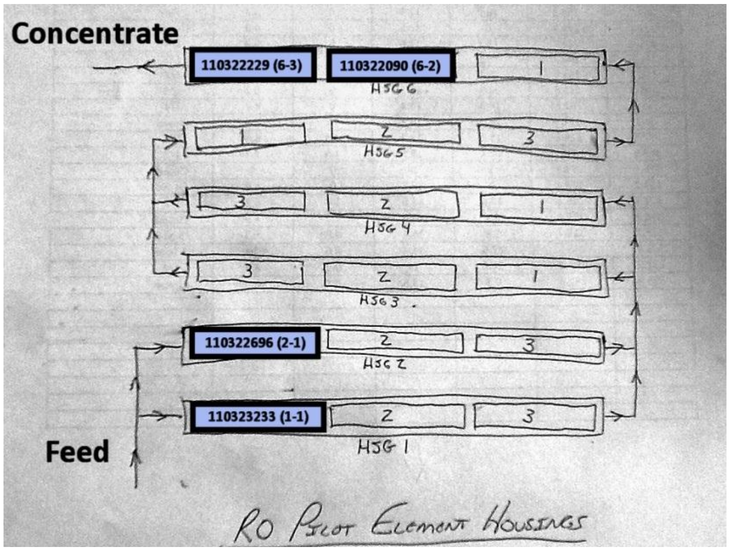
SPi

The Membrane Technology Consultants

TABLE OF CONTENTS

INTRODUCTION

SPI received four 4” GE AG-90 elements on 7/22/2013. The elements consisted of two first stage leads removed from vessels HSG1 and HSG2, as shown in the figure below, and two second stage tail elements removed from HSG6. The elements were used in an RO pilot unit treating water from the Area 5NW Pit with the goal of removing sulfate and other ‘parameters of concern’ (TDS, bicarbonates, total hardness, specific conductivity). The pilot system consisted of a traditional 2:1 array, comprised of 4 stages in a 2-2-1-1 configuration with three elements per vessel to make up 18 total elements. Pretreatment for the pilot system included a greensand filter and GE MDC 150 antiscalant. During the pilot test, the operator observed a significant increase in permeate conductivity and sulfate concentration. Conductivity profiling of each vessel suggested the increase was localized in the last vessel of the system, HSG6.



Element Numbering Map for the Pilot Unit.

FLOW AND REJECTION TESTING

The four elements received were characterized in order to establish the performance condition and to identify two elements for further inspection through autopsy, dye testing, and foulant analysis. The performance data for each element is provided below, and is compared with the nominal performance reported by the manufacturer for this element. Each of the elements exhibited a slightly higher flow than the nominal element performance. The two lead elements exhibited normalized rejection consistent with the nominal values, while both tail elements were lower than the nominal values. The element differential pressures for all four elements were significantly higher than expected for 4" elements, and each element weight was normal.

Table 2 – Element Characterization Results

Serial Number	Normalized Flow	Rejection	dP	Weight
Nominal Performance	2,200	99.8%	2-3	8
110323233 (1-1)	2,470	98.7%	**15**	8
110322696 (2-1)	2,463	99.4%	**12**	8
110322090 (6-2)	2,472	**97.8%**	**15**	8
110322229 (6-3)	2,510	**97.3%**	**13**	8

PHYSICAL EVALUATION

External Inspection

Elements 110322229 (6-3) & 110322090 (6-2)

Fiberglass Shell

The fiberglass shell was in good condition for both elements. There were no visible cracks or weak areas in the fiberglass. The fiberglass roving (the strands of fiberglass) was evenly distributed on each element.

Brine Seals

The Brine seals were undamaged.

Anti-telescoping Devices (ATD)

The ATDs were undamaged and still attached to the fiberglass.

Permeate Tubes

The central tube was clean and unmarred where the inter-connector would come in contact. A defect in this area would result in permeate contamination.

Spacer Migration

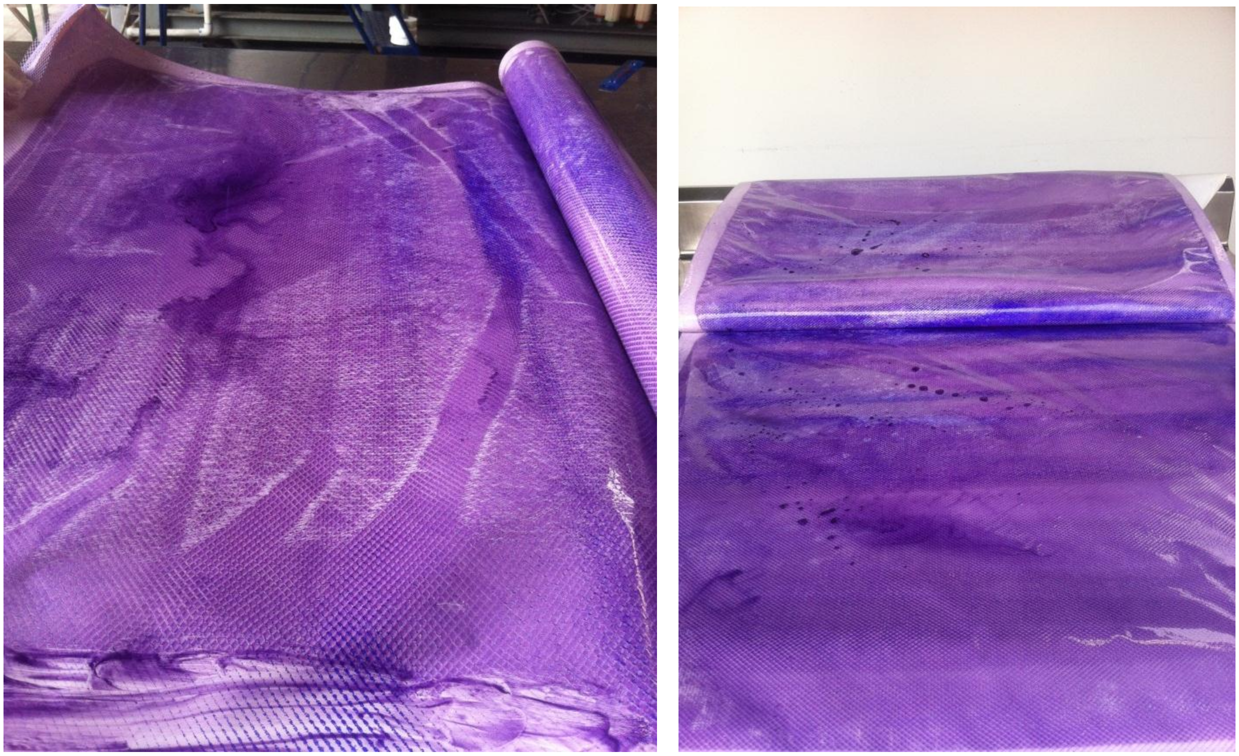
There was no apparent spacer migration or spacer damage, which can occur due to excessive differential pressure.

Internal Inspection

Element 110322229 (6-3)

Dye Test

Element 110322229 (6-3) was selected for dye testing and autopsy because the characterization data revealed the element to have low salt rejection. The dye test is a useful tool for confirming the mechanism of damage to RO membranes whereby a large molecular weight organic dye (Methyl Violet) is introduced into the element in the direction of normal flow along the feed/brine channel of the membrane element, coating the entire feed side of the membrane surface. Due the size of the dye molecule, it will be completely rejected by an integral RO membrane. Inspection of the permeate channel of the membrane will reveal whether dye was able to pass through the membrane, and lends to the understanding of how a membrane became damaged. Gernerally, the dye coats the membrane surface uniformly. In this case, there were distinct regions of heavy dye uptake within the membrane element.

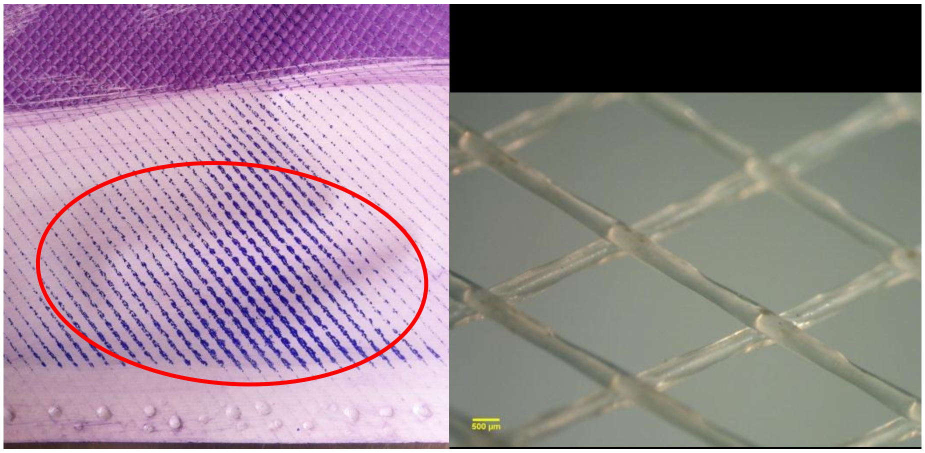


110322229 (6-3) – Dye coating the feed side of the membrane surface

Membrane Surface

As noted above, there were very specific regions within the membrane surface that appeared to have experienced heavier dye uptake. This can be an indication of heavier fouling or membrane damage within this area. The dye was wiped away in several locations, revealing significant uptake on the feed side of the membrane. The dye uptake was most obvious and severe near the permeate core tube, but was also observed in locations throughout the membrane sheet. The pattern of the damage was consistent with the feed/brine spacer used to maintain the flow path through the element.

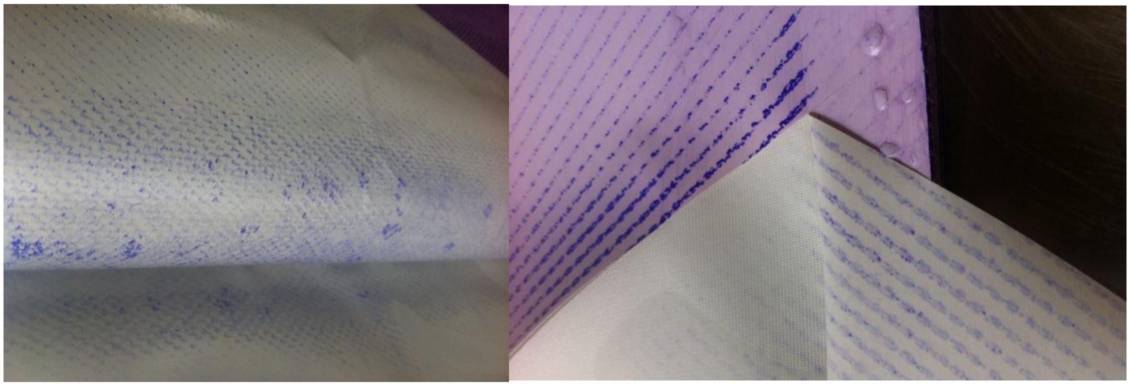
110322229 (6-3) – Heavy dye uptake near the permeate core tube (left). Wiped membrane showing dye uptake in central region of membrane leaf (right).



110322229 (6-3) – Wiped membrane showing dye uptake in pattern of feed/brine spacer on concentrate edge of membrane (left). Magnified image of feed/brine spacer (right).

Permeate Channel

The permeate side of the membrane was investigated in order to confirm whether dye passage was occurring through the membrane. Significant dye passage was observed throughout the membrane surface, with the heaviest passage of dye occurring in the regions of dark, heavy dye uptake on the membrane surface nearest the permeate core tube.



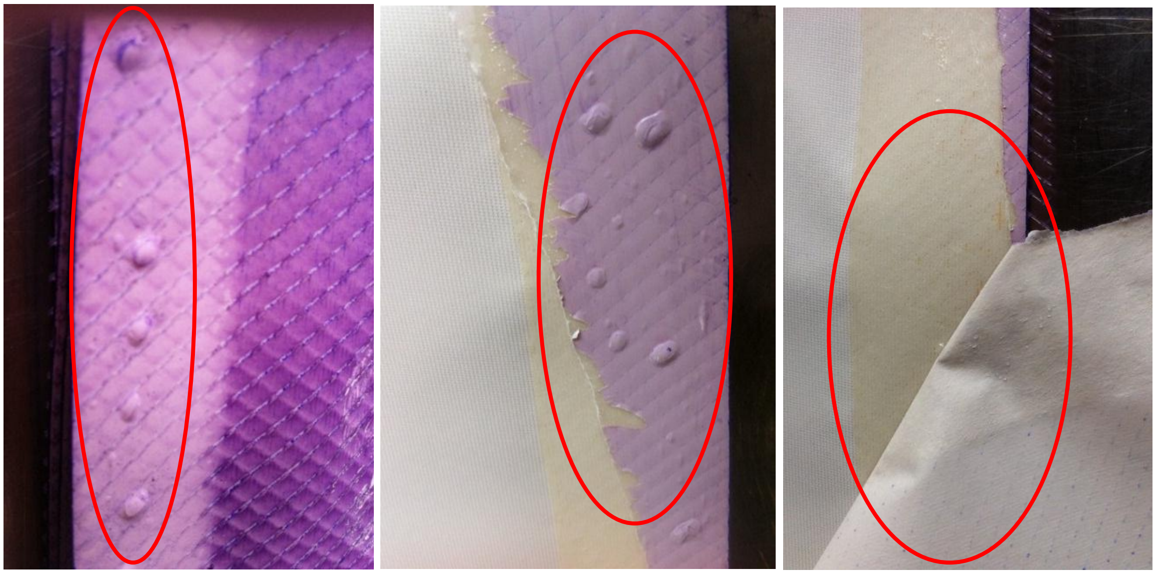
110322229 (6-3) – Dye passage near permeate core tube (left) and concentrate edge (right).

Membrane Adhesion

The membrane chemistry and polylsulfone layer were observed to be easily removed from the polyester backing, suggesting poor adhesion of the composite membrane.

Glue Lines

The presence of significant bubbling within the membrane glue line was observed throughout the element. These bubbles were prevalent throughout each individual membrane leaf, and spread around the entire perimeter of the membrane envelop. The glue line adhesion was also observed to be very weak, and the membrane sheets were readily peeled away from one another.



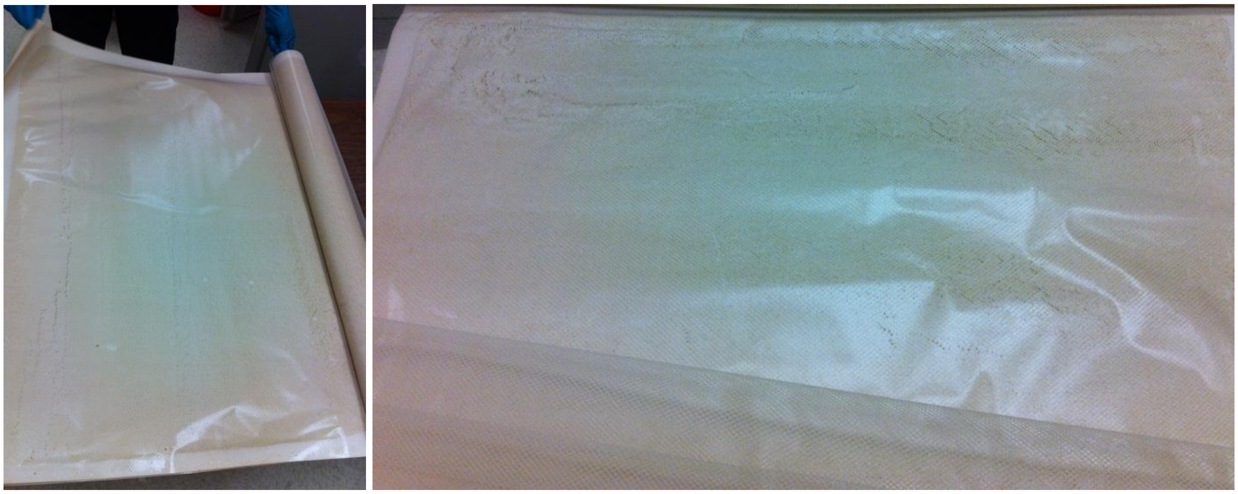
110322229 (6-3) – "Bubbling" within the membrane glue line (left, center). Poor adhesion within the glue line (right).

Element 110322090 (6-2)

It was anticipated that the dye test performed on element 110322229 (6-3) would mask the overall condition of the membrane and foulant layer. Element 110322090 (6-2) was selected for autopsy in order to confirm the identity of any foulant in the second stage of the system that might be contributing to the apparent sulfate increase observed during the pilot test. Additionally, given that all four elements exhibited extreme differential pressures, this element was also used to investigate whether there were any factors contributing to the high dP that may have been masked by the dye test of element 110322229 (6-3).

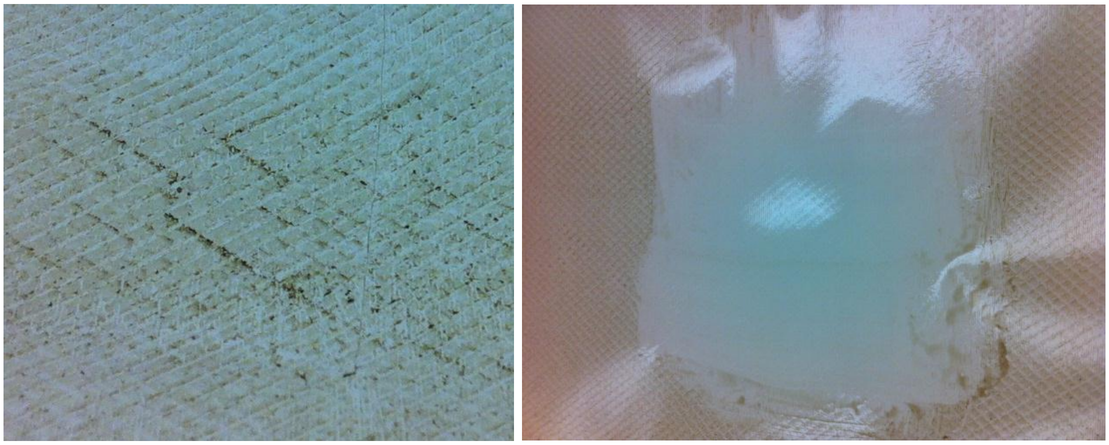
Membrane Surface

Upon opening element 110322090 (6-2), a brownish foulant was observed to cover the surface. The foulant covered the entirety of the membrane surface, but several specific regions appeared to have higher concentrations of foulant accumulated in the shape of the membrane feed/brine spacer. The foulant was readily wiped away to reveal the shiny membrane surface below. The area of heavies foulant accumulation was near the permeate core tube, consistent with the areas of heavy dye uptake observed in Element 110322229 (6-3). While not absolutely conclusive, this suggests the two elements may have experienced similar damage. Upon wiping away of the foulant, the membrane maintained its shiny appearance, and there was no evidence of damage visible to the naked eye.



110322090 (6-2) – Brownish foulant covering membrane surface(left, right).

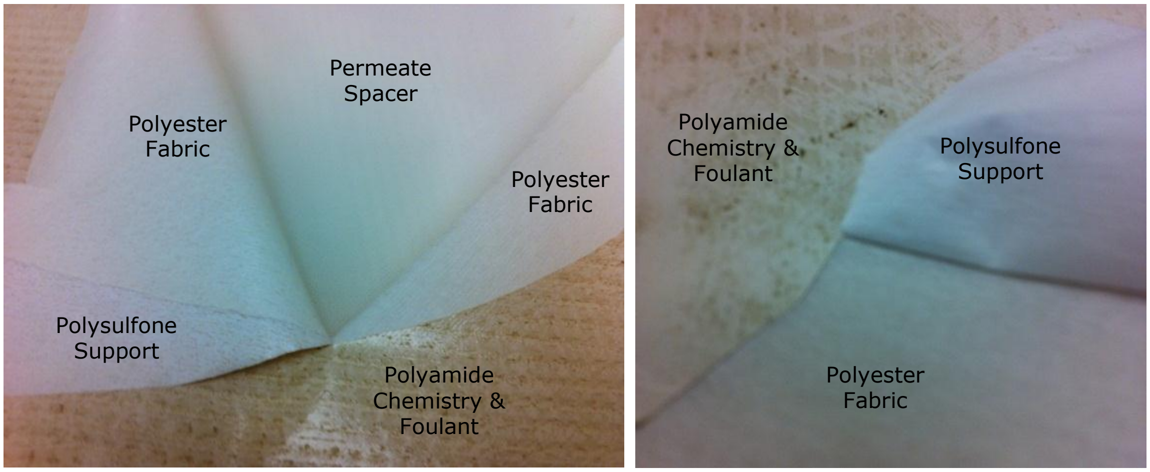
110322090 (6-2) – Heaviest foulant accumulation near the permeate core tube.



110322090 (6-2) – Heavier foulant accumulation in feed/brine spacer pattern (left). Foulant easily wiped from membrane surface (right).

Membrane Adhesion

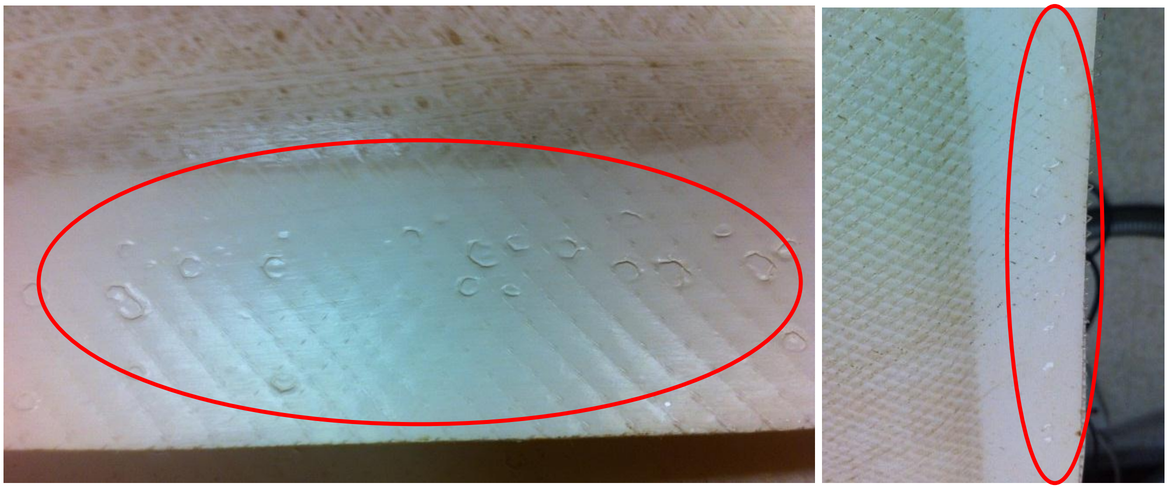
The membrane chemistry and polylsulfone layer were observed to be easily removed from the polyester backing, suggesting poor adhesion of the composite membrane.



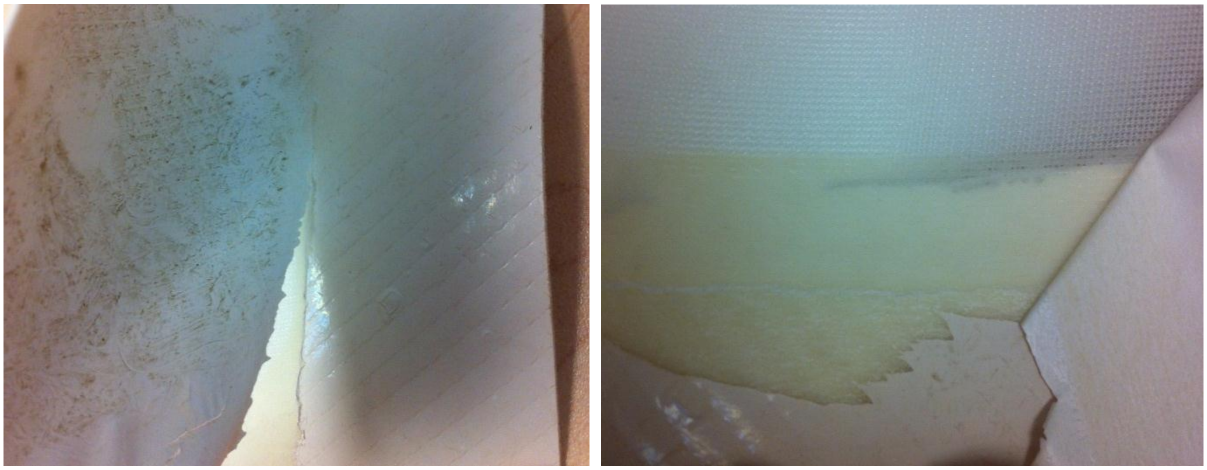
110322090 (6-2) – Poor adhesion properties of composite membrane allows separation of polysulfone support form polyester fabric.

Glue Lines

The presence of significant bubbling within the membrane glue line was observed throughout the element. Unlike Element 110322229 (6-3), where the bubbles were completely rounded and full, the bubbles observed in Element 110322090 (6-2) appeared to be mostly 'popped' or broken and flattened out against the glue line. These bubbles were prevalent throughout each individual membrane leaf, and spread around the entire perimeter of the membrane envelop. The glue line adhesion was also observed to be somewhat weakened, with one sample maintaining complete adhesion while another sample demonstrated weakened adhesion of the glue line.



110322090 (6-2) – "Bubbling" within the membrane glue line (left, right).

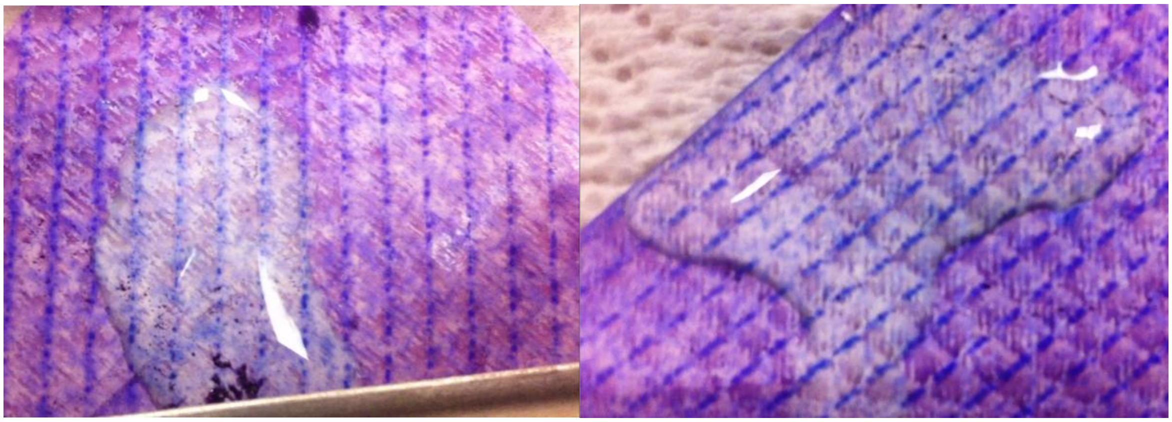


110322090 (6-2) – Acceptable adhesion: membrane tears at glue line before peeling (left). Partial peeling of glue line before membrane breaks reveals weakened adhesion (right).

FOULANT ANALYSES

Acid Test

To verify if calcium carbonate scale is present within the foulant on the membrane surface of the tail end element, a solution of 50% citric acid was dropped directly onto the membrane surface. Carbon dioxide bubbles were not observed for either element.



110322229 (6-3) – No observable carbon dioxide bubble formation in acid solution.

110322090 (6-2) – No observable carbon dioxide bubble formation in acid solution.

SEM/EDX

Scanning Electron Microscopy / Energy Dispersive X-Ray Analyses (SEM/EDX) are tools used in conjunction for studying the surface features of the membrane. The SEM is a type of electron microscope that images the sample surface by scanning it with a high-energy beam of electrons. The EDX is an analytical technique used for the elemental analysis or chemical characterization of a sample and can be used to identify the makeup of an inorganic foulant. A characteristic spectrum is produced and the composition of the foulant by weight percentage of elements present is determined.

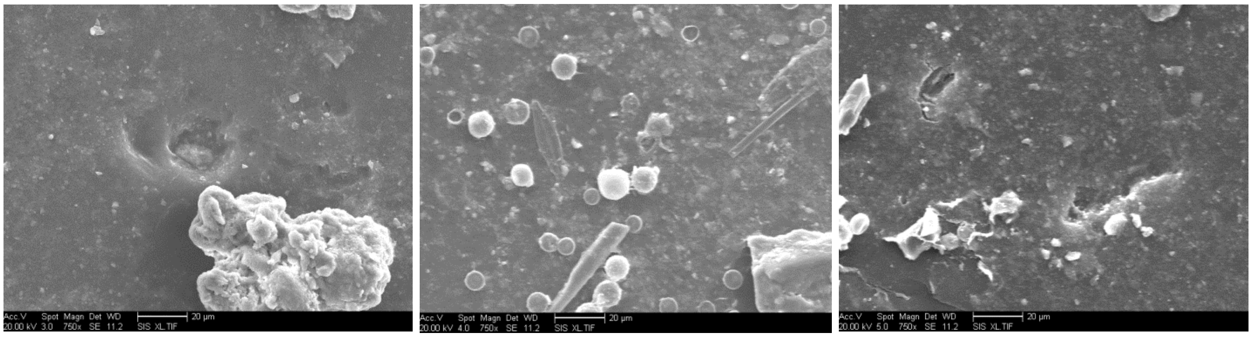
EDX was performed on a total of three samples, one from the dyed membrane element 110322229 (6-3) and two from element 110322090 (6-2). The elemental makeup of both the foulant and membrane are included in the results of this analysis. As a consequence, there are large contributions of carbon (C), oxygen (O), and sulfur (S) that are known to be part of the membrane chemistry and support structure. The presence of Iridium (Ir) is known to be a consequence of the test process.

The EDX results for the three samples were fairly similar, with notable concentrations of silica, aluminum, and iron present. There were also traces of Sodium (Na), Magnesium (Mg), Chloride (Cl), and Potasium (K). Table 2 below shows the weight percentages for the EDX performed for the membrane samples. The makeup of this foulant is consistent with sand, silt, and clays typical of groundwater or surface water sources. The substantial presence of calcium and slightly higher levels of sulfur for element 110322229 (6-3) suggest the possibility of calcium sulfate scale being present on the membrane, but this finding is considered inconclusive because of the dye.

Scanning Electron Microscopy revealed indentions in the foulant layer and membrane surface that is consistent with the dye passage results above.

Table 2 – EDX Analysis of Samples

Sample / Element	110322229 (6-3) with dye		110322090 (6-2) Sample A		110322090 (6-2) Sample B	
	Weight%	Atomic%	Weight%	Atomic%	Weight%	Atomic%
C K	41.14	53.94	41.13	52.84	50.38	61.74
O K	37.85	37.26	38.79	37.41	34.08	31.35
Na K	0.22	0.15	0.55	0.37	0.41	0.26
Mg K	0.26	0.17	0.55	0.35	0.60	0.36
Al K	0.86	0.50	2.20	1.26	1.05	0.57
Si K	2.46	1.38	7.37	4.05	3.51	1.84
P K	--	--	0.69	0.34	0.47	0.22
S K	6.18	3.04	4.24	2.04	5.95	2.73
Cl K	0.31	0.14	0.22	0.10	0.47	0.20
K K	0.20	0.08	0.53	0.21	0.29	0.11
Ca K	6.92	2.72	0.65	0.25	0.36	0.13
Ti K	--	--	0.11	0.03	0.08	0.02
Mn K	--	--	0.14	0.04	--	--
Fe K	1.65	0.46	2.48	0.69	1.44	0.38
Ir M	1.95	0.16	0.36	0.03	0.91	0.07
Totals	100.00		100.00		100.00	



SEM Photographs - 110322229 (6-3) (left), 110322090 (6-2) Sample A (center), 110322090 (6-2) Sample B (right)

CONCLUSION

There is clear evidence that physical damage to the membrane has caused the increased sulfate passage observed during the pilot test. All indicators suggest the damage to be a consequence of the feed/brine spacer burrowing into the membrane surface, causing scratches and holes within the polyamide chemistry layer. This was confirmed by the dye test results showing damage in the same pattern as the feed/brine spacer.

The cause of the membrane damage is not clear at this point. The fact that the damage is heavier in some regions of the membrane sheet suggests inconsistent tensioning during the rolling of the element. Movement of the feed/brine spacer during normal operation, or during the frequent startups and shutdowns of the pilot unit may have aggravated the damage over time.

The membrane may have also been exposed to some level of permeate backpressure during pilot testing (where the permeate pressure exceeds the feed/brine side pressure). Permeate backpressure damage usually occurs as a single, catastrophic event that causes delamination of the membrane layer from the support structure. Membrane delamination was *<u>not</u>* observed in this case. However, the findings of this autopsy are suggestive of a gradual or slight exposure to permeate backpressure where membrane ‘pouching’ may have occurred. ‘Pouching’ of the membrane occurs when the membrane envelope is pressurized from the permeate side, driving the feed side of the membrane into the feed/brine spacer. Based on the adhesion properties of the polysulfone support to the polyester fabric, it is surprising that membrane delamination was not observed if even a slight permeate backpressure occurred during testing.

The observation of high differential pressure for these elements is consistent with both possibilities presented for the cause of the damage. High differential pressure is usually a consequence of a restriction or obstruction within the feed/brine channel of the element. In this case, the quantity of foulant observed was not likely to have contributed to the high differential pressures. However, if the element were rolled too tightly in areas, or if the membrane had pouched, the feed/brine channel would have been restricted somewhat, potentially causing the elevated differential pressure. Additionally, while bubbling in the glue line is not uncommon, the severity of the bubbles observed could have contributed to the high differential pressure by restricting the flow path entering and exiting the elements.

RO membrane systems in this type of application generally have cartridge filters upstream. The cartridge filter rating typically ranges from 5-20 micron. It is unclear what the pilot unit cartridge filter rating was for this pilot unit, but particulates larger than 50 micron in size were observed on the membrane surface. Tighter cartridge filters should be consider in the future facility to better protect the membrane from the possibility of membrane damage.

Lastly, the EDX analysis of element 110322229 (6-3) suggests the possibility for calcium sulfate scale on the membrane surface, but this result is considered inconclusive due to the heavy concentrations of dye present on the membrane.

Appendix C

Data Performance Review for RO Membrane by Separation Processes, Inc.

The Membrane Technology Consultants

Separation Processes, Inc.
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Carlsbad, CA 92010
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Fax: 760-400-3661
www.spi-engineering.com

Date: August 21, 2013

To: Lisa Andrews – Barr Engineering

From: Eric Owens – SPI

Subject: Performance Review for RO membrane at Area 5 North, SD033

The following memo is intended to document the performance observed for the reverse osmosis membrane system at the Area 5 North surface discharge station SD033. SPI reviewed data for the period of January 29, 2013 – July 3, 2013. In order to make the data set more manageable, a daily average of filtered data was used in most cases. However, in some instances, the filtered data set was reviewed without averaging. Discussion of the RO system performance is below, and graphs illustrating RO system trends are included at the end of the document.

OPERATING CONDITIONS

Feedwater Characteristics (Figures 1 & 2)

Feedwater temperature, pH, conductivity, and ORP are online indicators of the feedwater characteristics, and can impact the rejection and fouling performance of the RO membrane. The feedwater characteristics were reviewed to determine how they may have changed during the pilot period and contributed to the overall performance. It is clear that the feedwater characteristics changed dramatically over the course of the pilot test, as noted below and illustrated in Figures 1 and 2.

Feedwater temperature was stable at approximately 5 ^{o}C between January and April. In May, the temperature began to increase, ultimately reaching 20 ^{o}C in July. The influent pH was observed to be relatively stable between pH 8.7-9.3 until early May, when it declined rapidly and then remained between 8.1-8.4 until July.

The feedwater conductivity had ranged between 2300 – 2500 µS/cm between February and April. In late April / early May, the feedwater conductivity decrease dramatically to values less than 500 µS/cm. It began to increase in mid-May and stabilized at approximately 2000-2100 µS/cm until the end of the pilot test.

The oxidation reduction potential (ORP) had averaged between 360-380 mV until early May. From May - July, this parameter averaged between 380-400 mV.

Permeate Flux (Figure 3)

Permeate flux is one of the most important parameters for RO performance. It not only impacts the RO fouling rate, but impacts the permeate quality as well. Between January 29 and March 18, the permeate flux ranged between 5 -16 gallons per square foot per day (gfd). On March 19, the flux was stabilized at approximately 15 gfd and remained at this value until the end of the test. Permeate flux data is shown in Figures 3 and 4 below, both filtered data and average daily values.

Permeate Recovery (Figure 4)

Similar to the permeate flux, the permeate recovery impacts both the RO fouling rate and the permeate quality for an RO system. The permeate recovery calculated from the online flow data varied widely between January 29 and March 18, from approximately 60% to values exceeding 90%. Figure 4 includes the calculated recovery using filtered online data, as well as a daily average.

The operator log included within the data set indicates the concentrate flow meter was problematic in the first 4-5 weeks of testing. This was likely the cause of the wide variation in the reported recovery values, and the data within this period is considered suspect. The flow meter was corrected on March 18. From March 19 through the end of the test, the permeate recovery remained relatively stable at approximately 80%.

The recovery setpoint can be confirmed using a mass balance of feed, permeate, and concentrate concentrations for several ionic constituents (alkalinity, chloride, TDS, sulfate, calcium, magnesium, silicon, and sodium). This mass balance calculation was applied to the water quality analyses collected throughout the test in order to confirm the operating recovery calculated using the online flow. This recovery is also included in Figure 4, and confirms that the recovery calculated using online flows did not match well with the mas balance recovery prior to March 19. Following March 19, there was good correlation between the two calculated recoveries, providing confidence in the data between March 19 and the end of testing.

REVERSE OSMOSIS PERFORMANCE

As noted above, feedwater characteristics such as temperature and conductivity, and operating conditions such as permeate flux and recovery can have a dramatic impact on the RO membrane performance. Normalization calculations are applied to the RO operating data in order to remove these variables and compare the day-to-day performance at a set of standard conditions. The pilot unit data set was normalized assuming the following standard conditions. Trends of the normalized parameters are discussed below.

Standard Condition	Value
Feedwater Temperature	25 ^{o}C
Feedwater Conductivity	2300 μS/cm
Permeate Flux	15.3 gfd
Permeate Recovery	80%

In addition to normalizing the operating data, SPI compared the RO membrane manufacturer's performance projection software (GE Winflows 3.1.2) to the actual performance observed during the pilot testing. The software projections for four dates throughout the test period were compiled and compared with actual performance, and are discussed in more detail below.

Specific Flux (Figure 5)

The specific flux, also known as water permeability, is a temperature corrected ratio of the permeate flux to the feed pressure required to produce that flux. A downward trend in this parameter can be an indicator of fouling occurring at the membrane surface. Figure 5 includes the specific flux trend observed during the pilot.

The specific flux between January 29 and March 18 varied widely between 0.06-0.14 gfd-cP/psi. The data in this period suggests a severe fouling rate was occurring, but the data is suspect and likely a result of the inaccurate flow meter. On March 19, the specific flux trend increased to approximately 0.11 gfd-cP/psi where it remained stable until early May. Between early May and July, the specific flux trend increased from 0.11 gfd-cP/psi to 0.122 gfd-cP/psi. Increasing trends in specific flux are generally an indication of less resistance through the membrane layer and can be an indicator of membrane damage or deterioration. This is consistent with the findings of the element autopsy, which revealed substantial damage in the tail end element. That damage is anticipated to have contributed to a slight increase in overall specific flux.

Figure 5 also includes the GE WinFlows 3.1.2 software projection for the specific flux during the test. This information shows that the permeability was higher than predicted by the software, and the difference between the two trends grew slightly larger as the test went on. The comparison of these two trends also reveals that the upward trend is at least partially related to the operating conditions, and not solely related to membrane deterioration.

Specific flux values for the individual stages of a pilot unit are ideal for determining where performance issues are localized within an RO train. Stage specific flux values are calculated using stage flows and pressures. This pilot unit did not have individual stage permeate flow instrumentation, so stage specific flux performance was not available for review.

Normalized Differential Pressure (Figure 5)

The normalized differential pressure is the pressure drop through the membrane system, corrected for variations in flow conditions and water viscosity. The normalized differential pressure can be an indicator of foulant buildup within the feed/brine channel. As foulant deposits within this channel, or the flow path is otherwise restricted, the normalized differential pressure trend will be observed to increase. Figure 5 includes the normalized differential pressure trend observed during the pilot.

The normalized differential pressure was initially extremely high. This was likely a consequence of the problematic concentrate flow measurement reported in the early weeks of testing. Similar to other trends, the value of this parameter stabilized significantly following March 19, when the operating conditions stabilized at 15 gfd and 80% recovery. The normalized differential pressure remained relatively stable between March 19 and April 30, when the parameter began to increase throughout the remainder of testing.

The normalized differential pressure suggests an increase of approximately 25% following March 19. This is in contrast to the actual differential pressure data, which shows an overall decrease during this time. The difference is considered to be a consequence of temperature influence on the water, having increased from approximately 5 ^{o}C to 20 ^{o}C during the testing. The normalized trend suggests an obstruction in the feed/brine flow path within the element, which is consistent with the feed element autopsies performed on the tail end elements. While the element autopsy did not show an appreciable buildup of foulant within the membrane, there was evidence of permeate backpressure contributing to ‘pouching’ within the element. In the case of pouching, the membrane sheet itself is lifted into the feed/brine flow path, restricting flow through the channel.

Differential pressure values for the individual stages of a pilot unit are ideal for determining where performance issues are localized within an RO train. Stage differential pressure is commonly available on most RO pilot units, either through discreet dP gauges or through calculation using an interstage pressure measurement. This pilot unit appears to have had neither, and individual stage differential pressure data was not available for review. As a consequence, it cannot be determined whether this observed normalized differential pressure increase was localized within the tail end elements, where membrane damage was known to occur.

Normalized Permeate Conductivity (Figures 5 & 6)

The normalized permeate conductivity is corrected for variations in feedwater conductivity, temperature, and flow conditions. This parameter is an online indicator of the membrane’s salt rejection, and can be used to indicate membrane fouling or damage.

Like the other normalized parameters, data prior March 19 is considered suspect and can be ignored. A notable increase in the normalized permeate conductivity is observable beginning as early as March 19. The normalized permeate conductivity experienced an increase from approximately 9 µS/cm on March 19 to 100 µS/cm in early May. During the period of extremely low feedwater conductivity (April 29-May 15), the normalized permeate conductivity reported extremely high values, likely a consequence of the inability of this equation to account for such a dramatic change. However, after May 15, when feedwater conductivities increased to more normal values, the normalized permeate conductivity remained in the 20-40 µS/cm range. Additionally, a significant step-increase in normalized permeate conductivity occurred on June 23. This data is consistent with the findings of the autopsies. But rather than a single, instantaneous event that caused the membrane damage, this data suggests the damage may have occurred gradually throughout the test period, with significant breakthrough occurring on June 23.

Individual stage permeate conductivity data, or periodic conductivity profiles, are required to monitor stage performance during a pilot test. Only conductivity profiles for June 7 and June 14 were available (Figure 6), so assessment of stage permeate conductivities throughout the test was not possible. The conductivity profile data confirms that the last pressure vessel (#6) had experienced the most significant damage. When compared with the manufacturer’s software prediction for vessel performance, there is evidence that every vessel on the pilot unit may have experienced some level of damage. Actual vessel permeate conductivities were at least twice as high as the predicted values. There is insufficient data to know when this damage may have occurred.

Membrane Rejection (Figures 7 & 8)

The permeate sulfate concentration and conductivity were observed to increase during the pilot test, as shown in Figure 7. When compared with the GE WinFlows RO projection software (Figure 7), it can be seen that the performance predictions were reasonably close at the beginning of the test. Throughout the duration of the test, the actual permeate sulfate concentration and conductivity diverged greatly from the projection model.

The rejection performance of the membrane throughout the test was calculated for several constituents, taking into account the average feed/brine concentration within the RO unit. For several ions such as chloride, bicarbonate, calcium and barium, the permeate concentrations remained below the detection limit throughout the test and calculating the rejection does not yield beneficial results. For several other ions, such as magnesium, strontium, and sodium the permeate concentrations were below detection at the beginning of the test, but increased above the detection limit during the test. For the divalent molecule sulfate, permeate concentrations were detectable throughout the test. Figure 8 includes the rejection calculation for several divalent and monovalent ions and molecules during this test. This data is consistent with the normalized permeate conductivity and the damage noted in the element autopsy.

The very low rejections observed during the period of very low feed water quality may not have been a direct consequence of membrane damage because the rejections increase following the increase in feed concentration. However, upon increase to higher concentrations, the rejection of all constituents was observed to be lower than before the questionable period. The rejection trends suggest that the membrane rejection capability began to decrease in April, and perhaps earlier. It's likely this performance was masked by the period of very low feed concentration, but it's clear the issue persisted, as the rejections appear to have continued to decrease until the end of the test.

Inorganic Scale Potential (Figure 9 & 10)

The inorganic scale potential (without antiscalant addition) was investigated using Genesys Chemical's Membrane Master III software. Concentrate water quality data from 3/19/13 and 6/10/13 were selected as representative dates before and after the feedwater quality change. Figures 9 and 10 include the output of the software for each date, with the bar chart representing the percent of saturation for each inorganic scale at the conditions of the respective date.

The concentrate concentration is observed to have a Calcium Carbonate scale potential throughout the test. However, the calcium carbonate percent saturations correspond to Langelier Saturation Indices (LSI) of <2.0 for both sample dates, and a reasonably effective antiscalant should be able to inhibit the calcium carbonate scale at these levels. This data is not concerning.

Barium Sulfate saturations for both samples dates are high, but should be within the capability of a reasonably effective antiscalant. Most antiscalant vendors have products that claim to control barium sulfate saturation to 6000% of saturation.

Iron concentration throughout the test was reported as <0.5 mg/L. The software alarm for this constituent is not considered conclusive as it is not clear how much less than 0.5 mg/L the iron concentration actually was. Additionally, the antiscalant should be capable of inhibiting iron deposition at these low concentrations without any issue.

There was no conclusive evidence of inorganic scaling found during the elements autopsy, but that information suggested the possibility of calcium sulfate scale. From review of the inorganic scale potentials during the pilot test, calcium sulfate does not appear to be a likely issue, as calculated saturations are well below with precipitation threshold.

CONCLUSIONS

Review of the performance data confirms that the membrane experienced damage during the pilot test which caused permeate concentrations to increase above the anticipated values. Based on the available data, it appears the damage was predominantly localized in the tail end vessel, but the damage may have been present in upstream elements as well. The tail-end element autopsy revealed physical damage to the membrane surface, but the findings were inconclusive as to the cause. The physical damage appeared to be a consequence of the feed/brine spacer burrowing into the membrane surface, causing scratches and holes within the polyamide chemistry layer.

It remains unclear as to the exact cause of the damage, but the performance data suggests the issues began early in the pilot test and continued to worsen throughout the pilot period. There was questionable data prior to March 19 that makes it difficult to know if the issue began before this date. Additionally, the feedwater quality decreased substantially in the month of May and appears to have masked the true performance of the membrane at that time. But it can be concluded with certainty that the salt passage during this test increased continually between March 19 and July 3, the end of testing. The membrane damage is still suspected to be a consequence of a slight but continual permeate backpressure resulting from some obstruction or restriction in the permeate piping, or the damage is related to inconsistent element rolling allowing the feed/brine spacer to move within the elements and scratch the membrane surface.

For the purposes of understanding the true membrane rejection properties, it is suggested that the period of March 18 – April 23 offered the most representative membrane performance. The data prior to this period was marred with questionable flux and recovery conditions. The data following this period was either influenced by the extreme change in feedwater quality or significant membrane damage.

The membrane did not experience significant fouling during the test, nor does it appear to have experienced inorganic scaling as the scale potentials at the conditions of the pilot test were minimal and should be easily controlled by the addition of the antiscalant product.

It is understood that the same pilot equipment is being used for the next phase of testing. It is recommended that the pilot equipment and setup be reviewed to confirm there is no restriction in the permeate flow path that may have contributed to the membrane damage. It is also recommended that the pilot unit be equipped with the ability to monitor individual stage differential pressure. Lastly, it is recommended that pressure vessel conductivity profiles be collected periodically during the test period.

Figure 1: RO Feedwater Temperature and pH (Daily Averages)

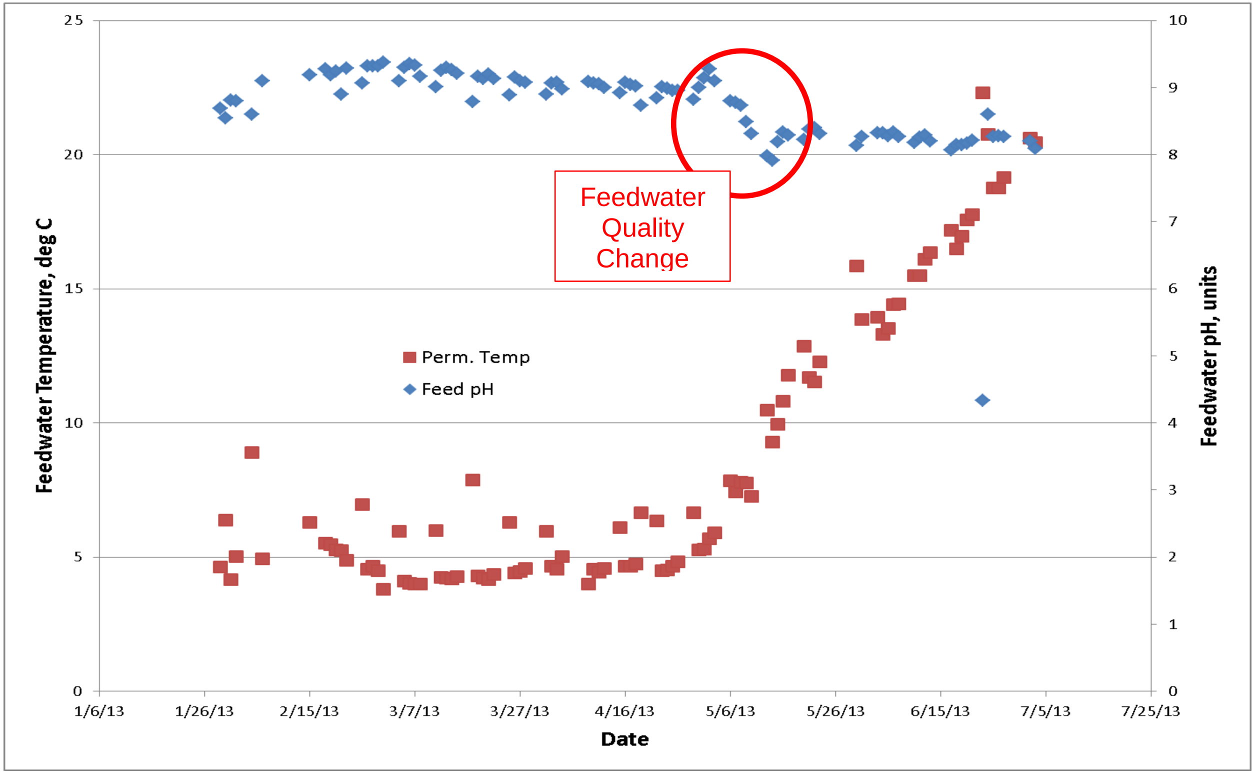


Figure 2: RO Feedwater Conductivity and ORP (Daily Averages)

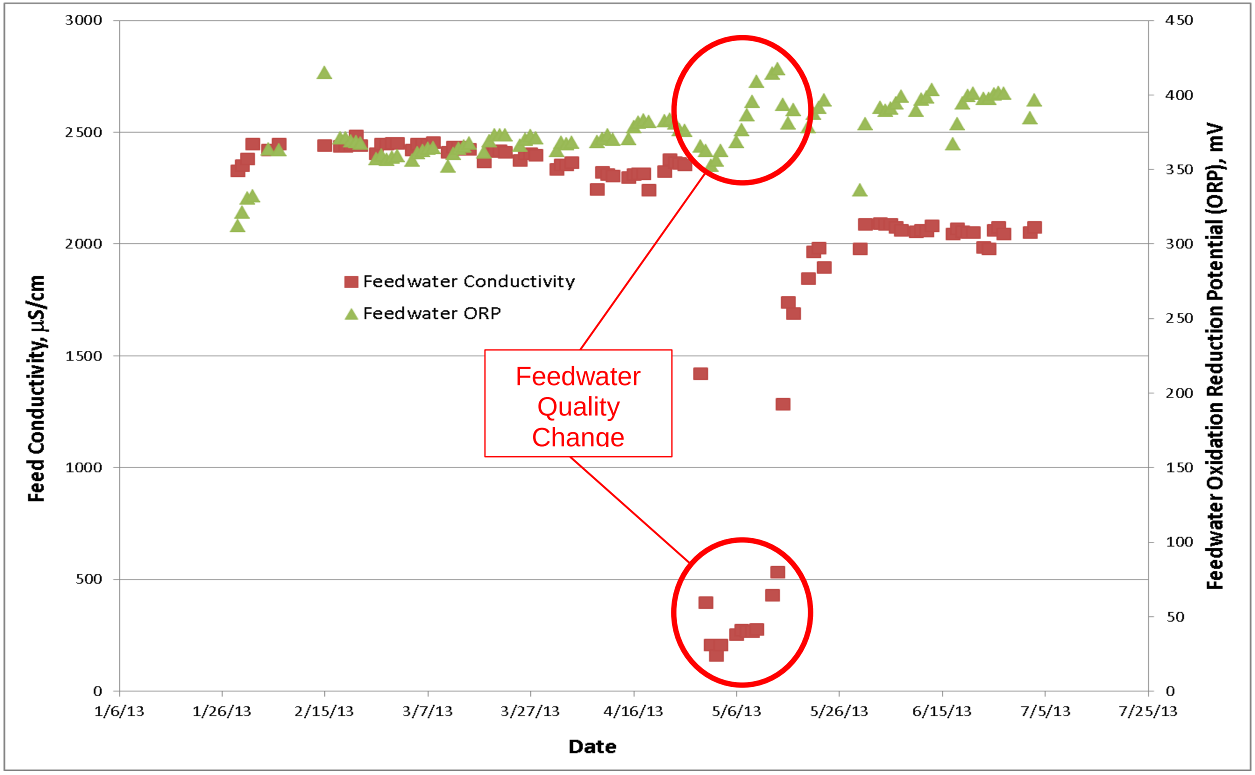


Figure 3: RO Permeate Flux

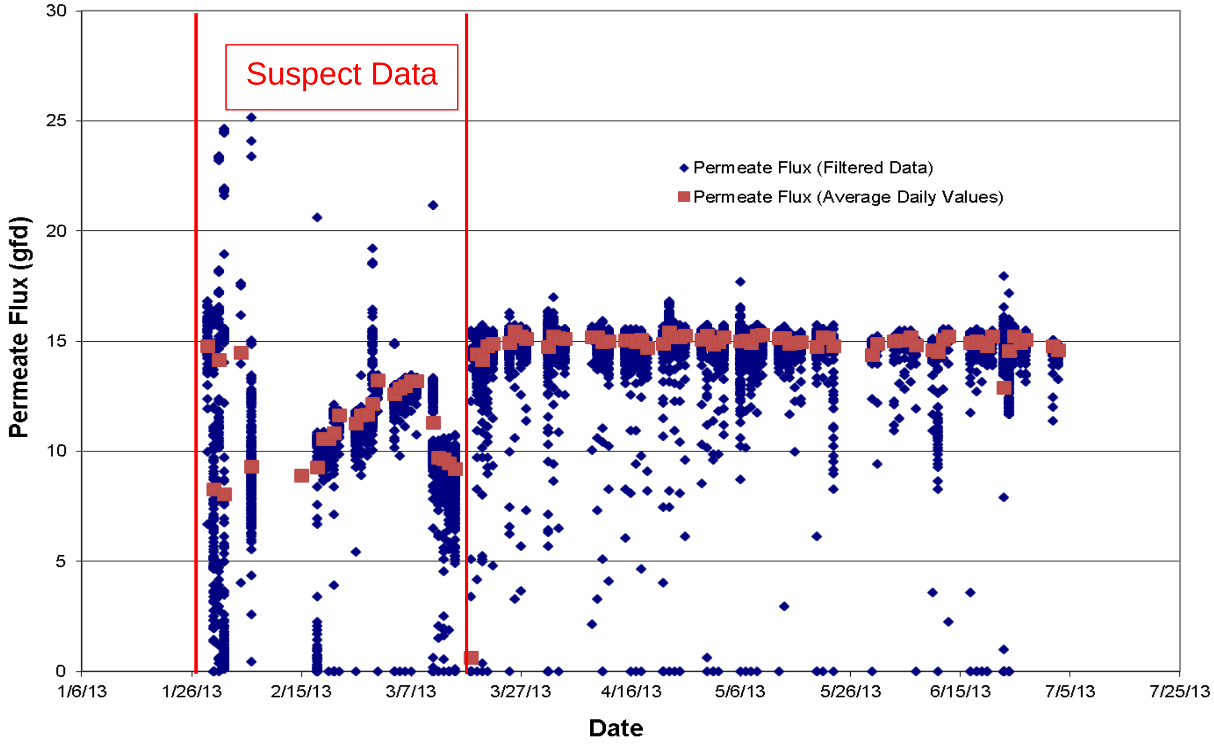


Figure 4: RO Permeate Recovery

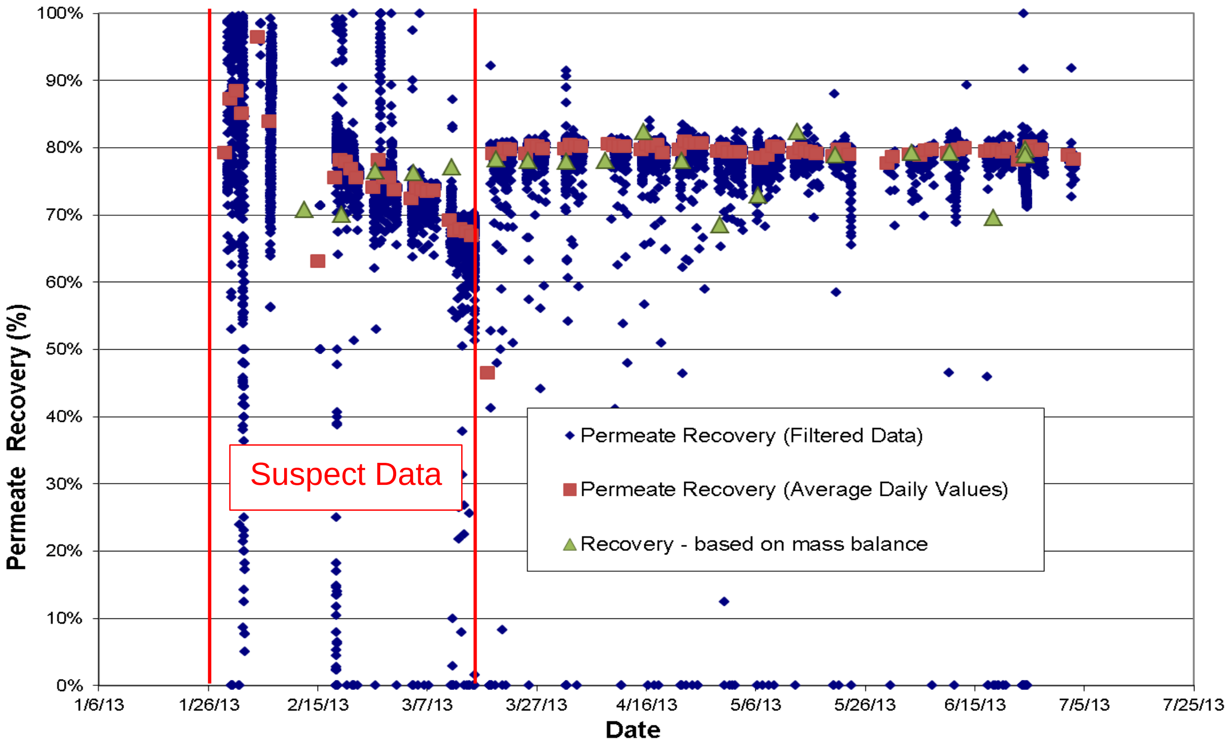


Figure 5: RO Normalized Performance Parameters

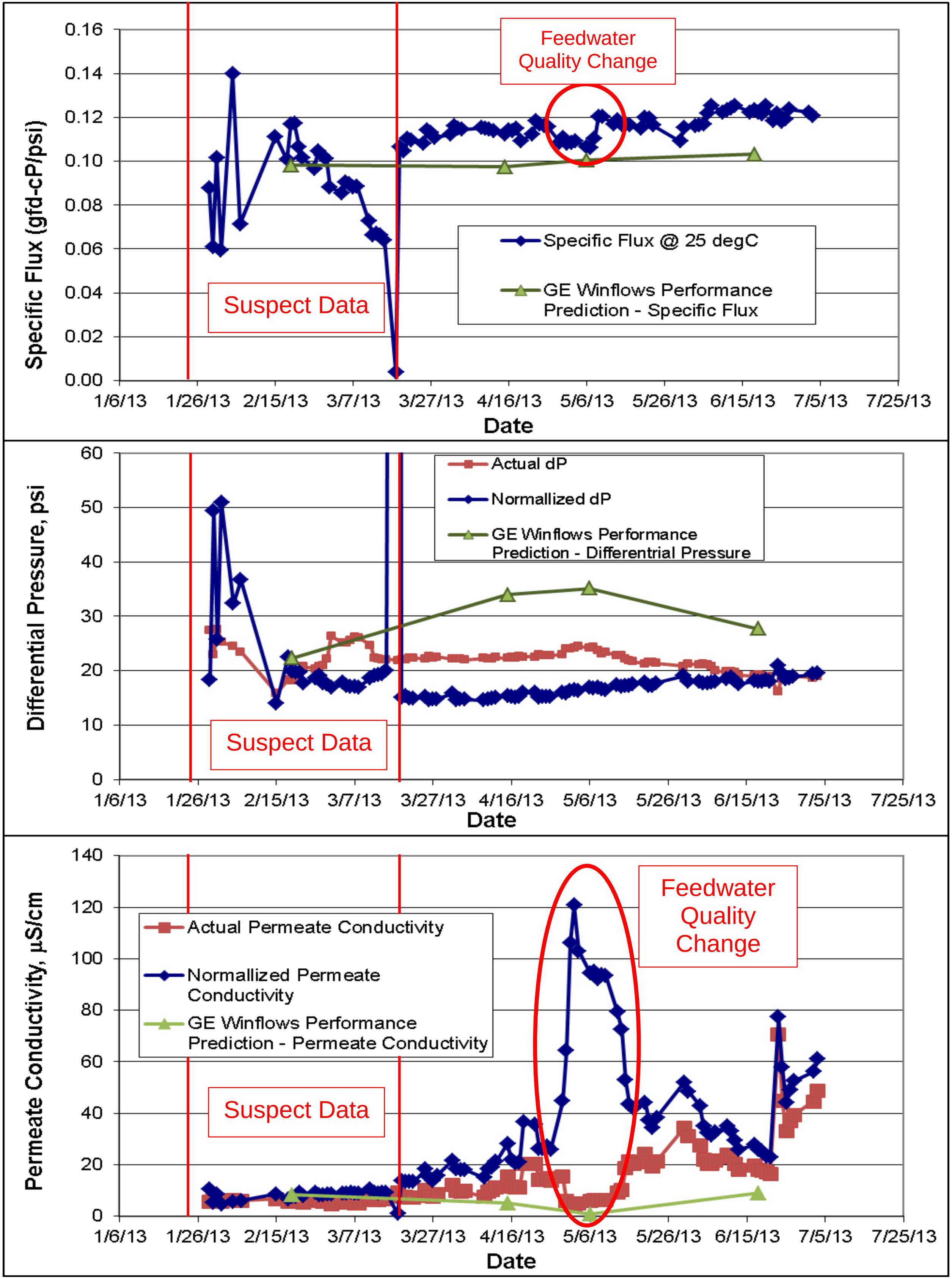


Figure 6: Permeate Quality Comparison (Sulfate Rejection and Conductivity).

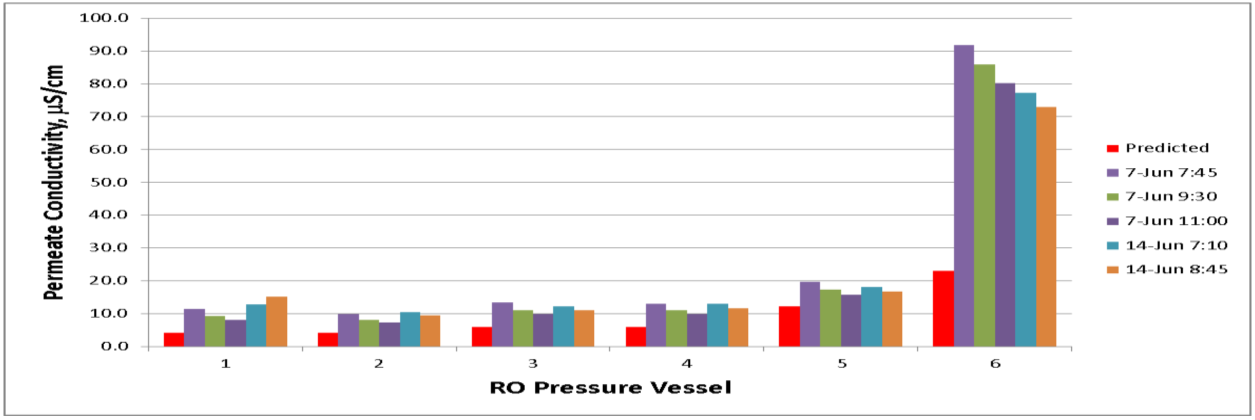


Figure 7: Permeate Quality Comparison (Sulfate Rejection and Conductivity).

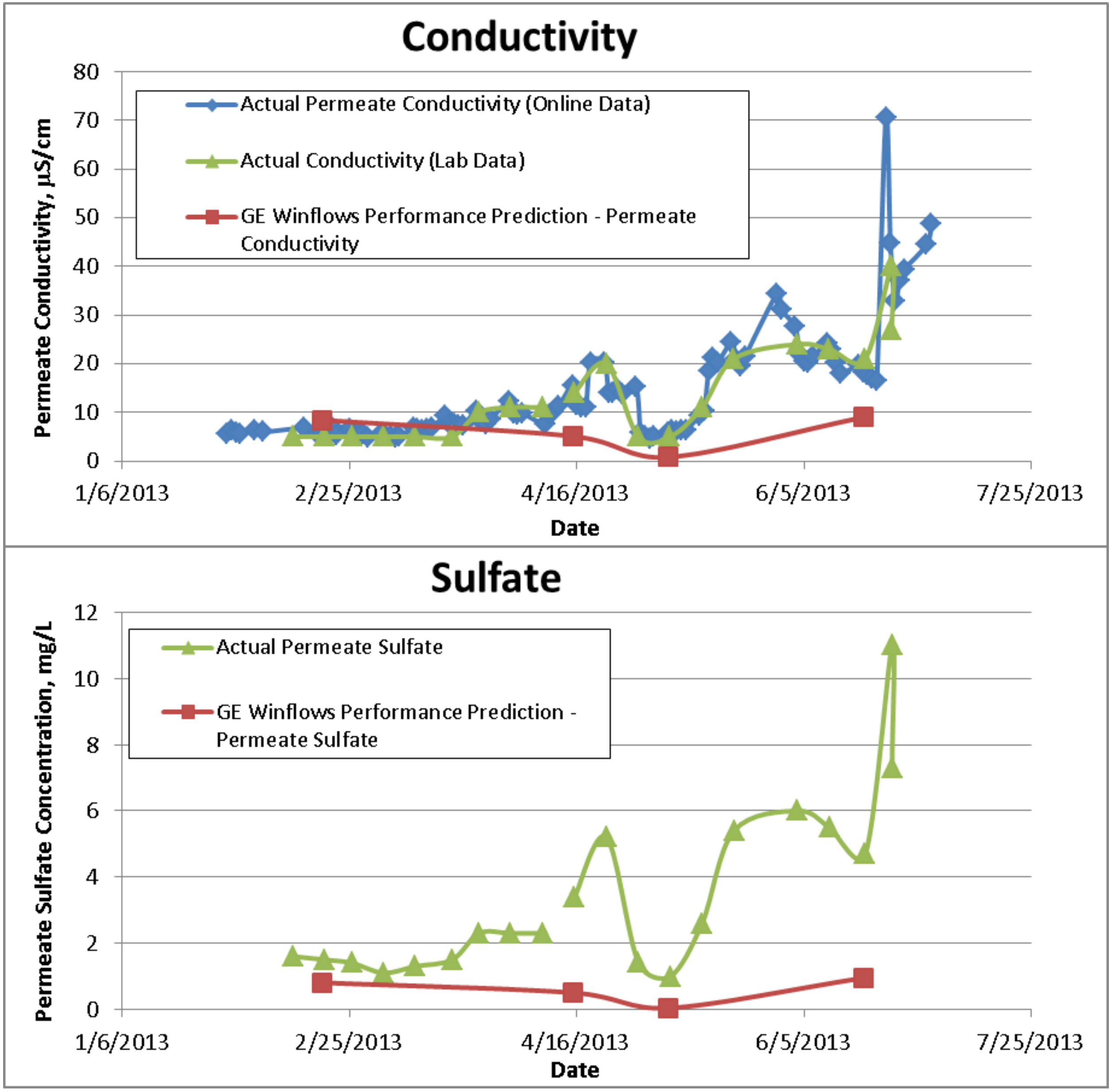


Figure 8: Rejection of divalent and monovalent ions and molecules.

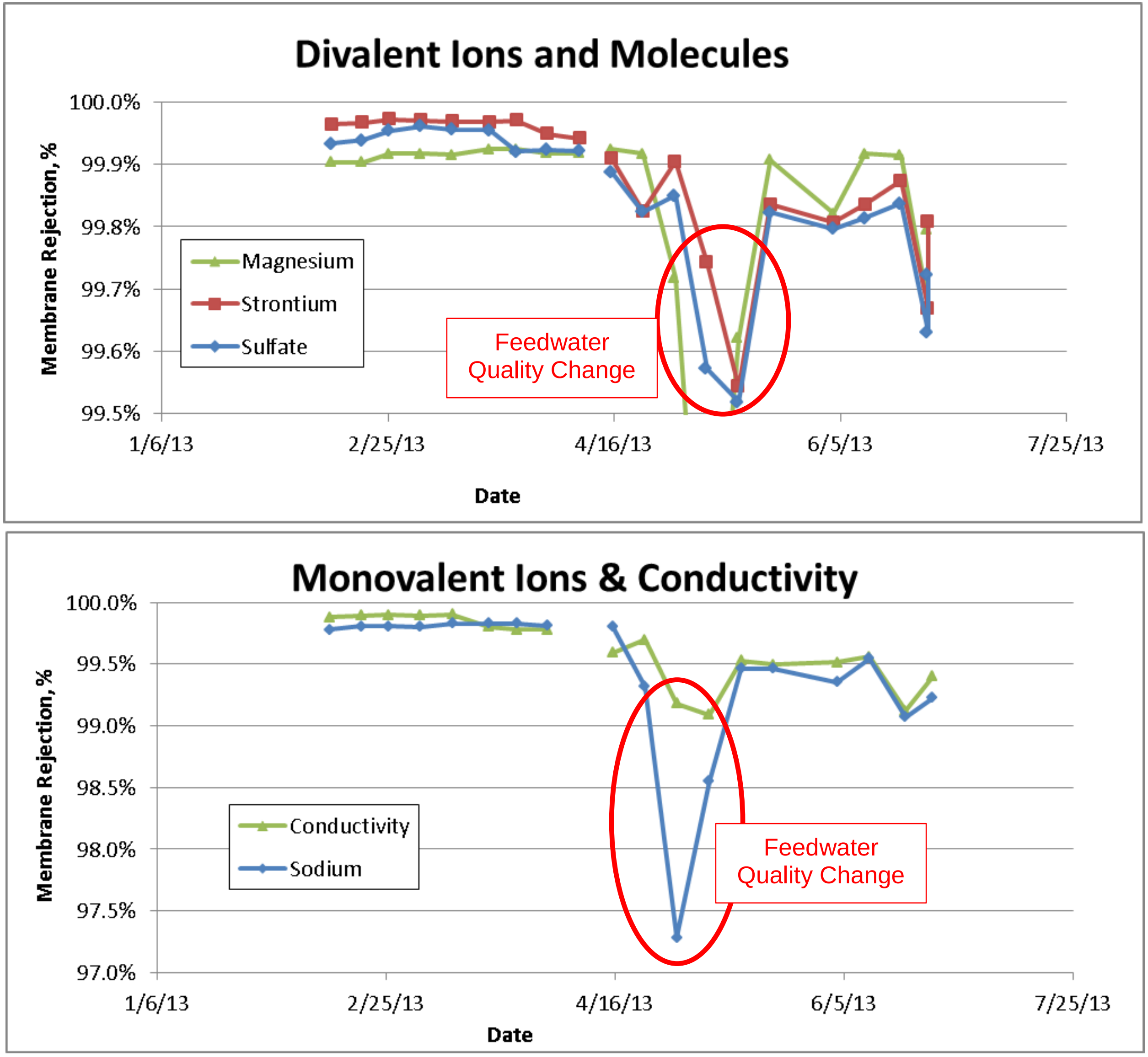


Figure 9: Inorganic Scale Potentials Calculated for 3/19/13 Water Quality Sample

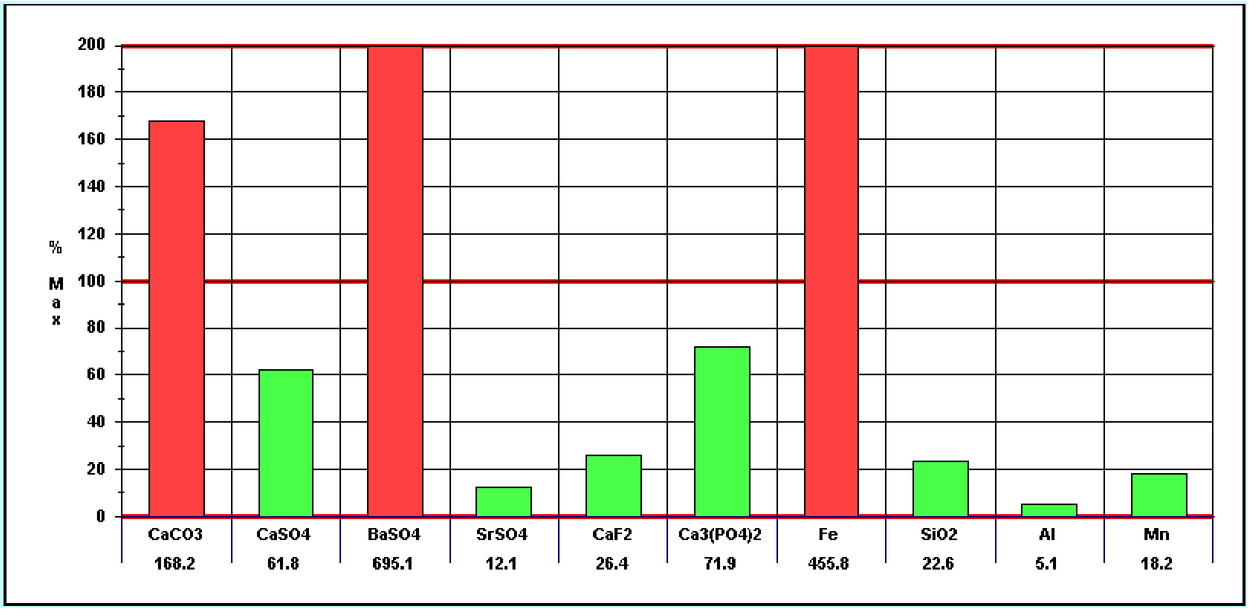
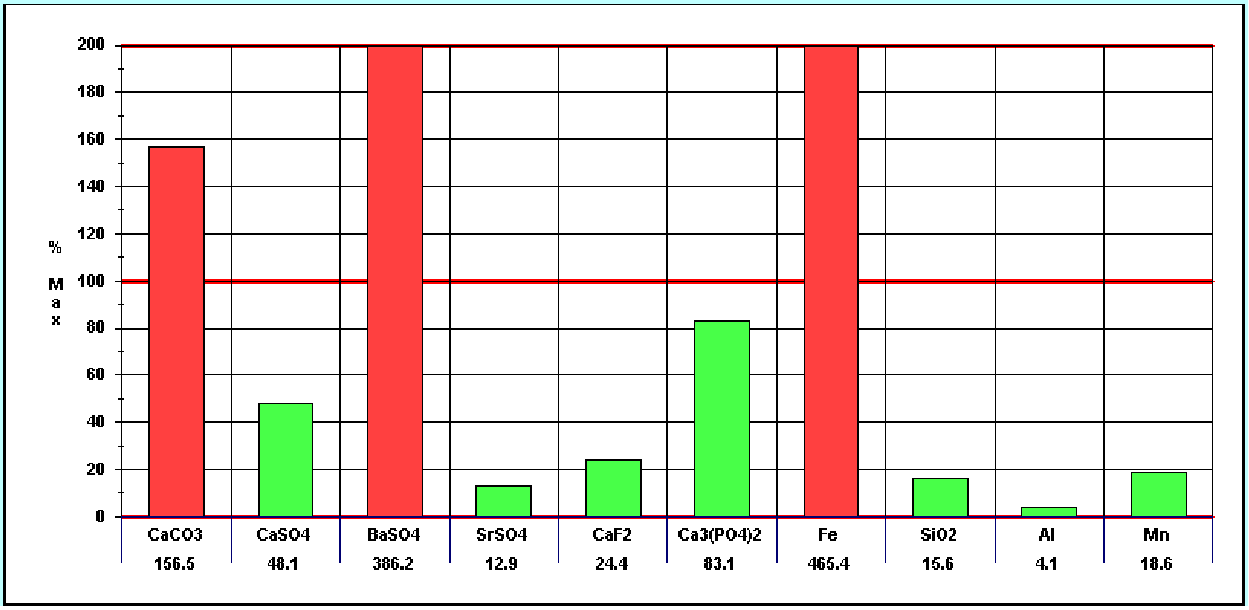


Figure 10: Inorganic Scale Potentials Calculated for 6/10/13 Water Quality Sample



Attachment E

Pilot-Testing Report – Waste Water Treatment Facility Pilot-Testing Program

Pilot-Testing Report

Waste Water Treatment Facility Pilot-Testing Program

Prepared for
Poly Met Mining, Inc.

July 2016

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Minneapolis, MN 55435
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Pilot-Testing Report
Waste Water Treatment Facility Pilot-Testing Program

July 2016

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Certifications

I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the State of Minnesota

07/11/2016

Todd DeJournett
License #: 47085

Date

Acronyms and Abbreviations

Dow	The Dow Chemical Company
ESPA	Hydranautics energy-saving polyamide membrane
FTB	Flotation Tailings Basin
GE	GE Water & Process Technologies
HDS	high-density sludge
NLR	New Logic Research
NF	nanofiltration
RO	reverse osmosis
TDS	total dissolved solids
TSS	total suspended solids
VSEP	vibratory shear enhanced processing
WWTF	Waste Water Treatment Facility
WWTP	Waste Water Treatment Plant

Units

^{o}C	degrees Celsius
GFD	gallons per square foot per day
gpm	gallons per minute
gpm/ft^2	gallons per minute per square foot
mg/L	milligrams per liter

Executive Summary

Treatment technology evaluations conducted by Poly Met Mining, Inc. and Barr Engineering Co. identified two commercially available primary nanofiltration (NF) membranes for removing sulfate and metals from waste water at the NorthMet Project (Project) Waste Water Treatment Facility (WWTF). NF has been selected as the primary unit process for water treatment for the WWTF, along with ancillary unit processes for NF pretreatment (greensand filtration) and concentrate management (a specialty, secondary membrane process called vibratory shear enhanced processing, [VSEP]). To evaluate these treatment processes, PolyMet completed a pilot-testing and bench testing program for the WWTF that evaluated:

- greensand filtration – for iron, manganese, and total suspended solids removal
- nanofiltration – for sulfate and dissolved solids removal
- VSEP – for NF concentrate volume reduction
- chemical precipitation of the VSEP concentrate – for removal of metals and sulfate

Pilot-testing commenced in July 2013 and was completed in October 2013. The primary objectives of the WWTF pilot-testing program were to collect sufficient information to:

- confirm that the selected technologies can reliably meet the Project water quality objectives
- support the design basis of the WWTF
- compare the use of a reverse osmosis (RO) membrane (Hydranautics energy-saving polyamide membrane [ESPA]) to an NF membrane (Dow NF-270) in the VSEP
- quantify metals removal via the greensand filter
- quantify rejection from each NF membrane to inform a computer model
- refine the capital and operating costs for the proposed system
- support performance guarantees and system warranties

The primary objectives of the bench testing program were to develop information that could be used in the chemical precipitation process model, including:

- removal of metals and inorganics, via the high-density sludge (HDS) process over several volume exchanges
- addition of ferrous sulfate (in lieu of ferric sulfate) as a means to enhance selenium removal across the HDS process
- the following components of the gypsum precipitation process:

    - use of gypsum seed sludge precipitated from feed water
    - optimization of pH to maximize removal of sulfate and minimize residual aluminum
    - evaluation of the removal of metals in the gypsum precipitation process
- addition of a metal scavenger in the recarbonation step as a means to polish residual cobalt

The pilot-testing program yielded several very important results, including the following:

- The greensand filter removed significant amounts of cationic metals and achieved WWTF effluent water quality targets for copper, nickel, lead, and zinc.
- Two primary NF membranes were tested. Both achieved the WWTF water quality targets.
    - The Dow NF-270 membrane achieved a permeate sulfate concentration below the WWTP water quality target (10 mg/L).
    - The GE HL4040FM membrane achieved lower concentrations of metals in the permeate than did the Dow NF-270.
- Two VSEP membranes were tested. Both achieved the WWTF water quality targets.
    - The Dow NF-270 membrane achieved a higher average flux, lower batch processing time, and higher passage of sodium, chloride, and silicon than the Hydranautics ESPA RO membrane.
    - The VSEP membranes exhibited a decrease in rejection for sulfate and other salts over the course of the pilot-test.

The chemical precipitation bench testing demonstrated that:

- Sufficient removal was observed across the chemical precipitation processes to support design and operation of the WWTF such that anticipated WWTF treatment targets can be achieved on a 12-month rolling average in the water conveyed to the Flotation Tailings Basin via the Central Pumping Station.
- The application of an organosulfide scavenger (MetClear MR2405) during recarbonation was observed to achieve an additional approximately 50% removal of copper, cobalt, and nickel.
- Observed removal efficiencies for selenium were approximately 30% across the HDS process and 50% across the gypsum precipitation process.
- The removal of metals via the HDS process was observed to decline with multiple exchanges of feed water for all metals tested, except arsenic and selenium. Arsenic removal was observed to be constant over multiple exchanges, while selenium removal was observed to increase over multiple exchanges.

The initial design for the WWTF will be based partly on the results of the bench and pilot-testing. While the primary purpose of this testing was to evaluate treatment technologies for the WWTF, because of the observed performance of the NF membrane for sulfate removal, the results of this testing have also been used to incorporate NF into the design of the WWTP in parallel with RO. This design modification helps to reduce chemical usage in the chemical precipitation and improve treatment efficiency of the chemical precipitation processes.

Because the WWTF is considered an adaptive engineering control, provisions for expansion of the plant and changes to the operating configuration of process units will be incorporated into the full-scale design to match the results of ongoing water quality monitoring and modeling efforts.

1.0 Introduction

As part of the waste water treatment design process for the NorthMet Project (Project), Poly Met Mining, Inc. (PolyMet) and Barr Engineering Co. (Barr) have conducted treatment technology evaluations for both the Waste Water Treatment Plant (WWTP) and the Waste Water Treatment Facility (WWTF). For the WWTP, a pilot-testing program was completed to test reverse osmosis (RO) with greensand filtration for pretreatment and a specialized secondary membrane process (vibratory shear-enhanced processing [VSEP]) for concentration volume reduction. This pilot-testing program was conducted from January 2012 through November 2012 and reported in the Plant Site Waste Water Treatment Plant Pilot-testing Program (Attachment B of the Waste Water Treatment System: Design and Operation Report). In a second stage of pilot-testing, technologies proposed for use at the WWTF were tested and are the subjects of this report. Some of this information has also been used to modify and update the design of the WWTP.

At the Mine Site, mine water is generated from dewatering of mine pits, drainage from active waste rock stockpiles, and other surface features where PolyMet has agreed to collect water. All process water will be collected, treated, and routed to the Flotation Tailings Basin (FTB) for reuse in the Beneficiation process.

Treatment technology evaluations conducted by PolyMet and Barr identified the following major unit processes for treatment of mine water:

- primary, spiral-wound nanofiltration (NF) membrane separation following greensand filter pretreatment
- secondary membrane treatment for concentrate volume reduction
- chemical precipitation

The preliminary process schematic for the WWTF is shown on Figure 1, along with its relationship to the WWTP.

In July 2013, PolyMet initiated a pilot-testing and bench testing program for the WWTF to test the major unit process for the proposed plant, including:

- greensand filtration – iron, manganese, and total suspended solids (TSS) removal
- nanofiltration – sulfate and metals removal using two different NF membranes
- VSEP – NF concentrate volume reduction, and sulfate and metals removal using both RO and NF membranes
- chemical precipitation – sulfate and metals removal

The pilot-scale treatment train is illustrated on Figure 2. Figure 2 also provides the locations for sample collection during the pilot-testing program and the associated nomenclature used for the pilot-testing program. The testing protocol developed for the program describes the objectives, schedules, and methods used for the testing (Appendix A).

Pilot-testing commenced in July 2013 and was completed in October 2013. This report provides the results obtained during the testing program, and evaluates the performance of the technologies with respect to the Project goals and future estimated water quality.

Bench testing was completed in August 2013. A summary of the methods and results is provided in Appendix B.

2.0 Testing Program Structure

2.1 Pilot-Test Program Overview

The primary objectives of the WWTF pilot-testing program were to collect sufficient information to:

- confirm that the selected technologies can reliably meet the Project water quality objectives
- support the design of the WWTF
- refine the capital and operating costs for the proposed system
- support performance guarantees and system warranties

The pilot-testing program was conducted in phases, to provide periods of time for collection of data to assess the performance of each membrane and membrane combination under investigation. Each of the testing phases and its objectives are described in the following sections.

2.1.1 Phase 1 - GE Primary NF and VSEP RO

Phase 1 of this pilot-testing program involved testing the GE NF membrane (HL4040FM) in the primary membrane pilot unit, and the Hydranautics energy-saving polyamide (ESPA) series RO membrane in the VSEP pilot unit. The pilot system was fed with water from the Area 5 pit. The Phase 1 test included spiking metals salt solutions into select points in the pilot treatment train to allow quantification of metals removal via the greensand filter and the primary NF membrane. Rejection of sulfate and other constituents via the primary NF and secondary VSEP systems was also quantified over the course of the Phase 1 pilot-test. A detailed description of the Phase 1 testing protocol is in Appendix A.

2.1.2 Phase 2 - Dow Primary NF and VSEP NF

Phase 2 of this pilot-testing program involved testing the Dow NF membrane (NF-270) in both the primary and VSEP pilot units. The pilot system was fed with water from the Area 5 pit, which is described further in Section 3. The Phase 2 test included spiking of metals salt solutions into select points in the pilot treatment train to allow quantification of metals removal via primary and secondary NF membranes. Rejection of sulfate and other constituents via the primary NF and secondary VSEP membranes was also quantified over the course of the Phase 2 pilot-test. A detailed description of the Phase 2 testing protocol is in Appendix A.

2.1.3 Chemical Precipitation Bench Testing

Chemical precipitation bench testing was completed using VSEP concentrate from Phase 2 of the pilot-test. This program supplements the previous bench testing that was completed as part of the Plant Site Wastewater Treatment Plant Pilot-testing Report (Attachment B of the Waste Water Treatment System: Design and Operation Report). This bench testing program included spiking the VSEP concentrate with metals, and then measuring the metals concentrations resulting from treatment under various chemical precipitation process conditions, including:

- high-density sludge precipitation at two pH set points, with and without sludge recycle, with and without the addition of ferrous sulfate
- gypsum precipitation at three different pH set points
- recarbonation (calcite precipitation) with and without scavenger addition

A description of the bench testing protocol is in Appendix B.

2.1.4 Testing Facilities

Water was pumped from the Area 5 Pit into tanker trucks, which transported the water to the Wayne Transports, Inc. facility in Virginia, MN. The pilot-test facility at Wayne Transports was equipped with city water, hot water, power, internet connectivity, and sanitary sewer service. Drawings of the pilot-test facility layout are provided in Appendix C.

Bench testing was conducted at Barr's water treatment laboratory in Edina, MN.

2.1.5 Roles

2.1.5.1 PolyMet

PolyMet was the lead organization in the pilot-testing effort. PolyMet activities included:

- contract development for the pilot-testing equipment, laboratories, and consultants
- management of the pilot-testing, equipment suppliers, laboratories, and consultants
- operation of the pilot units, including regular monitoring, assistance with process troubleshooting, and conducting clean-in-place procedures for the pilot units when required
- management and disposal of wastes generated during the pilot-testing program
- sample collection

2.1.5.2 Barr Engineering Co.

Barr staff provided the following services:

- development of testing protocols
- technical support for process troubleshooting, data evaluations and interpretation, and performance evaluation
- assistance with the development of the refined construction and O&M costs, based on pilot-testing results
- execution of chemical precipitation bench tests
- reporting of pilot-test results

2.1.5.3 Equipment Suppliers

The equipment suppliers for this pilot-test included:

- GE Water & Process Technologies (GE) – Greensand filter and RO pilot-test systems
- The Dow Chemical Company (Dow) – Primary NF membrane modules
- New Logic Research (NLR) – VSEP pilot unit

Equipment supplier activities included:

- provision of pilot-test equipment in accordance with their contracts
- provision of on-site supervision of installation and startup
- provision of training such that PolyMet staff had sufficient knowledge to support the pilot-testing program

2.1.5.4 Laboratories

Legend Technical Services, Inc. provided all analytical services for samples collected during the pilot-testing and bench testing programs.

3.0 Water Quality

3.1 Influent Water Quality

Feed water for pilot-testing was obtained from the Area 5 pit. Area 5 pit water has a similar sulfate concentration and total dissolved solids (TDS) to the anticipated WWTF influent. Area 5 pit water quality is summarized in Table 1. Note that all qualifiers for analytical data summarized in this report in Table 1 through Table 16 are included in Table 17.

Figure 3 shows the concentrations of TDS, total hardness, and sulfate for Area 5 pit water over the course of the pilot-test. Over the duration of the pilot-test, the influent water quality from the Area 5 pit was relatively constant, and TSS concentrations were relatively low. Figure 4 illustrates the iron and manganese concentrations in the Area 5 pit water. Influent iron and manganese concentrations were low compared to the Plant Site Wastewater Treatment Plant Pilot-Testing Report (Attachment B of the Waste Water Treatment System: Design and Operation Report).

3.2 Treated Water Quality Targets

Although the treated water from the WWTF will not be discharged to the environment, water quality targets have been established to facilitate routing of the treated water to the FTB. The treated water quality targets are shown in Table 2. The targets in Table 2 are the water quality targets for the blended mine water effluent, which will contain primary NF permeate, VSEP permeate, and chemical precipitation effluent from the WWTF along with runoff from process areas that do not require treatment, for example the overburden storage and laydown area.

4.0 Phase 1 Pilot-Test Results

This section describes the results of the Phase 1 pilot-test, which included testing the greensand filter, the GE NF membrane (HL4040FM) in the primary membrane pilot unit, and the Hydranautics ESPA series RO membrane in the VSEP pilot unit.

4.1 Greensand Filter Performance

The greensand filter pilot unit provided by GE for the pilot-test was a pressure filter (Figure 5). This filter is a 30-inch-diameter unit filled with coarse gravel (5 inches), greensand filter media (30 inches), and anthracite (12 inches). As described in Appendix A, metal salt solutions were added to the greensand filter feed to provide removal efficiency information to supplement the arsenic removal information collected as part of the Plant Site Wastewater Treatment Plant Pilot-Testing Report (Attachment B of the Waste Water Treatment System: Design and Operation Report). For the pilot-test, the influent was dosed continuously with potassium permanganate to: (1) oxidize iron and manganese for removal by filtration, and (2) regenerate the greensand media.

4.1.1 Filter Loading

Over the duration of the testing program, the influent flow was 22 gpm. The resultant hydraulic loading to the filter was 4.5 gpm/ft^2 of filter bed area.

4.1.2 Filter Removal Rates

The greensand filter removal rates for TSS, iron, manganese, arsenic (as arsenite) copper, cobalt, lead, nickel, selenite, selenate, and zinc are presented in Table 3. Table 4 displays the greensand filtrate water quality.

Removal efficiencies for TSS, iron, and manganese were variable and generally lower than observed for the Plant Site Wastewater Treatment Plant Pilot-Testing Report (Attachment B of the Waste Water Treatment System: Design and Operation Report). This was likely a function of the lower feed concentrations for these constituents.

Removal of cationic metals (cobalt, copper, nickel, lead, zinc) was high (>85%). Removal of cobalt and copper in particular was very high, averaging over 98% and 94%, respectively. Observed copper, nickel, and zinc concentrations in the effluent from the greensand filter were below treatment targets. Observed cobalt concentrations in the effluent from the greensand filter were very near the treatment target.

Removal of arsenite by the greensand filter averaged about 69%.

Selenite was better-removed than selenate, averaging 12% and 0%, respectively.

4.2 Nanofiltration – GE HL4040FM

The NF pilot unit was provided by GE, and is the same unit that was used for the Plant Site Wastewater Treatment Plant Pilot-Testing Report (Attachment B of the Waste Water Treatment System: Design and

Operation Report). A picture of the pilot-test unit employed for the Project is shown on Figure 6. The pilot unit provided eighteen 4-inch-diameter membrane modules housed in six vessels, in a 2-2-1-1 array. The membranes employed were NF membranes (GE model HL4040FM).

The greensand filter effluent was treated with 2.2 ppm of Hypersperse MDC700, a scale inhibitor, prior to feeding to the NF membranes.

The pilot unit was operated continuously for approximately 8 hours per day, typically 5 days per week. At the end of each 8-hour shift, the NF system was flushed with permeate and shut down.

4.2.1 Flux and Recovery

During Phase 1 of the test, the pilot system was operated at a recovery of approximately 80% and a flux of approximately 16 GFD. The NF system recovery setpoint was carried forward from previous Plant Site Wastewater Treatment Plant Pilot-Testing Report (Attachment B of the Waste Water Treatment System: Design and Operation Report), and was not optimized for the NF membrane.

For the duration of this phase, no operational problems were encountered. As shown in Figure 7, the feed to concentrate pressure drop across the NF membrane was generally less than 30 psi during Phase 1. As shown on Figure 8, the feed pressure to the NF membrane generally ranged between 65 and 90 psi during Phase 1. Also shown on Figure 8 is the permeate temperature during the pilot-test, which was generally between 20^{o}C and 25^{o}C during this phase of the test.

4.2.2 Permeate Water Quality

The NF feed (greensand filter effluent), permeate, and concentrate water quality data collected during Phase 1 are summarized in Table 4, Table 5, and Table 6, respectively.

4.2.2.1 Removal Rates

Average removal rates were estimated for those parameters with detectable concentrations in the greensand filter effluent (NF feed) and are displayed in Table 7. The average sulfate removal by the NF was 99.0% during the pilot-test. The sulfate concentrations in the NF permeate ranged from 11 to 13 mg/L. Figure 9 shows the observed sulfate removal over the course of the Phase 1 test.

Removal of metals by the NF membrane was very good, with removal efficiencies for most metals exceeding 99%. Average removal efficiencies for zinc, copper, and selenite were 98.4%, 93.8%, and 93.0%, respectively. Observed permeate concentrations for all metals studied were below their respective water quality targets for the duration of Phase 1, with the exception of copper and selenite. Copper concentrations greater than the water quality target was measured in two of the eight observations, and selenite concentrations were greater than the water quality target in four of eight observations.

Removal of monovalent ions, particularly sodium and chloride, was low, averaging 55.4% and 13.0%, respectively. Removal of silicon was low (29.8%).

4.2.2.2 Comparison to Equipment Supplier Model

The suppliers of NF membranes commonly use models to design their system and to estimate the permeate water quality. Each supplier typically has developed their own models for their membranes, and each supplier has significant operating data collected over the years for validation of the model output. The model water quality input and output is generally limited to the major anions and cations, pH, boron, and certain constituents of concern with respect to membrane fouling or scaling (e.g., aluminum, barium, silica, strontium). Because equipment supplier models will likely be used during the full-scale system design, a comparison of their output and measured water quality data was made. Table 8 and Figure 10 compare the equipment vendor model results with average measured permeate water quality from the pilot-test. It can be seen from the table and figure that the GE model reasonably estimates the order of magnitude of the measured result. For sulfate, the model results appear to be conservatively high relative to the observed sulfate concentrations, while projected sodium concentrations appear to be conservatively low. This result is discussed in more detail in Section 7.2.

While the manufacturer models do not provide projected rejections for trace metals, GE did provide estimated rejections for trace metals, including copper, cobalt, nickel, and zinc. GE estimated the rejection values for these metals at 60% for all operational years evaluated. The rejection values observed for these metals during the pilot-test were significantly higher than GE's estimate, and likely more accurately reflect actual rejections that can be expected for the Project.

4.3 VSEP Membrane (Hydranautics ESPA)

The VSEP pilot-test unit was provided by New Logic Research. A picture of the pilot-test unit that was used in the pilot-testing program is shown on Figure 11. Manufacturer's information on the VSEP pilot unit can be found in Appendix DD. The unit was operated in batch mode during Phase 1 testing activities. For the Phase 1 pilot-test, RO membranes (ESPA series by Hydranautics) were used. These were the same type of membranes used in the previous Plant Site Wastewater Treatment Plant Pilot-Testing Report (Attachment B of the Waste Water Treatment System: Design and Operation Report).

VSEP feed pH was adjusted via continuous addition of carbon dioxide to the feed tank, resulting in feed pH of approximately 6.5. Antiscalant (NLR 759) was added to the VSEP feed at 10 ppm. Recovery for the VSEP batches was 80%.

The cleaning program was as follows after each batch:

- 10-minute hot water flush
- 30-minute chemical cleaning with NLR 404
- 10-minute hot water flush
- 30-minute chemical cleaning with NLR 505

4.3.1 Flux and Recovery

Figure 12 depicts the temperature-corrected flux (10°C) vs. recovery curves for the VSEP pilot-test unit during Phase 1 testing. The flux for the VSEP membranes began at approximately 50 GFD, and declined over the course of each batch to approximately 30 GFD by the end of the batch.

4.3.2 Permeate and Concentrate Quality

Table 9 and Table 10 summarize the Phase 1 VSEP permeate and concentrate quality, respectively. Because previous WWTP pilot-testing focused on quantifying removal of constituents via the Hydranautics ESPA RO membrane in the VSEP pilot unit, limited data were collected in this regard during Phase 1 of this test.

The VSEP permeate typically achieved sulfate concentrations below 30 mg/L, sodium concentrations below 10 mg/L, and chloride and silicon concentrations below their respective detection limits.

The VSEP concentrate was characterized by sulfate concentrations above 20,000 mg/L, sodium concentrations ranging from 790 to 950 mg/L, and silicon concentrations ranging from 17 to 20 mg/L.

4.3.3 Removal Rates

Table 11 summarizes observed removal rates for the VSEP system during Phase 1. Mass removal rates were 99.6%, 97.3%, 99.0%, and 96.0% for sulfate, sodium, silicon, and chloride, respectively. Figure 13 shows the removal of sulfate, sodium, and TDS over the course of Phase 1.

4.4 Discussion

Phase 1 testing demonstrated successful removal of metals via both the greensand filter and GE NF membrane. The test also demonstrated excellent rejection of sulfate by both the GE NF membrane and the Hydranautics ESPA RO membrane in the VSEP unit.

While arsenate is anticipated to be the dominant arsenic species in the mine water (Reference (1)), testing of an arsenite salt was included in this pilot-test to provide data regarding removal of the reduced arsenic species by system components to provide a conservative estimate of arsenic removal. The arsenite removal observed during this test was lower than observed during the Plant Site Wastewater Treatment Plant Pilot-Testing Report (Attachment B of the Waste Water Treatment System: Design and Operation Report). This may have been due to a lower dose of potassium permanganate applied during this test. Arsenite rejection by the GE NF membrane was sufficient to achieve the water quality target for arsenic, with or without removal of arsenic by the greensand filter.

While selenate is anticipated to be the dominant selenium species in the mine water, both selenite and selenate salts were evaluated as part of this pilot-test. As expected, neither species was well-removed by the greensand filter at the feed pH, although selenite was slightly better-removed than selenate. As expected, selenate was better-rejected by the GE NF membrane than was selenite, due to its higher charge. Rejection of selenate by the GE NF membrane was sufficient to meet the water quality target in the primary NF permeate, and rejection of selenite by the GE NF membranes is capable of achieving selenium concentrations very near the water quality target (within 50%).

The greensand filter demonstrated the capability to remove sufficient copper to achieve the water quality target without any further treatment. While copper removal via the GE NF membrane was variable, the combined removal of copper via the greensand filter and NF membrane is anticipated to meet the water quality target.

For all other metals studied, rejection via the GE NF membrane was sufficient to achieve water quality targets in the primary NF permeate. Additional removal achieved via the greensand filter, which exceeds 90% in most cases, provides additional robustness to the design.

Rejection of sulfate via the GE NF membrane was sufficient to meet the WWTF water quality target for sulfate in the primary NF permeate.

The GE NF membrane demonstrated good passage of sodium and chloride. This is beneficial in that it reduces the ionic strength of the NF concentrate and, ultimately, the VSEP concentrate, which enhances the ability to precipitate sulfate from the concentrate.

The GE NF membrane also demonstrated good passage of silicon, which is beneficial in that cycling-up of silicon in the NF and VSEP concentrates can limit membrane system recovery. Thus, the ability of the membrane to pass silicon lends robustness to the design in that performance is less sensitive to fluctuations in feed silicon concentration.

The initial flux achieved via the ESPA RO membrane in the VSEP pilot unit was higher than previously observed for this membrane. This may have been due to the fact that VSEP feed during Phase 1 was NF concentrate, which has a lower TDS than the RO concentrate that was used in previous testing. Terminal fluxes were similar, suggesting the same mechanism may limit the terminal flux and recovery in both cases.

As expected, the ESPA RO membrane had high rejection of sodium, chloride, and silicon. As previously stated, it is desirable to minimize the concentrations of sodium and chloride in the VSEP concentrate, as sulfate precipitation is enhanced at lower ionic strength. Additionally, it is desirable to minimize silicon in the VSEP concentrate to reduce membrane fouling and enhance recovery. In Phase 2, the use of an NF membrane in the VSEP unit was investigated as an opportunity to reduce the concentrations of sodium, chloride, and silicon in the VSEP concentrate.

5.0 Phase 2 Pilot-test Results

This section describes the results of the Phase 2 pilot-test, which tested the Dow NF membrane (NF-270) in both the primary membrane pilot unit and in the VSEP pilot unit. The same greensand filter was used for both phases of the test. Metal salt solutions were spiked into the primary NF feed, as described in Appendix D to quantify removal of metals by the primary and secondary NF membranes.

5.1 Nanofiltration – Dow NF-270

The NF pilot unit was provided by GE, and it is the same unit that was used for the Phase 1 pilot-test. The membranes employed were NF membranes (Dow model NF-270).

The greensand filter effluent was treated with 2.2 ppm of Hypersperse MDC700, a scale inhibitor prior to feeding to the NF membranes.

The pilot unit was operated continuously for approximately 8 hours per day, typically 5 days per week. At the end of each 8-hour shift, the NF system was flushed with permeate and shut down.

5.1.1 Flux and Recovery

During Phase 2 of the test, the pilot system was operated at a recovery of approximately 80% and a flux of approximately 16 GFD. The recovery was carried forward from previous Plant Site Wastewater Treatment Plant Pilot-Testing Report (Attachment B of the Waste Water Treatment System: Design and Operation Report), and was not optimized for the NF membrane.

For the duration of this phase, no operational problems were encountered. As shown on Figure 7, the feed to concentrate pressure drop across the NF membrane was less than 30 psi, and commonly less than 25 psi during Phase 2. Figure 8 shows that the feed pressure for the NF-270 membrane was generally less than 80 psi. Permeate temperature was between 15 and 25°C during the Phase 2 test.

5.1.2 Permeate Water Quality

The NF feed (greensand filter effluent), permeate, and concentrate water quality data collected during Phase 2 are summarized in Table 4, Table 5, and Table 6, respectively.

5.1.2.1 Removal Rates

Average removal rates were estimated for those parameters with detectable concentrations in the greensand filter effluent (NF feed) and are displayed in Table 7. The average sulfate removal was 99.6% during the pilot-test. The sulfate concentrations in the NF permeate ranged from 4.3 to 5.2 mg/L over the course of the test. Permeate sulfate concentrations were therefore well below the 250 mg/L water quality target for the WWTF, and therefore well below what is required for meeting effluent targets when blended with the VSEP permeate and chemical precipitation effluent. Figure 14 shows the observed sulfate removal over the course of the Phase 2 test.

It is also notable that the permeate sulfate concentration is below the WWTP water quality target of 10 mg/L as well. This result suggests that some portion of the water at the WWTP could be treated using NF as the primary membrane separation process. This will provide some operational flexibility at the WWTP while also helping to minimize the build-up of sodium and other monovalent irons in the concentrate stream that may negatively influence the precipitation of sulfate.

Removal of metals by the NF membrane was good, with removal efficiencies for most metals exceeding 90%. Average removal efficiencies for copper and arsenic were 87.8% and 16.6%, respectively. Observed permeate concentrations for nickel, lead, zinc, and selenate were below their respective water quality targets for the duration of Phase 2. Permeate concentrations of copper, arsenite, selenite, and cobalt were greater than their respective water quality targets.

Removal of monovalent ions, particularly sodium and chloride, was low, averaging 65% and 9.2%, respectively. Removal of silicon was low (25.3%).

5.1.2.2 Comparison to Equipment Supplier Model

As with Phase 1, the pilot-testing results for the NF system were compared to vendor projections. Table 8 compares the model results with measured permeate water quality for Phase 2, and Figure 15 graphically displays the comparison for sulfate. As can be seen from the figure and table, Dow's model reasonably estimates the order of magnitude of the measured result. For sulfate, the model results appear to be conservatively low relative to the observed sulfate removal.

5.2 VSEP Membrane (Dow NF-270)

Phase 2 pilot-testing used the same VSEP pilot unit, provided by New Logic Research, which was used in the Phase 1 test. The unit was operated in batch mode during Phase 2 testing activities. For the Phase 2 pilot-test, NF membranes (Dow NF-270) were used.

VSEP feed pH was adjusted via continuous addition of carbon dioxide to the feed tank, resulting in feed pH of approximately 6.5. Antiscalant (NLR 759) was added to the VSEP feed at 10 ppm. Recovery for the VSEP batches was 80%.

The cleaning program was generally as follows after each batch:

- 10-minute hot water flush
- 30-minute chemical cleaning with NLR 404
- 10-minute hot water flush
- 30-minute chemical cleaning with NLR 505

5.2.1 Flux and Recovery

Figure 16 depicts the temperature-corrected flux (10°C) vs. recovery curves for the VSEP pilot unit during Phase 2 testing. The flux for the VSEP membranes began at approximately 90 GFD, and declined over the course of each batch to between 30 and 40 GFD by the end of the batch. Figure 17 compares the batch processing times resulting from the flux differences between the membrane types tested.

5.2.2 Permeate and Concentrate Quality

Table 9 and Table 10 summarize the Phase 2 VSEP permeate and concentrate quality, respectively. The VSEP permeate was characterized by sulfate concentrations ranging from 72 to 160 mg/L, sodium concentrations ranging from 120 to 140 mg/L, chloride ranging from 2.2 to 3.2 mg/L, and silicon ranging from 4.9 to 5.6 mg/L.

The VSEP concentrate was characterized by sulfate concentrations ranging from 16,000 to 24,000 mg/L, sodium concentrations ranging from 440 to 800 mg/L, and silicon concentrations ranging from less than 5 to 7.3 mg/L.

5.2.3 Removal Rates

Table 11 summarizes observed removal rates for the VSEP system during Phase 2. Sulfate mass removal averaged 98.0% over the course of the Phase 2 test. Sodium removal averaged 55.4%, while silicon removal averaged 29.8%. Figure 18 shows removal of sulfate, sodium, and TDS by the VSEP over the course of Phase 2 testing.

Removal of most metals via the VSEP system exceeded 90% during Phase 2. Arsenic and selenite removal averaged 50.6% and 66.7%, respectively.

5.3 Discussion

Table 12 summarizes the average observed concentrations of constituents in the greensand filter effluent after spiking the feed, as well as the calculated average concentrations in the primary NF and VSEP permeate blends for each primary membrane manufacturer after spiking the membrane feed. Table 12 demonstrates the ability of the combination of the GE NF primary membrane and the Dow NF-270 secondary membrane to achieve water quality targets in the blended permeates for all constituents except selenite and cobalt. The table further demonstrates the ability of the greensand filter to nearly achieve the water quality target for cobalt by itself, such that the combination of the greensand filter, GE primary NF membrane, and Dow NF-270 secondary membrane is capable of achieving water quality targets for all parameters except selenite.

Rejection of sulfate by the Dow NF membrane was sufficient to meet the WWTF water quality target for sulfate in both the primary membrane and VSEP permeates. The Phase 2 pilot-test also achieved the WWTP target for sulfate in the primary membrane permeate. The permeate sulfate concentration for the VSEP unit gradually increased over the course of the pilot-test, while feed concentrations remained relatively constant, suggesting some loss of sulfate rejection over the course of the pilot-test, perhaps due to repeated cleaning of the membrane or a mechanical issue on the pilot unit itself such as an O-ring gasket leak.

The Dow NF membrane demonstrated good passage of sodium and chloride. This is beneficial in that it reduces the ionic strength of the NF concentrate and, ultimately, the VSEP concentrate, which enhances the ability to precipitate sulfate from the concentrate. Sodium rejection via the VSEP unit declined over the course of the study, perhaps at a greater rate than the decline in sulfate rejection described above.

The Dow NF membrane also demonstrated good passage of silicon, which is beneficial in that cycling-up of silicon in the NF and VSEP concentrates can limit recovery. Thus, the ability of the membrane to pass silicon lends robustness to the design in that performance is less sensitive to fluctuations in feed silicon concentration.

The use of the Dow NF membrane in the primary membrane pilot-test may have resulted in a lower required feed pressure and a lower feed-to-concentrate pressure drop relative to the GE NF membrane. Permeate temperatures during testing of the Dow NF membrane were between 15°C and 25°C, compared to 20°C to 25°C for the GE NF membrane, so it is unlikely that temperature differences were responsible for the observed difference in feed pressure.

The use of the Dow NF membrane in the VSEP pilot unit facilitated an initial flux that was nearly twice that achieved with the Hydranautics ESPA RO membrane. However, over the course of each batch, the flux declined to nearly the same final value as observed with the RO membrane, suggesting a similar mechanism may limit terminal flux and recovery in both cases.

6.0 Bench Test Results

This section describes the results of the bench testing performed using the VSEP concentrate from Phase 2 of the pilot-test program. Composition of the VSEP concentrate used for the test is summarized in Table 13. The concentrate was spiked with metals and exposed to the treatments described in Appendix B.

6.1 HDS Metals Precipitation Results

Results of the HDS metals precipitation bench test are shown in Table 14, and presented graphically in Figure 19 through Figure 24. Removal was observed for all metals tested. The higher pH setpoint demonstrated better removal of metals, despite the lower concentration of iron solids that was used. Removal of cobalt, copper, nickel, and arsenic was most complete. Selenium and antimony were removed to lesser degrees, with removal efficiencies on the order of 30% and 50%, respectively.

Exposure of the same iron sludge to multiple volumes of spiked feed water resulted in decreased observed removal for all metals except arsenic and selenium. The decrease in removal observed upon multiple exchanges of feed water was more significant at the low pH setpoint than at the higher setpoint.

The addition of ferrous sulfate to the reactors was not observed to affect the removal of selenium during the test.

6.2 Sulfate Precipitation Results

Results of the sulfate precipitation test are shown in Table 15 and presented graphically in Figure 25 through Figure 32. Removal was observed for all metals tested, as well as sulfate. Removal of aluminum and antimony were most complete, although cobalt, copper, nickel, and arsenic were also removed to low concentrations.

Magnesium was also precipitated from the concentrate to undetectable concentrations, and sulfate was precipitated to concentrations as low as 2,700 mg/L, even in treatments that received a significant amount of additional sulfate from the alum spike that was added.

6.3 Scavenger Test Results

Results of the scavenger test are shown in Table 16 and presented graphically in Figure 33. Significant removal of cobalt, copper, and nickel was observed with and without the scavenger addition. Removal was greatest at the highest pH setpoint studied. The addition of scavenger reduced the final concentrations of the metals by approximately 50% at the highest pH setpoint, and this effect was less pronounced at the lower setpoints.

7.0 Conclusions

7.1 Greensand Filter

The greensand filter removed significant amounts of many of the metals studied and achieved effluent water quality targets for copper, nickel, lead, and zinc.

Arsenite removal via the greensand filter during this study was lower than previously observed as described in the Plant Site Wastewater Treatment Plant Pilot-Testing Report (Attachment B of the Waste Water Treatment System: Design and Operation Report); likely due to a lower dose of potassium permanganate oxidant ahead of the greensand filter. In addition to oxidizing iron and regenerating the manganese oxide greensand coating, permanganate has the ability to oxidize arsenite to arsenate. Arsenate is better adsorbed by iron oxyhydroxides, and thus more completely removed by the greensand filter.

Addition of permanganate ahead of the greensand filter also has the ability to oxidize selenite to selenate. While neither selenite nor selenate was well-removed by the greensand filter during this pilot-test, selenate was demonstrated to be better rejected by downstream NF membranes.

While this pilot-test did not include optimization of greensand filter operation for removal of metals or oxidation of selenite, such an optimization could be completed, if needed, to maximize removal of metals by the greensand filter, and removal of selenium via downstream NF membranes.

7.2 Comparison of Primary NF Membranes

Both NF membranes tested in the primary membrane pilot unit achieved permeate sulfate concentrations below the water quality target for the WWTF. The Dow NF-270 membrane achieved lower permeate sulfate concentrations than the GE HL4040FM, and achieved permeate sulfate concentrations below the water quality target for the WWTP as well.

The Dow NF membrane operated at a lower feed pressure and had a lower feed to concentrate pressure drop than the GE HL4040FM membrane. This may translate into lower power requirements for operation.

The GE NF membrane demonstrated better rejection of metals than the Dow NF membrane. The GE NF membrane achieved water quality targets for all metals studied except copper and selenite, and demonstrated much better rejection of copper, cobalt, nickel, and zinc than GE's previous estimate. The Dow NF membrane achieved water quality targets for lead, nickel, zinc, and selenate.

Both membranes demonstrated good passage of sodium, chloride, and silicon. Sodium passage was slightly greater for the GE NF membrane.

If deployed in conjunction with the greensand filter, both membranes are capable of achieving WWTF water quality targets for metals and sulfate in the blended permeates, although the GE NF membrane provides incrementally more robustness relative to metals removal.

While the purpose of this pilot-test was primarily to support design of the WWTF, the results also presented an opportunity to improve design of the WWTP. Because the NF membranes tested demonstrated excellent rejection of sulfate and good passage of sodium, it is possible to improve the design of the WWTP by using both RO and NF membranes in the primary separation step. This improvement will also increase the performance of the subsequent treatment steps by reducing the mass of monovalent ions within the concentrate streams.

7.3 Comparison of VSEP Membranes

Both the Hydranautics ESPA RO and Dow NF-270 membranes produced VSEP permeate sulfate concentrations below the water quality target for the WWTF. As expected, the Dow NF membrane demonstrated much better passage of sodium, chloride, and silicon relative to the ESPA RO membrane. The passage of sodium in particular is important for operation of the chemical precipitation equipment, as build-up of sodium in the chemical precipitation loop can limit sulfate precipitation efficiency.

Figure 18 provides a comparison of temperature-corrected instantaneous fluxes achieved for the ESPA RO and Dow NF membranes. As shown in the figure, the Dow NF membrane had an initial instantaneous flux nearly twice that of the ESPA RO membrane. Over the course of the batch, the fluxes eventually reached the same terminal values for both membranes. On average, however, the achievable flux for the batch was higher for the Dow NF membrane, as evidenced by a batch processing time on the order of four hours, compared to a batch processing time on the order of 5 to 6 hours for the ESPA RO membrane. This difference in average flux and batch processing time represents a significant potential advantage for the Dow NF-270 membrane, in that it allowed the same pilot-testing equipment to process more feed in the same time relative to the ESPA RO membrane.

The fact that both the ESPA RO and NF-270 membranes demonstrated the same terminal flux suggests that terminal flux/recovery may be limited by the precipitation of a similar foulant in both cases. Pretreatment of VSEP feed was not optimized as part of this study, and it is unknown if terminal fluxes for the VSEP membranes could be increased by modifying the pretreatment program. However, optimization of pretreatment may provide an opportunity to further increase the achievable average flux and reduce batch processing time, particularly in the case of the NF-270 membrane.

Rejection of metals by the ESPA membrane has been previously demonstrated to be sufficient to achieve effluent targets for metals (Plant Site Wastewater Treatment Plant Pilot-Testing Report; Attachment B of the Waste Water Treatment System: Design and Operation Report). As expected, this pilot-test demonstrated rejection of metals by the NF-270 membrane to be lower than observed for the ESPA RO membrane. Nonetheless, if deployed in conjunction with a greensand filter, the NF-270 membrane is capable of achieving VSEP permeate below water quality targets for metals.

The rejection of sulfate and other salts via both the ESPA RO and Dow NF membranes decreased over the course of the pilot-test period, potentially as a result of repeated cleaning of the membranes between batches. While the degree to which this decrease in rejection is representative of full-scale long-term operation is not known, estimates of typical rejections observed for a VSEP system equipped with NF membranes have been provided by New Logic Research (Appendix E). These estimates suggest that sulfate rejection for the Dow NF-270 membrane may be reduced to 82% after some degree of deterioration during service. The estimates also indicate a typical sodium rejection of 65%, though the average sodium removal was 55%. The decrease in sodium rejection observed over the course of the pilot-test suggests the observed results likely overestimate sodium rejection by a deteriorated membrane.

7.4 Chemical Precipitation

Bench testing confirmed the anticipated effects of recycling on the available adsorptive capacity of the sludge, and also confirmed that the higher pH setpoint was favorable for metals removal via the HDS process. The addition of ferrous sulfate to the HDS reactors did not improve selenium removal.

Metals removal in the sulfate precipitation process was better than expected, with all metals except selenium being removed with high efficiencies. Approximately 50% removal of selenium was observed across the sulfate precipitation process.

The removal of copper, cobalt, and nickel at high pH was further confirmed in the scavenger test, and scavenger application was also observed to improve removal of these metals, particularly at higher pH setpoints.

8.0 References

1. **Lollar, B.S.** *Environmental Geochemistry.* Elsevier, Oxford, UK : s.n., 2005.

Tables

Table 1 **Area 5 Pit (Pilot-Unit Feed) Water Quality**

Location		GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank
Date		7/25/2013	7/25/2013	7/29/2013	7/29/2013	7/30/2013	7/30/2013	8/7/2013	8/7/2013	8/8/2013	8/8/2013
Parameter	Total or Dissolved										
General Parameters											
Alkalinity, total, as CaCO3	NA	--	--	--	--	--	**250 mg/l**	--	**250 mg/l**	--	--
Chloride	NA	--	--	--	--	--	**2.9 mg/l**	--	**3.1 mg/l**	--	--
pH	NA	--	--	--	--	--	**8.6 pH units**	--	**8.5 pH units**	--	--
Silicon dioxide	NA	--	--	--	--	--	**6.99 mg/l**	--	**8.40 mg/l**	--	--
Solids, total dissolved	NA	--	--	--	--	--	**1600 mg/l**	--	**1600 mg/l**	--	--
Solids, total suspended	NA	--	--	--	--	--	< 4.0 mg/l	--	< 4.0 mg/l	--	--
Sulfate, as SO4	NA	--	--	--	--	--	**930 mg/l**	--	**880 mg/l**	--	--
Metals											
Aluminum	Total	--	--	--	--	--	< 10 ug/l	--	< 50 ug/l	--	--
Arsenic	Total	--	--	--	--	--	--	--	--	--	--
Barium	Total	--	--	--	--	--	**5.5 ug/l**	--	**5.5 ug/l**	--	--
Calcium	Total	--	--	--	--	--	**71 mg/l**	--	**71 mg/l**	--	--
Cobalt	Total	--	--	--	--	--	--	--	--	--	--
Copper	Total	--	--	--	--	--	--	--	--	--	--
Iron	Dissolved	--	--	--	--	--	< 0.050 mg/l	--	< 0.050 mg/l	--	--
Iron	Total	--	--	--	--	--	**0.12 mg/l**	--	**0.078 mg/l**	--	--
Lead	Total	**46 ug/l**	**34 ug/l**	**18 ug/l**	**25 ug/l**	**16 ug/l**	**6.0 ug/l**	--	--	--	--
Magnesium	Total	--	--	--	--	--	**190 mg/l**	--	**200 mg/l**	--	--
Manganese	Dissolved	--	--	--	--	--	**3.2 ug/l**	--	**9.7 ug/l**	--	--
Manganese	Total	--	--	--	--	--	**20 ug/l**	--	**28 ug/l**	--	--
Nickel	Total	--	--	--	--	--	--	--	--	--	--
Potassium	Total	--	--	--	--	--	**44 mg/l**	--	**45 mg/l**	--	--
Selenium	Total	--	--	--	--	--	--	**56 ug/l**	**56 ug/l**	**62 ug/l**	**57 ug/l**
Silicon	Total	--	--	--	--	--	**3.9 mg/l**	--	**4.0 mg/l**	--	--
Sodium	Total	--	--	--	--	--	**82 mg/l**	--	**82 mg/l**	--	--
Strontium	Total	--	--	--	--	--	**240 ug/l**	--	**230 ug/l**	--	--
Zinc	Total	--	--	--	--	--	--	--	--	--	--

Bold values denote concentrations above laboratory reporting limits

Location		GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank	GE Feed Tank
Date		8/13/2013	8/13/2013	8/14/2013	8/14/2013	8/18/2013	8/18/2013	8/19/2013	8/19/2013	8/22/2013	8/22/2013	8/26/2013	8/26/2013
Parameter	Total or Dissolved												
General Parameters													
Alkalinity, total, as CaCO3	NA	--	**250 mg/l**	--	--	--	**250 mg/l**	--	--	--	--	--	**250 mg/l**
Chloride	NA	--	**3.0 mg/l**	--	--	--	**3.9 mg/l**	--	--	--	--	--	**3.1 mg/l**
pH	NA	--	**8.5 pH units**	--	--	--	**8.5 pH units**	--	--	--	--	--	**8.5 pH units**
Silicon dioxide	NA	--	**6.93 mg/l**	--	--	--	**6.07 mg/l**	--	--	--	--	--	**7.96 mg/l**
Solids, total dissolved	NA	--	**1600 mg/l**	--	--	--	**1600 h mg/l**	--	--	--	--	--	**1600 mg/l**
Solids, total suspended	NA	--	**6.4 mg/l**	--	--	--	**6.0 h mg/l**	--	--	--	--	--	< 4.0 mg/l
Sulfate, as SO4	NA	--	**930 mg/l**	--	--	--	**940 mg/l**	--	--	--	--	--	**860 mg/l**
Metals													
Aluminum	Total	--	< 10 ug/l	--	--	--	< 10 ug/l	--	--	--	--	--	< 50 ug/l
Arsenic	Total	--	--	--	--	**70 ug/l**	**68 ug/l**	**68 ug/l**	**71 ug/l**	--	--	--	--
Barium	Total	--	**5.3 ug/l**	--	--	--	**5.5 ug/l**	--	--	--	--	--	**5.5 ug/l**
Calcium	Total	--	**71 mg/l**	--	--	--	**76 mg/l**	--	--	--	--	--	**71 mg/l**
Cobalt	Total	--	--	--	--	**450 ug/l**	**430 ug/l**	**450 ug/l**	**430 ug/l**	--	--	--	--
Copper	Total	--	--	--	--	--	--	--	--	**220 ug/l**	**270 ug/l**	**250 ug/l**	**250 ug/l**
Iron	Dissolved	--	< 0.050 mg/l	--	--	--	< 0.050 mg/l	--	--	--	--	--	< 0.25 mg/l
Iron	Total	--	**0.076 mg/l**	--	--	--	**0.12 mg/l**	--	--	--	--	--	< 0.25 mg/l
Lead	Total	--	--	--	--	--	--	--	--	--	--	--	--
Magnesium	Total	--	**190 mg/l**	--	--	--	**210 mg/l**	--	--	--	--	--	**200 mg/l**
Manganese	Dissolved	--	**10 ug/l**	--	--	--	**7.6 ug/l**	--	--	--	--	--	**2.5 ug/l**
Manganese	Total	--	**26 ug/l**	--	--	--	**29 ug/l**	--	--	--	--	--	**21 ug/l**
Nickel	Total	--	--	--	--	**220 ug/l**	**200 ug/l**	**220 ug/l**	**210 ug/l**	--	--	--	--
Potassium	Total	--	**43 mg/l**	--	--	--	**42 mg/l**	--	--	--	--	--	**43 mg/l**
Selenium	Total	**67 ug/l**	**47 ug/l**	**64 ug/l**	**64 ug/l**	--	--	--	--	--	--	--	--
Silicon	Total	--	**3.9 mg/l**	--	--	--	**4.1 mg/l**	--	--	--	--	--	**4.0 mg/l**
Sodium	Total	--	**81 mg/l**	--	--	--	**88 mg/l**	--	--	--	--	--	**74 mg/l**
Strontium	Total	--	**250 ug/l**	--	--	--	**250 ug/l**	--	--	--	--	--	**250 ug/l**
Zinc	Total	--	--	--	--	**740 ug/l**	**720 ug/l**	**720 ug/l**	**740 ug/l**	--	--	--	--

Bold values denote concentrations above laboratory reporting limits.

Location		**DOW-Feed-Tank**	**DOW-Feed-Tank**	**DOW-Feed-Tank**	**DOW-Feed-Tank**	**DOW-Feed-Tank**	**DOW-Feed-Tank**	**DOW-Feed-Tank**	**DOW-Feed-Tank**	**DOW-Feed-Tank**
Date		**9/18/2013**	**9/18/2013**	**9/24/2013**	**9/24/2013**	**9/25/2013**	**9/25/2013**	**9/26/2013**	**9/30/2013**	**9/30/2013**
Parameter	Total or Dissolved									
General Parameters										
Alkalinity, total, as CaCO3	NA	**260 mg/l**	**260 mg/l**	--	--	**250 mg/l**	**260 mg/l**	--	**250 mg/l**	**250 mg/l**
Chloride	NA	**3.0 mg/l**	**3.3 mg/l**	--	--	**3.2 mg/l**	**3.2 mg/l**	--	**3.2 mg/l**	**3.2 mg/l**
pH	NA	**8.6 pH units**	**8.6 pH units**	--	--	**8.4 pH units**	**8.5 pH units**	--	**8.5 pH units**	**8.5 pH units**
Silicon dioxide	NA	**7.86 mg/l**	**7.77 mg/l**	--	--	**7.83 mg/l**	**7.76 mg/l**	--	**8.49 mg/l**	**8.46 mg/l**
Solids, total dissolved	NA	**1500 mg/l**	**1500 mg/l**	--	--	**1600 mg/l**	**1700 mg/l**	--	**1800 mg/l**	**1600 mg/l**
Solids, total suspended	NA	**7.6 mg/l**	**11 mg/l**	--	--	< 4.0 mg/l	< 4.0 mg/l	--	**4.8 mg/l**	< 4.0 mg/l
Sulfate, as SO4	NA	**950 mg/l**	**950 mg/l**	--	--	**940 mg/l**	**900 mg/l**	--	**980 mg/l**	**1000 mg/l**
Metals										
Aluminum	Total	< 10 ug/l	< 10 ug/l	--	--	< 10 ug/l	< 10 ug/l	--	< 10 ug/l	< 10 ug/l
Arsenic	Total	--	--	--	--	--	--	--	--	--
Barium	Total	**5.9 ug/l**	**5.8 ug/l**	--	--	**5.6 ug/l**	**5.6 ug/l**	--	**5.6 ug/l**	**5.6 ug/l**
Calcium	Total	**73 mg/l**	**67 mg/l**	--	--	**72 mg/l**	**74 mg/l**	--	**82 mg/l**	**80 mg/l**
Cobalt	Total	--	--	--	--	--	--	--	--	--
Copper	Total	--	--	--	--	--	--	--	--	--
Iron	Dissolved	< 0.25 mg/l	< 0.25 mg/l	--	--	< 0.050 mg/l	< 0.050 mg/l	--	< 0.050 mg/l	< 0.050 mg/l
Iron	Total	< 0.25 mg/l	< 0.25 mg/l	--	--	**0.074 mg/l**	**0.068 mg/l**	--	**0.13 mg/l**	**0.13 mg/l**
Lead	Total	**2.0 ug/l**	**2.0 ug/l**	**2.4 ug/l**	**5.0 ug/l**	--	--	--	--	--
Magnesium	Total	**210 mg/l**	**190 mg/l**	--	--	**200 mg/l**	**200 mg/l**	--	**220 mg/l**	**220 mg/l**
Manganese	Dissolved	**3.3 ug/l**	**3.7 ug/l**	--	--	**3.5 ug/l**	**4.1 ug/l**	--	**17 ug/l**	**24 ug/l**
Manganese	Total	**30 ug/l**	**31 ug/l**	--	--	**25 ug/l**	**24 ug/l**	--	**18 ug/l**	**25 ug/l**
Nickel	Total	--	--	--	--	--	--	--	--	--
Potassium	Total	**46 mg/l**	**41 mg/l**	--	--	**45 mg/l**	**46 mg/l**	--	**50 mg/l**	**50 mg/l**
Selenium	Total	--	--	--	--	**1.3 ug/l**	**1.3 ug/l**	**2.0 ug/l**	**1.1 ug/l**	**1.2 ug/l**
Silicon	Total	**4.1 mg/l**	**3.8 mg/l**	--	--	**4.1 mg/l**	**4.2 mg/l**	--	**4.7 mg/l**	**4.6 mg/l**
Sodium	Total	**78 mg/l**	**69 mg/l**	--	--	**81 mg/l**	**83 mg/l**	--	**92 mg/l**	**91 mg/l**
Strontium	Total	**270 ug/l**	**270 ug/l**	--	--	**260 ug/l**	**260 ug/l**	--	**260 ug/l**	**260 ug/l**
Zinc	Total	--	--	--	--	--	--	--	--	--

Bold values denote concentrations above laboratory reporting limits.

Location		DOW-Feed-Tank	DOW-Feed-Tank	DOW-Feed-Tank	DOW-Feed-Tank	DOW-Feed-Tank	DOW-Feed-Tank	DOW-Feed-Tank	DOW-Feed-Tank	DOW-Feed-Tank	DOW-Feed-Tank
Date		10/1/2013	10/1/2013	10/2/2013	10/2/2013	10/3/2013	10/3/2013	10/8/2013	10/8/2013	10/9/2013	10/9/2013
Parameter	Total or Dissolved										
General Parameters											
Alkalinity, total, as CaCO3	NA	--	--	**260 mg/l**	**260 mg/l**	--	--	**250 mg/l**	**260 mg/l**	--	--
Chloride	NA	--	--	**3.2 mg/l**	**3.3 mg/l**	--	--	**3.3 mg/l**	**3.3 mg/l**	--	--
pH	NA	--	--	**8.3 pH units**	**8.5 pH units**	--	--	**8.4 pH units**	**8.5 pH units**	--	--
Silicon dioxide	NA	--	--	**9.28 mg/l**	**8.50 mg/l**	--	--	**8.58 mg/l**	**8.67 mg/l**	--	--
Solids, total dissolved	NA	--	--	**1700 mg/l**	**1700 mg/l**	--	--	**1700 mg/l**	**1600 mg/l**	--	--
Solids, total suspended	NA	--	--	< 4.0 mg/l	< 4.0 mg/l	--	--	< 4.0 mg/l	< 4.0 mg/l	--	--
Sulfate, as SO4	NA	--	--	**1000 mg/l**	**2500 mg/l**	--	--	**1000 mg/l**	**1000 mg/l**	--	--
Metals											
Aluminum	Total	--	--	< 10 ug/l	< 10 ug/l	--	--	< 10 ug/l	< 10 ug/l	--	--
Arsenic	Total	--	--	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	--	--	--	--
Barium	Total	--	--	**5.9 ug/l**	**6.1 ug/l**	--	--	**5.8 ug/l**	**5.8 ug/l**	--	--
Calcium	Total	--	--	**75 mg/l**	**78 mg/l**	--	--	**75 mg/l**	**77 mg/l**	--	--
Cobalt	Total	--	--	**0.27 ug/l**	**0.48 ug/l**	**0.93 ug/l**	**0.77 ug/l**	--	--	--	--
Copper	Total	--	--	--	--	--	--	**23 ug/l**	**37 ug/l**	**24 ug/l**	**61 ug/l**
Iron	Dissolved	--	--	< 0.050 mg/l	< 0.050 mg/l	--	--	< 0.050 mg/l	< 0.050 mg/l	--	--
Iron	Total	--	--	**0.13 mg/l**	**0.086 mg/l**	--	--	**0.13 mg/l**	**0.11 mg/l**	--	--
Lead	Total	--	--	--	--	--	--	--	--	--	--
Magnesium	Total	--	--	**200 mg/l**	**210 mg/l**	--	--	**200 mg/l**	**200 mg/l**	--	--
Manganese	Dissolved	--	--	**4.9 ug/l**	**5.1 ug/l**	--	--	**3.6 ug/l**	**5.8 ug/l**	--	--
Manganese	Total	--	--	**23 ug/l**	**25 ug/l**	--	--	**20 ug/l**	**24 ug/l**	--	--
Nickel	Total	--	--	**3.2 ug/l**	**3.5 ug/l**	**3.8 ug/l**	**3.1 ug/l**	--	--	--	--
Potassium	Total	--	--	**46 mg/l**	**48 mg/l**	--	--	**47 mg/l**	**47 mg/l**	--	--
Selenium	Total	**1.4 ug/l**	**1.5 ug/l**	--	--	--	--	--	--	--	--
Silicon	Total	--	--	**4.3 mg/l**	**4.5 mg/l**	--	--	**4.3 mg/l**	**4.3 mg/l**	--	--
Sodium	Total	--	--	**83 mg/l**	**86 mg/l**	--	--	**84 mg/l**	**85 mg/l**	--	--
Strontium	Total	--	--	**270 ug/l**	**270 ug/l**	--	--	**270 ug/l**	**270 ug/l**	--	--
Zinc	Total	--	--	**14 ug/l**	**15 ug/l**	**21 ug/l**	**19 ug/l**	--	--	--	--

Bold values denote concentrations above laboratory reporting limits.

Table 2 **WWTF Effluent Water Quality Targets**

Parameter	Target	Basis
Metals/Inorganics (total in µg/L, except where noted)		
Aluminum	125	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Antimony	31	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Arsenic(1,2)	10	Federal Drinking Water Standard (Primary MCLs)
Barium	2,000	Minnesota Groundwater Standards (HRL, HBV, or RAA)
Beryllium	4	Federal Drinking Water Standard (Primary MCLs)
Boron	500	Minnesota Rules, part 7050.0224 Class 4A (chronic standard)
Cadmium(2,3)	5.1	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Chromium(4)	11	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Cobalt	5	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Copper(2,3)	20	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Iron	300	Federal Drinking Water Standard (Secondary MCLs)
Lead(2,3)	10.2	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Manganese	50	Federal Drinking Water Standard (Secondary MCLs)
Nickel(3)	113	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Selenium	5	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
Silver	1	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Thallium	0.56	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Zinc(2,3)	260	Minnesota Rules, part 7052.0100 Class 2B (chronic standard)
General Parameters (total, except where noted)		
Chloride	230 (mg/L)	Minnesota Rules, part 7050.0222 Class 2B (chronic standard)
Fluoride	2 (mg/L)	Federal Drinking Water Standard (Secondary MCLs)
Hardness(5)	250 (mg/L)	FEIS modeling assumption
Sodium	60% of cations	Minnesota Rules, part 7050.0224 Class 4A (chronic standard)
Sulfate	250 (mg/L)	Federal Drinking Water Standard (Secondary MCLs)

(1) Minnesota Rules, part 7050.0222 Class 2B standard for arsenic is 53 µg/L.
(2) Parameter with an effluent limit guideline in 40 CFR 440, which is less stringent than the listed target.
(3) Surface water standard based on hardness, value shown assumes hardness of 250 mg/L
(4) The Chromium (+6) standard of 11 µg/L is used rather than the total Chromium standard to be conservative.
(5) Minnesota Rules, part 7050.0223 Class 3C standard for hardness is 500 mg/L

Table 3 **Greensand Filter Removal Efficiencies**

GE Greensand Influent Quality (GE Feed Tank)	Species	Average	Minimum	Maximum		Date	7/25/2013	7/25/2013	7/29/2013	7/29/2013	7/30/2013	7/30/2013	8/7/2013	8/8/2013	8/8/2013	8/13/2013	8/13/2013
Parameter					Total or Dissolved	Influent or Effluent											
General Parameters																	
Alkalinity, total, as CaCO3					NA	Influent	--	--	--	--	--	**250 mg/l**	**250 mg/l**	--	--	--	**250 mg/l**
						Effluent	--	--	--	--	--	**250 mg/l**	**250 mg/l**	--	--	--	**250 mg/l**
Chloride					NA	Influent	--	--	--	--	--	**2.9 mg/l**	**3.1 mg/l**	--	--	--	**3.0 mg/l**
						Effluent	--	--	--	--	--	**2.9 mg/l**	**3.1 mg/l**	--	--	--	**3.1 mg/l**
pH					NA	Influent	--	--	--	--	--	**8.6 pH units**	**8.5 pH units**	--	--	--	**8.5 pH units**
						Effluent	--	--	--	--	--	**8.5 pH units**	**8.5 pH units**	--	--	--	**8.5 pH units**
Silicon dioxide					NA	Influent	--	--	--	--	--	**6.99 mg/l**	**8.40 mg/l**	--	--	--	**6.93 mg/l**
						Effluent	--	--	--	--	--	**7.53 mg/l**	**7.88 mg/l**	--	--	--	**5.08 mg/l**
Solids, total dissolved					NA	Influent	--	--	--	--	--	**1600 mg/l**	**1600 mg/l**	--	--	--	**1600 mg/l**
						Effluent	--	--	--	--	--	**1500 mg/l**	**1500 mg/l**	--	--	--	**1500 mg/l**
Solids, total suspended	TSS	7.08%	-100.00%	68.75%	NA	Influent	--	--	--	--	--	< 4.0 mg/l	< 4.0 mg/l	--	--	--	**6.4 mg/l**
						Effluent	--	--	--	--	--	**4.0 mg/l**	< 4.0 mg/l	--	--	--	< 4.0 mg/l
Sulfate, as SO4					NA	Influent	--	--	--	--	--	**930 mg/l**	**880 mg/l**	--	--	--	**930 mg/l**
						Effluent	--	--	--	--	--	**900 mg/l**	**950 mg/l**	--	--	--	**920 mg/l**
Metals																	
Aluminum					Total	Influent	--	--	--	--	--	< 10 ug/l	< 50 ug/l	--	--	--	< 10 ug/l
						Effluent	--	--	--	--	--	< 10 ug/l	< 50 ug/l	--	--	--	**13 ug/l**
Arsenic	Arsenite	68.64%	54.93%	87.29%	Total	Influent	--	--	--	--	--	--	--	--	--	--	--
						Effluent							--	--	--		--
Barium					Total	Influent	--	--	--	--	--	**5.5 ug/l**	**5.5 ug/l**	--	--	--	**5.3 ug/l**
						Effluent	--	--	--	--	--	**4.2 ug/l**	**4.6 ug/l**	--	--	--	**21 ug/l**
Calcium					Total	Influent	--	--	--	--	--	**71 mg/l**	**71 mg/l**	--	--	--	**71 mg/l**
						Effluent	--	--	--	--	--	**67 mg/l**	**73 mg/l**	--	--	--	**68 mg/l**
Cobalt	Cobalt (II)	98.53%	98.35%	98.76%	Total	Influent	--	--	--	--	--	--	--	--	--	--	--
						Effluent	--	--	--	--	--	--	--	--	--	--	--
Copper	Copper (II)	94.19%	92.73%	95.20%	Total	Influent	--	--	--	--	--	--	--	--	--	--	--
						Effluent	--	--	--	--	--	--	--	--	--	--	--
Iron	Iron (III)	74.68%	67.11%	80.00%	Dissolved	Influent	--	--	--	--	--	< 0.050 mg/l	< 0.050 mg/l	--	--	--	< 0.050 mg/l
						Effluent	--	--	--	--	--	< 0.050 mg/l	< 0.050 mg/l	--	--	--	< 0.050 mg/l
Iron					Total	Influent	--	--	--	--	--	**0.12 mg/l**	**0.078 mg/l**	--	--	--	**0.076 mg/l**
						Effluent	--	--	--	--	--	< 0.050 mg/l	< 0.050 mg/l	--	--	--	< 0.050 mg/l
Lead	Lead (II)	89.63%	82.78%	96.09%	Total	Influent	**46 ug/l**	**34 ug/l**	**18 ug/l**	**25 ug/l**	**16 ug/l**	**6.0 ug/l**	--	--	--	--	--
						Effluent	**1.8 ug/l**	**2.3 ug/l**	**3.1 ug/l**	**3.4 ug/l**	**1.3 ug/l**	**1.2 ug/l**	--	--	--	--	--

GE Greensand Influent Quality (GE Feed Tank)	Species	Average	Minimum	Maximum		Date	7/25/2013	7/25/2013	7/29/2013	7/29/2013	7/30/2013	7/30/2013	8/7/2013	8/8/2013	8/8/2013	8/13/2013	8/13/2013
Parameter					Total or Dissolved	Influent or Effluent											
Magnesium					Total	Influent	--	--	--	--	--	**190 mg/l**	**200 mg/l**	--	--	--	**190 mg/l**
						Effluent	--	--	--	--	--	**180 mg/l**	**200 mg/l**	--	--	--	**190 mg/l**
Manganese	Manganese (II)	22.16%	-100.00%	68.10%	Dissolved	Influent	--	--	--	--	--	**3.2 ug/l**	**9.7 ug/l**	--	--	--	**10 ug/l**
						Effluent	--	--	--	--	--	**4.5 ug/l**	**13 ug/l**	--	--	--	**13 ug/l**
Manganese					Total	Influent	--	--	--	--	--	**20 ug/l**	**28 ug/l**	--	--	--	**26 ug/l**
						Effluent	--	--	--	--	--	**6.9 ug/l**	**17 ug/l**	--	--	--	**52 ug/l**
Nickel	Nickel (II)	86.90%	72.86%	97.27%	Total	Influent	--	--	--	--	--	--	--	--	--	--	--
						Effluent	--	--	--	--	--	--	--	--	--	--	--
Potassium					Total	Influent	--	--	--	--	--	**44 mg/l**	**45 mg/l**	--	--	--	**43 mg/l**
						Effluent	--	--	--	--	--	**41 mg/l**	**47 mg/l**	--	--	--	**42 mg/l**
Selenium	Selenite	12.38%	0.00%	23.21%	Total	Influent	--	--	--	--	--	--	**56 ug/l**	**62 ug/l**	**57 ug/l**	**67 ug/l**	**47 ug/l**
	Selenate	0.05%	-3.13%	6.25%		Effluent	--	--	--	--	--	--	**53 ug/l**	**49 ug/l**	**57 ug/l**	**69 ug/l**	**310 ug/l**
Silicon					Total	Influent	--	--	--	--	--	**3.9 mg/l**	**4.0 mg/l**	--	--	--	**3.9 mg/l**
						Effluent	--	--	--	--	--	**3.7 mg/l**	**4.1 mg/l**	--	--	--	**3.7 mg/l**
Sodium					Total	Influent	--	--	--	--	--	**82 mg/l**	**82 mg/l**	--	--	--	**81 mg/l**
						Effluent	--	--	--	--	--	**76 mg/l**	**84 mg/l**	--	--	--	**77 mg/l**
Strontium					Total	Influent	--	--	--	--	--	**240 ug/l**	**230 ug/l**	--	--	--	**250 ug/l**
						Effluent	--	--	--	--	--	**240 ug/l**	**240 ug/l**	--	--	--	**1200 ug/l**
Zinc	Zinc	97.84%	97.70%	97.97%	Total	Influent	--	--	--	--	--	--	--	--	--	--	--
						Effluent	--	--	--	--	--	**--**	**--**	--	--	--	**--**

Bold values denote concentrations above laboratory reporting limits.

GE Greensand Influent Quality (GE Feed Tank)	**Species**	**Average**	**Minimum**	**Maximum**		**Date**	**8/14/2013**	**8/14/2013**	**8/18/2013**	**8/19/2013**	**8/19/2013**	**8/22/2013**	**8/22/2013**	**8/26/2013**	**8/26/2013**
Parameter					**Total or Dissolved**	**Influent or Effluent**									
General Parameters															
Alkalinity, total, as CaCO3					NA	Influent	--	--	**250 mg/l**	--	--	--	--	--	**250 mg/l**
						Effluent	--	--	**250 mg/l**	--	--	--	--	--	**250 mg/l**
Chloride					NA	Influent	--	--	**3.9 mg/l**	--	--	--	--	--	**3.1 mg/l**
						Effluent	--	--	**4.0 mg/l**	--	--	--	--	--	**3.1 mg/l**
pH					NA	Influent	--	--	**8.5 pH units**	--	--	--	--	--	**8.5 pH units**
						Effluent	--	--	**8.4 pH units**	--	--	--	--	--	**8.5 pH units**
Silicon dioxide					NA	Influent	--	--	**6.07 mg/l**	--	--	--	--	--	**7.96 mg/l**
						Effluent	--	--	**6.68 mg/l**	--	--	--	--	--	**6.53 mg/l**
Solids, total dissolved					NA	Influent	--	--	**1600 h mg/l**	--	--	--	--	--	**1600 mg/l**
						Effluent	--	--	**1500 mg/l**	--	--	--	--	--	**1600 mg/l**
Solids, total suspended	TSS	7.08%	-100.00%	68.75%	NA	Influent	--	--	**6.0 h mg/l**	--	--	--	--	--	< 4.0 mg/l
						Effluent	--	--	< 4.0 mg/l	--	--	--	--	--	< 4.0 mg/l
Sulfate, as SO4					NA	Influent	--	--	**940 mg/l**	--	--	--	--	--	**860 mg/l**
						Effluent	--	--	**930 mg/l**	--	--	--	--	--	**970 mg/l**
Metals															
Aluminum					Total	Influent	--	--	< 10 ug/l	--	--	--	--	--	< 50 ug/l
						Effluent	--	--	< 10 ug/l	--	--	--	--	--	< 50 ug/l
Arsenic	Arsenite	68.64%	54.93%	87.29%	Total	Influent	--	--	**68 ug/l**	**68 ug/l**	**71 ug/l**	--	--	--	--
						Effluent	--	--	**23 ug/l**	**23 ug/l**	**32 ug/l**	--	--	--	
Barium					Total	Influent	--	--	**5.5 ug/l**	--	--	--	--	--	**5.5 ug/l**
						Effluent	--	--	**4.8 ug/l**	--	--	--	--	--	**4.6 ug/l**
Calcium					Total	Influent	--	--	**76 mg/l**	--	--	--	--	--	**71 mg/l**
						Effluent	--	--	**74 mg/l**	--	--	--	--	--	**76 mg/l**
Cobalt	Cobalt (II)	98.53%	98.35%	98.76%	Total	Influent	--	--	**430 ug/l**	**450 ug/l**	**430 ug/l**	--	--	--	--
						Effluent	--	--	**7.1 ug/l**	**5.6 ug/l**	**6.0 ug/l**	--	--	--	--
Copper	Copper (II)	94.19%	92.73%	95.20%	Total	Influent	--	--	--	--	--	**220 ug/l**	**270 ug/l**	**250 ug/l**	**250 ug/l**
						Effluent	--	--	--	--	--	**16 ug/l**	**15 ug/l**	**14 ug/l**	**12 ug/l**
Iron	Iron (III)	74.68%	67.11%	80.00%	Dissolved	Influent	--	--	< 0.050 mg/l	--	--	--	--	--	< 0.25 mg/l
						Effluent	--	--	< 0.050 mg/l	--	--	--	--	--	< 0.050 mg/l
Iron					Total	Influent	--	--	**0.12 mg/l**	--	--	--	--	--	< 0.25 mg/l
						Effluent	--	--	< 0.050 mg/l	--	--	--	--	--	< 0.050 mg/l
Lead	Lead (II)	89.63%	82.78%	96.09%	Total	Influent	--	--	--	--	--	--	--	--	--
						Effluent	--	--	--	--	--	--	--	--	--
Magnesium					Total	Influent	--	--	**210 mg/l**	--	--	--	--	--	**200 mg/l**
						Effluent	--	--	**200 mg/l**	--	--	--	--	--	**210 mg/l**

GE Greensand Influent Quality (GE Feed Tank)	Species	Average	Minimum	Maximum		Date	8/14/2013	8/14/2013	8/18/2013	8/19/2013	8/19/2013	8/22/2013	8/22/2013	8/26/2013	8/26/2013
Parameter					Total or Dissolved	Influent or Effluent									
Manganese	Manganese (II)	22.16%	-100.00%	68.10%	Dissolved	Influent	--	--	**7.6 ug/l**	--	--	--	--	--	**2.5 ug/l**
						Effluent	--	--	**15 ug/l**	--	--	--	--	--	**4.8 ug/l**
Manganese					Total	Influent	--	--	**29 ug/l**	--	--	--	--	--	**21 ug/l**
						Effluent	--	--	**18 ug/l**	--	--	--	--	--	**6.7 ug/l**
Nickel	Nickel (II)	86.90%	72.86%	97.27%	Total	Influent	--	--	**200 ug/l**	**220 ug/l**	**210 ug/l**	--	--	--	--
						Effluent	--	--	**26 ug/l**	**21 ug/l**	**57 ug/l**	--	--	--	--
Potassium					Total	Influent	--	--	**42 mg/l**	--	--	--	--	--	**43 mg/l**
						Effluent	--	--	**42 mg/l**	--	--	--	--	--	**47 mg/l**
Selenium	Selenite	12.38%	0.00%	23.21%	Total	Influent	**64 ug/l**	**64 ug/l**	--	--	--	--	--	--	--
	Selenate	0.05%	-3.13%	6.25%		Effluent	**60 ug/l**	**66 ug/l**	--	--	--	--	--	--	--
Silicon					Total	Influent	--	--	**4.1 mg/l**	--	--	--	--	--	**4.0 mg/l**
						Effluent	--	--	**4.0 mg/l**	--	--	--	--	--	**4.3 mg/l**
Sodium					Total	Influent	--	--	**88 mg/l**	--	--	--	--	--	**74 mg/l**
						Effluent	--	--	**86 mg/l**	--	--	--	--	--	**85 mg/l**
Strontium					Total	Influent	--	--	**250 ug/l**	--	--	--	--	--	**250 ug/l**
						Effluent	--	--	**260 ug/l**	--	--	--	--	--	**250 ug/l**
Zinc	Zinc	97.84%	97.70%	97.97%	Total	Influent	--	--	**720 ug/l**	**720 ug/l**	**740 ug/l**	--	--	--	--
						Effluent	--	--	**16 ug/l**	**16 ug/l**	**17 ug/l**	--	--	--	**--**

Bold values denote concentrations above laboratory reporting limits.

Table 4 **Greensand Filter Effluent Water Quality**

Location		GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF
Date		7/25/2013	7/25/2013	7/29/2013	7/29/2013	7/30/2013	7/30/2013	7/31/2013	7/31/2013	8/1/2013	8/1/2013	8/6/2013	8/6/2013	8/7/2013	8/7/2013
Parameter	Total or Dissolved														
General Parameters															
Alkalinity, total, as CaCO3	NA	--	--	--	--	--	**250 mg/l**	--	--	--	--	--	--	--	**250 mg/l**
Chloride	NA	--	--	--	--	--	**2.9 mg/l**	--	--	--	--	--	--	--	**3.1 mg/l**
pH	NA	--	--	--	--	--	**8.5 pH units**	--	--	--	--	--	--	--	**8.5 pH units**
Silicon dioxide	NA	--	--	--	--	--	**7.53 mg/l**	--	--	--	--	--	--	--	**7.88 mg/l**
Solids, total dissolved	NA	--	--	--	--	--	**1500 mg/l**	--	--	--	--	--	--	--	**1500 mg/l**
Solids, total suspended	NA	--	--	--	--	--	**4.0 mg/l**	--	--	--	--	--	--	--	< 4.0 mg/l
Sulfate, as SO4	NA	--	--	--	--	--	**900 mg/l**	--	--	--	--	--	--	--	**950 mg/l**
Metals															
Aluminum	Total	--	--	--	--	--	< 10 ug/l	--	--	--	--	--	--	--	< 50 ug/l
Arsenic	Total									--	--	--	--	--	--
Barium	Total	--	--	--	--	--	**4.2 ug/l**	--	--	--	--	--	--	--	**4.6 ug/l**
Calcium	Total	--	--	--	--	--	**67 mg/l**	--	--	--	--	--	--	--	**73 mg/l**
Cobalt		--	--	--	--	--	--	--	--	--	--	--	--	--	--
Copper	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Iron	Dissolved	--	--	--	--	--	< 0.050 mg/l	--	--	--	--	--	--	--	< 0.050 mg/l
Iron	Total	--	--	--	--	--	< 0.050 mg/l	--	--	--	--	--	--	--	< 0.050 mg/l
Lead	Total	**1.8 ug/l**	**2.3 ug/l**	**3.1 ug/l**	**3.4 ug/l**	**1.3 ug/l**	**1.2 ug/l**	**1.3 ug/l**	**1.0 ug/l**	--	--	--	--	--	--
Magnesium	Total	--	--	--	--	--	**180 mg/l**	--	--	--	--	--	--	--	**200 mg/l**
Manganese	Dissolved	--	--	--	--	--	**4.5 ug/l**	--	--	--	--	--	--	--	**13 ug/l**
Manganese	Total	--	--	--	--	--	**6.9 ug/l**	--	--	--	--	--	--	--	**17 ug/l**
Nickel	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Potassium	Total	--	--	--	--	--	**41 mg/l**	--	--	--	--	--	--	--	**47 mg/l**
Selenium	Total	--	--	--	--	--	--	--	--	**1.3 ug/l**	**1.7 ug/l**	**2.4 ug/l**	**1.8 ug/l**	**43 ug/l**	**53 ug/l**
Silicon	Total	--	--	--	--	--	**3.7 mg/l**	--	--	--	--	--	--	--	**4.1 mg/l**
Sodium	Total	--	--	--	--	--	**76 mg/l**	--	--	--	--	--	--	--	**84 mg/l**
Strontium	Total	--	--	--	--	--	**240 ug/l**	--	--	--	--	--	--	--	**240 ug/l**
Zinc	Total	--	--	--	--	--	**--**	--	--	--	--	--	--	--	**--**

Location		GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF
Date		**8/8/2013**	**8/8/2013**	**8/11/2013**	**8/11/2013**	**8/12/2013**	**8/12/2013**	**8/13/2013**	**8/13/2013**	**8/14/2013**	**8/14/2013**	**8/15/2013**	**8/15/2013**	**8/16/2013**	**8/16/2013**
Parameter	Total or Dissolved														
General Parameters															
Alkalinity, total, as CaCO3	NA	--	--	--	--	--	--	--	**250 mg/l**	--	--	--	--	--	--
Chloride	NA	--	--	--	--	--	--	--	**3.1 mg/l**	--	--	--	--	--	--
pH	NA	--	--	--	--	--	--	--	**8.5 pH units**	--	--	--	--	--	--
Silicon dioxide	NA	--	--	--	--	--	--	--	**5.08 mg/l**	--	--	--	--	--	--
Solids, total dissolved	NA	--	--	--	--	--	--	--	**1500 mg/l**	--	--	--	--	--	--
Solids, total suspended	NA	--	--	--	--	--	--	--	< 4.0 mg/l	--	--	--	--	--	--
Sulfate, as SO4	NA	--	--	--	--	--	--	--	**920 mg/l**	--	--	--	--	--	--
Metals															
Aluminum	Total	--	--	--	--	--	--	--	**13 ug/l**	--	--	--	--	--	--
Arsenic	Total	--	--	--	--	--	--		--	--	--	**69 ug/l**	**62 ug/l**	**75 ug/l**	**73 ug/l**
Barium	Total	--	--	--	--	--	--	--	**21 ug/l**	--	--	--	--	--	--
Calcium	Total	--	--	--	--	--	--	--	**68 mg/l**	--	--	--	--	--	--
Cobalt		--	--	--	--	--	--	--	--	--	--	**470 ug/l**	**450 ug/l**	**460 ug/l**	**450 ug/l**
Copper	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Iron	Dissolved	--	--	--	--	--	--	--	< 0.050 mg/l	--	--	--	--	--	--
Iron	Total	--	--	--	--	--	--	--	< 0.050 mg/l	--	--	--	--	--	--
Lead	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Magnesium	Total	--	--	--	--	--	--	--	**190 mg/l**	--	--	--	--	--	--
Manganese	Dissolved	--	--	--	--	--	--	--	**13 ug/l**	--	--	--	--	--	--
Manganese	Total	--	--	--	--	--	--	--	**52 ug/l**	--	--	--	--	--	--
Nickel	Total	--	--	--	--	--	--	--	--	--	--	**230 ug/l**	**220 ug/l**	**220 ug/l**	**220 ug/l**
Potassium	Total	--	--	--	--	--	--	--	**42 mg/l**	--	--	--	--	--	--
Selenium	Total	**49 ug/l**	**57 ug/l**	**2.0 ug/l**	< 1.0 ug/l	**1.3 ug/l**	**1.2 ug/l**	**69 ug/l**	**310 ug/l**	**60 ug/l**	**66 ug/l**	--	--	--	--
Silicon	Total	--	--	--	--	--	--	--	**3.7 mg/l**	--	--	--	--	--	--
Sodium	Total	--	--	--	--	--	--	--	**77 mg/l**	--	--	--	--	--	--
Strontium	Total	--	--	--	--	--	--	--	**1200 ug/l**	--	--	--	--	--	--
Zinc	Total	--	--	--	--	--	--	--	**--**	--	--	**900 ug/l**	**810 ug/l**	**780 ug/l**	**760 ug/l**

Bold values denote concentrations above laboratory reporting limits.

Location		GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF	GE GSF EFF
Date		8/18/2013	8/18/2013	8/19/2013	8/19/2013	8/20/2013	8/20/2013	8/21/2013	8/21/2013	8/22/2013	8/22/2013	8/26/2013	8/26/2013
Parameter	Total or Dissolved												
General Parameters													
Alkalinity, total, as CaCO3	NA	--	**250 mg/l**	--	--	--	--	--	--	--	--	--	**250 mg/l**
Chloride	NA	--	**4.0 mg/l**	--	--	--	--	--	--	--	--	--	**3.1 mg/l**
pH	NA	--	**8.4 pH units**	--	--	--	--	--	--	--	--	--	**8.5 pH units**
Silicon dioxide	NA	--	**6.68 mg/l**	--	--	--	--	--	--	--	--	--	**6.53 mg/l**
Solids, total dissolved	NA	--	**1500 mg/l**	--	--	--	--	--	--	--	--	--	**1600 mg/l**
Solids, total suspended	NA	--	< 4.0 mg/l	--	--	--	--	--	--	--	--	--	< 4.0 mg/l
Sulfate, as SO4	NA	--	**930 mg/l**	--	--	--	--	--	--	--	--	--	**970 mg/l**
Metals													
Aluminum	Total	--	< 10 ug/l	--	--	--	--	--	--	--	--	--	< 50 ug/l
Arsenic	Total	**8.9 ug/l**	**23 ug/l**	**23 ug/l**	**32 ug/l**	--	--	--	--	--	--	--	
Barium	Total	--	**4.8 ug/l**	--	--	--	--	--	--	--	--	--	**4.6 ug/l**
Calcium	Total	--	**74 mg/l**	--	--	--	--	--	--	--	--	--	**76 mg/l**
Cobalt		**7.2 ug/l**	**7.1 ug/l**	**5.6 ug/l**	**6.0 ug/l**	--	--	--	--	--	--	--	--
Copper	Total	--	--	--	--	**200 ug/l**	**190 ug/l**	**200 ug/l**	**200 ug/l**	**16 ug/l**	**15 ug/l**	**14 ug/l**	**12 ug/l**
Iron	Dissolved	--	< 0.050 mg/l	--	--	--	--	--	--	--	--	--	< 0.050 mg/l
Iron	Total	--	< 0.050 mg/l	--	--	--	--	--	--	--	--	--	< 0.050 mg/l
Lead	Total	--	--	--	--	--	--	--	--	--	--	--	--
Magnesium	Total	--	**200 mg/l**	--	--	--	--	--	--	--	--	--	**210 mg/l**
Manganese	Dissolved	--	**15 ug/l**	--	--	--	--	--	--	--	--	--	**4.8 ug/l**
Manganese	Total	--	**18 ug/l**	--	--	--	--	--	--	--	--	--	**6.7 ug/l**
Nickel	Total	**6.0 ug/l**	**26 ug/l**	**21 ug/l**	**57 ug/l**	--	--	--	--	--	--	--	--
Potassium	Total	--	**42 mg/l**	--	--	--	--	--	--	--	--	--	**47 mg/l**
Selenium	Total	--	--	--	--	--	--	--	--	--	--	--	--
Silicon	Total	--	**4.0 mg/l**	--	--	--	--	--	--	--	--	--	**4.3 mg/l**
Sodium	Total	--	**86 mg/l**	--	--	--	--	--	--	--	--	--	**85 mg/l**
Strontium	Total	--	**260 ug/l**	--	--	--	--	--	--	--	--	--	**250 ug/l**
Zinc	Total	**15 ug/l**	**16 ug/l**	**16 ug/l**	**17 ug/l**	--	--	--	--	--	--	--	**--**

Bold values denote concentrations above laboratory reporting limits.

Table 5 Primary NF Permeate Water Quality

Location		GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm
Date		7/25/2013	7/25/2013	7/29/2013	7/29/2013	7/30/2013	7/30/2013	7/31/2013	7/31/2013	8/1/2013	8/1/2013	8/6/2013	8/6/2013	8/7/2013	8/7/2013
Parameter	Total or Dissolved														
General Parameters															
Alkalinity, total, as CaCO3	NA	--	--	--	--	--	**150 mg/l**	--	--	--	--	--	--	--	**160 mg/l**
Chloride	NA	--	--	--	--	--	**3.6 mg/l**	--	--	--	--	--	--	--	**3.6 mg/l**
pH	NA	--	--	--	--	--	**8.4 pH units**	--	--	--	--	--	--	--	**8.4 pH units**
Silicon dioxide	NA	--	--	--	--	--	**6.96 mg/l**	--	--	--	--	--	--	--	**7.14 mg/l**
Solids, total dissolved	NA	--	--	--	--	--	**190 mg/l**	--	--	--	--	--	--	--	**230 mg/l**
Solids, total suspended	NA	--	--	--	--	--	< 4.0 mg/l	--	--	--	--	--	--	--	< 4.0 mg/l
Sulfate, as SO4	NA	--	--	--	--	--	**13 mg/l**	--	--	--	--	--	--	--	**13 mg/l**
Metals															
Aluminum	Total	--	--	--	--	--	< 10 ug/l	--	--	--	--	--	--	--	< 10 ug/l
Arsenic	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Barium	Total	--	--	--	--	--	**0.33 ug/l**	--	--	--	--	--	--	--	**0.36 ug/l**
Calcium	Total	--	--	--	--	--	**6.4 mg/l**	--	--	--	--	--	--	--	**6.3 mg/l**
Cobalt	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Copper	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Iron	Dissolved	--	--	--	--	--	< 0.050 mg/l	--	--	--	--	--	--	--	< 0.050 mg/l
Iron	Total	--	--	--	--	--	< 0.050 mg/l	--	--	--	--	--	--	--	< 0.050 mg/l
Lead	Total	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	< 0.20 ug/l	--	--	--	--	--	--
Magnesium	Total	--	--	--	--	--	**12 mg/l**	--	--	--	--	--	--	--	**12 mg/l**
Manganese	Dissolved	--	--	--	--	--	< 0.50 ug/l	--	--	--	--	--	--	--	< 0.50 ug/l
Manganese	Total	--	--	--	--	--	< 0.50 ug/l	--	--	--	--	--	--	--	< 0.50 ug/l
Nickel	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Potassium	Total	--	--	--	--	--	**22 mg/l**	--	--	--	--	--	--	--	**24 mg/l**
Selenium	Total	--	--	--	--	--	--	--	--	**7.0 ug/l**	**7.5 ug/l**	< 1.0 ug/l	**7.6 ug/l**	**1.2 ug/l**	**5.7 ug/l**
Silicon	Total	--	--	--	--	--	**3.7 mg/l**	--	--	--	--	--	--	--	**3.8 mg/l**
Sodium	Total	--	--	--	--	--	**43 mg/l**	--	--	--	--	--	--	--	**43 mg/l**
Strontium	Total	--	--	--	--	--	**18 ug/l**	--	--	--	--	--	--	--	**18 ug/l**
Zinc	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--

Bold values denote concentrations above laboratory reporting limits.

Location		GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm
Date		8/8/2013	8/8/2013	8/11/2013	8/11/2013	8/12/2013	8/12/2013	8/13/2013	8/13/2013	8/14/2013	8/14/2013	8/15/2013	8/15/2013	8/16/2013	8/16/2013
Parameter	Total or Dissolved														
General Parameters															
Alkalinity, total, as CaCO3	NA	--	--	--	--	--	--	--	**160 mg/l**	--	--	--	--	--	--
Chloride	NA	--	--	--	--	--	--	--	**3.7 mg/l**	--	--	--	--	--	--
pH	NA	--	--	--	--	--	--	--	**8.4 pH units**	--	--	--	--	--	--
Silicon dioxide	NA	--	--	--	--	--	--	--	< 5.00 mg/l	--	--	--	--	--	--
Solids, total dissolved	NA	--	--	--	--	--	--	--	**200 mg/l**	--	--	--	--	--	--
Solids, total suspended	NA	--	--	--	--	--	--	--	< 4.0 mg/l	--	--	--	--	--	--
Sulfate, as SO4	NA	--	--	--	--	--	--	--	**12 mg/l**	--	--	--	--	--	--
Metals															
Aluminum	Total	--	--	--	--	--	--	--	< 10 ug/l	--	--	--	--	--	--
Arsenic	Total	--	--	--	--	--	--	--	--	--	--	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l
Barium	Total	--	--	--	--	--	--	--	**0.31 ug/l**	--	--	--	--	--	--
Calcium	Total	--	--	--	--	--	--	--	**6.0 mg/l**	--	--	--	--	--	--
Cobalt	Total	--	--	--	--	--	--	--	--	--	--	< 0.20 ug/l	< 0.20 ug/l	**0.97 ug/l**	**0.88 ug/l**
Copper	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Iron	Dissolved	--	--	--	--	--	--	--	< 0.050 mg/l	--	--	--	--	--	--
Iron	Total	--	--	--	--	--	--	--	< 0.050 mg/l	--	--	--	--	--	--
Lead	Total	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Magnesium	Total	--	--	--	--	--	--	--	**12 mg/l**	--	--	--	--	--	--
Manganese	Dissolved	--	--	--	--	--	--	--	< 0.50 ug/l	--	--	--	--	--	--
Manganese	Total	--	--	--	--	--	--	--	< 0.50 ug/l	--	--	--	--	--	--
Nickel	Total	--	--	--	--	--	--	--	--	--	--	< 0.50 ug/l	< 0.50 ug/l	**0.77 ug/l**	**1.0 ug/l**
Potassium	Total	--	--	--	--	--	--	--	**21 mg/l**	--	--	--	--	--	--
Selenium	Total	**2.4 ug/l**	**2.5 ug/l**	< 1.0 ug/l	**1.1 ug/l**	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	--	--	--	--
Silicon	Total	--	--	--	--	--	--	--	**3.6 mg/l**	--	--	--	--	--	--
Sodium	Total	--	--	--	--	--	--	--	**41 mg/l**	--	--	--	--	--	--
Strontium	Total	--	--	--	--	--	--	--	**18 ug/l**	--	--	--	--	--	--
Zinc	Total	--	--	--	--	--	--	--	--	--	--	< 10 ug/l	< 10 ug/l	**27 ug/l**	**26 ug/l**

Bold values denote concentrations above laboratory reporting limits.

Location		GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm	GE NF Perm
Date		8/18/2013	8/18/2013	8/19/2013	8/19/2013	8/20/2013	8/20/2013	8/21/2013	8/21/2013	8/22/2013	8/22/2013	8/26/2013	8/26/2013
Parameter	Total or Dissolved												
General Parameters													
Alkalinity, total, as CaCO3	NA	--	**160 mg/l**	--	--	--	--	--	--	--	--	--	**170 mg/l**
Chloride	NA	--	**4.6 mg/l**	--	--	--	--	--	--	--	--	--	**3.5 mg/l**
pH	NA	--	**8.4 pH units**	--	--	--	--	--	--	--	--	--	**8.6 pH units**
Silicon dioxide	NA	--	**6.97 mg/l**	--	--	--	--	--	--	--	--	--	**7.53 mg/l**
Solids, total dissolved	NA	--	**190 h mg/l**	--	--	--	--	--	--	--	--	--	**220 mg/l**
Solids, total suspended	NA	--	< 4.0 h mg/l	--	--	--	--	--	--	--	--	--	< 4.0 mg/l
Sulfate, as SO4	NA	--	**11 mg/l**	--	--	--	--	--	--	--	--	--	**12 mg/l**
Metals													
Aluminum	Total	--	< 10 ug/l	--	--	--	--	--	--	--	--	--	< 50 ug/l
Arsenic	Total	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	< 1.0 ug/l	--	--	--	--	--	--	--	--
Barium	Total	--	**0.34 ug/l**	--	--	--	--	--	--	--	--	--	< 1.0 ug/l
Calcium	Total	--	**6.8 mg/l**	--	--	--	--	--	--	--	--	--	**7.2 mg/l**
Cobalt	Total	**0.32 ug/l**	**0.25 ug/l**	< 0.20 ug/l	**0.20 ug/l**	--	--	--	--	--	--	--	--
Copper	Total	--	--	--	--	**1.9 ug/l**	**1.4 ug/l**	**28 ug/l**	**31 ug/l**	**18 ug/l**	**18 ug/l**	**2.8 ug/l**	< 2.5 ug/l
Iron	Dissolved	--	< 0.050 mg/l	--	--	--	--	--	--	--	--	--	< 0.050 mg/l
Iron	Total	--	< 0.050 mg/l	--	--	--	--	--	--	--	--	--	< 0.050 mg/l
Lead	Total	--	--	--	--	--	--	--	--	--	--	--	--
Magnesium	Total	--	**13 mg/l**	--	--	--	--	--	--	--	--	--	**14 mg/l**
Manganese	Dissolved	--	< 0.50 ug/l	--	--	--	--	--	--	--	--	--	< 0.50 ug/l
Manganese	Total	--	< 0.50 ug/l	--	--	--	--	--	--	--	--	--	< 0.50 ug/l
Nickel	Total	< 0.50 ug/l	< 0.50 ug/l	**0.50 ug/l**	< 0.50 ug/l	--	--	--	--	--	--	--	--
Potassium	Total	--	**22 mg/l**	--	--	--	--	--	--	--	--	--	**24 mg/l**
Selenium	Total	--	--	--	--	--	--	--	--	--	--	--	--
Silicon	Total	--	**3.8 mg/l**	--	--	--	--	--	--	--	--	--	**4.1 mg/l**
Sodium	Total	--	**46 mg/l**	--	--	--	--	--	--	--	--	--	**45 mg/l**
Strontium	Total	--	**19 ug/l**	--	--	--	--	--	--	--	--	--	**20 ug/l**
Zinc	Total	**16 ug/l**	< 10 ug/l	< 10 ug/l	< 10 ug/l	--	--	--	--	--	--	--	--

Bold values denote concentrations above laboratory reporting limits.

Table 6 Primary NF Concentrate Water Quality

Location		DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc
Date		**9/18/2013**	**9/18/2013**	**9/24/2013**	**9/24/2013**	**9/25/2013**	**9/25/2013**	**9/26/2013**	**9/26/2013**	**9/30/2013**	**9/30/2013**
Parameter	Total or Dissolved										
General Parameters											
Alkalinity, total, as CaCO3	NA	**680 mg/l**	**680 mg/l**	--	--	**280 mg/l**	**590 mg/l**	--	--	**590 mg/l**	**580 mg/l**
Chloride	NA	**2.4 mg/l**	**2.5 mg/l**	--	--	**2.0 mg/l**	**2.1 mg/l**	--	--	**2.1 mg/l**	**2.2 mg/l**
pH	NA	**8.4 pH units**	**8.4 pH units**	--	--	**8.4 pH units**	**8.4 pH units**	--	--	**8.4 pH units**	**8.4 pH units**
Silicon dioxide	NA	**10.1 mg/l**	**10.2 mg/l**	--	--	**11.4 mg/l**	**10.3 mg/l**	--	--	**11.1 mg/l**	**11.3 mg/l**
Solids, total dissolved	NA	**7600 mg/l**	**7700 mg/l**	--	--	**7100 mg/l**	**6600 mg/l**	--	--	**7100 mg/l**	**3300 mg/l**
Solids, total suspended	NA	**18 mg/l**	**15 mg/l**	--	--	**8.4 mg/l**	**6.4 mg/l**	--	--	**9.2 mg/l**	**8.0 mg/l**
Sulfate, as SO4	NA	**5200 mg/l**	**5200 mg/l**	--	--	**4600 mg/l**	**4700 mg/l**	--	--	**4900 mg/l**	**4800 mg/l**
Metals											
Aluminum	Total	< 50 ug/l	< 50 ug/l	--	--	< 50 ug/l	< 50 ug/l	--	--	< 50 ug/l	< 50 ug/l
Arsenic	Total	--	--	--	--	--	--	--	--	--	--
Barium	Total	**20 ug/l**	**20 ug/l**	--	--	**18 ug/l**	**19 ug/l**	--	--	**20 ug/l**	**20 ug/l**
Calcium	Total	**330 mg/l**	**330 mg/l**	--	--	**330 mg/l**	**330 mg/l**	--	--	**340 mg/l**	**340 mg/l**
Cobalt	Total	--	--	--	--	--	--	--	--	--	--
Copper	Total	--	--	--	--	--	--	--	--	--	--
Iron	Dissolved	< 0.25 mg/l	< 0.25 mg/l	--	--	< 0.50 mg/l	< 0.50 mg/l	--	--	< 0.50 mg/l	< 0.50 mg/l
Iron	Total	< 0.25 mg/l	< 0.25 mg/l	--	--	< 0.50 mg/l	< 0.50 mg/l	--	--	< 0.50 mg/l	< 0.50 mg/l
Lead	Total	**61 ug/l**	**61 ug/l**	**60 ug/l**	**64 ug/l**	--	--	--	--	--	--
Magnesium	Total	**910 mg/l**	**900 mg/l**	--	--	**920 mg/l**	**920 mg/l**	--	--	**940 mg/l**	**940 mg/l**
Manganese	Dissolved	**20 ug/l**	**23 ug/l**	--	--	**17 ug/l**	**18 ug/l**	--	--	**22 ug/l**	**30 ug/l**
Manganese	Total	**37 ug/l**	**42 ug/l**	--	--	**31 ug/l**	**32 ug/l**	--	--	**24 ug/l**	**31 ug/l**
Nickel	Total	--	--	--	--	--	--	--	--	--	--
Potassium	Total	**140 mg/l**	**140 mg/l**	--	--	**150 mg/l**	**150 mg/l**	--	--	**150 mg/l**	**150 mg/l**
Selenium	Total	--	--	--	--	**300 ug/l**	**320 ug/l**	**300 ug/l**	**290 ug/l**	**320 ug/l**	**300 ug/l**
Silicon	Total	**5.1 mg/l**	**5.2 mg/l**	--	--	**5.6 mg/l**	**5.5 mg/l**	--	--	**5.7 mg/l**	**5.8 mg/l**
Sodium	Total	**250 mg/l**	**250 mg/l**	--	--	**240 mg/l**	**240 mg/l**	--	--	**250 mg/l**	**250 mg/l**
Strontium	Total	**1300 ug/l**	**1300 ug/l**	--	--	**1200 ug/l**	**1200 ug/l**	--	--	**1200 ug/l**	**1200 ug/l**
Zinc	Total	--	--	--	--	--	--	--	--	--	--

Bold values denote concentrations above laboratory reporting limits.

Location		DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc	DOW-NF-Conc
Date		10/1/2013	10/1/2013	10/2/2013	10/2/2013	10/3/2013	10/3/2013	10/8/2013	10/8/2013	10/9/2013	10/9/2013
Parameter	Total or Dissolved										
General Parameters											
Alkalinity, total, as CaCO3	NA	--	--	**600 mg/l**	**600 mg/l**	--	--	**590 mg/l**	**610 mg/l**	--	--
Chloride	NA	--	--	**2.7 mg/l**	**3.0 mg/l**	--	--	**2.3 mg/l**	**2.3 mg/l**	--	--
pH	NA	--	--	**8.4 pH units**	**8.3 pH units**	--	--	**8.3 pH units**	**8.4 pH units**	--	--
Silicon dioxide	NA	--	--	**11.4 mg/l**	**11.5 mg/l**	--	--	**11.5 mg/l**	**11.6 mg/l**	--	--
Solids, total dissolved	NA	--	--	**7100 mg/l**	**7100 mg/l**	--	--	**7100 mg/l**	**6900 mg/l**	--	--
Solids, total suspended	NA	--	--	**6.4 mg/l**	**4.8 mg/l**	--	--	**8.0 mg/l**	**6.8 mg/l**	--	--
Sulfate, as SO4	NA	--	--	**4900 mg/l**	**5700 mg/l**	--	--	**4900 mg/l**	**4700 mg/l**	--	--
Metals											
Aluminum	Total	--	--	< 50 ug/l	< 50 ug/l	--	--	< 100 ug/l	< 100 ug/l	--	--
Arsenic	Total	--	--	**84 ug/l**	**87 ug/l**	**87 ug/l**	**82 ug/l**	--	--	--	--
Barium	Total	--	--	**22 ug/l**	**23 ug/l**	--	--	**21 ug/l**	**22 ug/l**	--	--
Calcium	Total	--	--	**340 mg/l**	**340 mg/l**	--	--	**340 mg/l**	**350 mg/l**	--	--
Cobalt	Total	--	--	**2100 ug/l**	**2200 ug/l**	**2200 ug/l**	**2200 ug/l**	--	--	--	--
Copper	Total	--	--	--	--	--	--	**960 ug/l**	**940 ug/l**	**960 ug/l**	**830 ug/l**
Iron	Dissolved	--	--	< 0.50 mg/l	< 0.50 mg/l	--	--	< 0.50 mg/l	< 0.50 mg/l	--	--
Iron	Total	--	--	< 0.50 mg/l	< 0.50 mg/l	--	--	< 0.50 mg/l	< 0.50 mg/l	--	--
Lead	Total	--	--	--	--	--	--	--	--	--	--
Magnesium	Total	--	--	**940 mg/l**	**930 mg/l**	--	--	**940 mg/l**	**960 mg/l**	--	--
Manganese	Dissolved	--	--	**20 ug/l**	**19 ug/l**	--	--	**15 ug/l**	**18 ug/l**	--	--
Manganese	Total	--	--	**32 ug/l**	**33 ug/l**	--	--	**26 ug/l**	**30 ug/l**	--	--
Nickel	Total	--	--	**1000 ug/l**	**1100 ug/l**	**1100 ug/l**	**1100 ug/l**	--	--	--	--
Potassium	Total	--	--	**150 mg/l**	**140 mg/l**	--	--	**150 mg/l**	**150 mg/l**	--	--
Selenium	Total	**320 ug/l**	**280 ug/l**	--	--	--	--	--	--	--	--
Silicon	Total	--	--	**5.6 mg/l**	**5.6 mg/l**	--	--	**5.5 mg/l**	**5.6 mg/l**	--	--
Sodium	Total	--	--	**250 mg/l**	**250 mg/l**	--	--	**250 mg/l**	**260 mg/l**	--	--
Strontium	Total	--	--	**1200 ug/l**	**1200 ug/l**	--	--	**1200 ug/l**	**1200 ug/l**	--	--
Zinc	Total	--	--	**3800 ug/l**	**3800 ug/l**	**4300 ug/l**	**4400 ug/l**	--	--	--	--

Bold values denote concentrations above laboratory reporting limits.

Table 7 Primary NF Removal Rates

	GE			DOW		
Parameter	**Ave**	**Min**	**Max**	**Ave**	**Min**	**Max**
Alkalinity, total	48.8%	45.6%	50.4%	48.8%	45.6%	52.6%
Chloride	9.4%	6.5%	11.7%	9.2%	1.3%	15.2%
Silicon dioxide	24.2%	7.7%	45.5%	29.8%	24.3%	43.8%
Solids, total dissolved	89.6%	88.2%	90.9%	92.2%	90.5%	94.1%
Sulfate	99.0%	98.9%	99.1%	99.6%	99.6%	99.7%
Barium	93.5%	91.3%	94.4%	92.1%	89.6%	92.8%
Calcium	92.6%	92.4%	92.9%	93.2%	92.5%	94.1%
Iron	45.0%	20.0%	71.4%	>20.0%	>20.0%	>20.0%
Magnesium	94.8%	94.5%	95.2%	93.8%	93.2%	94.8%
Manganese	97.8%	96.0%	98.9%	89.4%	40.9%	96.7%
Potassium	59.0%	57.7%	61.0%	64.5%	61.8%	68.0%
Silicon	24.1%	23.7%	24.5%	25.3%	20.0%	33.7%
Sodium	57.6%	57.2%	58.3%	65.0%	62.1%	67.8%
Strontium	94.2%	93.6%	94.8%	93.6%	93.2%	93.8%
Seeded Metals						
Arsenic	>99.4%	>99.4%	>99.5%	16.6%	14.4%	17.8%
Cobalt	>99.9%	99.8%	>99.98%	93.6%	93.4%	94%
Copper	93.8%	87.6%	99.4%	87.8%	87.0%	89.0%
Lead	>99.4%	>99.4%	>99.4%	>99.4%	>99.4%	>99.4%
Nickel	>99.8%	99.6%	>99.9%	94.2%	94.0%	94.6%
Selenite	>93.0%	90.6%	>99.3%	90.9%	90.8%	91.2%
Selenate	>99.2%	98.6%	>99.4%	>99.4%	>99.4%	>99.4%
Zinc	98.4%	97.2%	99.6%	92.4%	92.0%	92.9%

Table 8 Comparison of Measured and Modeled Primary NF Permeate Quality

	GE				DOW			
Name	Adjusted Feed	Projected Permeate	Projected Removal	Average Measured Removal	Adjusted Feed	Projected Permeate	Projected Removal	Average Measured Removal
Parameter	**mg/L**		**Percentage**		**mg/L**		**Percentage**	
Potassium	7.20	2.12	76.4%	59.0%	44.0	19.8	64.0%	64.5%
Sodium	60.75	8.82	88.4%	57.6%	107.6	49.6	63.1%	65.0%
Magnesium	34.70	1.50	96.6%	94.8%	190.0	18.0	92.4%	93.8%
Calcium	13.60	0.57	96.6%	92.6%	73.0	11.1	87.8%	93.2%
Strontium	0.04500	0.00189	96.6%	94.2%	0.3	0.1	71.2%	93.6%
Barium	0.00100	0.00004	96.7%	93.5%	0.0	0.0	80.0%	92.1%
Chloride	0.62	0.39	49.9%	9.4%	3.2	3.1	21.5%	9.2%
Sulfate	248.06	10.49	96.6%	99.0%	950.0	41.8	96.5%	99.6%
Silica	1.84	1.83	20.2%	24.2%	4.0	3.2	35.4%	29.8%
Total Dissolved Solids	438.53	47.79	91.3%	89.6%	1,691.97	376.2	82.2%	92.2%

Table 9 **VSEP Permeate Water Quality**

Location		GE VSEP Perm	GE VSEP Perm	GE VSEP Perm	GE VSEP Perm
Date		8/5/2013	8/7/2013	8/12/2013	8/13/2013
Parameter	Total or Dissolved				
General Parameters					
Alkalinity, total, as CaCO3	NA	< 20 mg/l	< 20 mg/l	< 20 mg/l	< 20 mg/l
Chloride	NA	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l	< 0.20 mg/l
pH	NA	**5.8 pH units**	**5.3 pH units**	**5.1 pH units**	**5.1 pH units**
Silicon dioxide	NA	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l	< 0.500 mg/l
Solids, total dissolved	NA	**43 mg/l**	**69 mg/l**	**160 mg/l**	**92 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
Sulfate, as SO4	NA	**24 mg/l**	**27 mg/l**	**26 mg/l**	**29 mg/l**
Metals					
Aluminum	Total	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l
Barium	Total	< 0.20 ug/l	**1.0 ug/l**	< 0.20 ug/l	**0.22 ug/l**
Calcium	Total	**1.1 mg/l**	**1.6 mg/l**	**1.7 mg/l**	**1.9 mg/l**
Iron	Dissolved	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Magnesium	Total	**3.8 mg/l**	**5.3 mg/l**	**5.3 mg/l**	**5.9 mg/l**
Manganese	Dissolved	< 0.50 ug/l	**0.59 ug/l**	**0.77 ug/l**	< 0.50 ug/l
Manganese	Total	< 0.50 ug/l	**0.98 ug/l**	< 0.50 ug/l	**0.79 ug/l**
Potassium	Total	**3.7 mg/l**	**4.0 mg/l**	**7.0 mg/l**	**7.1 mg/l**
Selenium	Total	**3.3 ug/l**	**3.4 ug/l**	**2.0 ug/l**	**1.9 ug/l**
Silicon	Total	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l	< 0.25 mg/l
Sodium	Total	**5.6 mg/l**	**6.1 mg/l**	**8.6 mg/l**	**9.5 mg/l**
Strontium	Total	**4.0 ug/l**	**5.6 ug/l**	**6.1 ug/l**	**6.8 ug/l**

Bold values denote concentrations above laboratory reporting limits.

Location		**DOW-VSEP-Perm**	**DOW-VSEP-Perm**	**DOW-VSEP-Perm**	**DOW-VSEP-Perm**	**DOW-VSEP-Perm**	**DOW-VSEP-Perm**	**DOW-VSEP-Perm**	**DOW-VSEP-Perm**	**DOW-VSEP-Perm**	**DOW-VSEP-Perm**
Date		**9/24/2013**	**9/25/2013**	**9/26/2013**	**9/30/2013**	**10/1/2013**	**10/2/2013**	**10/3/2013**	**10/7/2013**	**10/9/2013**	**10/10/2013**
Parameter	Total or Dissolved										
General Parameters											
Alkalinity, total, as CaCO3	NA	**430 mg/l**	**480 mg/l**	**450 mg/l**	**430 mg/l**	**430 mg/l**	**450 mg/l**	**460 mg/l**	**440 mg/l**	**490 mg/l**	**460 mg/l**
Chloride	NA	**2.4 mg/l**	**2.3 mg/l**	**2.2 mg/l**	**2.2 mg/l**	**2.2 mg/l**	**2.3 mg/l**	**3.1 mg/l**	**3.2 mg/l**	**2.5 mg/l**	**2.6 mg/l**
pH	NA	**6.4 pH units**	**6.2 pH units**	**6.3 pH units**	**6.3 pH units**	**6.1 pH units**	**6.1 pH units**	**6.2 pH units**	**6.3 pH units**	**6.2 pH units**	**6.4 pH units**
Silicon dioxide	NA	**10.1 mg/l**	**8.48 mg/l**	**9.18 mg/l**	**10.1 mg/l**	**10.1 mg/l**	**10.1 mg/l**	**10.6 mg/l**	**9.83 mg/l**	**10.6 mg/l**	**10.5 mg/l**
Solids, total dissolved	NA	**580 mg/l**	**570 mg/l**	**540 mg/l**	**630 mg/l**	**590 mg/l**	**630 mg/l**	**660 mg/l**	**680 mg/l**	**760 mg/l**	**770 mg/l**
Solids, total suspended	NA	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
Sulfate, as SO4	NA	**72 mg/l**	**100 mg/l**	**96 mg/l**	**99 mg/l**	**110 mg/l**	**120 mg/l**	**130 mg/l**	**150 mg/l**	**170 mg/l**	**160 mg/l**
Metals											
Aluminum	Total	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l	< 10 ug/l
Arsenic	Total	--	--	--	--	--	--	**71 ug/l**	**17 ug/l**	--	--
Barium	Total	**0.88 ug/l**	**0.98 ug/l**	**0.96 ug/l**	**0.95 ug/l**	**0.98 ug/l**	**1.1 ug/l**	**1.2 ug/l**	**1.3 ug/l**	**1.3 ug/l**	**1.3 ug/l**
Calcium	Total	**19 mg/l**	**23 mg/l**	**21 mg/l**	**19 * mg/l**	**23 mg/l**	**24 mg/l**	**25 mg/l**	**25 mg/l**	**25 mg/l**	**25 mg/l**
Cobalt	Total	--	--	--	--	--	--	**130 * ug/l**	**130 ug/l**	--	--
Copper	Total	--	--	--	--	--	--	--	--	**46 ug/l**	**35 ug/l**
Iron	Dissolved	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Iron	Total	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l	< 0.050 mg/l
Lead	Total	**1.4 ug/l**	**0.94 ug/l**	--	--	--	--	--	--	--	--
Magnesium	Total	**38 mg/l**	**51 mg/l**	**47 mg/l**	**39 mg/l**	**48 mg/l**	**53 mg/l**	**56 mg/l**	**56 mg/l**	**57 mg/l**	**56 mg/l**
Manganese	Dissolved	**1.4 ug/l**	**2.3 ug/l**	**2.1 ug/l**	**1.8 ug/l**	**1.5 ug/l**	**2.3 ug/l**	**1.6 ug/l**	**2.0 ug/l**	**1.6 ug/l**	**2.0 ug/l**
Manganese	Total	**1.3 ug/l**	**2.4 ug/l**	**2.2 ug/l**	**1.8 ug/l**	**1.4 ug/l**	**2.1 ug/l**	**1.6 ug/l**	**2.2 ug/l**	**1.2 ug/l**	**1.6 ug/l**
Nickel	Total	--	--	--	--	--	--	**55 ug/l**	**58 ug/l**	--	--
Potassium	Total	**57 mg/l**	**61 mg/l**	**58 mg/l**	**55 mg/l**	**61 mg/l**	**60 mg/l**	**60 mg/l**	**58 mg/l**	**60 mg/l**	**64 mg/l**
Selenium	Total	--	--	**120 ug/l**	**85 ug/l**	**10 ug/l**	**7.7 ug/l**	--	--	--	--
Silicon	Total	**5.2 mg/l**	**5.4 mg/l**	**5.1 mg/l**	**5.0 mg/l**	**5.6 mg/l**	**5.6 mg/l**	**5.5 mg/l**	**5.4 mg/l**	**4.9 mg/l**	**5.2 mg/l**
Sodium	Total	**130 mg/l**	**140 mg/l**	**130 mg/l**	**120 mg/l**	**140 mg/l**	**140 mg/l**	**140 mg/l**	**130 mg/l**	**130 mg/l**	**140 mg/l**
Strontium	Total	**58 ug/l**	**69 ug/l**	**67 ug/l**	**59 ug/l**	**64 ug/l**	**68 ug/l**	**75 ug/l**	**75 ug/l**	**81 ug/l**	**77 ug/l**
Zinc	Total	--	--	--	--	--	--	**240 ug/l**	**270 ug/l**	--	--

Bold values denote concentrations above laboratory reporting limits.

Table 10 VSEP Concentrate Water Quality

Location		**GE VSEP Conc**	**GE VSEP Conc**	**GE VSEP Conc**	**GE VSEP Conc**
Date		**8/5/2013**	**8/7/2013**	**8/12/2013**	**8/13/2013**
Parameter	Total or Dissolved				
General Parameters					
Alkalinity, total, as CaCO3	NA	**1,300 mg/l**	**870 mg/l**	**2,500 mg/l**	**2,700 mg/l**
Chloride	NA	**8.6 mg/l**	**8.9 mg/l**	**8.4 mg/l**	**8.4 mg/l**
pH	NA	**7.3 pH units**	**6.7 pH units**	**6.4 pH units**	**6.4 pH units**
Silicon dioxide	NA	**44.9 mg/l**	**44.8 mg/l**	**35.4 mg/l**	**37.9 mg/l**
Solids, total dissolved	NA	**33,000 mg/l**	**34,000 mg/l**	**31,000 mg/l**	**32,000 mg/l**
Solids, total suspended	NA	**75 mg/l**	**76 mg/l**	**70 mg/l**	**65 mg/l**
Sulfate, as SO4	NA	**23,000 mg/l**	**25,000 mg/l**	**21,000 mg/l**	**21,000 mg/l**
Metals					
Aluminum	Total	< 100 ug/l	< 100 ug/l	**62 ug/l**	**63 ug/l**
Barium	Total	**84 ug/l**	**88 ug/l**	**92 ug/l**	**84 ug/l**
Calcium	Total	**760 mg/l**	**860 mg/l**	**680 mg/l**	**640 mg/l**
Iron	Dissolved	**0.088 mg/l**	**0.17 mg/l**	**0.22 mg/l**	**0.16 mg/l**
Iron	Total	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l
Magnesium	Total	**3,200 mg/l**	**3,800 mg/l**	**3,500 mg/l**	**3,600 mg/l**
Manganese	Dissolved	**77 ug/l**	**200 ug/l**	**220 ug/l**	**240 ug/l**
Manganese	Total	**170 ug/l**	**220 ug/l**	**240 ug/l**	**260 ug/l**
Potassium	Total	**490 mg/l**	**500 mg/l**	**460 mg/l**	**480 mg/l**
Selenium	Total	**1,200 ug/l**	**1,500 ug/l**	**1,400 ug/l**	**1,300 ug/l**
Silicon	Total	**17 mg/l**	**20 mg/l**	**18 mg/l**	**19 mg/l**
Sodium	Total	**790 mg/l**	**950 mg/l**	**850 mg/l**	**900 mg/l**
Strontium	Total	**3,500 ug/l**	**4,400 ug/l**	**3,900 ug/l**	**3,500 ug/l**

Bold values denote concentrations above laboratory reporting limits.

Location		DOW-VSEP-Conc	DOW-VSEP-Conc	DOW-VSEP-Conc	DOW-VSEP-Conc	DOW-VSEP-Conc	DOW-VSEP-Conc	DOW-VSEP-Conc	DOW-VSEP-Conc	DOW-VSEP-Conc	DOW-VSEP-Conc
Date		9/24/2013	9/25/2013	9/26/2013	9/30/2013	10/1/2013	10/2/2013	10/3/2013	10/7/2013	10/9/2013	10/10/2013
Parameter	Total or Dissolved										
General Parameters											
Alkalinity, total, as CaCO3	NA	**1,300 mg/l**	**520 mg/l**	**990 mg/l**	**1,100 mg/l**	**1,100 mg/l**	**1,000 mg/l**	**1,100 mg/l**	**970 mg/l**	**930 mg/l**	**1,200 mg/l**
Chloride	NA	**27 mg/l**	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l	< 4.0 mg/l
pH	NA	**6.2 pH units**	**6.0 pH units**	**6.1 pH units**	**6.2 pH units**	**6.0 pH units**	**6.0 pH units**	**6.0 pH units**	**6.7 pH units**	**6.0 pH units**	**6.1 pH units**
Silicon dioxide	NA	**16.5 mg/l**	**14.8 mg/l**	**13.6 mg/l**	**15.2 mg/l**	**14.6 mg/l**	**14.6 mg/l**	**14.9 mg/l**	**14.3 mg/l**	**14.1 mg/l**	**15.5 mg/l**
Solids, total dissolved	NA	**30,000 mg/l**	**29,000 mg/l**	**26,000 mg/l**	**34,000 mg/l**	**28,000 mg/l**	**32,000 mg/l**	**38,000 mg/l**	**30,000 mg/l**	**26,000 mg/l**	**38,000 mg/l**
Solids, total suspended	NA	**27 mg/l**	**38 mg/l**	**37 mg/l**	**47 mg/l**	**18 mg/l**	**34 mg/l**	**54 mg/l**	**35 mg/l**	**24 mg/l**	**44 mg/l**
Sulfate, as SO4	NA	**20,000 mg/l**	**20,000 mg/l**	**19,000 mg/l**	**24,000 mg/l**	**22,000 mg/l**	**22,000 mg/l**	**23,000 mg/l**	**20,000 mg/l**	**16,000 mg/l**	**23,000 mg/l**
Metals											
Aluminum	Total	< 50 ug/l	**130 ug/l**	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 50 ug/l	< 100 ug/l	< 100 ug/l
Arsenic	Total	--	--	--	--	--	--	**130 ug/l**	**270 ug/l**	--	--
Barium	Total	**79 ug/l**	**81 ug/l**	**86 ug/l**	**110 ug/l**	**94 ug/l**	**98 ug/l**	**120 ug/l**	**94 ug/l**	**70 ug/l**	**100 ug/l**
Calcium	Total	**900 mg/l**	**920 mg/l**	**660 mg/l**	**620 mg/l**	**860 mg/l**	**960 mg/l**	**1,600 mg/l**	**1,000 mg/l**	**720 mg/l**	**890 mg/l**
Cobalt	Total	--	--	--	--	--	--	**12,000 ug/l**	**9,100 ug/l**	--	--
Copper	Total	--	--	--	--	--	--	--	--	**2,900 ug/l**	**4,400 ug/l**
Iron	Dissolved	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l
Iron	Total	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 0.50 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l	< 1.0 mg/l
Lead	Total	**170 ug/l**	**250 ug/l**	--	--	--	--	--	--	--	--
Magnesium	Total	**3,500 mg/l**	**3,300 mg/l**	**2,700 mg/l**	**4,000 mg/l**	**3,600 mg/l**	**3,600 mg/l**	**4,900 mg/l**	**3,900 mg/l**	**2,400 mg/l**	**3,700 mg/l**
Manganese	Dissolved	**93 ug/l**	**160 ug/l**	**150 ug/l**	**140 ug/l**	**38 ug/l**	**130 ug/l**	**44 ug/l**	**100 ug/l**	**59 ug/l**	**120 ug/l**
Manganese	Total	**120 ug/l**	**170 ug/l**	**150 ug/l**	**140 ug/l**	**100 ug/l**	**140 ug/l**	**160 ug/l**	**120 ug/l**	**85 ug/l**	**140 ug/l**
Nickel	Total	--	--	--	--	--	--	**5,500 ug/l**	**4500 ug/l**	--	--
Potassium	Total	**400 mg/l**	**370 mg/l**	**300 mg/l**	**410 mg/l**	**400 mg/l**	**430 mg/l**	**510 mg/l**	**420 mg/l**	**290 mg/l**	**420 mg/l**
Selenium	Total	--	--	**730 ug/l**	**850 ug/l**	**1,500 ug/l**	**1,300 ug/l**	--	--	--	--
Silicon	Total	**7.3 mg/l**	**6.1 mg/l**	**4.8 mg/l**	**6.6 mg/l**	**6.5 mg/l**	**7.2 mg/l**	**5.9 mg/l**	**6.4 mg/l**	< 5.0 mg/l	**5.4 mg/l**
Sodium	Total	**670 mg/l**	**600 mg/l**	**480 mg/l**	**670 mg/l**	**660 mg/l**	**710 mg/l**	**800 mg/l**	**660 mg/l**	**440 mg/l**	**640 mg/l**
Strontium	Total	**4,400 ug/l**	**4,400 ug/l**	**3,800 ug/l**	**4,100 ug/l**	**4,200 ug/l**	**3,600 ug/l**	**3,800 ug/l**	**3,900 ug/l**	**3,500 ug/l**	**3,700 ug/l**
Zinc	Total	--	--	--	--	--	--	**21,000 ug/l**	**17,000 ug/l**	--	--

Bold values denote concentrations above laboratory reporting limits.

Table 11 VSEP Removal Efficiencies

Mass Based Removal						
	GE			DOW		
Parameter	Ave	Min	Max	Ave	Min	Max
Chloride	96.0%	95.6%	96.7%	13.0%	7.4%	16.7%
Silcon dioxide	99.0%	97.0%	98.0%	29.8%	26.1%	39.4%
Solids, total dissolved	99.0%	98.3%	99.5%	92.9%	90.2%	94.3%
Sulfate	99.6%	99.6%	99.6%	98.0%	97.0%	98.9%
Barium	98.2%	95.8%	99.6%	95.7%	94.8%	96.5%
Calcium	99.6%	99.5%	99.7%	94.3%	93.1%	95.5%
Magnesium	99.6%	99.5%	99.7%	95.6%	94.7%	96.8%
Potassium	96.6%	95.3%	97.9%	66.2%	63.1%	70.7%
Selenite	99.1%	99.0%	99.1%	66.8%	63.1%	70.4%
Selenate	98.1%	96.7%	99.5%	97.7%	97.5%	97.9%
Sodium	97.3%	96.5%	98.1%	55.4%	49.1%	63.1%
Strontium	99.2%	98.0%	99.7%	95.4%	94.6%	96.4%
Arsenic	-	-	-	50.6%	21.1%	80.0%
Cobalt	-	-	-	95.1%	94.8%	95.5%
Copper	-	-	-	96.6%	96.1%	97.2%
Lead	-	-	-	98.5%	98.1%	98.8%
Nickel	-	-	-	95.7%	95.6%	95.8%
Zinc	-	-	-	94.9%	94.8%	95.0%

Concentration Based Removal						
	GE			DOW		
Parameter	Ave	Min	Max	Ave	Min	Max
Chloride	95.0%	94.4%	95.8%	-8.8%	-16.0%	-4.2%
Silcon dioxide	98.8%	96.3%	97.5%	12.3%	7.6%	24.3%
Solids, total dissolved	98.8%	97.9%	99.4%	91.1%	87.8%	92.9%
Sulfate	99.5%	99.5%	99.5%	97.5%	96.2%	98.7%
Barium	97.7%	94.7%	99.5%	94.7%	93.5%	95.6%
Calcium	99.5%	99.4%	99.7%	92.9%	91.4%	94.4%
Magnesium	99.5%	99.3%	99.6%	94.5%	93.4%	95.9%
Potassium	95.7%	94.1%	97.4%	57.8%	53.8%	63.3%
Selenite	98.8%	98.8%	98.9%	58.4%	53.8%	63.0%
Selenate	97.7%	95.9%	99.4%	97.1%	96.9%	97.3%
Sodium	96.7%	95.7%	97.6%	44.2%	36.4%	53.8%
Strontium	99.0%	97.6%	99.6%	94.2%	93.3%	95.5%
Arsenic	-	-	-	38.2%	1.4%	75.0%
Cobalt	-	-	-	93.9%	93.5%	94.3%
Copper	-	-	-	95.8%	95.1%	96.5%
Lead	-	-	-	98.1%	97.6%	98.5%
Nickel	-	-	-	94.6%	94.4%	94.7%
Zinc	-	-	-	93.6%	93.5%	93.7%

Table 12 Comparison of Greensand Filter Effluent and Blended Permeates to WQ Targets

Parameter	Total or Dissolved	Target	GSF Effluent	Percent of Target	Blended GE NF + DOW VSEP	Percent of Target	Blended DOW NF + DOW VSEP	Percent of Target
General Parameters								
Alkalinity, total, as CaCO3	NA				209 mg/l		213 mg/l	
Chloride	NA	230 mg/l			3.58 mg/l	1.6%	3.66 mg/l	1.6%
pH	NA				8.03		8.12	
Silicon dioxide	NA				6.84 mg/l		7.8 mg/l	
Solids, total dissolved	NA				279 mg/l		236 mg/l	
Solids, total suspended	NA				2 mg/l		2.67 mg/l	
Sulfate, as SO4	NA	250 mg/l			30.3 mg/l	12.1%	23.9 mg/l	9.6%
Metals								
Aluminum	Total	125 ug/l			8.33 ug/l	6.7%	5 ug/l	4.0%
Arsenic	Total	10 ug/l	26 ug/L	130.0%	7.75 ug/l	77.5%	69.2 ug/l	692.0%
Barium	Total	2000 ug/l			0.414 ug/l	0.0%	0.554 ug/l	0.0%
Calcium	Total				9.27 mg/l		9.02 mg/l	
Cobalt	Total	5 ug/l	6.5 ug/L	130.0%	22 ug/l	440.0%	54.8 ug/l	1096.0%
Copper	Total	20 ug/l	14.3 ug/L	71.5%	18.8 ug/l	94.0%	33.4 ug/l	167.0%
Iron	Dissolved				0.0625 mg/l		0.0625 mg/l	
Iron	Total	0.3 mg/l			0.0625 mg/l	20.8%	0.0625 mg/l	20.8%
Lead	Total	10.2 ug/l	1.9 ug/L	18.6%	0.278 ug/l	2.7%	0.278 ug/l	2.7%
Magnesium	Total				18.9 mg/l		21.2 mg/l	
Manganese	Dissolved				0.518 ug/l		1.17 ug/l	
Manganese	Total	50 ug/l			0.505 ug/l	1.0%	2.79 ug/l	5.6%
Nickel	Total	113 ug/l	27.5 ug/L	24.3%	9.76 ug/l	8.6%	24 ug/l	21.2%
Potassium	Total				28.7 mg/l		26.8 mg/l	
Selenite	Total	5 ug/l	65.0 ug/L	1300.0%	20.7 ug/l	414.0%	23.3 ug/l	466.0%
Selenate	Total	5 ug/l	50.5 ug/L	1010.0%	1.95 ug/l	39.0%	1.89 ug/l	37.8%
Silicon	Total				4.05 mg/l		4.17 mg/l	

Parameter	Total or Dissolved	Target	GSF Effluent	Percent of Target	Blended GE NF + DOW VSEP	Percent of Target	Blended DOW NF + DOW VSEP	Percent of Target
Sodium	Total	60% of cations			58.7 mg/l	97.8%	52.6 mg/l	87.7%
Strontium	Total				27.1 ug/l		29.2 ug/l	
Zinc	Total	260	16 ug/L	6.2%	52.3 ug/l	20.1%	116 ug/l	44.6%

Bold values denote concentrations above laboratory reporting limits.

Table 13 **Composition of VSEP Concentrate used for Bench Testing**

Parameter	Total	Dissolved
Calcium, mg/L	1,600	460
Magnesium, mg/L	4,300	3,200
Sodium, mg/L	890	640
Potassium, mg/L	540	440
Sulfate, mg/L	22,000	--
Bicarbonate Alkalinity, mg/L as CaCO3	2,400	--

Table 14 HDS Precipitation Bench Test Results

					Dissolved Concentrations									
	pH	Iron Solids Content	Ferrous Sulfate Dose	Volumes Water Exchanged	Antimony	Arsenic	Cobalt	Copper	Iron	Lead	Magnesium	Nickel	Selenium	Sulfate
Sample ID	Std. Units	% (weight iron)	mg/L		µg/L	µg/L	µg/L	µg/L	mg/L	µg/L	mg/L	µg/L	µg/L	mg/L
Raw Spiked Water	**7.5**	**NA**	**NA**	**NA**	**1,350**	**82**	**1,160**	**5,214**		**405**	**3,200**	**20,929**	**395**	**22,000**
HDS1-1	7.9	0.2	0	1	410	17	170	140	<1.0	12	3,500	3000	330	20,000
HDS1-4	7.8	0.2	0	4	540	16	550	220	<1.0	14	3,100	11000	270	11,000
HDS2-1	7.8	0.2	350	1	160	17	220	54	7.8	10	3,700	2700	340	17,000
HDS2-4	7.8	0.2	350	4	270	14	400	130	<1.0	13	3,400	6600	270	16,000
HDS3-1	9.6	0.1	0	1	400	14	7.3	140	<1.0	3	2,800	86	300	18,000
HDS3-4	9.6	0.1	0	4	610	14	24	170	<1.0	4.6	3,100	480	270	20,000
HDS4-1	9.7	0.1	350	1	340	12	5.4	130	<1.0	3.4	2,800	45	310	19,000
HDS4-4	9.0	0.1	350	4	390	16	8.8	88	<1.0	8.3	3,700	87	280	22,000

Table 15 Sulfate Precipitation Bench Test Results

	pH	Aluminum Spike	Aluminum, Dissolved	Antimony, Dissolved	Arsenic, Dissovled	Calcium, Dissolved	Cobalt, Dissolved	Copper, Dissolved	Magnesium, Dissolved	Nickel, Dissolved	Selenium, Dissolved	Carbonate Alkalinity as $CaCO_3$	Sulfate
Sample ID	SU	mg/L	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	mg/L	µg/L	µg/L	mg/L	mg/L
Spiked Raw Water	7.5			1,511	82	460	1,160	5,214	3,200	20,929	395	0	22,000
GYP-1	11.5	753	<0.20	56	10	480	2.9	34	30	13	150	<40	3,500
GYP-2	11.8	753	<0.20	67	12	480	3.2	32	<10	15	180	72	3,200
GYP-3	12	753	<0.20	59	11	500	3.3	34	<10	20	180	190	3,200
GYP-4	12.5	753	<0.20	5.8	9.6	570	1.7	32	<10	18	180	1,400	2,700
GYP-5	12	0	<0.20	37	12	430	4.4	37	47	17	200	<40	3,500
GYP-6	12.5	0	<0.20	44	12	380	1.3	36	<10	14	210	400	2,900

Table 16 Scavenger Test Results

Sample ID	pH Std. Units	Scavenger Dose ppm	Cobalt µg/L	Copper µg/L	Nickel µg/L
Raw Gypsum Sludge Supernatant	12.5	0	116	521	2,093
Scav-1	10.5	0	2.4	67	300
Scav-2	10.5	5	1.2	28	97
Scav-3	10	0	6.3	82	550
Scav-4	10	5	8.6	41	580
Scav-5	9	0	52	100	1,300
Scav-6	9	5	27	51	920

Table 17 Analytical Data Notes and Qualifiers

Qualifier	Definition
--	Not analyzed/not available
b	Potential false positive value based on blank data validation procedures
e	Estimated value, exceeded the instrument calibration range
h	EPA recommended sample preservation, extraction, or analysis holding time was exceeded.
j	Reported value is less than the stated laboratory quantitation limit and is considered an estimated value
*	Estimated value, QA/QC criteria not met
**	Unusable value, QA/QC criteria not met
N	Sample Type: Normal
FD	Sample Type: Field Duplicate

Figures

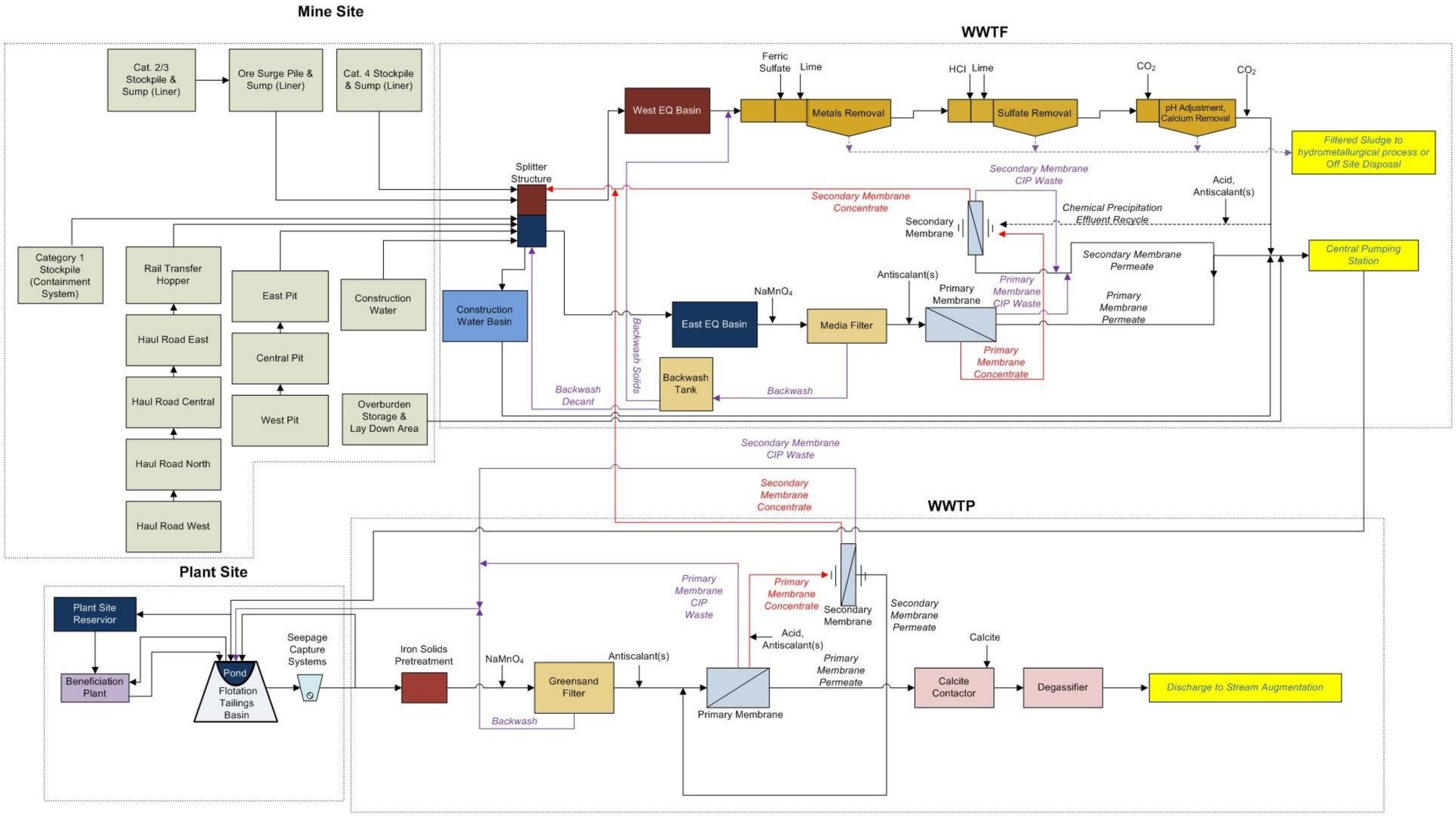
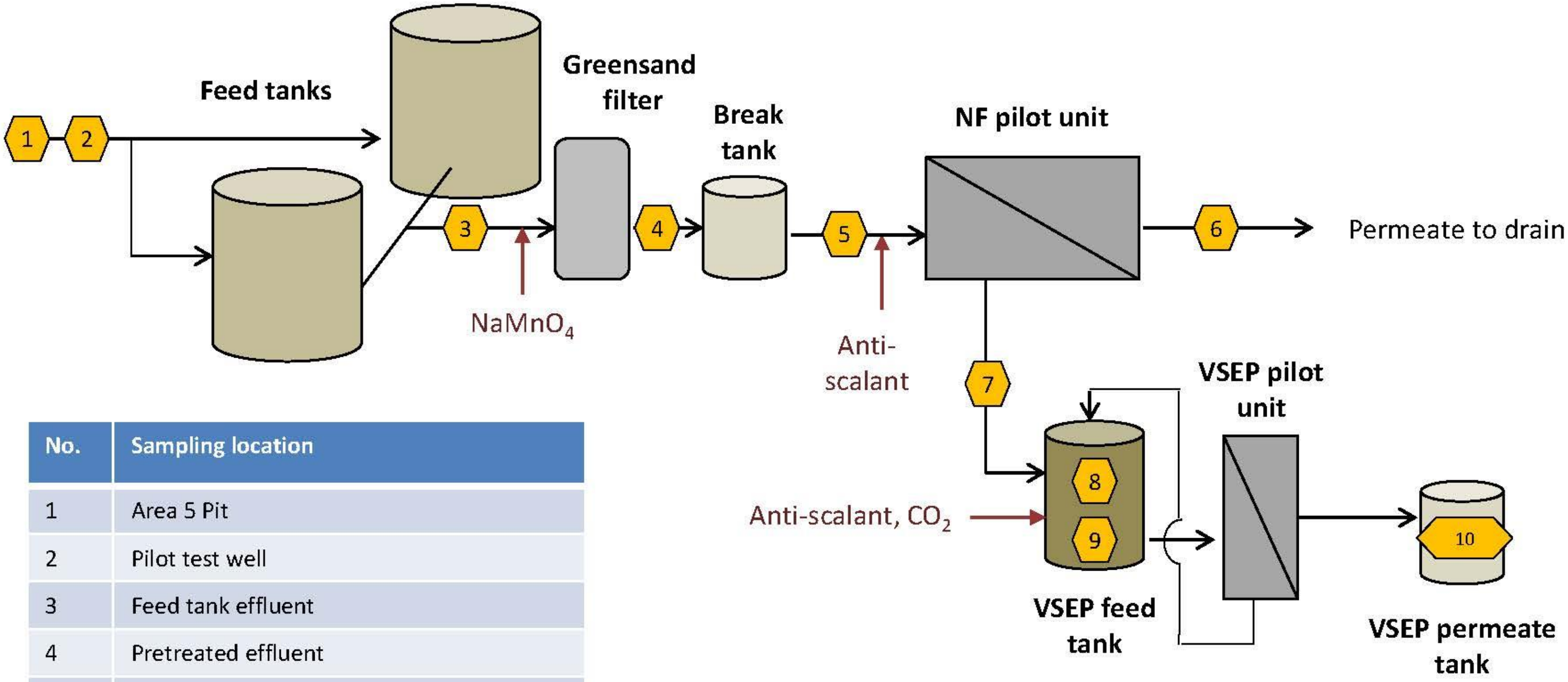


Figure 1 **Water Treatment Overall Flow Sheet-Operations**



No.	Sampling location
1	Area 5 Pit
2	Pilot test well
3	Feed tank effluent
4	Pretreated effluent
5	NF feed
6	NF permeate
7	NF concentrate
8	VSEP feed (beginning of batch)
9	VSEP concentrate (end of batch)
10	VSEP permeate (end of batch)

\# Sampling location

Figure 2 **Pilot-Testing Program Components and Sampling Locations**

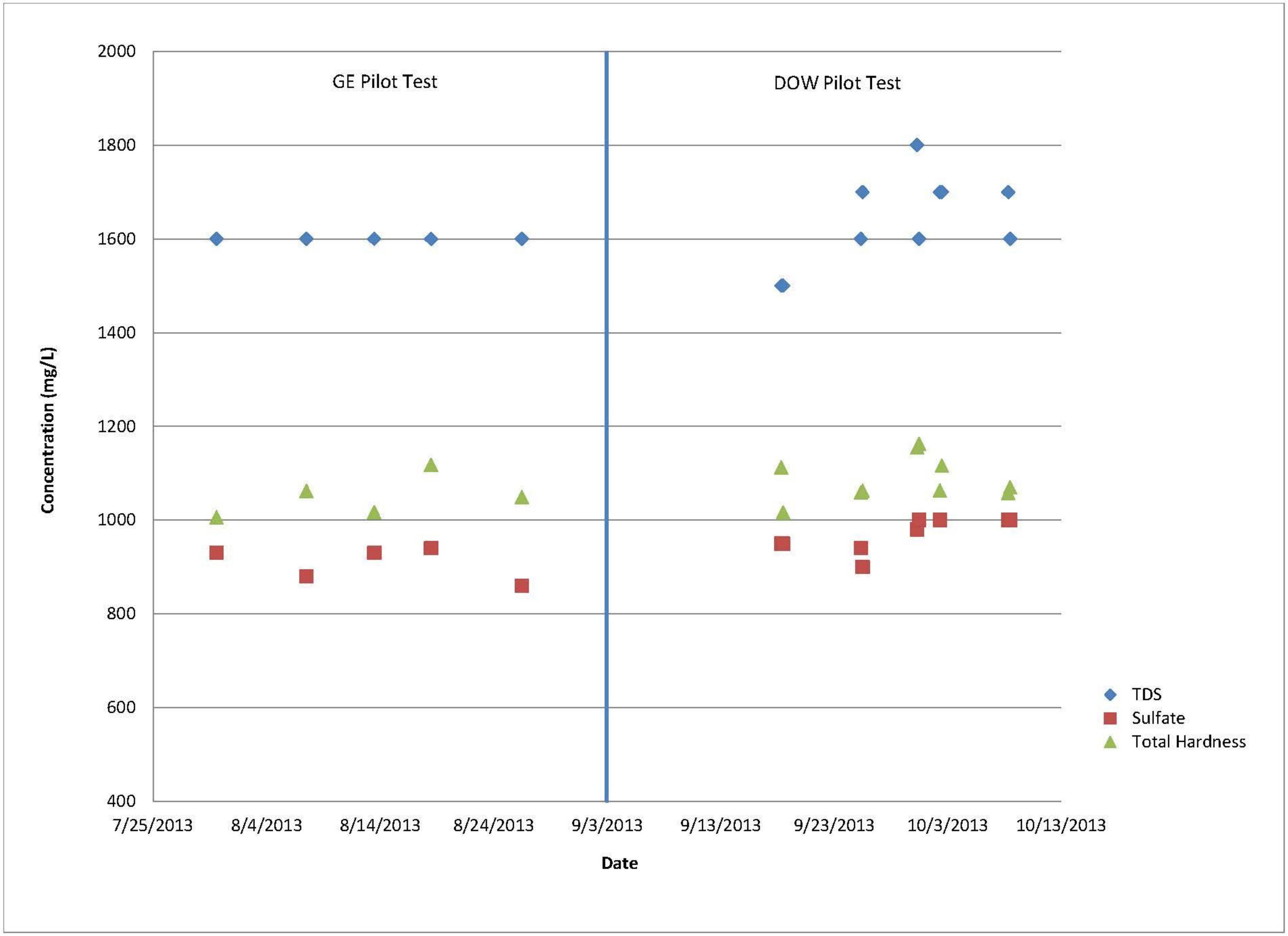


Figure 3 Influent Dissolved Solids, Total Hardness, and Sulfate Concentrations

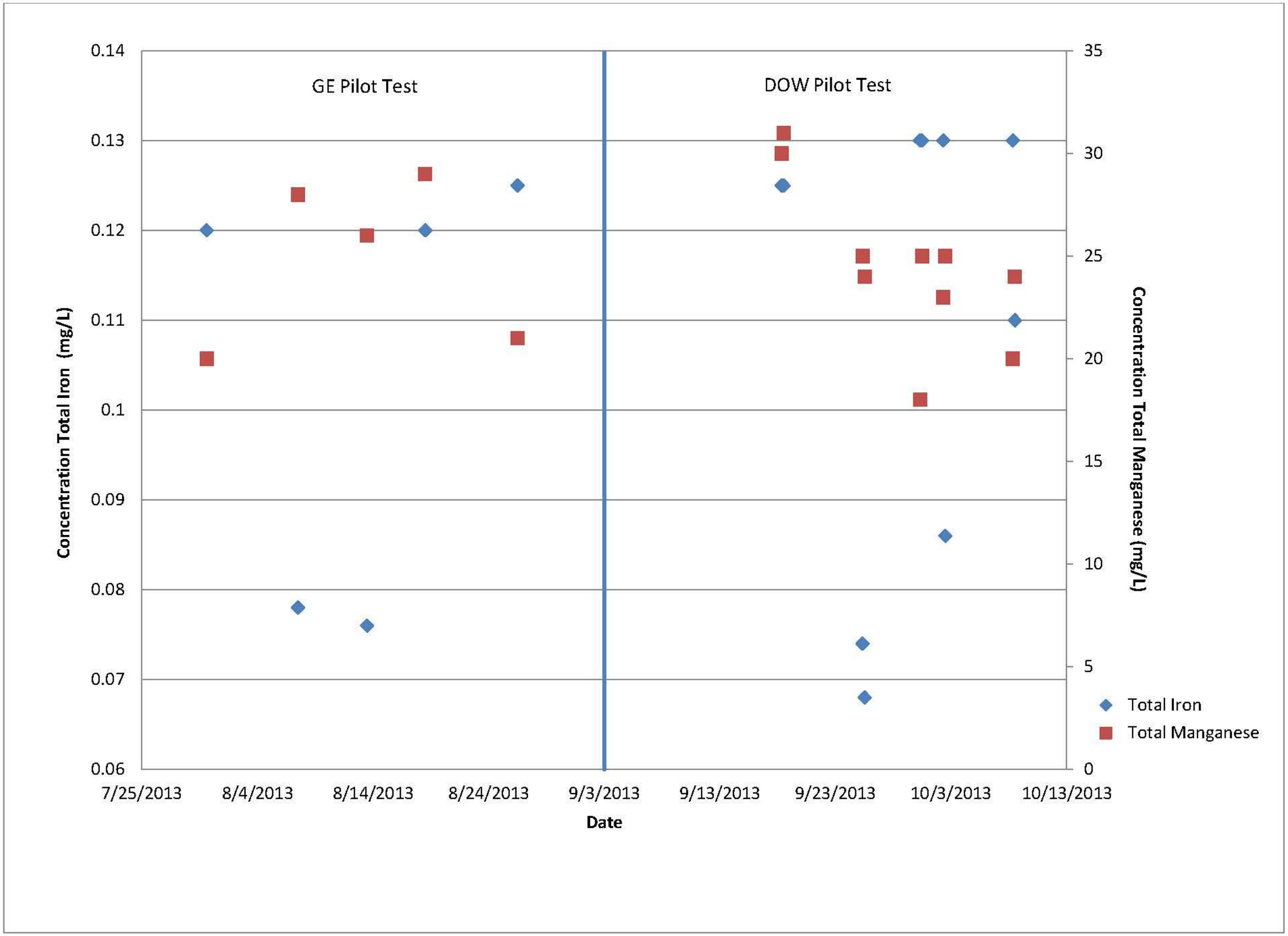


Figure 4 Influent Iron and Manganese Concentrations

Figure 5 Greensand Filter Pilot Unit

Figure 6 **Primary NF Pilot Unit**

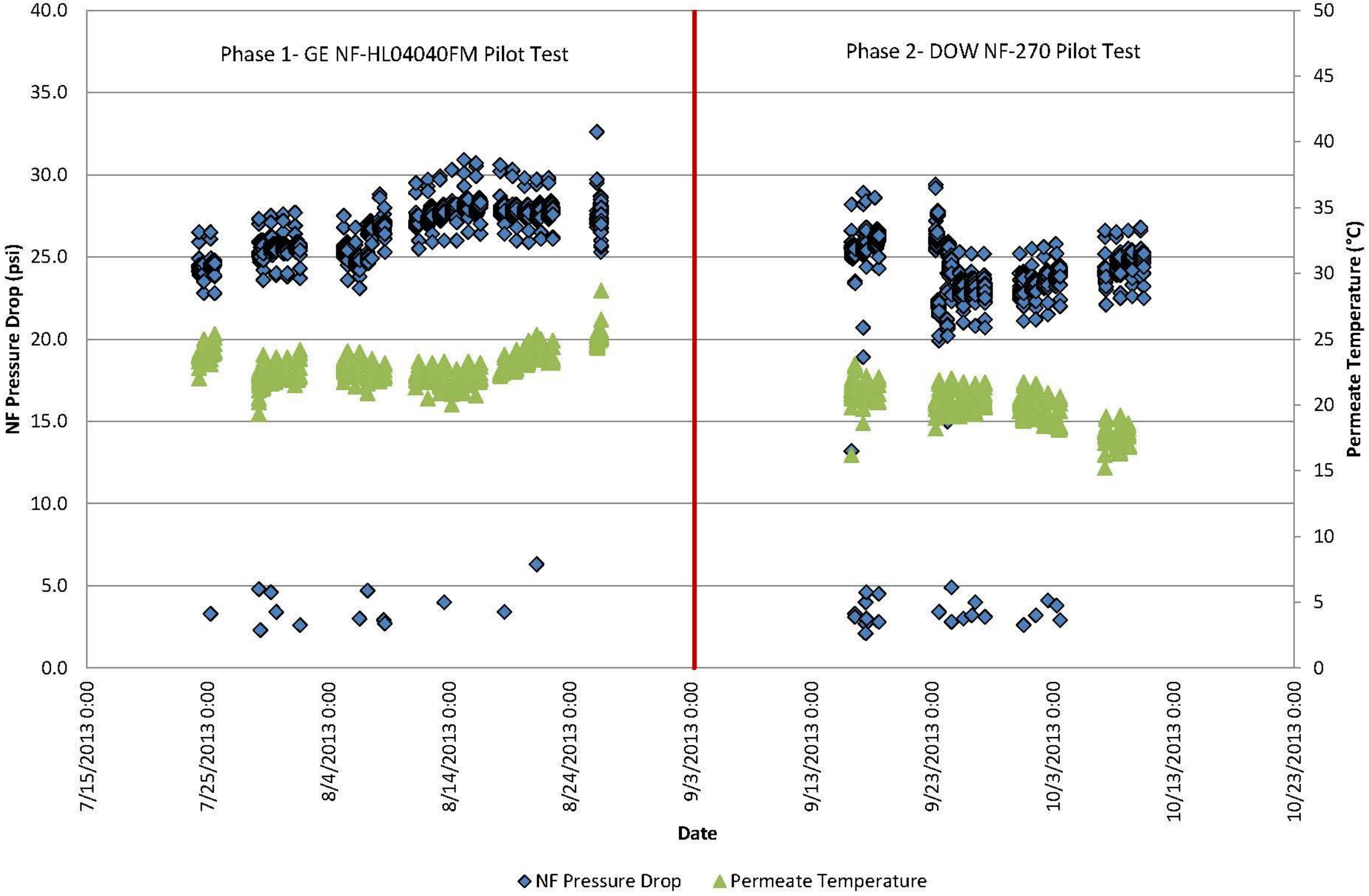


Figure 7 Primary NF Feed-to-Concentrate Pressure Drop and Permeate Temperature

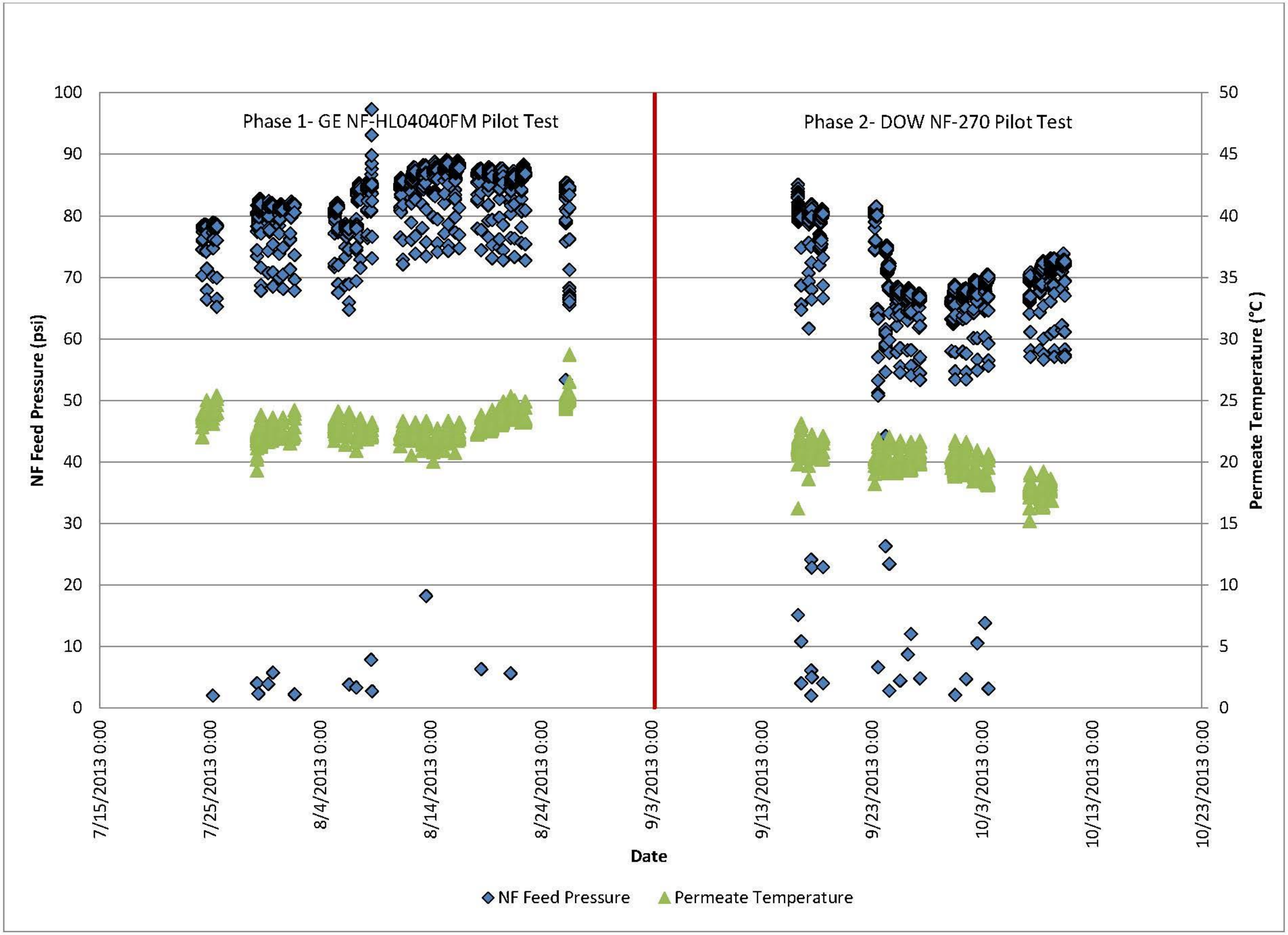


Figure 8 Primary NF Feed Pressure and Permeate Temperature

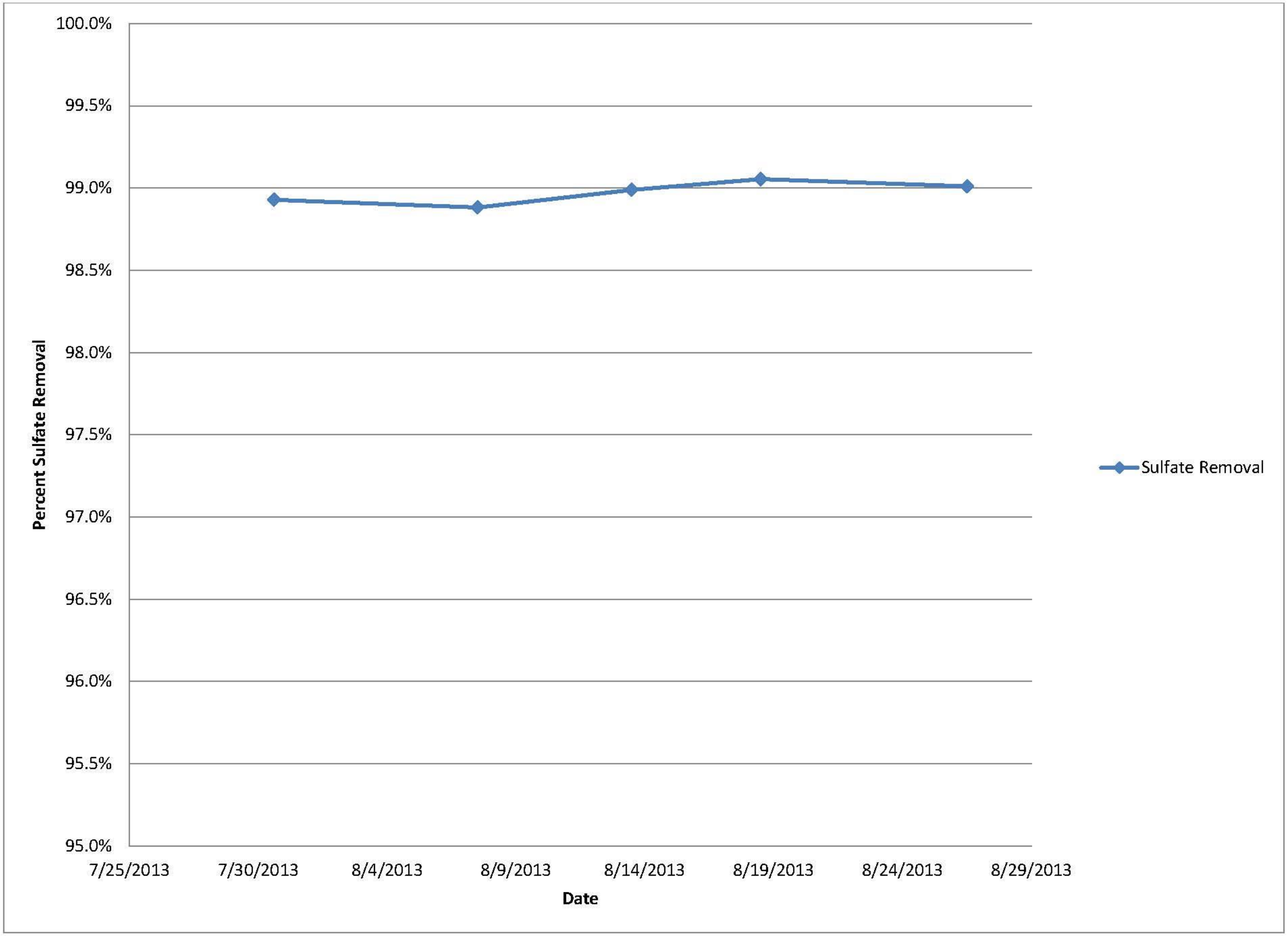


Figure 9 Primary NF Sulfate Removal – Phase 1 Pilot-test Results

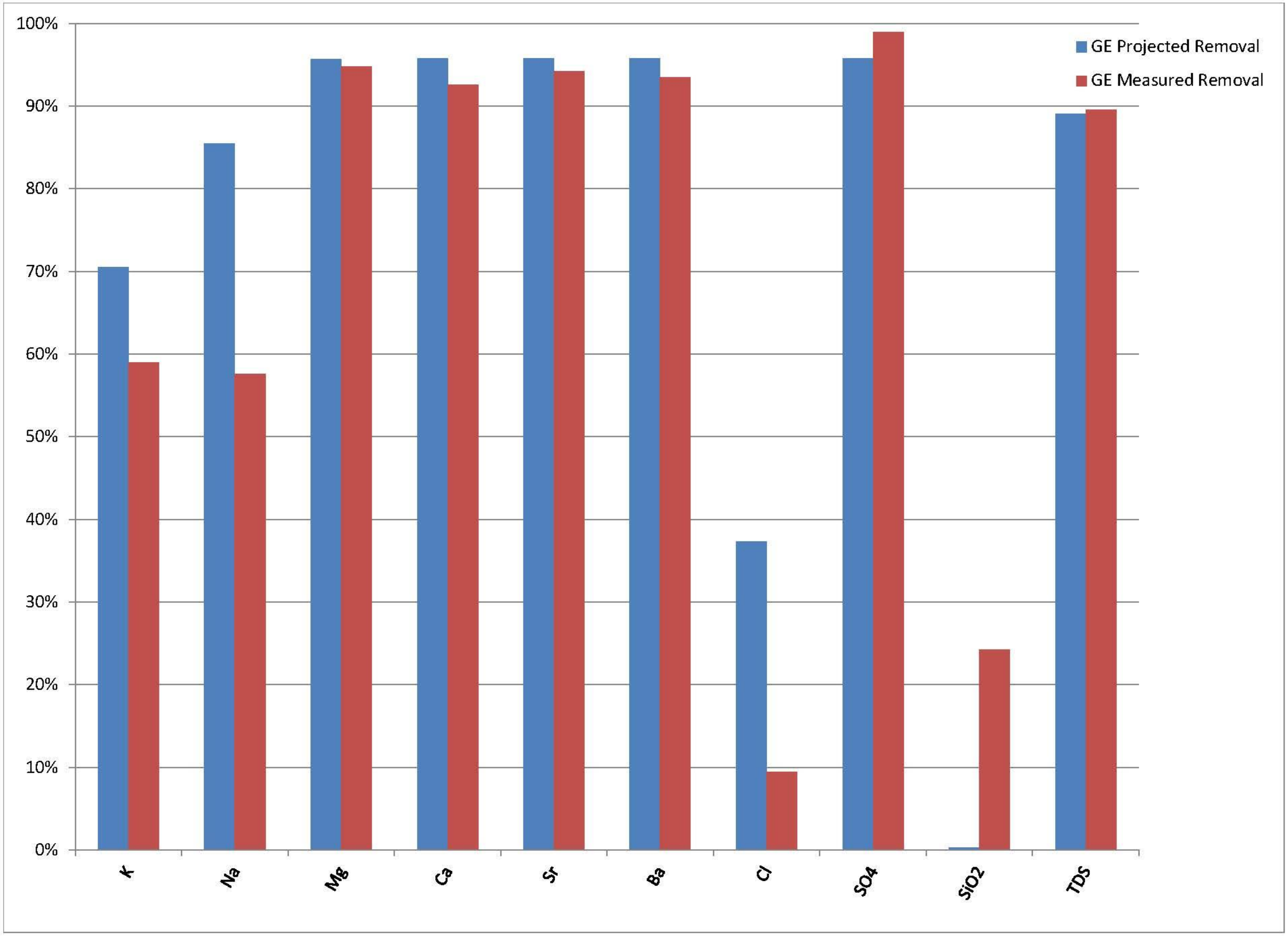


Figure 10 Primary NF – Comparison of Modeled (Projected) vs. Observed (Measured) Removal – Phase 1 Pilot-test Results

Figure 11 **VSEP Pilot Unit**

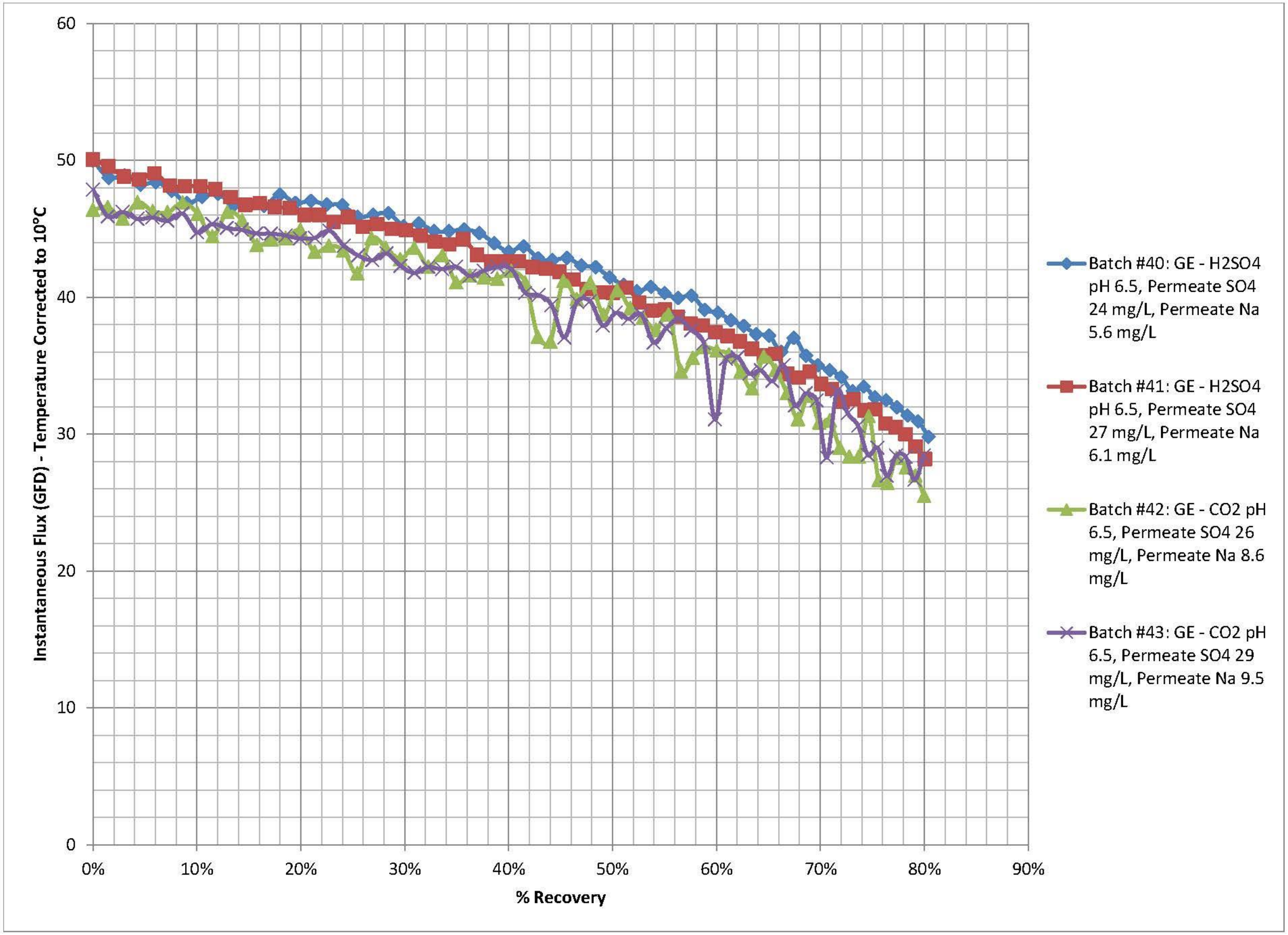


Figure 12 VSEP Flux vs. Recovery Curves – Phase 1 Pilot-test Results

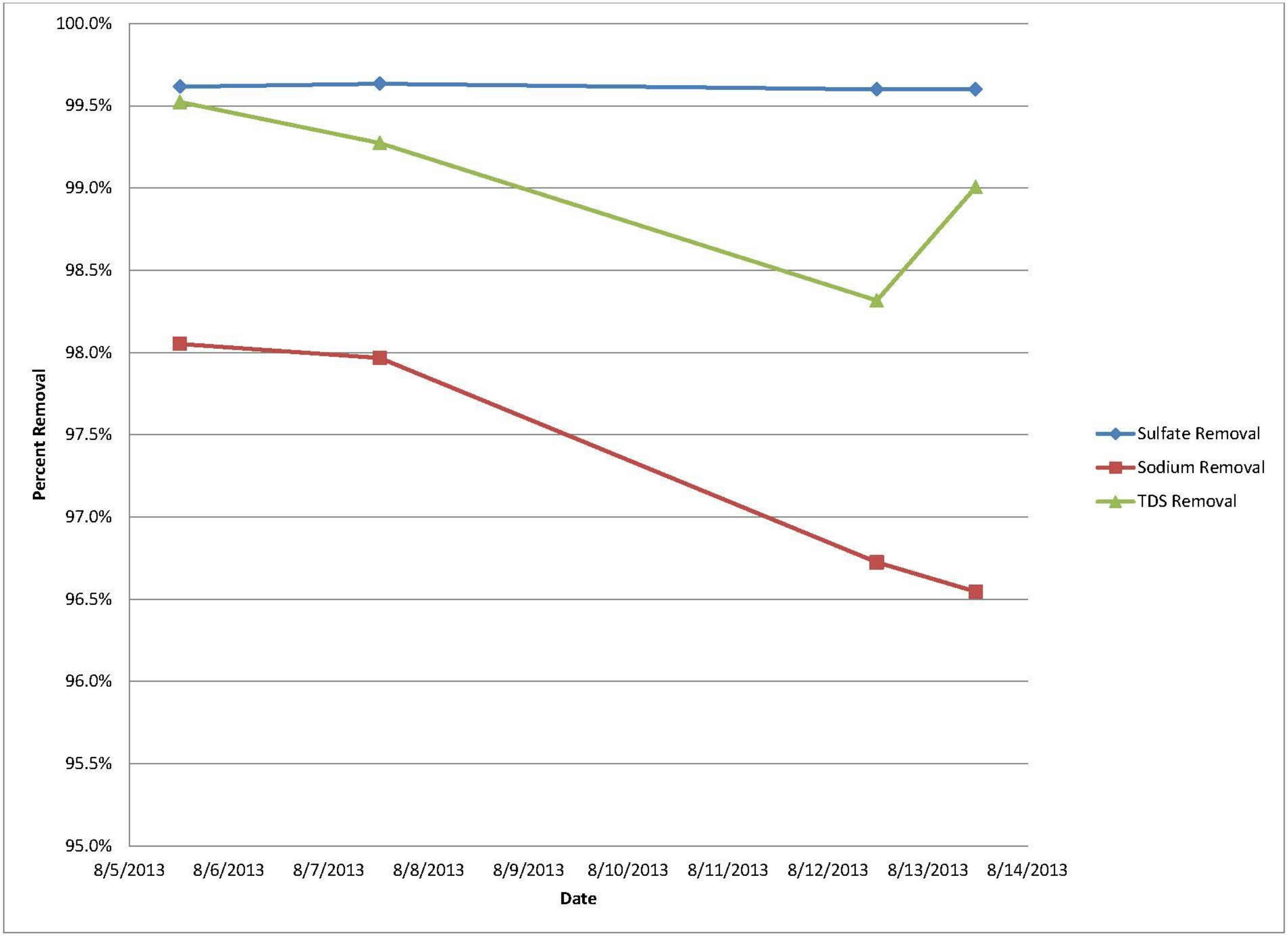


Figure 13 VSEP Sulfate, Sodium, and TDS Removal Rates – Phase 1 Pilot-test Results

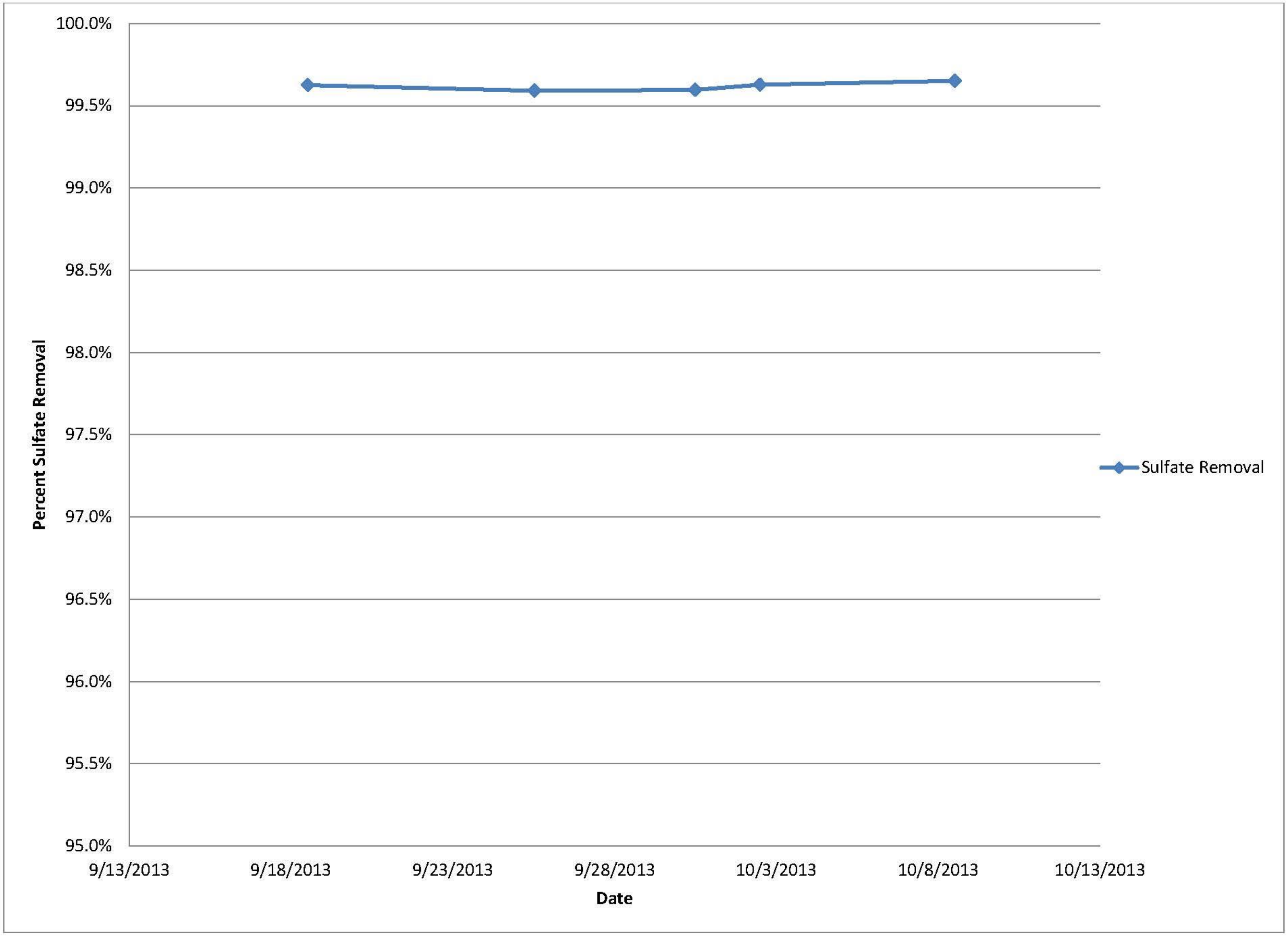


Figure 14 **Primary NF Sulfate Removal – Phase 2 Pilot-test Results**

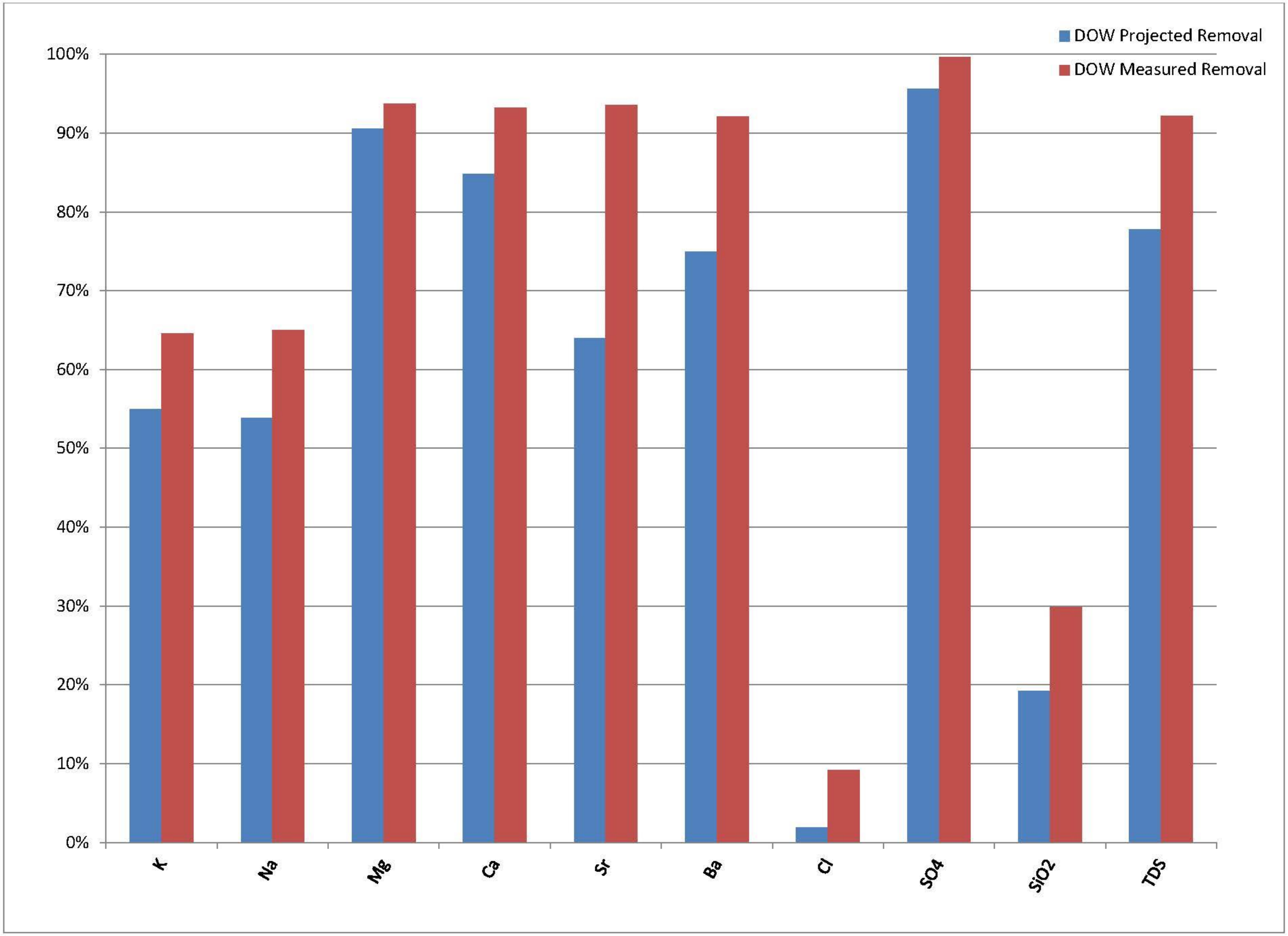


Figure 15 Primary NF Comparison of Modeled (Projected) vs. Observed (Measured) Removal – Phase 2 Pilot-test Results

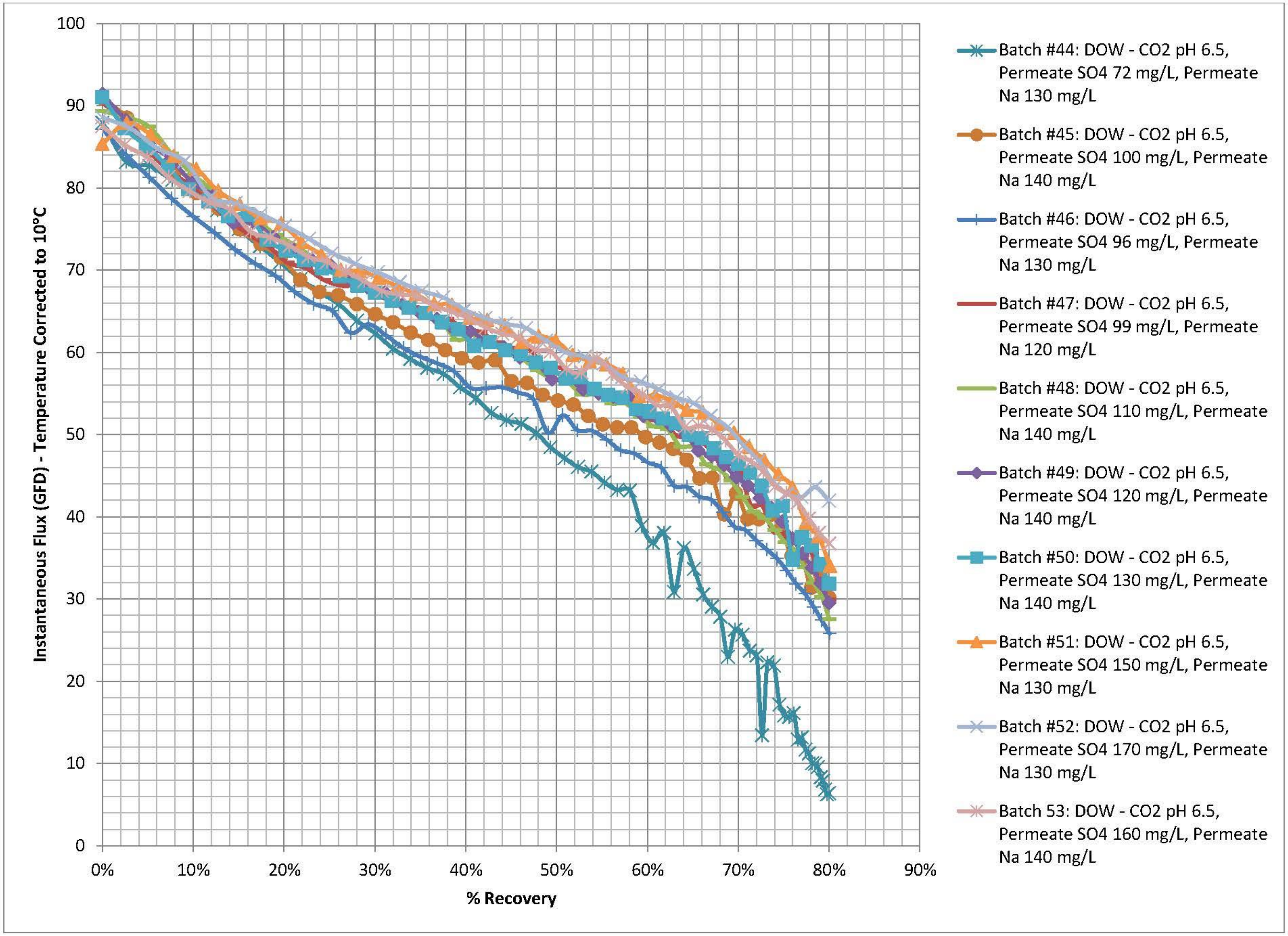


Figure 16 VSEP Flux vs. Recovery Curves – Phase 2 Pilot-test Results

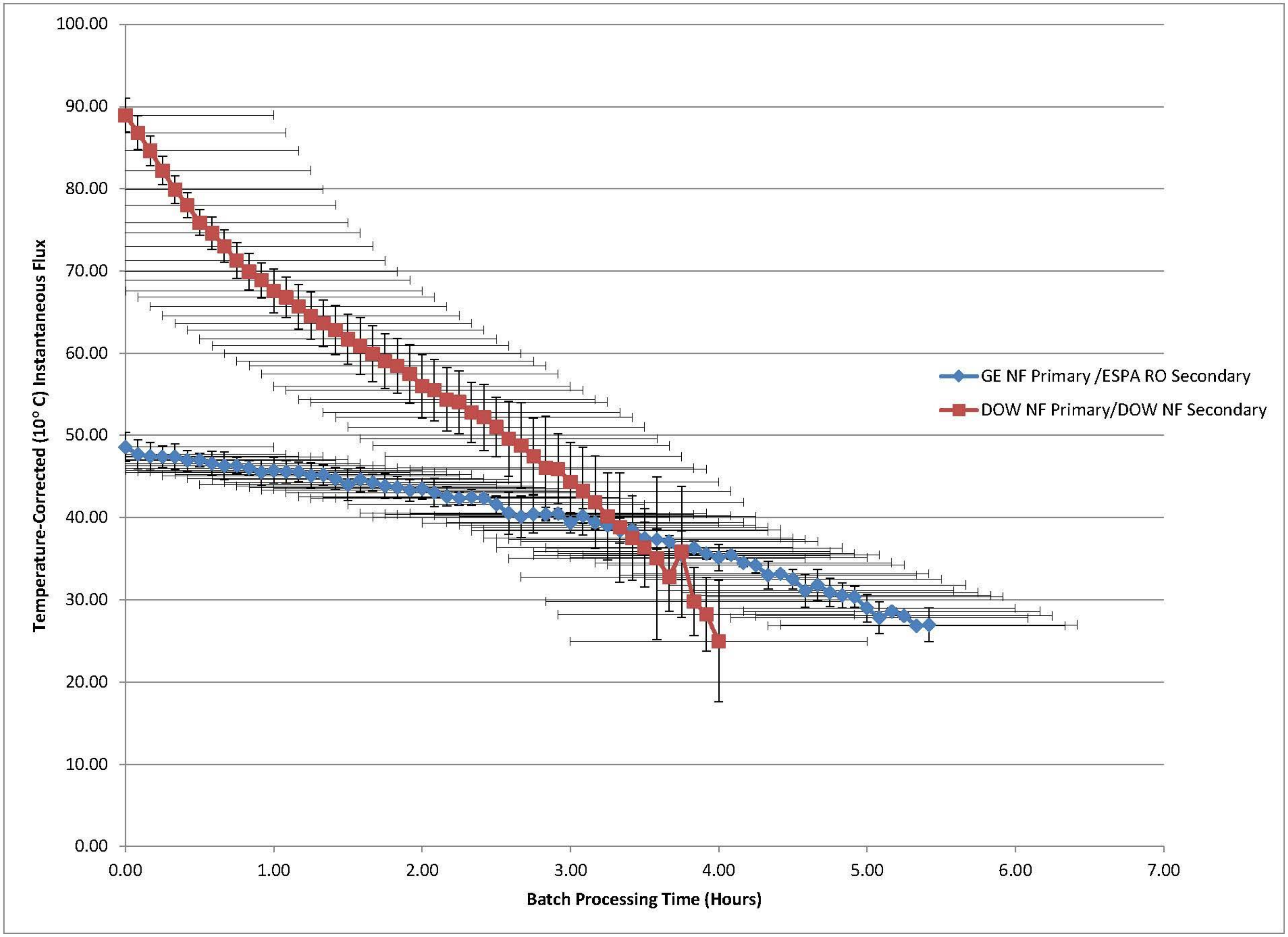


Figure 17 Comparison of Flux and Batch Processing Time – Phase 1 and Phase 2 VSEP Pilot-Test Results

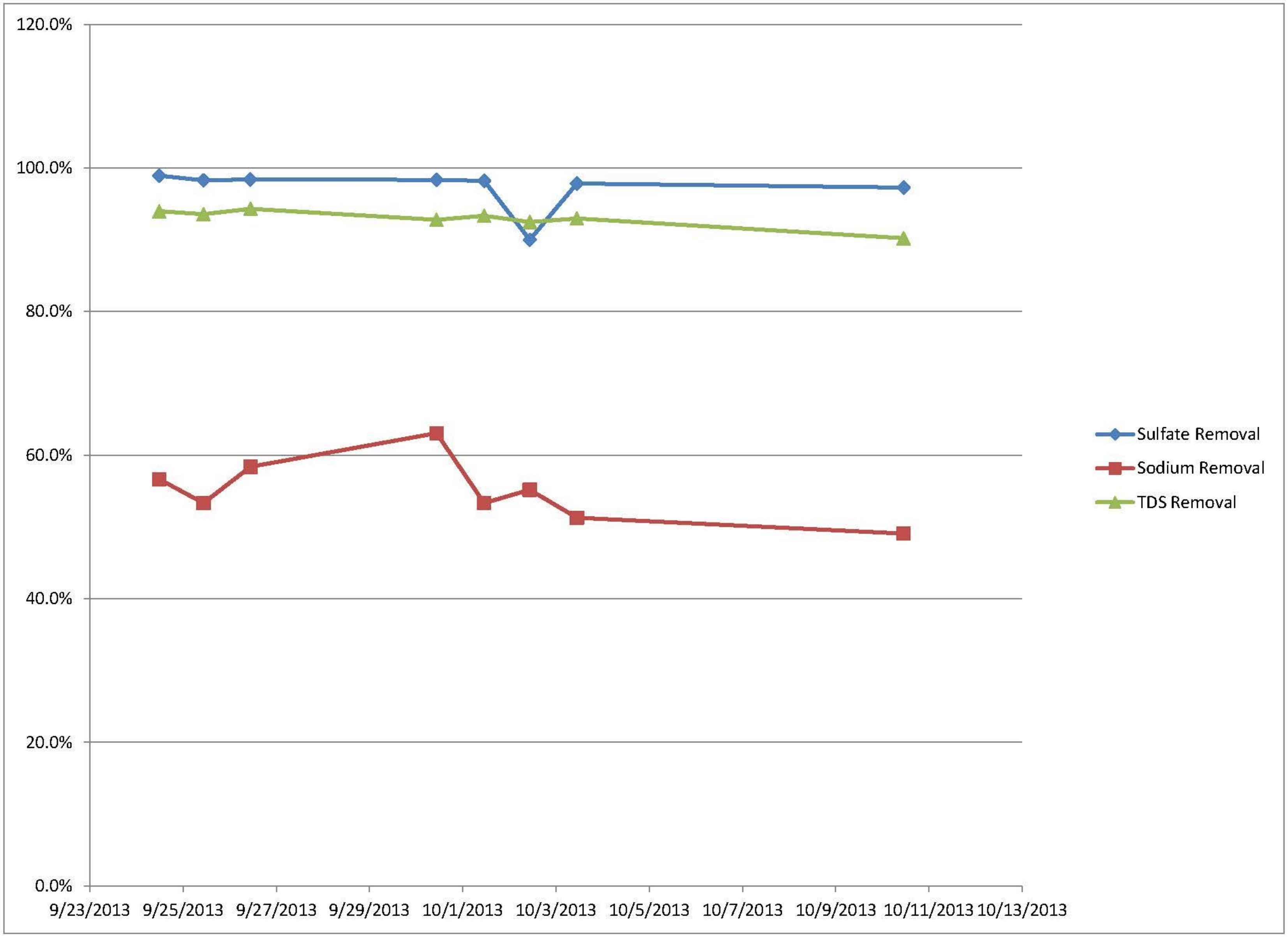


Figure 18 **VSEP Sulfate, Sodium, and TDS Removal Rates – Phase 2 Pilot-test Results**

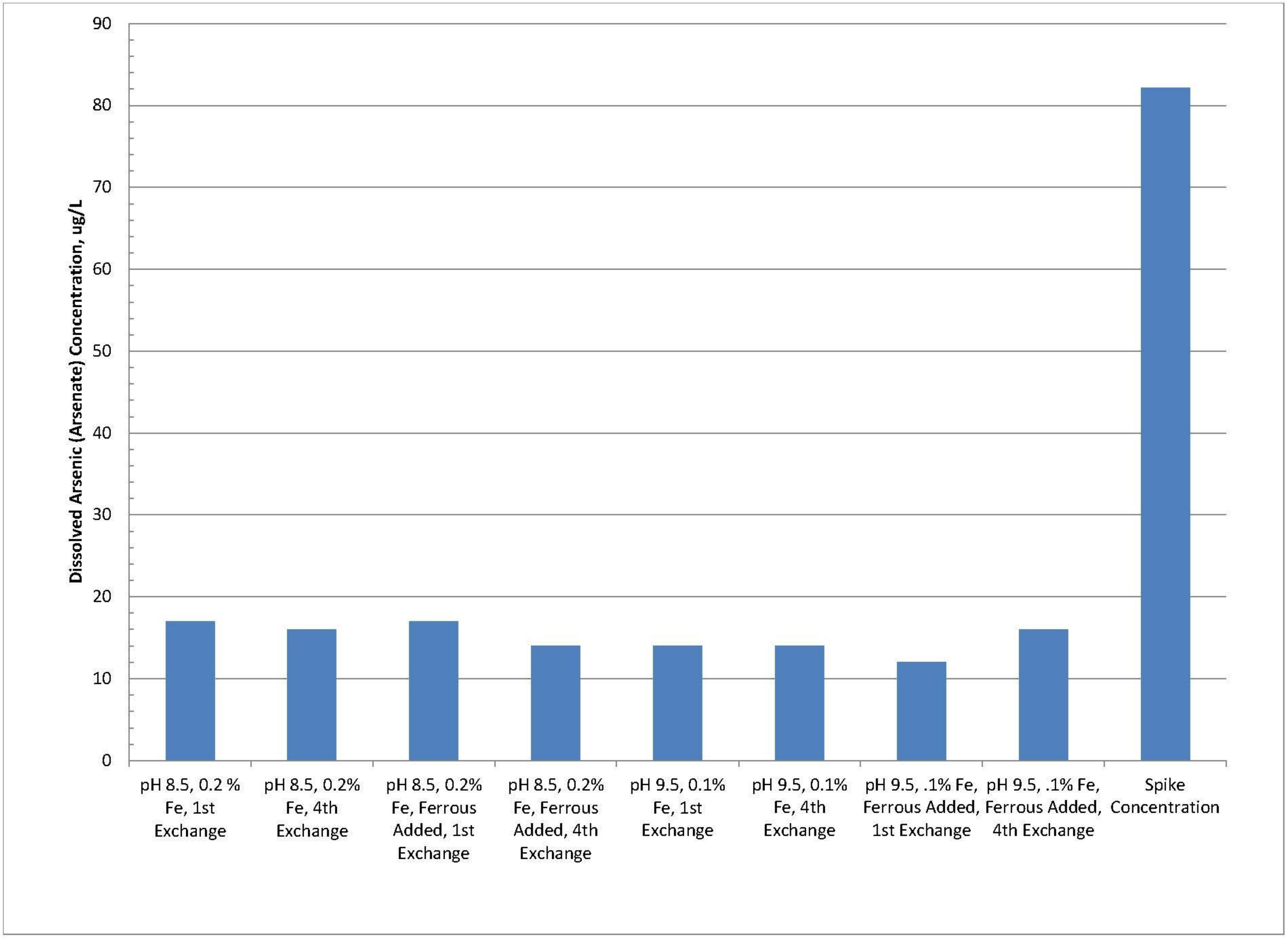


Figure 19 **HDS Bench Test Results – Arsenic**

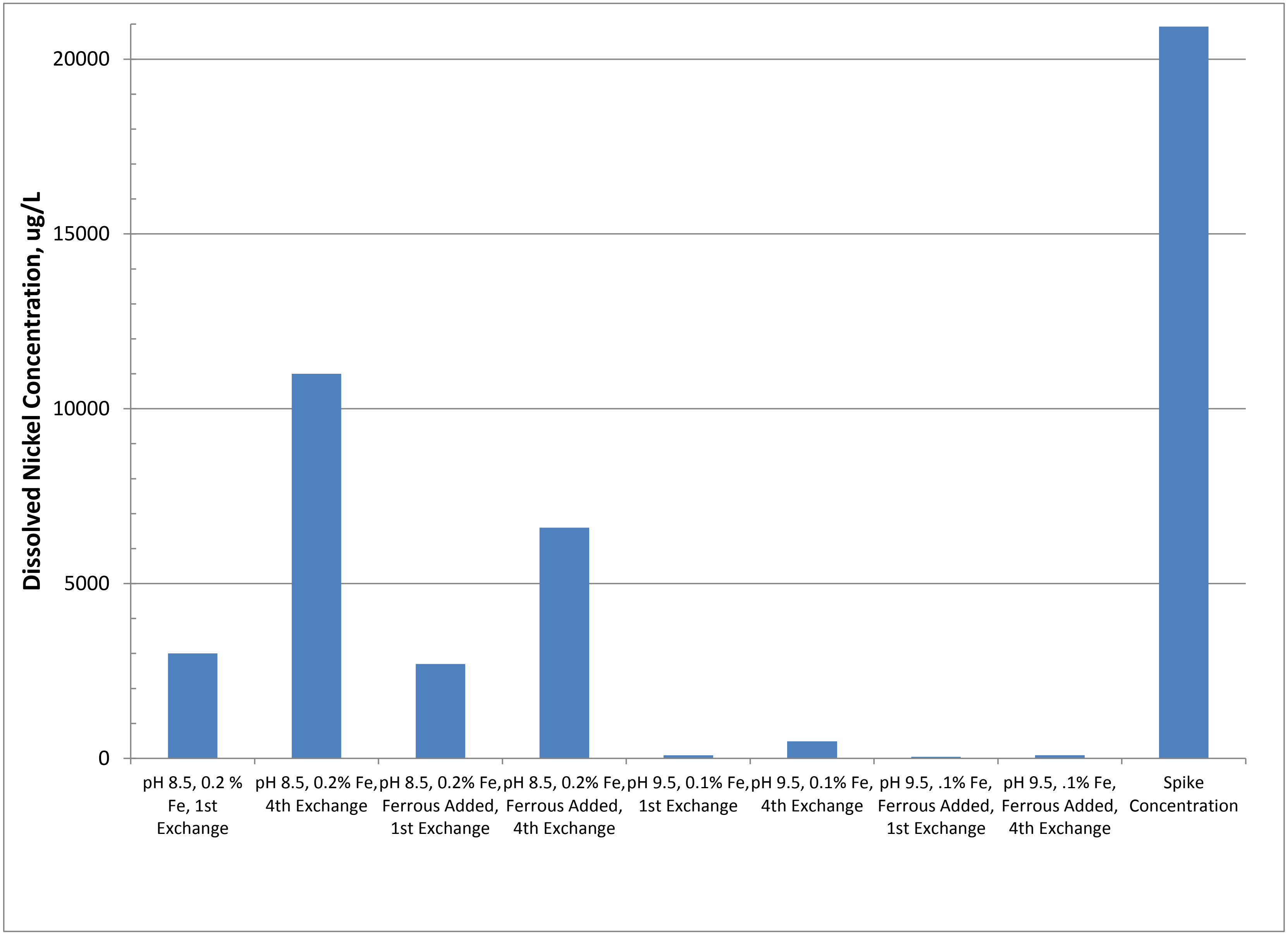


Figure 20 **HDS Bench Test Results – Nickel**

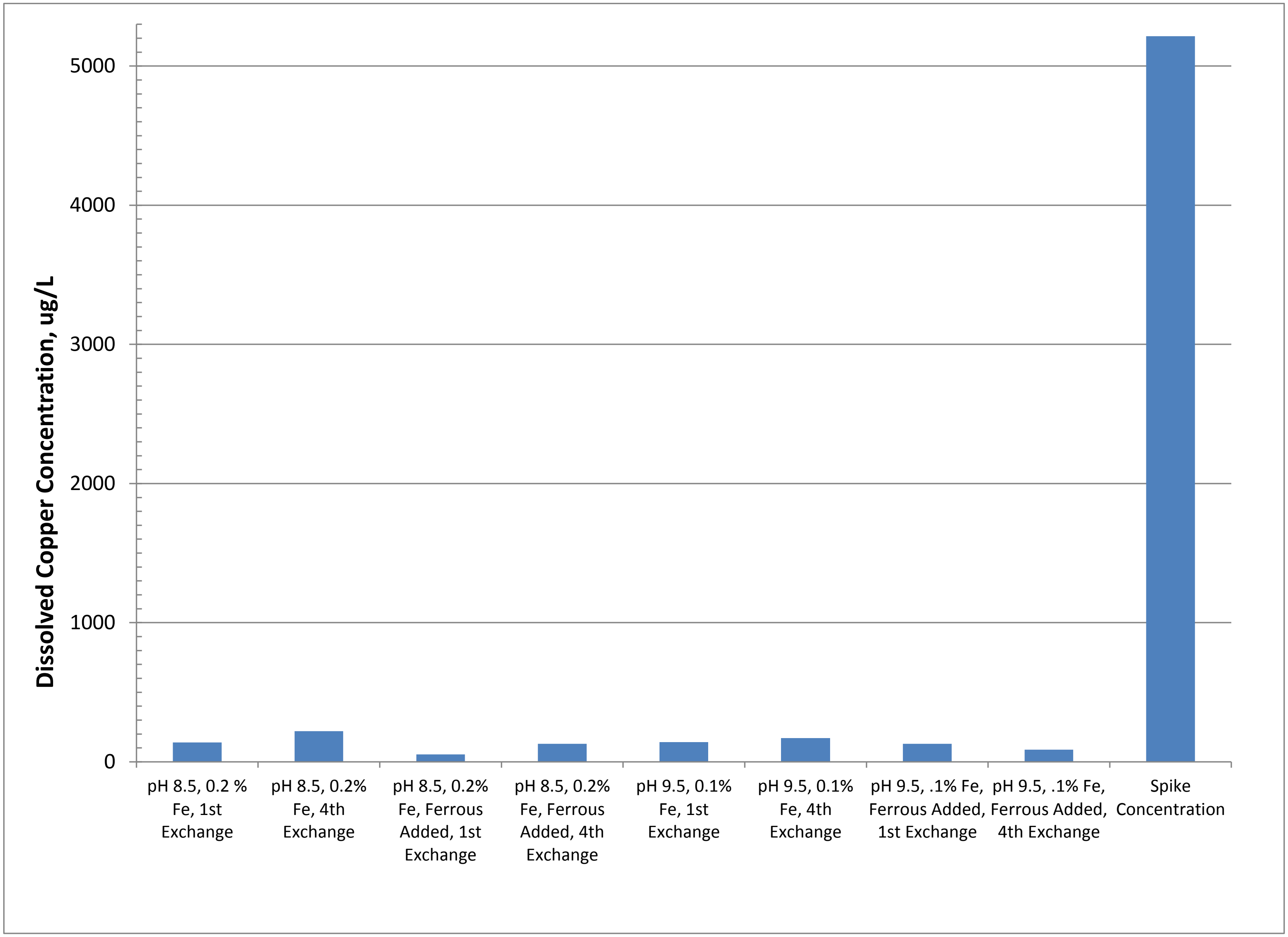


Figure 21 **HDS Bench Test Results – Copper**

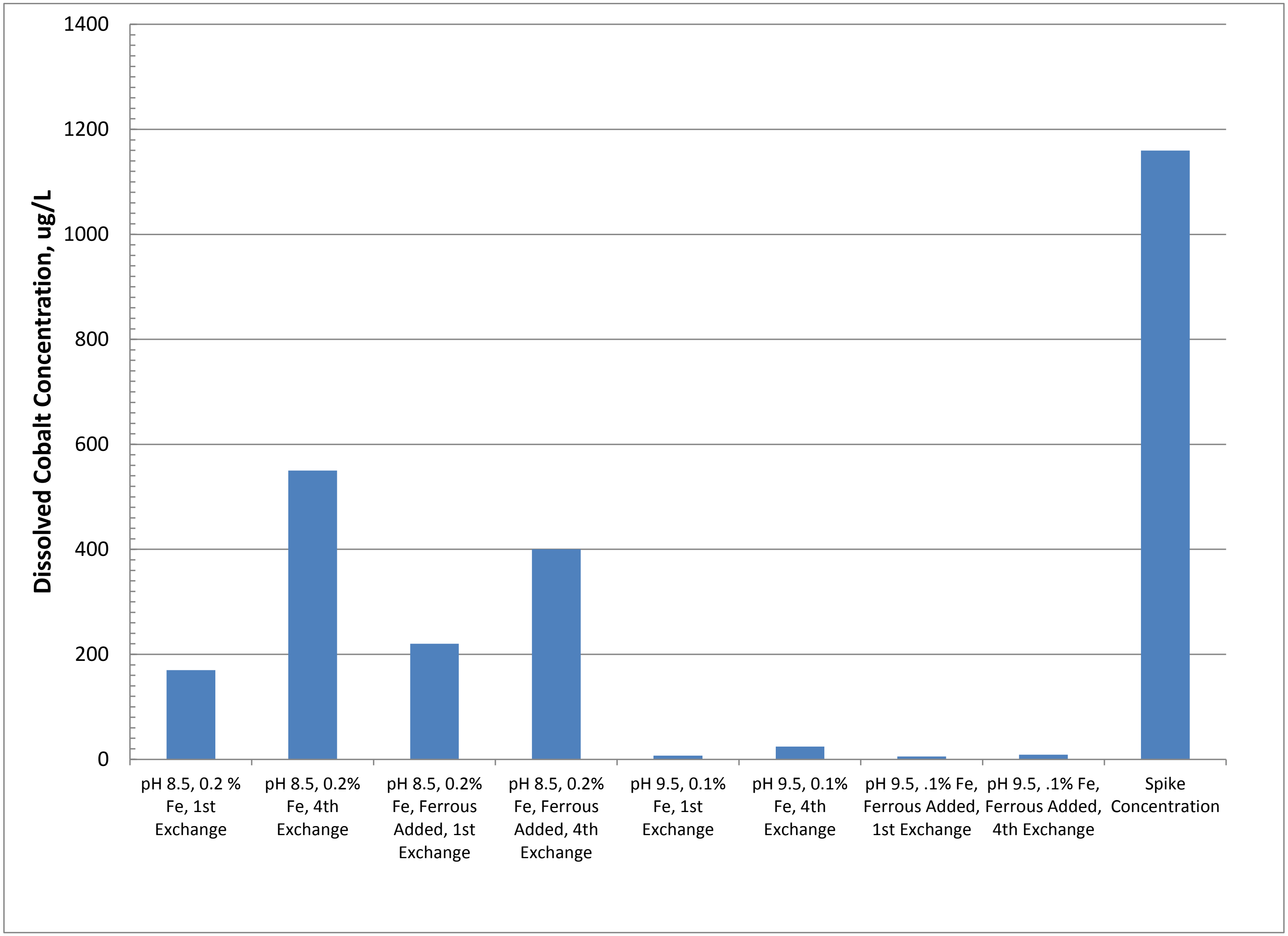


Figure 22 **HDS Bench Test Results – Cobalt**

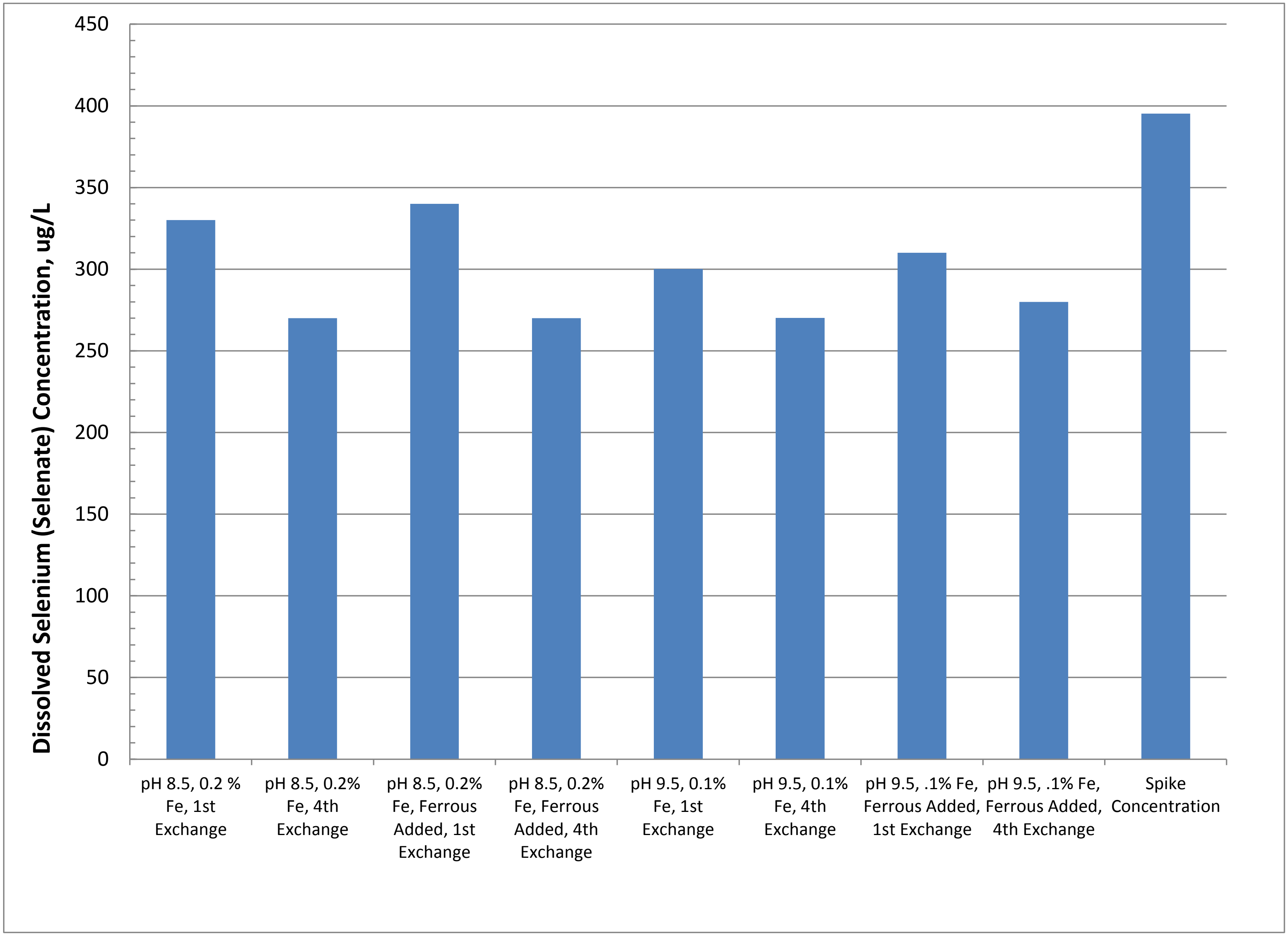


Figure 23 **HDS Bench Test Results – Selenium**

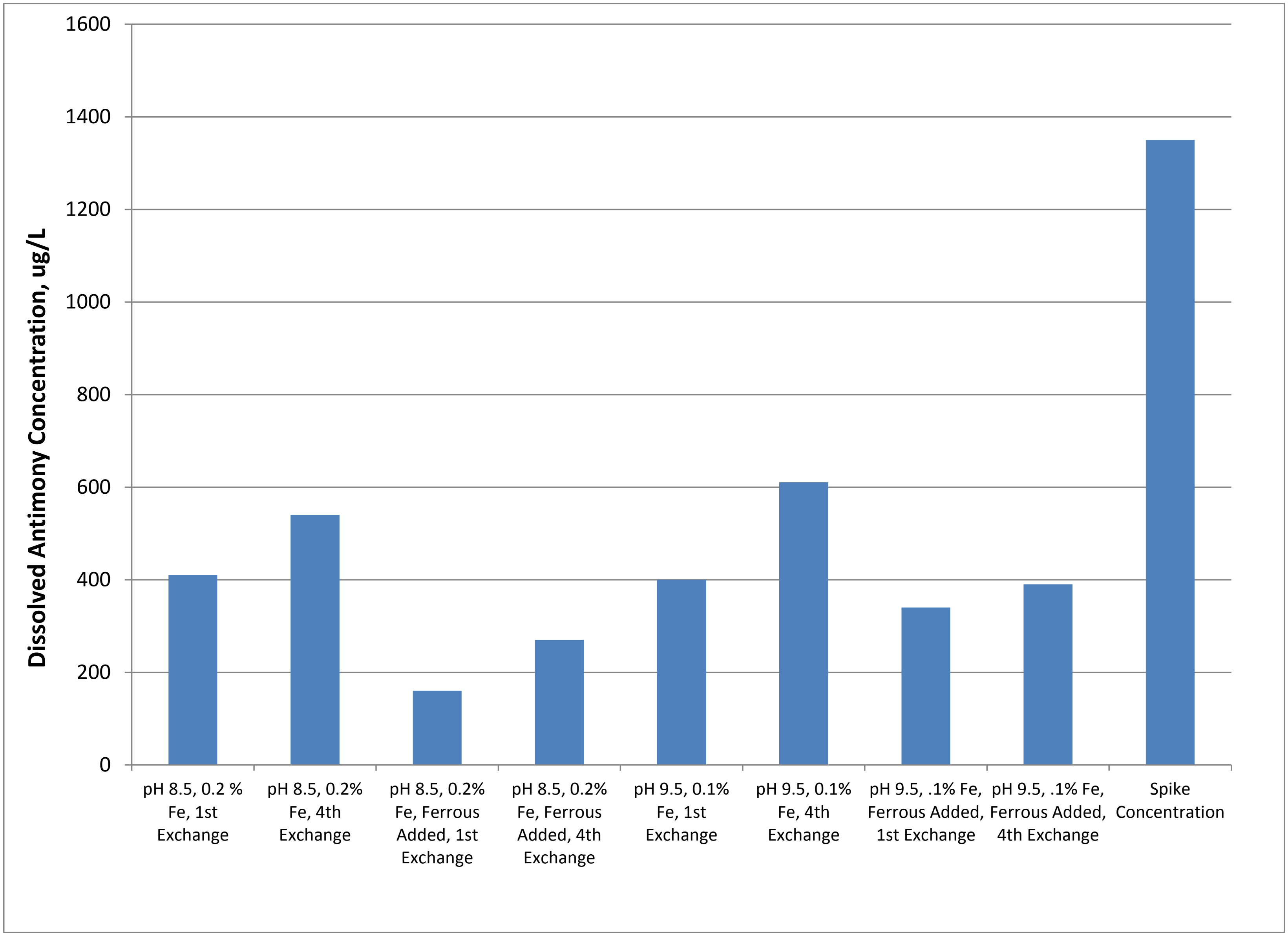


Figure 24 **HDS Bench Test Results – Antimony**

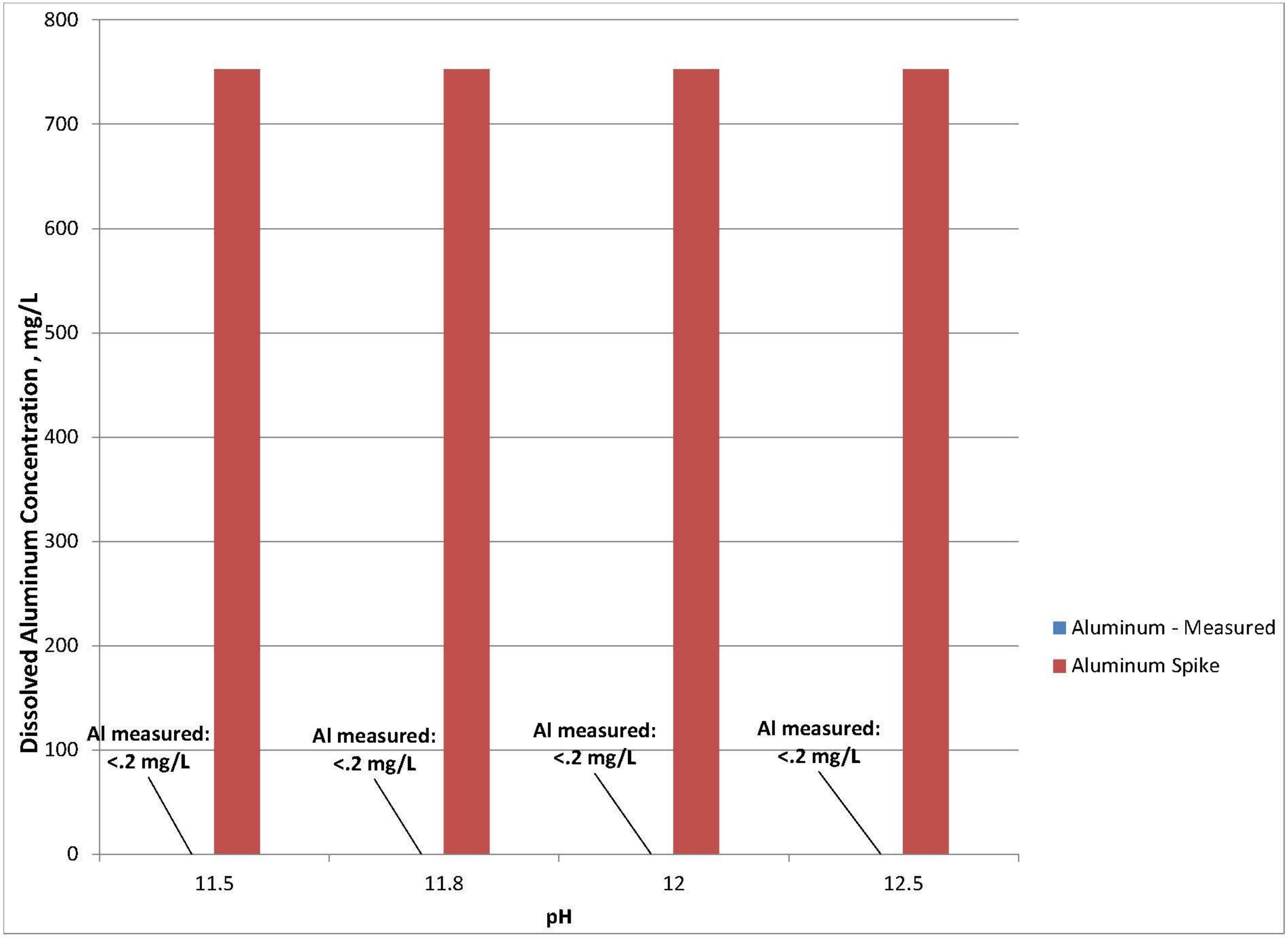


Figure 25 Sulfate Precipitation Results – Aluminum

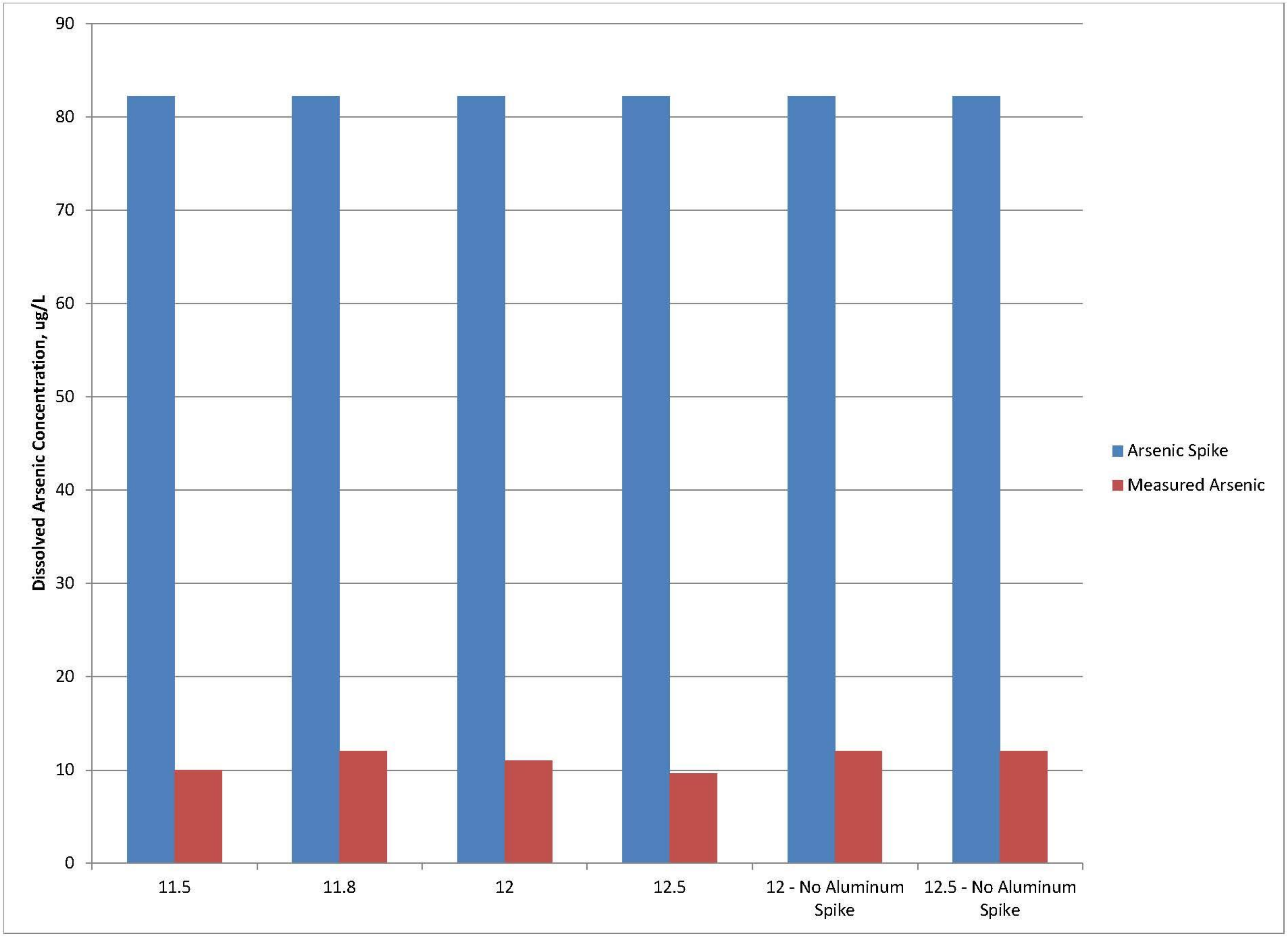


Figure 26 Sulfate Precipitation Results – Arsenic

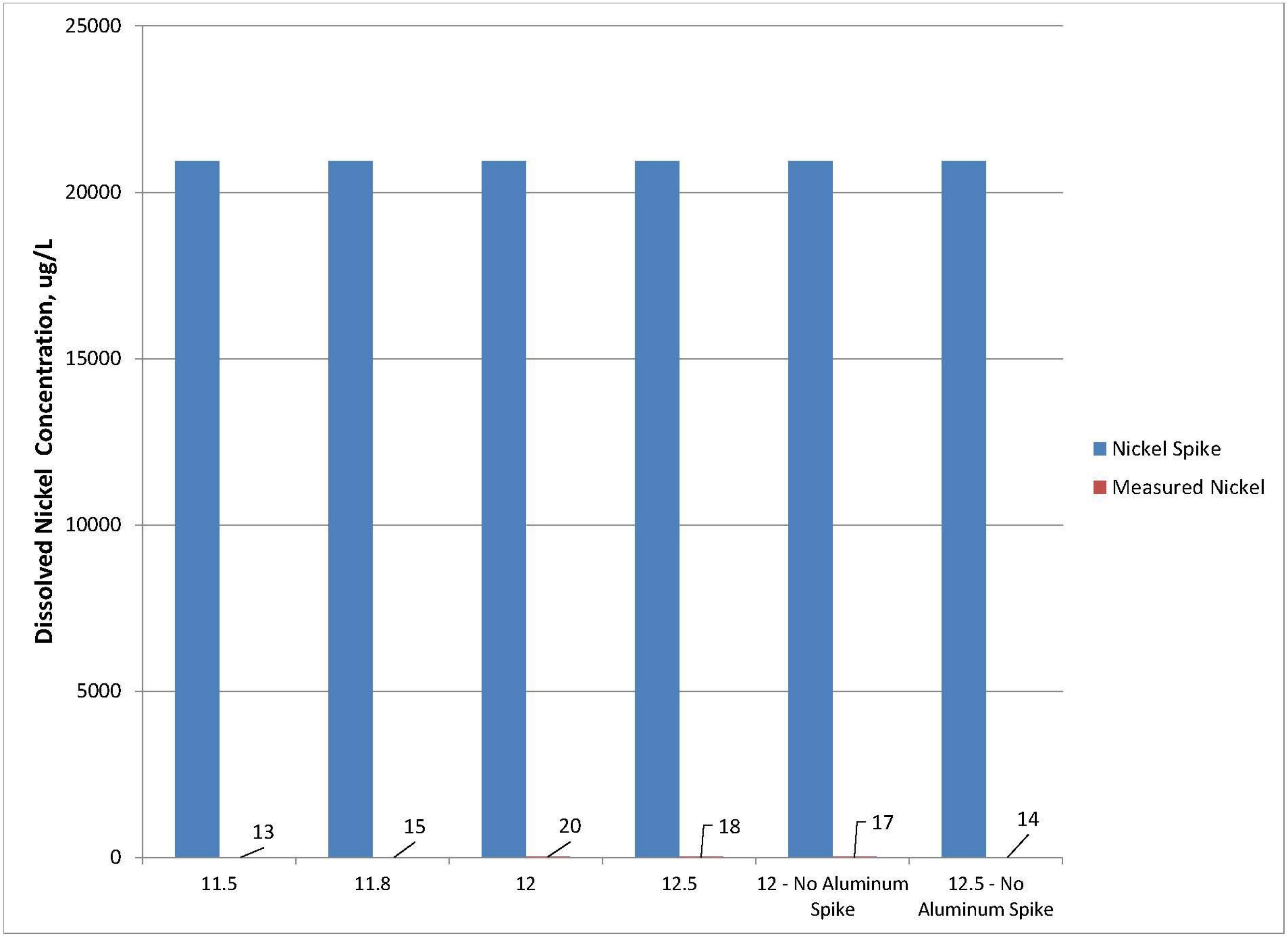


Figure 27 Sulfate Precipitation Results – Nickel

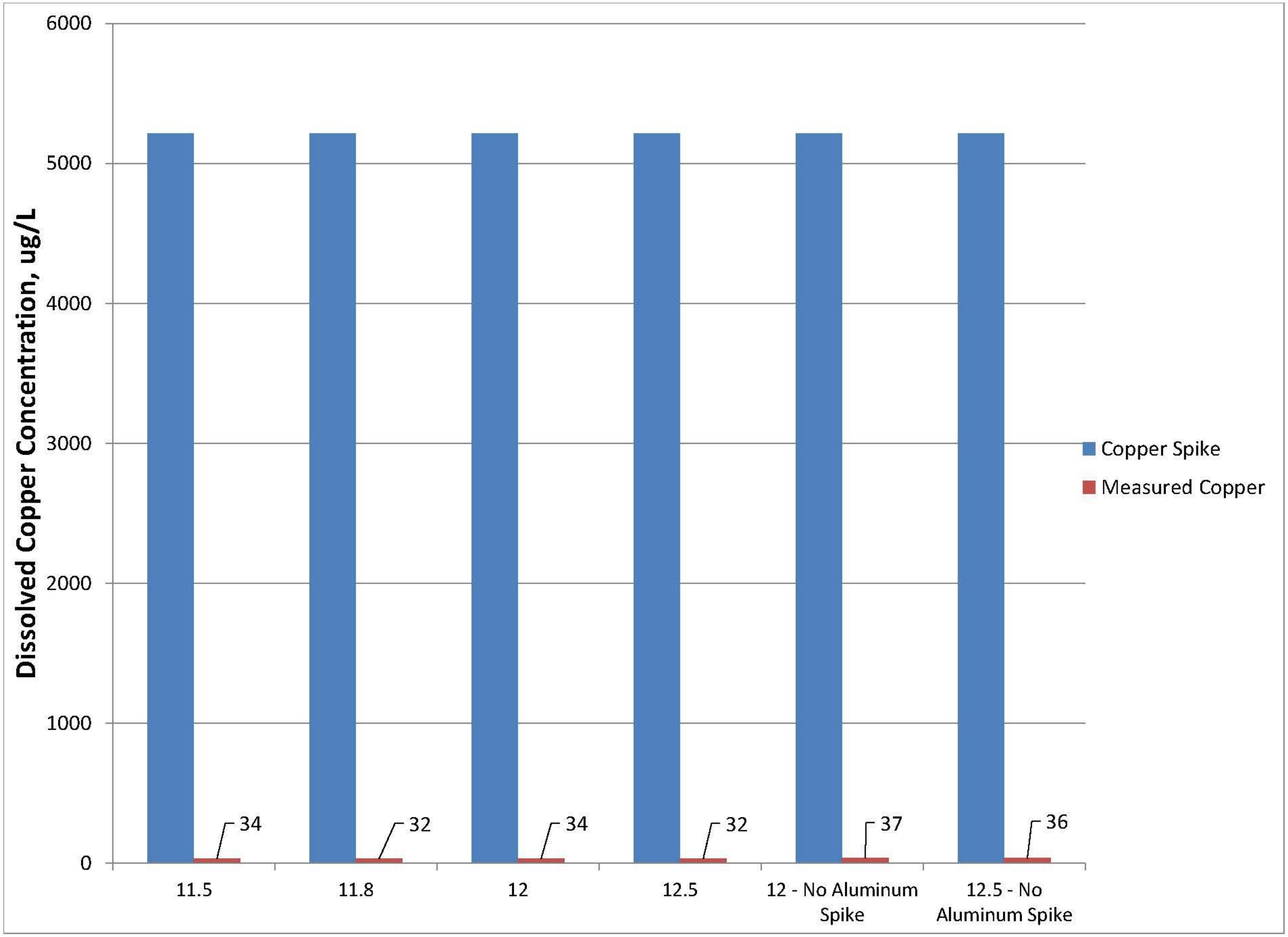


Figure 28 **Sulfate Precipitation Results – Copper**

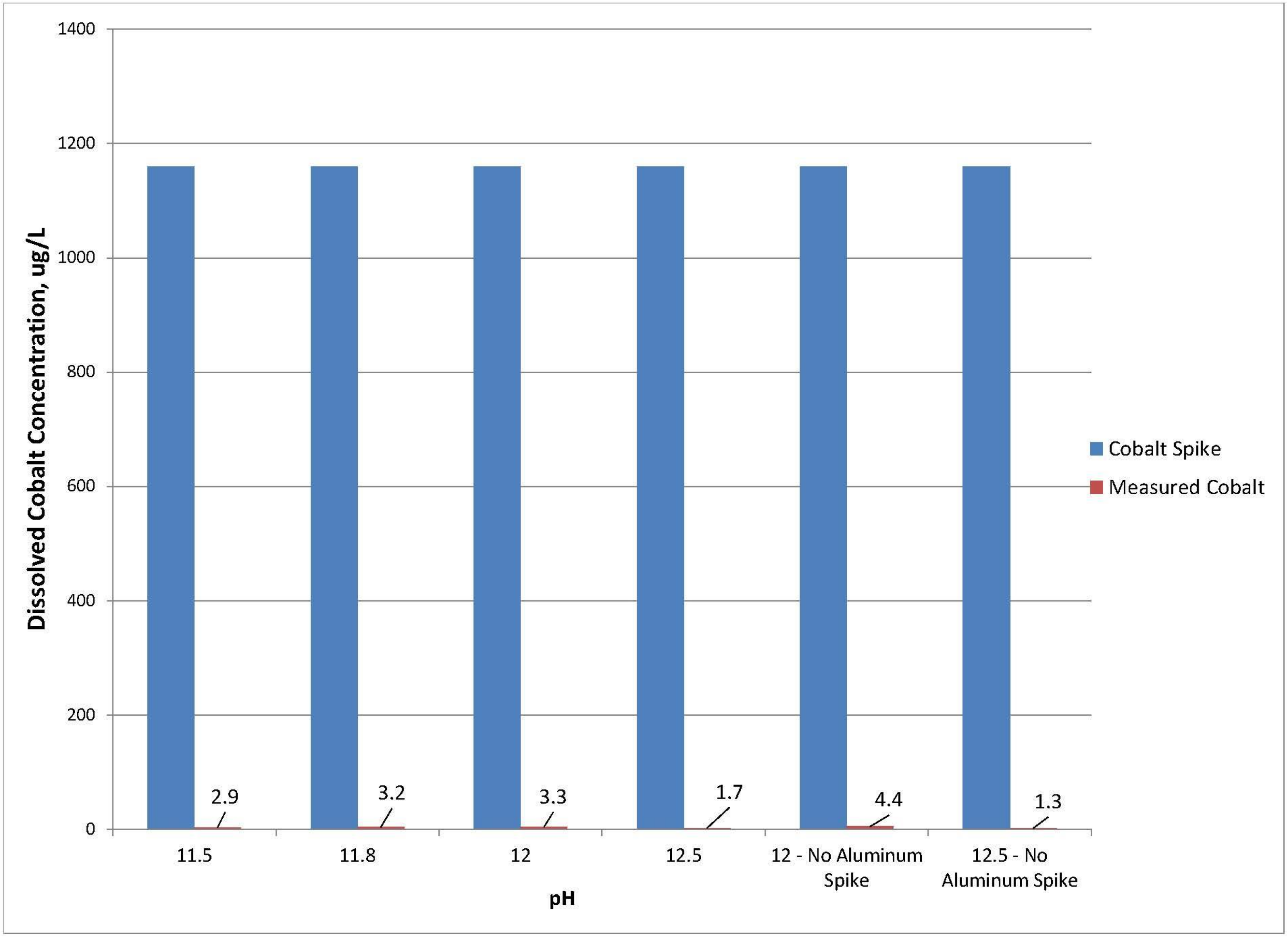


Figure 29 Sulfate Precipitation Results – Cobalt

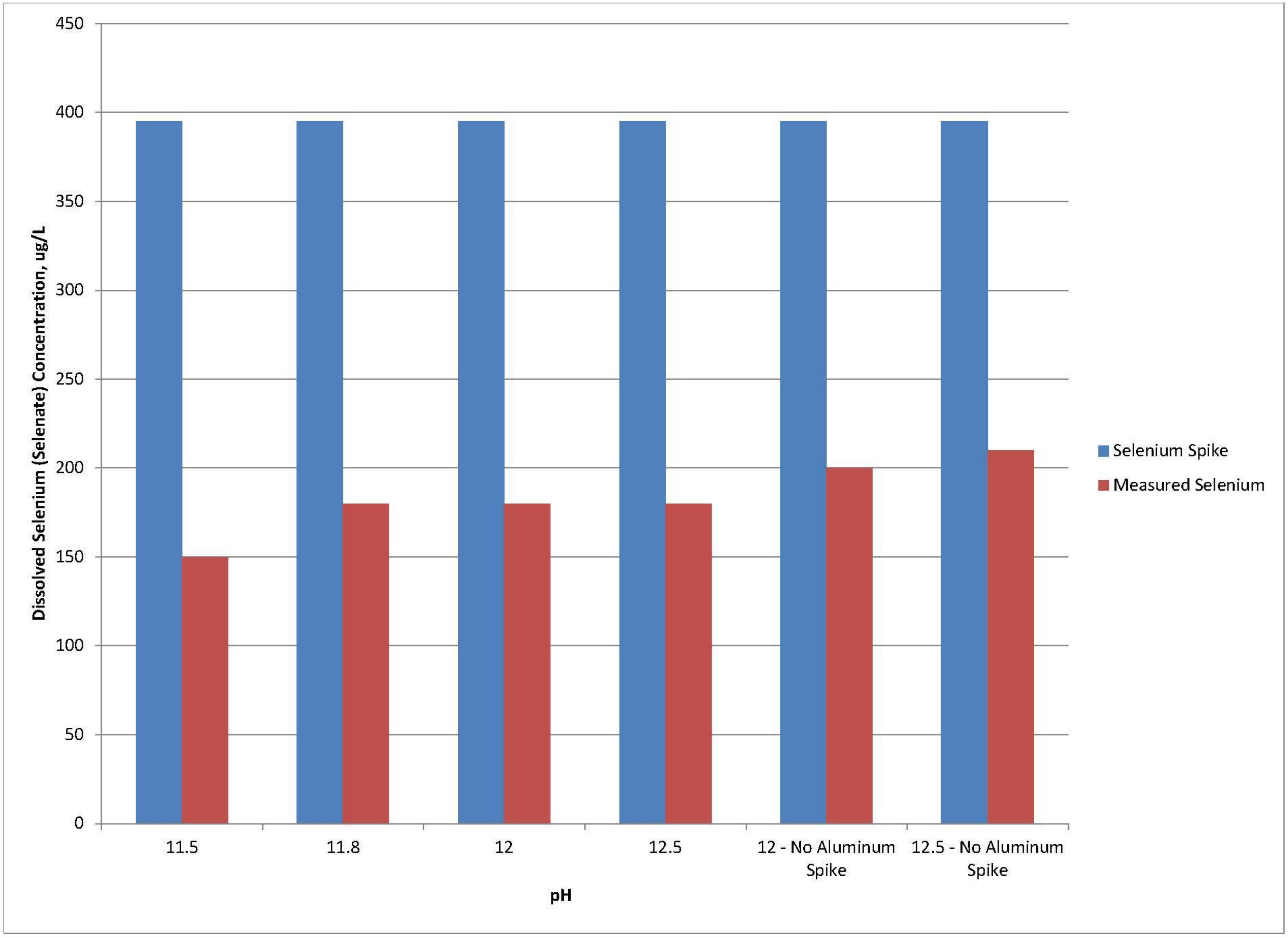


Figure 30 Sulfate Precipitation Results – Selenium

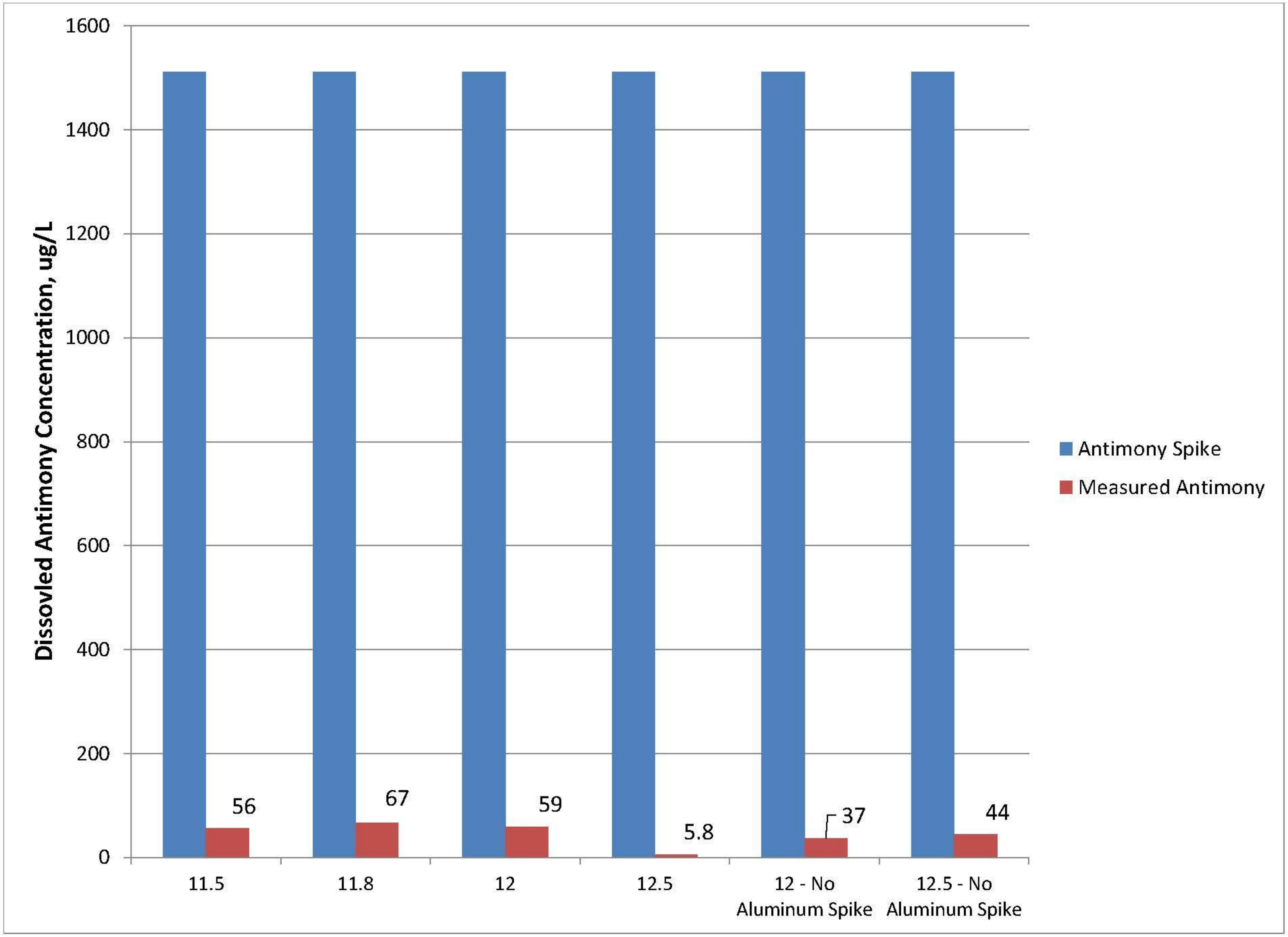


Figure 31 Sulfate Precipitation Results – Antimony

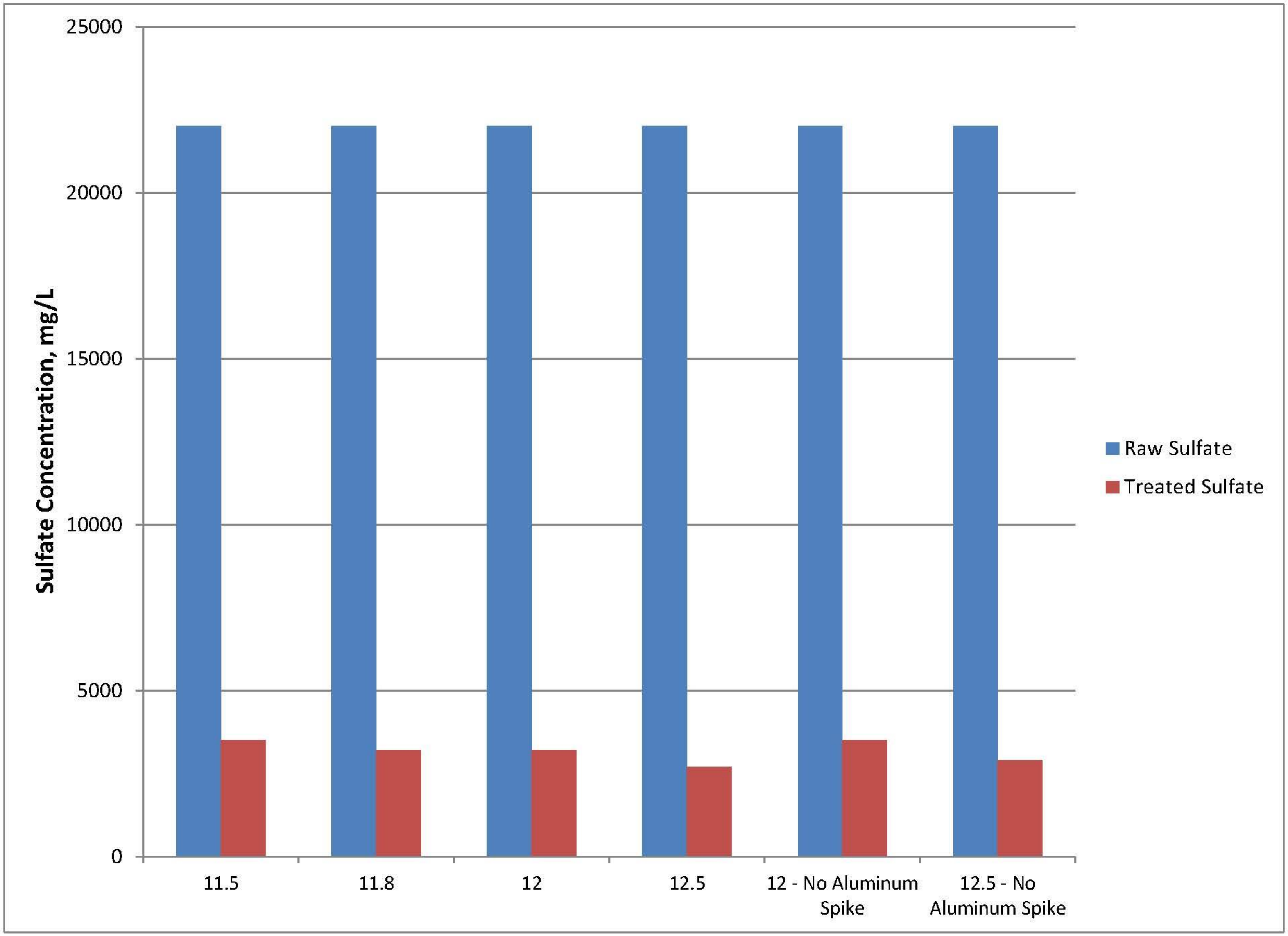


Figure 32 Sulfate Precipitation Results – Sulfate

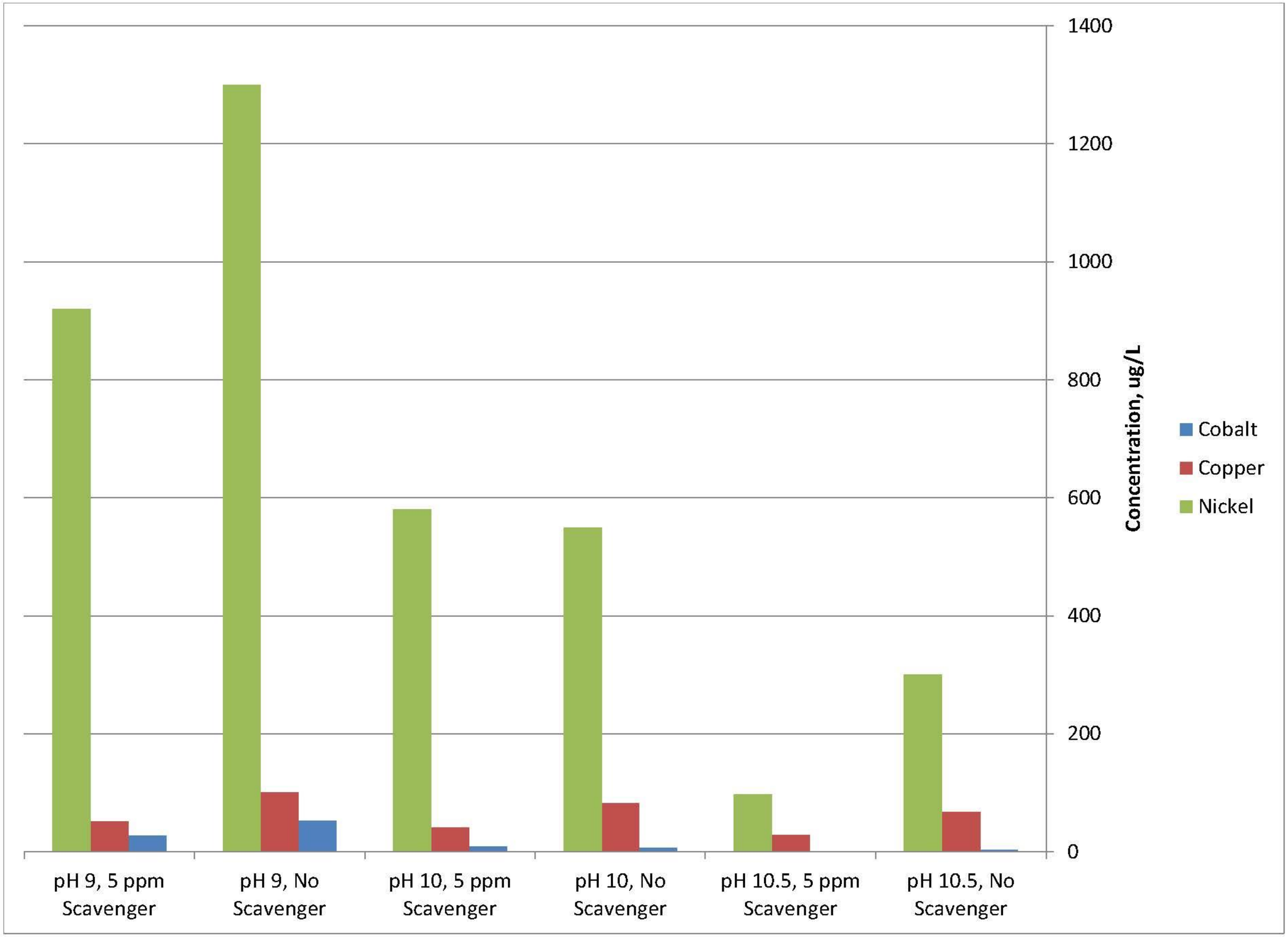


Figure 33 **Metal Scavenger Test Results**

Appendices

Appendix A

Greensand Filtration and Nanofiltration Pilot-test Protocol

Greensand Filtration and Nanofiltration Pilot Test Protocol

Mine Site WWTF

Prepared for
PolyMet Mining, Inc.

July 2013

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Greensand Filtration and Nanofiltration Pilot Test Protocol

July 2013

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1.0 Nanofiltration Pilot Test Standard Operating Procedures

The goal of this document is to provide standard operating procedures for the greensand filtration and nanofiltration (NF) pilot tests at Hoyt Lakes, MN.

1.1 Safety

Safety glasses, nitrile gloves and steel-toed boots should be worn at all times when performing work that could result in contact with hazardous substances used in this experiment. When handling dry chemicals, a dust mask should be worn to prevent accidental inhalation of the chemicals, and to read and follow the MSDSs sheets for additional handling precautions. It is recommended that PolyMet staff wear long sleeves when handling dry chemicals to prevent skin contact.

1.2 Terms

GSF	Green Sand Filter
NF	Nanofiltration
VSEP	Vibratory Shear Enhanced Processing
GE	General Electric
Dow	Dow Chemical

1.3 Equipment

The pilot test system configuration to be employed during the test is illustrated in Figure 1.

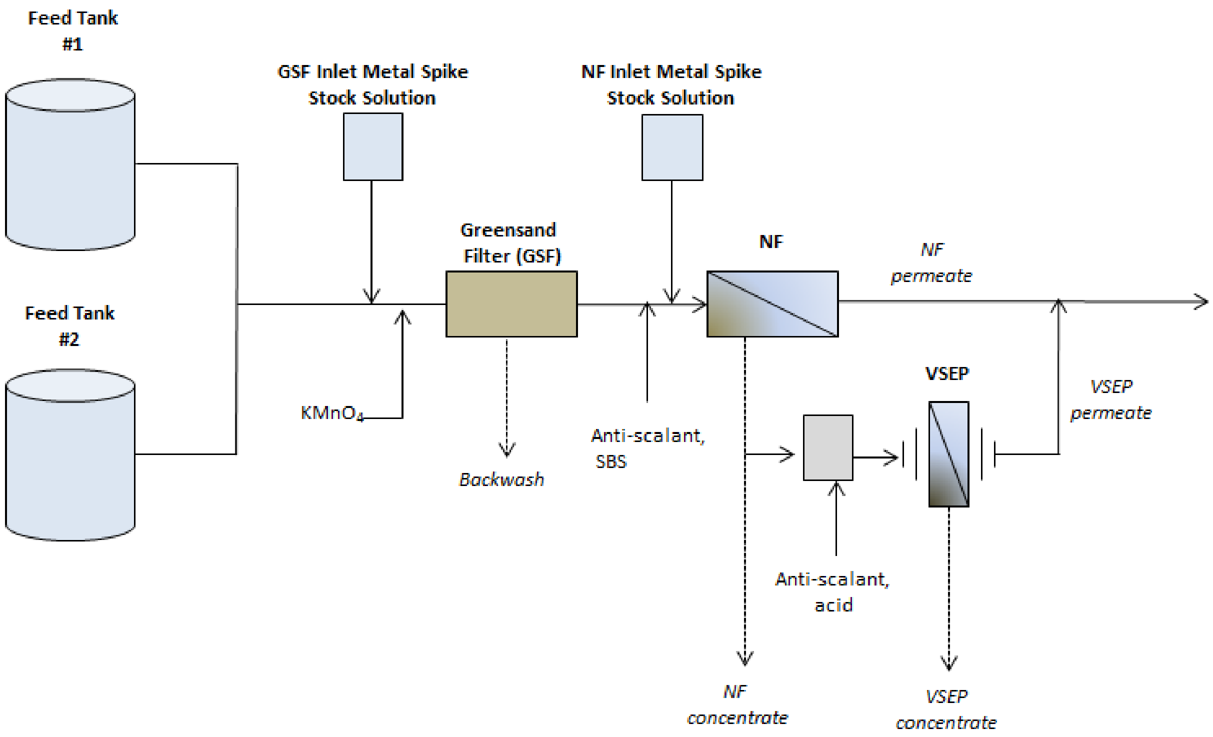


Figure 1 **Pilot Test Equipment Illustration**

2.0 GE Membrane Protocol

This section describes the stepwise protocol for testing the GE NF membrane system for metals removal. An overview of the operating plan and a summary of the sampling and analytical protocols can be found in the Tables section at the end of this document.

2.1 GE Membrane - Day 1

Summary of Day 1 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the GSF.
3. Add the “GE Lead Nitrate #1” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the total amount of sulfuric acid added and the final pH.
    a. If the lead nitrate is still visible in the solution, slowly add acid until the solution is clear. Record the amount of sulfuric acid added and the final pH**. Do not go lower than pH 4.**
5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet (**before the GSF filter**) at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Operate the NF membrane at a recovery rate of 80%.
8. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
9. Two hours after the recorded start time (see step 6) for the addition of the stock solution, collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle “GE-Feed-Tank-Day1-#1”
    b. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day1-#1”
    c. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day1-#1”

    d. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day1-#1”

10. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
11. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle “GE-Feed-Tank-Day1-#2”
    b. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day1-#2”
    c. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day1-#2”
    d. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day1-#2”
12. Fill out the pre-prepared chain of custody for day 1 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
13. Shut down the system after 8 hours of feeding the stock solution.
14. Empty any excess stock solution into waste storage containers for later disposal.

Day 1 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	YES	YES	x	x				
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.2 GE Membrane - Day 2

Day 2 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.

2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the GSF.
3. Add the "GE Lead Nitrate #2" bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the total amount of sulfuric acid added and the final pH.
    a. If the lead nitrate is still visible in the solution, slowly add acid until the solution is clear. Record the amount of sulfuric acid added and the final pH**. Do not go lower than pH 4.**
5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet (**before the GSF filter**) at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Operate the NF membrane at a recovery rate of 80%.
8. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
9. Two hours after the recorded start time (see step 6) for the addition of the stock solution, collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day2-#1"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day2-#1"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day2-#1"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day2-#1"
10. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
11. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day2-#2"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day2-#2"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day2#2"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day2-#2"
12. Fill out the pre-prepared chain of custody for day 2 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
13. Shut down the system after 8 hours of feeding the stock solution.
14. Empty any excess stock solution into waste storage containers for later disposal.

Day 2 Sample Bottle Summary

Samples	Sampling Time		Bottle Type to be Used					
	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x				
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.3 GE Membrane - Day 3

Day 3 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the "GE Lead Nitrate #3" bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the total amount of sulfuric acid added and the final pH.
    a. If the lead nitrate is still visible in the solution, slowly add acid until the solution is clear. Record the amount of sulfuric acid added and the final pH**. Do not go lower than pH 4.**
5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.

7. Operate the NF membrane at a recovery rate of 80%.
8. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
9. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day3-#1"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day3-#1"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day3#1"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day3-#1"
10. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
11. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle. For "Dissolved" sample locations filter the sample through a 0.45 μm filter and pour filtered water into the labeled nitric preserved bottle. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day3-#2"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day3-#2"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day3-#2"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day3-#2"
    e. Feed Tank Effluent –Unpreserved Bottle "GE-Feed-Tank-Day3-#2"
    f. GSF Effluent - Unpreserved Bottle "GE-GSF-EFF-Day3-#2"
    g. NF Permeate - Unpreserved Bottle "GE-NF-Perm-Day3-#2"
    h. NF Concentrate – Unpreserved Bottle "GE-NF-Conc-Day3-#2"
    i. Feed Tank Effluent – "Dissolved" Nitric Preserved Bottle "GE-Feed-Tank-Day3-#2"
    j. GSF Effluent – "Dissolved" Nitric Preserved Bottle "GE-GSF-EFF-Day3-#2"
12. Fill out the pre-prepared chain of custody for Day 3 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
13. Shut down the system after 8 hours of feeding the stock solution.
14. Empty any excess stock solution into waste storage containers for later disposal.

Day 3 Sample Bottle Summary

Samples	Sampling Time		Bottle Type to be Used					
	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x		x		x
GSF effluent	YES	YES	x	x		x		x
NF permeate	YES	YES	x	x		x		
NF concentrate	YES	YES	x	x		x		
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.4 GE Membrane - Day 4

Day 4 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the “GE Lead Nitrate #4” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the total amount of sulfuric acid added and the final pH.
    a. If the lead nitrate is still visible in the solution, slowly add acid until the solution is clear. Record the amount of sulfuric acid added and the final pH**. Do not go lower than pH 4.**
5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.

7. Operate the NF membrane at a recovery rate of 80%.
8. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
9. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
   a. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day4-#1"
   b. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day4-#1"
   c. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day4-#1"
10. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
11. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
   a. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day4-#2"
   b. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day4#2"
   c. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day4-#2"
12. Fill out the pre-prepared chain of custody for Day 4 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
13. Shut down the system after 8 hours of feeding the stock solution.
14. Empty any excess stock solution into waste storage containers for later disposal.

Day 4 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.5 GE Membrane - Day 5

Day 5 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the "GE Sodium Selenite #1" bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
5. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
6. Collect all NF concentrate into a feed tank for use at the VSEP in day 6.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 5) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day5-#1"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day5-#1"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day5-#1"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day5-#1"
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day5-#2"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day5-#2"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day5#2"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day5-#2"
11. Fill out the pre-prepared chain of custody for Day 5 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.

12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 5 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x				
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.6 GE Membrane - Day 6

Day 6 Operating Conditions

Membrane	GE
Recovery	NOT OPERATING
Feed flow	NOT OPERATING
NF and GSF pretreatment	
Potassium permanganate	OFF
Antiscalant	OFF
VSEP recovery	80%
VSEP feed pH	6.5

1. Adjust the NF concentrate collected on Day 5 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, at shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle “GE-VSEP-Feed-Day6-#1”
    b. VSEP Feed Tank– Unpreserved Bottle “GE-VSEP-Feed-Day6-#1”
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle “GE-VSEP-Perm-Day6-#2”

    b. VSEP Concentrate - Nitric Preserved Bottle “GE-VSEP-Conc-Day6-#2
    c. VSEP Permeate – Unpreserved Bottle “GE-VSEP-Perm-Day6-#2”
    d. VSEP Concentrate – Unpreserved Bottle “GE-VSEP-Conc-Day6-#2

7. Fill out the pre-prepared chain of custody for Day 6 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut down the system after 8 hours of operation.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 6 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
GSF effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x			
VSEP permeate	YES	YES		x		x		
VSEP Concentrate	YES	YES		x		x		

2.7 GE Membrane - Day 7

Day 7 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the “GE Sodium Selenite #2” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.

4. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant, and Potassium Permanganate.
5. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
6. Collect all NF concentrate into a feed tank for use at the VSEP in day 8.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 5) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day7-#1"
    b. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day7-#1"
    c. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day7-#1"
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day7-#2"
    b. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day7-#2"
    c. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day7-#2"
11. Fill out the pre-prepared chain of custody for Day 7 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 7 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.8 GE Membrane - Day 8

Day 8 Operating Conditions

Membrane	GE
Recovery	NOT OPERATING
Feed flow	NOT OPERATING
NF and GSF pretreatment	
Potassium permanganate	OFF
Antiscalant	OFF
VSEP recovery	80%
VSEP feed pH	6.5

1. Adjust the NF concentrate collected on Day 7 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle "GE-VSEP-Feed-Day8-#1"
    b. VSEP Feed Tank– Unpreserved Bottle "GE-VSEP-Feed-Day8-#1"
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle "GE-VSEP-Perm-Day8-#2"
    b. VSEP Concentrate - Nitric Preserved Bottle "GE-VSEP-Conc-Day8-#2
    c. VSEP Permeate – Unpreserved Bottle "GE-VSEP-Perm-Day8-#2"
    d. VSEP Concentrate – Unpreserved Bottle "GE-VSEP-Conc-Day8-#2
7. Fill out the pre-prepared chain of custody for Day 8 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut down the system after 8 hours of operation.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 8 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
GSF effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x			
VSEP permeate	YES	YES		x		x		
VSEP Concentrate	YES	YES		x		x		

2.9 GE Membrane - Day 9

Day 9 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the GSF.
3. Add the “GE Sodium Selenite #3” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant, and Potassium Permanganate.
5. Begin feeding the stock solution into the inlet (**before the GSF unit**) at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
6. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.

7. Two hours after the recorded start time (see step 5) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle “GE-Feed-Tank-Day9-#1”
    b. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day9-#1”
    c. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day9-#1”
    d. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day9-#1”
8. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
9. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle. For “Dissolved” sample locations filter the sample through a 0.45 µm filter and pour filtered water into the labeled nitric preserved bottle. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle “GE-Feed-Tank-Day9-#2”
    b. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day9-#2”
    c. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day9-#2”
    d. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day9-#2”
    e. Feed Tank Effluent –Unpreserved Bottle “GE-Feed-Tank-Day9-#2”
    f. GSF Effluent - Unpreserved Bottle “GE-GSF-EFF-Day9-#2”
    g. NF Permeate - Unpreserved Bottle “GE-NF-Perm-Day9-#2”
    h. NF Concentrate – Unpreserved Bottle “GE-NF-Conc-Day9-#2”
    i. Feed Tank Effluent – “Dissolved” Nitric Preserved Bottle “GE-Feed-Tank-Day9-#2”
    j. GSF Effluent – “Dissolved” Nitric Preserved Bottle “GE-GSF-EFF-Day9-#2”
10. Fill out the pre-prepared chain of custody for Day 9 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
11. Shut down the system after 8 hours of feeding the stock solution.
12. Empty any excess stock solution into waste storage containers for later disposal.

Day 9 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	YES	YES	x	x		x		x
GSF effluent	YES	YES	x	x		x		x
NF permeate	YES	YES	x	x		x		
NF concentrate	YES	YES	x	x		x		
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.10 GE Membrane - Day 10

Day 10 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the GSF.
3. Add the "GE Sodium Selenite #4" bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant, and Potassium Permanganate.
5. Begin feeding the stock solution into the inlet (**before the GSF unit**) at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
6. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
7. Two hours after the recorded start time (see step 5) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day10-#1"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day10-#1"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day10-#1"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day10-#1"
8. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
9. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day10-#2"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day10-#2"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day10-#2"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day10-#2"
10. Fill out the pre-prepared chain of custody for Day 10 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
11. Shut down the system after 8 hours of feeding the stock solution.

12. Empty any excess stock solution into waste storage containers for later disposal.

Day 10 Sample Bottle Summary

Samples	Sampling Time		Bottle Type to be Used					
	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x				
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.11 GE Membrane - Day 11

Day 11 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the “GE Sodium Selenite #1” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
    a. Record the amount of sulfuric acid added and the final pH**. Do not go lower than pH 4.**
4. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
5. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
6. Collect all NF concentrate into a feed tank for use at the VSEP in day 12.

7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 5) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day11-#1”
    b. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day11-#1”
    c. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day11-#1”
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day11-#2”
    b. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day11-#2”
    c. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day11-#2”
11. Fill out the pre-prepared chain of custody for Day 11 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 11 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.12 GE Membrane - Day 12

Day 12 Operating Conditions

Membrane	GE
Recovery	NOT OPERATING
Feed flow	NOT OPERATING
NF and GSF pretreatment	
Potassium permanganate	OFF
Antiscalant	OFF
VSEP recovery	80%
VSEP feed pH	6.5

1. Adjust the NF concentrate collected on Day 11 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle "GE-VSEP-Feed-Day12-#1"
    b. VSEP Feed Tank– Unpreserved Bottle "GE-VSEP-Feed-Day12-#1"
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle "GE-VSEP-Perm-Day12-#2"
    b. VSEP Concentrate - Nitric Preserved Bottle "GE-VSEP-Conc-Day12-#2
    c. VSEP Permeate – Unpreserved Bottle "GE-VSEP-Perm-Day12-#2"
    d. VSEP Concentrate – Unpreserved Bottle "GE-VSEP-Conc-Day12-#2
7. Fill out the pre-prepared chain of custody for Day 12 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut down the system after 8 hours of operation.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 12 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
GSF effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x			
VSEP permeate	YES	YES		x		x		
VSEP Concentrate	YES	YES		x		x		

2.13 GE Membrane - Day 13

Day 13 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the “GE Sodium Selenite #2” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant, and Potassium Permanganate.
5. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
6. Collect all NF concentrate into a feed tank for use at the VSEP in day 14.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.

8. Two hours after the recorded start time (see step 5) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day13-#1”
    b. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day13-#1”
    c. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day13-#1”
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day13-#2”
    b. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day13-#2”
    c. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day13-#2”
11. Fill out the pre-prepared chain of custody for Day 13 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 13 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.14 GE Membrane - Day 14

Day 14 Operating Conditions

Membrane	GE
Recovery	NOT OPERATING
Feed flow	NOT OPERATING
NF and GSF pretreatment	
Potassium permanganate	OFF
Antiscalant	OFF
VSEP recovery	80%
VSEP feed pH	6.5

1. Adjust the NF concentrate collected on Day 13 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle "GE-VSEP-Feed-Day14-#1"
    b. VSEP Feed Tank– Unpreserved Bottle "GE-VSEP-Feed-Day14-#1"
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle "GE-VSEP-Perm-Day14-#2"
    b. VSEP Concentrate - Nitric Preserved Bottle "GE-VSEP-Conc-Day14-#2
    c. VSEP Permeate – Unpreserved Bottle "GE-VSEP-Perm-Day14-#2"
    d. VSEP Concentrate – Unpreserved Bottle "GE-VSEP-Conc-Day14-#2
7. Fill out the pre-prepared chain of custody for Day 14 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut the system down after 8 hours of operation.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 14 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	NO	NO						
GSF effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x			
VSEP permeate	YES	YES		x		x		
VSEP Concentrate	YES	YES		x		x		

2.15 GE Membrane - Day 15

Day 15 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the GSF inlet.
3. Add the "GE Sodium Selenite #3" bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant, and Potassium Permanganate.
5. Begin feeding the stock solution into the inlet (**before the GSF unit**) at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
6. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
7. Two hours after the recorded start time (see step 5) for the addition of the stock solution collect samples from the following locations in the following bottles. For "Dissolved" sample locations

filter the sample through a 0.45 µm filter and pour filtered water into the labeled nitric preserved bottle. Record the sample time and date on each bottle.

   a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day15-#1"
   b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day15-#1"
   c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day15-#1"
   d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day15-#1"
   e. Feed Tank Effluent –Unpreserved Bottle "GE-Feed-Tank-Day15-#1"
   f. GSF Effluent - Unpreserved Bottle "GE-GSF-EFF-Day15-#1"
   g. NF Permeate - Unpreserved Bottle "GE-NF-Perm-Day15-#1"
   h. NF Concentrate – Unpreserved Bottle "GE-NF-Conc-Day15-#1"
   i. Feed Tank Effluent – "Dissolved" Nitric Preserved Bottle "GE-Feed-Tank-Day15-#1"
   j. GSF Effluent – "Dissolved" Nitric Preserved Bottle "GE-GSF-EFF-Day15-#1"

8. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
9. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
   a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day15-#2"
   b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day15-#2"
   c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day15-#2"
   d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day15-#2"
10. Fill out the pre-prepared chain of custody for Day 15 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
11. Shut down the system after 8 hours of feeding the stock solution.
12. Empty any excess stock solution into waste storage containers for later disposal.

Day 15 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	YES	YES	x	x	x		x	
GSF effluent	YES	YES	x	x	x		x	
NF permeate	YES	YES	x	x	x			
NF concentrate	YES	YES	x	x	x			
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.16 GE Membrane - Day 16

Day 16 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the GSF inlet.
3. Add the "GE Sodium Selenite #4" bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant, and Potassium Permanganate.
5. Begin feeding the stock solution into the inlet (**before the GSF unit**) at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
6. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown, and every two hours during operation.
7. Two hours after the recorded start time (see step 5) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day16-#1"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day16-#1"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day16-#1"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day16-#1"
8. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
9. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day16-#2"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day16-#2"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day16-#2"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day16-#2"
10. Fill out the pre-prepared chain of custody for Day 16 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
11. Shut down the system after 8 hours of feeding the stock solution.

12. Empty any excess stock solution into waste storage containers for later disposal.

Day 16 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x				
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.17 GE Membrane - Day 17

Day 17 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the four bottles below to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
    a. GE Cobalt Chloride #1
    b. GE Zinc Sulfate #1
    c. GE Nickel Chloride #1
    d. GE Sodium Arsenite #1
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the total amount of sulfuric acid added and the final pH.

    a. If the solid salt is still visible in the solution, slowly add acid until the solution is clear. Record the amount of sulfuric acid added and the final pH**. Do not go lower than pH 4.**

5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day17-#1"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day17-#1"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day17-#1"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day17-#1"
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day17-#2"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day17-#2"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day17-#2"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day17-#2"
11. Fill out the pre-prepared chain of custody for Day 17 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 17 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x				
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.18 GE Membrane - Day 18

Day 18 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the four bottles below to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
    a. GE Cobalt Chloride #2
    b. GE Zinc Sulfate #2
    c. GE Nickel Chloride #2
    d. GE Sodium Arsenite #2
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the total amount of sulfuric acid added and the final pH.
    a. If the solid salt is still visible in the solution, slowly add acid until the solution is clear. Record the amount of sulfuric acid added and the final pH**. Do not go lower than pH 4.**
5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day18-#1"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day18-#1"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day18-#1"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day18-#1"
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.

10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day18-#2"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day18-#2"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day18-#2"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day18-#2"
11. Fill out the pre-prepared chain of custody for Day 18 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 18 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x				
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.19 GE Membrane - Day 19

Day 19 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the GSF inlet.

3. Add the four bottles below to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
   a. GE Cobalt Chloride #3
   b. GE Zinc Sulfate #3
   c. GE Nickel Chloride #3
   d. GE Sodium Arsenite #3
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the total amount of sulfuric acid added and the final pH.
   a. If the solid salt is still visible in the solution, slowly add acid until the solution is clear. Record the amount of sulfuric acid added and the final pH**. Do not go lower than pH 4.**
5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet (**before the GSF unit**) at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. For “Dissolved” sample locations filter the sample through a 0.45 µm filter and pour filtered water into the labeled nitric preserved bottle. Record the sample time and date on each bottle Record the sample time and date on each bottle.
   a. Feed Tank Effluent – Nitric Preserved Bottle “GE-Feed-Tank-Day19-#1”
   b. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day19-#1”
   c. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day19-#1”
   d. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day19-#1”
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. For “Dissolved” sample locations filter the sample through a 0.45 µm filter and pour filtered water into the labeled nitric preserved bottle. Record the sample time and date on each bottle Record the sample time on each bottle. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle “GE-Feed-Tank-Day19-#2”
    b. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day19-#2”
    c. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day19-#2”
    d. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day19-#2”
    e. Feed Tank Effluent –Unpreserved Bottle “GE-Feed-Tank-Day19-#2”
    f. GSF Effluent - Unpreserved Bottle “GE-GSF-EFF-Day19-#2”
    g. NF Permeate - Unpreserved Bottle “GE-NF-Perm-Day19-#2”
    h. NF Concentrate – Unpreserved Bottle “GE-NF-Conc-Day19-#2”
    i. Feed Tank Effluent – “Dissolved” Nitric Preserved Bottle “GE-Feed-Tank-Day19-#2”
    j. GSF Effluent – “Dissolved” Nitric Preserved Bottle “GE-GSF-EFF-Day19-#2”
11. Fill out the pre-prepared chain of custody for Day 19 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.

12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 19 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	YES	YES	x	x		x		x
GSF effluent	YES	YES	x	x		x		x
NF permeate	YES	YES	x	x		x		
NF concentrate	YES	YES	x	x		x		
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.20 GE Membrane - Day 20

Day 20 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the GSF inlet.
3. Add the four bottles below to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
    a. GE Cobalt Chloride #4
    b. GE Zinc Sulfate #4
    c. GE Nickel Chloride #4
    d. GE Sodium Arsenite #4
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the total amount of sulfuric acid added and the final pH.

   a. If the solid salt is still visible in the solution, slowly add acid until the solution is clear. Record the amount of sulfuric acid added and the final pH**. Do not go lower than pH 4.**

5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet (**before the GSF unit**) at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
   a. Feed Tank Effluent – Nitric Preserved Bottle “GE-Feed-Tank-Day20-#1”
   b. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day20-#1”
   c. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day20-#1”
   d. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day20-#1”
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle “GE-Feed-Tank-Day20-#2”
    b. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day20-#2”
    c. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day20-#2”
    d. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day20-#2”
11. Fill out the pre-prepared chain of custody for Day 20 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 20 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	YES	YES	x	x				
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.21 GE Membrane - Day 21

Day 21 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the "GE Copper Sulfate #1" bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the total amount of sulfuric acid added and the final pH.
    a. If the solid salt is still visible in the solution, slowly add acid until the solution is clear. Record the amount of sulfuric acid added and the final pH**. Do not go lower than pH 4.**
5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day21-#1"
    b. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day21-#1"
    c. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day21-#1"
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day21-#2"
    b. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day21-#2"
    c. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day21-#2"

11. Fill out the pre-prepared chain of custody for Day 21 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 21 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	NO	NO						
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.22 GE Membrane - Day 22

Day 22 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the “GE Copper Sulfate #2” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the total amount of sulfuric acid added and the final pH.
    a. If the solid salt is still visible in the solution, slowly add acid until the solution is clear. Record the amount of sulfuric acid added and the final pH**. Do not go lower than pH 4.**

5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day22-#1"
    b. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day22-#1"
    c. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day22-#1"
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day22-#2"
    b. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day22-#2"
    c. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day22-#2"
11. Fill out the pre-prepared chain of custody for Day 22 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 22 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.23 GE Membrane - Day 23

Day 23 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the GSF inlet.
3. Add the "GE Copper Sulfate #3" bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the total amount of sulfuric acid added and the final pH.
    a. If the solid salt is still visible in the solution, slowly add acid until the solution is clear. Record the amount of sulfuric acid added and the final pH**. Do not go lower than pH 4.**
5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet (**before the GSF unit**) at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day23-#1"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day23-#1"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day23-#1"
    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day23-#1"
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "GE-Feed-Tank-Day23-#2"
    b. GSF Effluent - Nitric Preserved Bottle "GE-GSF-EFF-Day23-#2"
    c. NF Permeate - Nitric Preserved Bottle "GE-NF-Perm-Day23-#2"

    d. NF Concentrate – Nitric Preserved Bottle "GE-NF-Conc-Day23-#2"

11. Fill out the pre-prepared chain of custody for Day 23 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 23 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	YES	YES	x	x				
GSF effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

2.24 GE Membrane - Day 24

Day 24 Operating Conditions

Membrane	GE
Recovery	80%
Feed flow	21.25 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the GSF inlet.
3. Add the "GE Copper Sulfate #4" bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the total amount of sulfuric acid added and the final pH.

    a. If the solid salt is still visible in the solution, slowly add acid until the solution is clear. Record the amount of sulfuric acid added and the final pH**. Do not go lower than pH 4.**

5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 21.25 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet (**before the GSF unit**) at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle “GE-Feed-Tank-Day24-#1”
    b. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day24-#1”
    c. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day24-#1”
    d. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day24-#1”
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. For “Dissolved” sample locations filter the sample through a 0.45 µm filter and pour filtered water into the labeled nitric preserved bottle. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle “GE-Feed-Tank-Day24-#2”
    b. GSF Effluent - Nitric Preserved Bottle “GE-GSF-EFF-Day24-#2”
    c. NF Permeate - Nitric Preserved Bottle “GE-NF-Perm-Day24-#2”
    d. NF Concentrate – Nitric Preserved Bottle “GE-NF-Conc-Day24-#2”
    e. Feed Tank Effluent –Unpreserved Bottle “GE-Feed-Tank-Day24-#2”
    f. GSF Effluent - Unpreserved Bottle “GE-GSF-EFF-Day24-#2”
    g. NF Permeate - Unpreserved Bottle “GE-NF-Perm-Day24-#2”
    h. NF Concentrate – Unpreserved Bottle “GE-NF-Conc-Day24-#2”
    i. Feed Tank Effluent – “Dissolved” Nitric Preserved Bottle “GE-Feed-Tank-Day24-#2”
    j. GSF Effluent – “Dissolved” Nitric Preserved Bottle “GE-GSF-EFF-Day24-#2”
11. Fill out the pre-prepared chain of custody for Day 24 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 24 Sample Bottle Summary

Samples	Sampling Time		Bottle Type to be Used					
			Nitric preserved		Unpreserved		Filtered (Dissolved)	
	AM	PM	AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x		x		x
GSF effluent	YES	YES	x	x		x		x
NF permeate	YES	YES	x	x		x		
NF concentrate	YES	YES	x	x		x		
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

3.0 Dow Membrane Protocol

This section describes the stepwise protocol for testing the DOW NF membrane system for metals removal. An overview of the operating plan and a summary of the sampling and analytical protocols can be found in the Tables section at the end of this document.

3.1 DOW Membrane - Day 1

Day 1 Operating Conditions

Membrane	Dow
Recovery	80%
Feed flow	20 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the "DOW Lead Nitrate #1" bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the final pH.
    a. If the lead nitrate is still visible in solution slowly add acid until the solution is clear. Record the final pH**. Do not go lower than pH 4.**
5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 20 GPM. Confirm the following dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Operate the NF membrane at a recovery rate of 80%.
8. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
9. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day1-#1"
    b. Feed Tank Effluent – Nitric Preserved Filtered Bottle "DOW-Feed-Tank-Day1-#1"

   c. Feed Tank Effluent- Unpreserved Bottle “DOW-Feed-Tank-Day1-#1”
   d. Pretreated Effluent - Nitric Preserved Bottle “DOW-Pretrtd-Eff-Day1-#1”
   e. Pretreated Effluent - Nitric Preserved Filtered Bottle “DOW-Pretrtd-Eff-Day1-#1”
   f. Pretreated Effluent - Unpreserved Bottle “DOW-Pretrtd-Eff-Day1-#1”
   g. NF Permeate - Nitric Preserved Bottle “DOW-NF-Perm-Day1-#1”
   h. NF Permeate - Nitric Preserved Filtered Bottle “DOW-NF-Perm-Day1-#1”
   i. NF Permeate - Unpreserved Bottle “DOW-NF-Perm-Day1-#1”
   j. NF Concentrate – Nitric Preserved Bottle “DOW-NF-Conc-Day1-#1”
   k. NF Concentrate – Nitric Preserved Filtered Bottle “DOW-NF-Conc-Day1-#1”
   l. NF Concentrate – Unpreserved Bottle “DOW-NF-Conc-Day1-#1”
10. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
11. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle “DOW-Feed-Tank-Day1-#2”
    b. Feed Tank Effluent – Nitric Preserved Filtered Bottle “DOW-Feed-Tank-Day1-#2”
    c. Feed Tank Effluent- Unpreserved Bottle “DOW-Feed-Tank-Day1-#2”
    d. Pretreated Effluent - Nitric Preserved Bottle “DOW-Pretrtd-Eff-Day1-#2”
    e. Pretreated Effluent - Nitric Preserved Bottle “DOW-Pretrtd-Eff-Day1-#2”
    f. Pretreated Effluent - Unpreserved Bottle “DOW-Pretrtd-Eff-Day1-#2”
    g. NF Permeate - Nitric Preserved Bottle “DOW-NF-Perm-Day1-#2”
    h. NF Permeate - Nitric Preserved Filtered Bottle “DOW-NF-Perm-Day1-#2”
    i. NF Permeate - Unpreserved Bottle “DOW-NF-Perm-Day1-#2”
    j. NF Concentrate – Nitric Preserved Bottle “DOW-NF-Conc-Day1-#2”
    k. NF Concentrate – Nitric Preserved Filtered Bottle “DOW-NF-Conc-Day1-#2”
    l. NF Concentrate – Unpreserved Bottle “DOW-NF-Conc-Day1-#2”
12. Fill out the pre-prepared chain of custody for Day 1 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
13. Shut down the system after 8 hours of feeding the stock solution.
14. Empty any excess stock solution into waste storage containers for later disposal.

Day 1 Sample Bottle Summary

Samples	Sampling Time		Bottle Type to be Used					
			Nitric preserved		Unpreserved		Filtered (Dissolved)	
	AM	PM	AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x	x	x	x	x
Pretreated effluent	YES	YES	x	x	x	x	x	x
NF permeate	YES	YES	x	x	x	x	x	x
NF concentrate	YES	YES	x	x	x	x	x	x
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

3.2 Dow Membrane - Day 2

Day 2 Operating Conditions Summary

Membrane	Dow
Recovery	NOT OPERATING
Feed flow	NOT OPERATING
NF and GSF pretreatment	
Potassium permanganate	OFF
Antiscalant	OFF
VSEP recovery	80%
VSEP feed pH	6.5

1. Adjust the NF concentrate collected on Day 1 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle “DOW-VSEP-Feed-Day2-#1”
    b. VSEP Feed Tank– Nitric Preserved Filtered Bottle “DOW-VSEP-Feed-Day2-#1”
    c. VSEP Feed Tank– Unpreserved Bottle “DOW-VSEP-Feed-Day2-#1”
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle “DOW-VSEP-Perm-Day2-#2”
    b. VSEP Permeate - Nitric Preserved Filtered Bottle “DOW-VSEP-Perm-Day2-#2”
    c. VSEP Concentrate - Nitric Preserved Bottle “DOW-VSEP-Conc-Day2-#2

    d. VSEP Concentrate - Nitric Preserved Filtered Bottle “DOW-VSEP-Conc-Day2-#2
    e. VSEP Permeate – Unpreserved Bottle “DOW-VSEP-Perm-Day2-#2”
    f. VSEP Concentrate – Unpreserved Bottle “DOW-VSEP-Conc-Day2-#2

7. Fill out the pre-prepared chain of custody for Day 2 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut down the system after 8 hours of feeding the stock solution.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 2 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
GSF effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x		x	
VSEP permeate	YES	YES		x		x		x
VSEP Concentrate	YES	YES		x		x		X

3.3 DOW Membrane - Day 3

Day 3 Operating Conditions

Membrane	DOW
Recovery	80%
Feed flow	20 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the “DOW Lead Nitrate #2” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.

4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the final pH.
    a. If the lead nitrate is still visible in the solution, slowly add acid until the solution is clear. Record the final pH**. Do not go lower than pH 4.**
5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 20 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Operate the NF membrane at a recovery rate of 80%.
8. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
9. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day3-#1"
    b. Pretreated Effluent - Nitric Preserved Bottle "DOW- Pretrtd -Eff-Day3-#1"
    c. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day3-#1"
    d. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day3-#1"
10. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
11. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day3-#2"
    b. Pretreated Effluent - Nitric Preserved Bottle "DOW- Pretrtd -Eff-Day3-#2"
    c. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day3-#2"
    d. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day3-#2"
12. Fill out the pre-prepared chain of custody for Day 3 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
13. Shut down the system after 8 hours of feeding the stock solution.
14. Empty any excess stock solution into waste storage containers for later disposal.

Day 3 Sample Bottle Summary

Samples	Sampling Time		Bottle Type to be Used					
	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x				
Pretreated effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

3.4 Dow Membrane - Day 4

Day 4 Operating Conditions Summary

Membrane	Dow
Recovery	NOT OPERATING
Feed flow	NOT OPERATING
NF and GSF pretreatment	
Potassium permanganate	OFF
Antiscalant	OFF
VSEP recovery	80%
VSEP feed pH	6.5

1. Adjust the NF concentrate collected on Day 3 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle "DOW-VSEP-Feed-Day4-#1"
    b. VSEP Feed Tank– Nitric Preserved Filtered Bottle "DOW-VSEP-Feed-Day4-#1"
    c. VSEP Feed Tank– Unpreserved Bottle "DOW-VSEP-Feed-Day4-#1"
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle "DOW-VSEP-Perm-Day4-#2"
    b. VSEP Permeate - Nitric Preserved Filtered Bottle "DOW-VSEP-Perm-Day4-#2"
    c. VSEP Concentrate - Nitric Preserved Bottle "DOW-VSEP-Conc-Day4-#2"

   d. VSEP Concentrate - Nitric Preserved Filtered Bottle “DOW-VSEP-Conc-Day4-#2”
   e. VSEP Permeate – Unpreserved Bottle “DOW-VSEP-Perm-Day4-#2”
   f. VSEP Concentrate – Unpreserved Bottle “DOW-VSEP-Conc-Day4-#2”
7. Fill out the pre-prepared chain of custody for Day 4 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut down the system after 8 hours of feeding the stock solution.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 4 Sample Bottle Summary

Samples	Sampling Time AM	Sampling Time PM	Bottle Type to be Used: Nitric preserved AM	Nitric preserved PM	Unpreserved AM	Unpreserved PM	Filtered (Dissolved) AM	Filtered (Dissolved) PM
Feed tank effluent	NO	NO						
Pretreated effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x		x	
VSEP permeate	YES	YES		x		x		x
VSEP Concentrate	YES	YES		x		x		X

3.5 Dow Membrane - Day 5

Day 5 Operating Conditions

Membrane	Dow
Recovery	80%
Feed flow	20 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the “DOW Sodium Selenite #1” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.

4. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 20 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
5. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
6. Collect all NF concentrate into a feed tank for use at the VSEP in day 6.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 5) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day5-#1"
    b. Feed Tank Effluent – Nitric Preserved Filtered Bottle "DOW-Feed-Tank-Day5-#1"
    c. Feed Tank Effluent- Unpreserved Bottle "DOW-Feed-Tank-Day5-#1"
    d. Pretreated Effluent - Nitric Preserved Bottle "DOW-Pretrtd-Eff-Day5-#1"
    e. Pretreated Effluent - Nitric Preserved Filtered Bottle "DOW-Pretrtd-Eff-Day5-#1"
    f. Pretreated Effluent - Unpreserved Bottle "DOW-Pretrtd-Eff-Day5-#1"
    g. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day5-#1"
    h. NF Permeate - Nitric Preserved Filtered Bottle "DOW-NF-Perm-Day5-#1"
    i. NF Permeate - Unpreserved Bottle "DOW-NF-Perm-Day5-#1"
    j. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day5-#1"
    k. NF Concentrate – Nitric Preserved Filtered Bottle "DOW-NF-Conc-Day5-#1"
    l. NF Concentrate – Unpreserved Bottle "DOW-NF-Conc-Day5-#1"
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day5-#2"
    b. Feed Tank Effluent – Nitric Preserved Filtered Bottle "DOW-Feed-Tank-Day5-#2"
    c. Feed Tank Effluent- Unpreserved Bottle "DOW-Feed-Tank-Day5-#2"
    d. Pretreated Effluent - Nitric Preserved Bottle "DOW-Pretrtd-Eff-Day5-#2"
    e. Pretreated Effluent - Nitric Preserved Filtered Bottle "DOW-Pretrtd-Eff-Day5-#2"
    f. Pretreated Effluent - Unpreserved Bottle "DOW-Pretrtd-Eff-Day5-#2"
    g. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day5-#2"
    h. NF Permeate - Nitric Preserved Filtered Bottle "DOW-NF-Perm-Day5-#2"
    i. NF Permeate - Unpreserved Bottle "DOW-NF-Perm-Day5-#2"
    j. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day5-#2"
    k. NF Concentrate – Nitric Preserved Filtered Bottle "DOW-NF-Conc-Day5-#2"
    l. NF Concentrate – Unpreserved Bottle "DOW-NF-Conc-Day5-#2"
11. Fill out the pre-prepared chain of custody for Day 5 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 5 Sample Bottle Summary

Samples	Sampling Time		Bottle Type to be Used					
	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x	x	x	x	x
Pretreated effluent	YES	YES	x	x	x	x	x	x
NF permeate	YES	YES	x	x	x	x	x	x
NF concentrate	YES	YES	x	x	x	x	x	x
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

3.6 DOW Membrane - Day 6

Day 6 Operating Conditions Summary

Membrane	Dow
Recovery	NOT OPERATING
Feed flow	NOT OPERATING
NF and GSF pretreatment	
Potassium permanganate	OFF
Antiscalant	OFF
VSEP recovery	80%
VSEP feed pH	6.5

1. Adjust the NF concentrate collected on Day 5 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle "DOW-VSEP-Feed-Day6-#1"
    b. VSEP Feed Tank– Nitric Preserved Filtered Bottle "DOW-VSEP-Feed-Day6-#1"
    c. VSEP Feed Tank– Unpreserved Bottle "DOW-VSEP-Feed-Day6-#1"
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle "DOW-VSEP-Perm-Day6-#2"
    b. VSEP Permeate - Nitric Preserved Filtered Bottle "DOW-VSEP-Perm-Day6-#2"
    c. VSEP Concentrate - Nitric Preserved Bottle "DOW-VSEP-Conc-Day6-#2

    d. VSEP Concentrate - Nitric Preserved Filtered Bottle “DOW-VSEP-Conc-Day6-#2
    e. VSEP Permeate – Unpreserved Bottle “DOW-VSEP-Perm-Day6-#2”
    f. VSEP Concentrate – Unpreserved Bottle “DOW-VSEP-Conc-Day6-#2

7. Fill out the pre-prepared chain of custody for Day 6 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut down the system after 8 hours of feeding the stock solution.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 6 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
Pretreated effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x		x	
VSEP permeate	YES	YES		x		x		x
VSEP Concentrate	YES	YES		x		x		X

3.7 Dow Membrane - Day 7

Day 7 Operating Conditions

Membrane	**Dow**
Recovery	80%
Feed flow	20 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the “DOW Sodium Selenite #2” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.

4. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 20 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
5. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
6. Collect all NF concentrate into a feed tank for use at the VSEP in day 8.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 5) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day7-#1"
    b. Pretreated Effluent - Nitric Preserved Bottle "DOW- Pretrtd -EFF-Day7-#1"
    c. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day7-#1"
    d. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day7-#1"
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day7-#2"
    b. Pretreated Effluent - Nitric Preserved Bottle "DOW- Pretrtd -EFF-Day7-#2"
    c. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day7-#2"
    d. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day7-#2"
11. Fill out the pre-prepared chain of custody for Day 7 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 7 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	YES	YES	x	x				
Pretreated effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

3.8 Dow Membrane - Day 8

Day 8 Operating Conditions Summary

Membrane	Dow
Recovery	NOT OPERATING
Feed flow	NOT OPERATING
NF and GSF pretreatment	
Potassium permanganate	OFF
Antiscalant	OFF
VSEP recovery	80%
VSEP feed pH	6.5

1. Adjust the NF concentrate collected on Day 7 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle "DOW-VSEP-Feed-Day8-#1"
    b. VSEP Feed Tank– Nitric Preserved Filtered Bottle "DOW-VSEP-Feed-Day8-#1"
    c. VSEP Feed Tank– Unpreserved Bottle "DOW-VSEP-Feed-Day8-#1"
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle "DOW-VSEP-Perm-Day8-#2"
    b. VSEP Permeate - Nitric Preserved Filtered Bottle "DOW-VSEP-Perm-Day8-#2"
    c. VSEP Concentrate - Nitric Preserved Bottle "DOW-VSEP-Conc-Day8-#2"
    d. VSEP Concentrate - Nitric Preserved Filtered Bottle "DOW-VSEP-Conc-Day8-#2"
    e. VSEP Permeate – Unpreserved Bottle "DOW-VSEP-Perm-Day8-#2"
    f. VSEP Concentrate – Unpreserved Bottle "DOW-VSEP-Conc-Day8-#2"
7. Fill out the pre-prepared chain of custody for Day 8 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut down the system after 8 hours of feeding the stock solution.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 8 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	NO	NO						
Pretreated effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x		x	
VSEP permeate	YES	YES		x		x		x
VSEP Concentrate	YES	YES		x		x		X

3.9 Dow Membrane - Day 9

Day 9 Operating Conditions

Membrane	Dow
Recovery	80%
Feed flow	20 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the “DOW Sodium Selenate #1” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 20 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
5. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
6. Collect all NF concentrate into a feed tank for use at the VSEP in day 10.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.

8. Two hours after the recorded start time (see step 5) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day9-#1"
    b. Feed Tank Effluent – Nitric Preserved Filtered Bottle "DOW-Feed-Tank-Day9-#1"
    c. Feed Tank Effluent- Unpreserved Bottle "DOW-Feed-Tank-Day9-#1"
    d. Pretreated Effluent - Nitric Preserved Bottle "DOW-Pretrtd-Eff-Day9-#1"
    e. Pretreated Effluent - Nitric Preserved Filtered Bottle "DOW-Pretrtd-Eff-Day9-#1"
    f. Pretreated Effluent - Unpreserved Bottle "DOW-Pretrtd-Eff-Day9-#1"
    g. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day9-#1"
    h. NF Permeate - Nitric Preserved Filtered Bottle "DOW-NF-Perm-Day9-#1"
    i. NF Permeate - Unpreserved Bottle "DOW-NF-Perm-Day9-#1"
    j. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day9-#1"
    k. NF Concentrate – Nitric Preserved Filtered Bottle "DOW-NF-Conc-Day9-#1"
    l. NF Concentrate – Unpreserved Bottle "DOW-NF-Conc-Day9-#1"
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day9-#2"
    b. Feed Tank Effluent – Nitric Preserved Filtered Bottle "DOW-Feed-Tank-Day9-#2"
    c. Feed Tank Effluent- Unpreserved Bottle "DOW-Feed-Tank-Day9-#2"
    d. Pretreated Effluent - Nitric Preserved Bottle "DOW-Pretrtd-Eff-Day9-#2"
    e. Pretreated Effluent - Nitric Preserved Filtered Bottle "DOW-Pretrtd-Eff-Day9-#2"
    f. Pretreated Effluent - Unpreserved Bottle "DOW-Pretrtd-Eff-Day9-#2"
    g. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day9-#2"
    h. NF Permeate - Nitric Preserved Filtered Bottle "DOW-NF-Perm-Day9-#2"
    i. NF Permeate - Unpreserved Bottle "DOW-NF-Perm-Day9-#2"
    j. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day9-#2"
    k. NF Concentrate – Nitric Preserved Filtered Bottle "DOW-NF-Conc-Day9-#2"
    l. NF Concentrate – Unpreserved Bottle "DOW-NF-Conc-Day9-#2"
11. Fill out the pre-prepared chain of custody for Day 9 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 9 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x	x	x	x	x
Pretreated effluent	YES	YES	x	x	x	x	x	x
NF permeate	YES	YES	x	x	x	x	x	x
NF concentrate	YES	YES	x	x	x	x	x	x
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

3.10 Dow Membrane - Day 10

Day 10 Operating Conditions Summary

Membrane	Dow
Recovery	NOT OPERATING
Feed flow	NOT OPERATING
NF and GSF pretreatment	
Potassium permanganate	OFF
Antiscalant	OFF
VSEP recovery	80%
VSEP feed pH	6.5

1. Adjust the NF concentrate collected on Day 9 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle “DOW-VSEP-Feed-Day10-#1”
    b. VSEP Feed Tank– Nitric Preserved Filtered Bottle “DOW-VSEP-Feed-Day10-#1”
    c. VSEP Feed Tank– Unpreserved Bottle “DOW-VSEP-Feed-Day10-#1”
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle “DOW-VSEP-Perm-Day10-#2”
    b. VSEP Permeate - Nitric Preserved Filtered Bottle “DOW-VSEP-Perm-Day10-#2”
    c. VSEP Concentrate - Nitric Preserved Bottle “DOW-VSEP-Conc-Day10-#2

    d. VSEP Concentrate - Nitric Preserved Filtered Bottle “DOW-VSEP-Conc-Day10-#2
    e. VSEP Permeate – Unpreserved Bottle “DOW-VSEP-Perm-Day10-#2”
    f. VSEP Concentrate – Unpreserved Bottle “DOW-VSEP-Conc-Day10-#2
7. Fill out the pre-prepared chain of custody for Day 10 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut down the system after 8 hours of feeding the stock solution.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 10 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
Pretreated effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x		x	
VSEP permeate	YES	YES		x		x		x
VSEP Concentrate	YES	YES		x		x		X

3.11 Dow Membrane - Day 11

Day 11 Operating Conditions Summary

Membrane	Dow
Recovery	80%
Feed flow	20 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the “DOW Sodium Selenate #2” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.

4. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 20 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
5. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
6. Collect all NF concentrate into a feed tank for use at the VSEP in day 12.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 5) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day11-#1"
    b. Pretreated Effluent - Nitric Preserved Bottle "DOW- Pretrtd -EFF-Day11-#1"
    c. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day11-#1"
    d. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day11-#1"
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day11-#2"
    b. Pretreated Effluent - Nitric Preserved Bottle "DOW- Pretrtd -EFF-Day11-#2"
    c. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day11-#2"
    d. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day11-#2"
11. Fill out the pre-prepared chain of custody for Day 11 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 11 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	YES	YES	x	x				
Pretreated effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

3.12 Dow Membrane - Day 12

Day 12 Operating Conditions Summary

Membrane	Dow
Recovery	NOT OPERATING
Feed flow	NOT OPERATING
NF and GSF pretreatment	
Potassium permanganate	OFF
Antiscalant	OFF
VSEP recovery	80%
VSEP feed pH	6.5

1. Adjust the NF concentrate collected on Day 11 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle "DOW-VSEP-Feed-Day12-#1"
    b. VSEP Feed Tank– Nitric Preserved Filtered Bottle "DOW-VSEP-Feed-Day12-#1"
    c. VSEP Feed Tank– Unpreserved Bottle "DOW-VSEP-Feed-Day12-#1"
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle "DOW-VSEP-Perm-Day12-#2"
    b. VSEP Permeate - Nitric Preserved Bottle "DOW-VSEP-Perm-Day12-#2"
    c. VSEP Concentrate - Nitric Preserved Bottle "DOW-VSEP-Conc-Day12-#2"
    d. VSEP Concentrate - Nitric Preserved Filtered Bottle "DOW-VSEP-Conc-Day12-#2"
    e. VSEP Permeate – Unpreserved Bottle "DOW-VSEP-Perm-Day12-#2"
    f. VSEP Concentrate – Unpreserved Bottle "DOW-VSEP-Conc-Day12-#2"
7. Fill out the pre-prepared chain of custody for Day 12 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut down the system after 8 hours of feeding the stock solution.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 12 Sample Bottle Summary

Samples	Sampling Time		Bottle Type to be Used					
	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	NO	NO						
Pretreated effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x		x	
VSEP permeate	YES	YES		x		x		x
VSEP Concentrate	YES	YES		x		x		X

3.13 Dow Membrane - Day 13

Day 13 Operating Conditions Summary

Membrane	Dow
Recovery	80%
Feed flow	20 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the four bottles below to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
    a. DOW Cobalt Chloride #1
    b. DOW Zinc Sulfate #1
    c. DOW Nickel Chloride #1
    d. DOW Sodium Arsenite #1
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the final pH.
    a. If the solid salt is still visible in the solution, slowly add acid until the solution is clear. Record the final pH**. Do not go lower than pH 4.**

5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 20 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Collect all NF concentrate into a feed tank for use at the VSEP in day 14.
8. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
9. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day13-#1"
    b. Feed Tank Effluent – Nitric Preserved Filtered Bottle "DOW-Feed-Tank-Day13-#1"
    c. Feed Tank Effluent- Unpreserved Bottle "DOW-Feed-Tank-Day13-#1"
    d. Pretreated Effluent - Nitric Preserved Bottle "DOW-Pretrtd-Eff-Day13-#1"
    e. Pretreated Effluent - Nitric Preserved Filtered Bottle "DOW-Pretrtd-Eff-Day13-#1"
    f. Pretreated Effluent - Unpreserved Bottle "DOW-Pretrtd-Eff-Day13-#1"
    g. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day13-#1"
    h. NF Permeate - Nitric Preserved Filtered Bottle "DOW-NF-Perm-Day13-#1"
    i. NF Permeate - Unpreserved Bottle "DOW-NF-Perm-Day13-#1"
    j. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day13-#1"
    k. NF Concentrate – Nitric Preserved Filtered Bottle "DOW-NF-Conc-Day13-#1"
    l. NF Concentrate – Unpreserved Bottle "DOW-NF-Conc-Day13-#1"
10. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
11. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day13-#2"
    b. Feed Tank Effluent – Nitric Preserved Filtered Bottle "DOW-Feed-Tank-Day13-#2"
    c. Feed Tank Effluent- Unpreserved Bottle "DOW-Feed-Tank-Day13-#2"
    d. Pretreated Effluent - Nitric Preserved Bottle "DOW-Pretrtd-Eff-Day13-#2"
    e. Pretreated Effluent - Nitric Preserved Filtered Bottle "DOW-Pretrtd-Eff-Day13-#2"
    f. Pretreated Effluent - Unpreserved Bottle "DOW-Pretrtd-Eff-Day13-#2"
    g. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day13-#2"
    h. NF Permeate - Nitric Preserved Filtered Bottle "DOW-NF-Perm-Day13-#2"
    i. NF Permeate - Unpreserved Bottle "DOW-NF-Perm-Day13-#2"
    j. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day13-#2"
    k. NF Concentrate – Nitric Preserved Filtered Bottle "DOW-NF-Conc-Day13-#2"
    l. NF Concentrate – Unpreserved Bottle "DOW-NF-Conc-Day13-#2"
12. Fill out the pre-prepared chain of custody for Day 13 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
13. Shut down the system after 8 hours of feeding the stock solution.
14. Empty any excess stock solution into waste storage containers for later disposal.

Day 13 Sample Bottle Summary

Samples	Sampling Time		Bottle Type to be Used					
	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x	x	x	x	x
Pretreated effluent	YES	YES	x	x	x	x	x	x
NF permeate	YES	YES	x	x	x	x	x	x
NF concentrate	YES	YES	x	x	x	x	x	x
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

3.14 Dow Membrane - Day 14

Day 14 Operating Conditions Summary

Membrane	Dow
Recovery	NOT OPERATING
Feed flow	NOT OPERATING
NF and GSF pretreatment	
Potassium permanganate	OFF
Antiscalant	OFF
VSEP recovery	80%
VSEP feed pH	6.5

1. Adjust the NF concentrate collected on Day 13 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle “DOW-VSEP-Feed-Day14-#1”
    b. VSEP Feed Tank– Nitric Preserved Filtered Bottle “DOW-VSEP-Feed-Day14-#1”
    c. VSEP Feed Tank– Unpreserved Bottle “DOW-VSEP-Feed-Day14-#1”
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle “DOW-VSEP-Perm-Day14-#2”
    b. VSEP Permeate - Nitric Preserved Filtered Bottle “DOW-VSEP-Perm-Day14-#2”
    c. VSEP Concentrate - Nitric Preserved Bottle “DOW-VSEP-Conc-Day14-#2

    d. VSEP Concentrate - Nitric Preserved Filtered Bottle “DOW-VSEP-Conc-Day14-#2
    e. VSEP Permeate – Unpreserved Bottle “DOW-VSEP-Perm-Day14-#2”
    f. VSEP Concentrate – Unpreserved Bottle “DOW-VSEP-Conc-Day14-#2
7. Fill out the pre-prepared chain of custody for Day 14 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut down the system after 8 hours of feeding the stock solution.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 14 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
Pretreated effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x		x	
VSEP permeate	YES	YES		x		x		x
VSEP Concentrate	YES	YES		x		x		X

3.15 Dow Membrane - Day 15

Day 15 Operating Conditions Summary

Membrane	Dow
Recovery	80%
Feed flow	20 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the four bottles below to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
    a. DOW Cobalt Chloride #2

    b. DOW Zinc Sulfate #2
    c. DOW Nickel Chloride #2
    d. DOW Sodium Arsenite #2
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the final pH.
    a. If the solid salt is still visible in the solution, slowly add acid until the solution is clear. Record the final pH**. Do not go lower than pH 4.**
5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 20 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Collect all NF concentrate into a feed tank for use at the VSEP in day 16.
8. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
9. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day15-#1"
    b. Pretreated Effluent - Nitric Preserved Bottle "DOW- Pretrtd -EFF-Day15-#1"
    c. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day15-#1"
    d. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day15-#1"
10. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
11. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day15-#2"
    b. Pretreated Effluent - Nitric Preserved Bottle "DOW- Pretrtd -EFF-Day15-#2"
    c. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day15-#2"
    d. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day15-#2"
12. Fill out the pre-prepared chain of custody for Day 15 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
13. Shut down the system after 8 hours of feeding the stock solution.
14. Empty any excess stock solution into waste storage containers for later disposal.

Day 15 Sample Bottle Summary

Samples	Sampling Time		Bottle Type to be Used					
	AM	PM	Nitric preserved		Unpreserved		Filtered (Dissolved)	
			AM	PM	AM	PM	AM	PM
Feed tank effluent	YES	YES	x	x				
Pretreated effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

3.16 Dow Membrane - Day 16

Day 16 Operating Conditions Summary

Membrane	Dow
Recovery	NOT OPERATING
Feed flow	NOT OPERATING
NF and GSF pretreatment	
Potassium permanganate	OFF
Antiscalant	OFF
VSEP recovery	80%
VSEP feed pH	6.5

1. Adjust the NF concentrate collected on Day 15 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle “DOW-VSEP-Feed-Day16-#1”
    b. VSEP Feed Tank– Nitric Preserved Filtered Bottle “DOW-VSEP-Feed-Day16-#1”
    c. VSEP Feed Tank– Unpreserved Bottle “DOW-VSEP-Feed-Day16-#1”
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle “DOW-VSEP-Perm-Day16-#2”
    b. VSEP Permeate - Nitric Preserved Filtered Bottle “DOW-VSEP-Perm-Day16-#2”
    c. VSEP Concentrate - Nitric Preserved Bottle “DOW-VSEP-Conc-Day16-#2”

   d. VSEP Concentrate - Nitric Preserved Filtered Bottle “DOW-VSEP-Conc-Day16-#2”
   e. VSEP Permeate – Unpreserved Bottle “DOW-VSEP-Perm-Day16-#2”
   f. VSEP Concentrate – Unpreserved Bottle “DOW-VSEP-Conc-Day16-#2”
7. Fill out the pre-prepared chain of custody for Day 16 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut down the system after 8 hours of feeding the stock solution.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 16 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
Pretreated effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x		x	
VSEP permeate	YES	YES		x		x		x
VSEP Concentrate	YES	YES		x		x		X

3.17 Dow Membrane - Day 17

Day 17 Operating Conditions Summary

Membrane	**Dow**
Recovery	80%
Feed flow	20 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.
3. Add the “DOW Copper Sulfate #1” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.

4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the final pH.
    a. If the solid salt is still visible in the solution, slowly add acid until the solution is clear. Record the final pH**. Do not go lower than pH 4.**
5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 20 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day17-#1"
    b. Feed Tank Effluent – Nitric Preserved Filtered Bottle "DOW-Feed-Tank-Day17-#1"
    c. Feed Tank Effluent- Unpreserved Bottle "DOW-Feed-Tank-Day17-#1"
    d. Pretreated Effluent - Nitric Preserved Bottle "DOW-Pretrtd-Eff-Day17-#1"
    e. Pretreated Effluent - Nitric Preserved Filtered Bottle "DOW-Pretrtd-Eff-Day17-#1"
    f. Pretreated Effluent - Unpreserved Bottle "DOW-Pretrtd-Eff-Day17-#1"
    g. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day17-#1"
    h. NF Permeate - Nitric Preserved Filtered Bottle "DOW-NF-Perm-Day17-#1"
    i. NF Permeate - Unpreserved Bottle "DOW-NF-Perm-Day17-#1"
    j. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day17-#1"
    k. NF Concentrate – Nitric Preserved Filtered Bottle "DOW-NF-Conc-Day17-#1"
    l. NF Concentrate – Unpreserved Bottle "DOW-NF-Conc-Day17-#1"
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle "DOW-Feed-Tank-Day17-#2"
    b. Feed Tank Effluent – Nitric Preserved Filtered Bottle "DOW-Feed-Tank-Day17-#2"
    c. Feed Tank Effluent- Unpreserved Bottle "DOW-Feed-Tank-Day17-#2"
    d. Pretreated Effluent - Nitric Preserved Bottle "DOW-Pretrtd-Eff-Day17-#2"
    e. Pretreated Effluent - Nitric Preserved Filtered Bottle "DOW-Pretrtd-Eff-Day17-#2"
    f. Pretreated Effluent - Unpreserved Bottle "DOW-Pretrtd-Eff-Day17-#2"
    g. NF Permeate - Nitric Preserved Bottle "DOW-NF-Perm-Day17-#2"
    h. NF Permeate - Nitric Preserved Filtered Bottle "DOW-NF-Perm-Day17-#2"
    i. NF Permeate - Unpreserved Bottle "DOW-NF-Perm-Day17-#2"
    j. NF Concentrate – Nitric Preserved Bottle "DOW-NF-Conc-Day17-#2"
    k. NF Concentrate – Nitric Preserved Filtered Bottle "DOW-NF-Conc-Day17-#2"
    l. NF Concentrate – Unpreserved Bottle "DOW-NF-Conc-Day17-#2"
11. Fill out the pre-prepared chain of custody for Day 17 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.

12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 17 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	YES	YES	x	x	x	x	x	x
Pretreated effluent	YES	YES	x	x	x	x	x	x
NF permeate	YES	YES	x	x	x	x	x	x
NF concentrate	YES	YES	x	x	x	x	x	x
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

3.18 Dow Membrane - Day 18

Day 18 Operating Conditions Summary

Membrane	Dow
Recovery	NOT OPERATING
Feed flow	NOT OPERATING
NF and GSF pretreatment	
Potassium permanganate	OFF
Antiscalant	OFF
VSEP recovery	80%
VSEP feed pH	6.5

1. Adjust the NF concentrate collected on Day 17 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle “DOW-VSEP-Feed-Day18-#1”
    b. VSEP Feed Tank– Nitric Preserved Filtered Bottle “DOW-VSEP-Feed-Day18-#1”
    c. VSEP Feed Tank– Unpreserved Bottle “DOW-VSEP-Feed-Day18-#1”
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle “DOW-VSEP-Perm-Day18-#2”

   b. VSEP Permeate - Nitric Preserved Filtered Bottle “DOW-VSEP-Perm-Day18-#2”
   c. VSEP Concentrate - Nitric Preserved Bottle “DOW-VSEP-Conc-Day18-#2”
   d. VSEP Concentrate - Nitric Preserved Filtered Bottle “DOW-VSEP-Conc-Day18-#2”
   e. VSEP Permeate – Unpreserved Bottle “DOW-VSEP-Perm-Day18-#2”
   f. VSEP Concentrate – Unpreserved Bottle “DOW-VSEP-Conc-Day18-#2”

7. Fill out the pre-prepared chain of custody for Day 18 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut down the system after 8 hours of feeding the stock solution.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 18 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
Pretreated effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x		x	
VSEP permeate	YES	YES		x		x		x
VSEP Concentrate	YES	YES		x		x		X

3.19 Dow Membrane - Day 19

Day 19 Operating Conditions Summary

Membrane	**Dow**
Recovery	80%
Feed flow	20 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Ensure that the Antiscalant and Potassium Permanganate tanks are full and that their pumps are working.
2. Add 60 liters of NF permeate water to the stock solution tank that feeds into the line before the NF inlet.

3. Add the “DOW Copper Sulfate #2” bottle to the 60 liter stock solution. Gently mix the 60 liter stock solution to dissolve the metal salt.
4. While mixing, slowly add sulfuric acid to the stock solution tank until a pH of 5.5 is reached. Record the final pH.
    a. If the solid salt is still visible in the solution, slowly add acid until the solution is clear. Record the final pH**. Do not go lower than pH 4.**
5. Verify that the pilot treatment system is working correctly and that forward flow into the NF membrane is 20 GPM. Confirm the dosing rates for Antiscalant and Potassium Permanganate.
6. Begin feeding the stock solution into the inlet **(before the NF membrane)** at a flow rate of 125 ml/min. Record the time when you begin feeding the stock solution.
7. Fill out the Pilot Test Data Log Sheet at stock solution dosing startup, at shutdown and every two hours during operation.
8. Two hours after the recorded start time (see step 6) for the addition of the stock solution collect samples from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle “DOW-Feed-Tank-Day19-#1”
    b. Pretreated Effluent - Nitric Preserved Bottle “DOW- Pretrtd -EFF-Day19-#1”
    c. NF Permeate - Nitric Preserved Bottle “DOW-NF-Perm-Day19-#1”
    d. NF Concentrate – Nitric Preserved Bottle “DOW-NF-Conc-Day19-#1”
9. Refill the feed tanks with Area Five Pit NW water within four hours of system startup.
10. Collect samples two hours before system shutdown from the following locations in the following bottles. Record the sample time and date on each bottle.
    a. Feed Tank Effluent – Nitric Preserved Bottle “DOW-Feed-Tank-Day19-#2”
    b. Pretreated Effluent - Nitric Preserved Bottle “DOW- Pretrtd -EFF-Day19-#2”
    c. NF Permeate - Nitric Preserved Bottle “DOW-NF-Perm-Day19-#2”
    d. NF Concentrate – Nitric Preserved Bottle “DOW-NF-Conc-Day19-#2”
11. Fill out the pre-prepared chain of custody for Day 19 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
12. Shut down the system after 8 hours of feeding the stock solution.
13. Empty any excess stock solution into waste storage containers for later disposal.

Day 19 Sample Bottle Summary

	Sampling Time		Bottle Type to be Used					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	YES	YES	x	x				
Pretreated effluent	YES	YES	x	x				
NF permeate	YES	YES	x	x				
NF concentrate	YES	YES	x	x				
VSEP feed	NO	NO						
VSEP permeate	NO	NO						
VSEP Concentrate	NO	NO						

3.20 Dow Membrane - Day 20

Day 20 Operating Conditions Summary

Membrane	Dow
Recovery	80%
Feed flow	20 gpm
NF and GSF pretreatment	
Potassium permanganate	ON
Antiscalant	ON
VSEP recovery	NOT OPERATING
VSEP feed pH	N/A

1. Adjust the NF concentrate collected on Day 19 to a pH of 6.5 with carbon dioxide. Record the final pH and the tank level.
2. Ensure that the antiscalant is dosed into feed tank at the correct dose.
3. Operate the VSEP at a recovery rate of 80%.
4. Fill out the VSEP Pilot Test Data Log Sheet at startup, shutdown and every hour during operation.
5. After the feed has been adjusted, collect the sample:
    a. VSEP Feed Tank– Nitric Preserved Bottle “DOW-VSEP-Feed-Day20-#1”
    b. VSEP Feed Tank– Nitric Preserved Filtered Bottle “DOW-VSEP-Feed-Day20-#1”
    c. VSEP Feed Tank– Unpreserved Bottle “DOW-VSEP-Feed-Day20-#1”
6. At the end of the batch, collect the following samples. Record the sample time and date on each bottle.
    a. VSEP Permeate - Nitric Preserved Bottle “DOW-VSEP-Perm-Day20-#2”
    b. VSEP Permeate - Nitric Preserved Filtered Bottle “DOW-VSEP-Perm-Day20-#2”
    c. VSEP Concentrate - Nitric Preserved Bottle “DOW-VSEP-Conc-Day20-#2”

    d. VSEP Concentrate - Nitric Preserved Filtered Bottle “DOW-VSEP-Conc-Day20-#2”
    e. VSEP Permeate – Unpreserved Bottle “DOW-VSEP-Perm-Day20-#2”
    f. VSEP Concentrate – Unpreserved Bottle “DOW-VSEP-Conc-Day20-#2”
7. Fill out the pre-prepared chain of custody for Day 20 with the correct date and sample time for each bottle. Ship the bottles to Legend Technical Services.
8. Shut down the system after 8 hours of feeding the stock solution.
9. Empty any excess stock solution into waste storage containers for later disposal.

Day 20 Sample Bottle Summary

	Sampling Time		**Bottle Type to be Used**					
Samples	**AM**	**PM**	**Nitric preserved**		**Unpreserved**		**Filtered (Dissolved)**	
			AM	**PM**	**AM**	**PM**	**AM**	**PM**
Feed tank effluent	NO	NO						
Pretreated effluent	NO	NO						
NF permeate	NO	NO						
NF concentrate	NO	NO						
VSEP feed	YES	YES	x		x		x	
VSEP permeate	YES	YES		x		x		x
VSEP Concentrate	YES	YES		x		x		X

4.0 Tables: GE Membrane

4.1 Metal Spike Dosing Bottle Names for the GE Membrane

	Metal Salt Dosing Bottle Names	
	Before GSF	**At NF inlet**
Day 1	GE Lead Nitrate #1	
Day 2	GE Lead Nitrate #2	
Day 3		GE Lead Nitrate #3
Day 4		GE Lead Nitrate #4
Day 5		GE Sodium Selenite #1
Day 6		
Day 7		GE Sodium Selenite #2
Day 8		
Day 9	GE Sodium Selenite #3	
Day 10	GE Sodium Selenite #4	
Day 11		GE Sodium Selenate #1
Day 12		
Day 13		GE Sodium Selenate #2
Day 14		
Day 15	GE Sodium Selenate #3	
Day 16	GE Sodium Selenate #4	
Day 17		GE Cobalt Chloride #1
		GE Zinc Sulfate #1
		GE Nickel Chloride #1
		GE Sodium Arsenite #1
Day 18		GE Cobalt Chloride #2
		GE Zinc Sulfate #2
		GE Nickel Chloride #2
		GE Sodium Arsenite #2
Day 19	GE Cobalt Chloride #3	
	GE Zinc Sulfate #3	
	GE Nickel Chloride #3	
	GE Sodium Arsenite #3	
Day 20	GE Cobalt Chloride #4	
	GE Zinc Sulfate #4	
	GE Nickel Chloride #4	
	GE Sodium Arsenite #4	
Day 21		GE Copper Sulfate
Day 22		GE Copper Sulfate
Day 23	GE Copper Sulfate	
Day 24	GE Copper Sulfate	

5.0 Tables: Dow Membrane

5.1 Metal Spike Dosing Bottle Names for the Dow Membrane

	Metal Salt Dosing Bottle Names
	At NF inlet
Day 1	DOW Lead Nitrate #1
Day 2	
Day 3	DOW Lead Nitrate #2
Day 4	
Day 5	DOW Sodium Selenite #1
Day 6	
Day 7	DOW Sodium Selenite #2
Day 8	
Day 9	DOW Sodium Selenate #1
Day 10	
Day 11	DOW Sodium Selenate #2
Day 12	
Day 13	DOW Cobalt Chloride #1
	DOW Zinc Sulfate #1
	DOW Nickel Chloride #1
	DOW Sodium Arsenite #1
Day 14	
Day 15	DOW Cobalt Chloride #2
	DOW Zinc Sulfate #2
	DOW Nickel Chloride #2
	DOW Sodium Arsenite #2
Day 16	
Day 17	DOW Copper Sulfate #1
Day 18	
Day 19	DOW Copper Sulfate #2
Day 20	

5.2 Analytical Parameters and Bottles for the GE and Dow Membrane Tests

Bottle Required	Full Suite -Parameter List	Target Species -Parameter List
Sample Frequency	Weekly	Twice Daily
1 Liter Unpreserved	Silicon	
	Silica (SiO_2)	
	Sulfate	
	Chloride	
	Total Dissolved Solids	
	Total Suspended Solids	
	pH	
	Alkalinity, Total	
250 mL Liter Nitric Preserved (Unfiltered)	Calcium	
	Magnesium	
	Sodium	
	Potassium	
	Aluminum	
	Iron	
	Barium	
	Manganese	
	Strontium	
	Target Species (Lead or Selenium(IV) or Selenium(VI) or Cobalt-Zinc-Arsenic-Nickel or Copper)	Target Species (Lead or Selenium(IV) or Selenium(VI) or Cobalt-Zinc-Arsenic-Nickel or Copper)
250 mL Liter Nitric Preserved (Filtered)	Iron	
	Manganese	
On-Site Testing	pH	pH

Tables

Table 1 **Dosing and Sampling Frequency for the GE Membrane**

Day	Dose Locations and Metal Salt to Add		Sample Locations and Times													
	Before GSF	At NF inlet	Feed Tank Effluent		GSF Effluent		NF Permeate		NF Concentrate		VSEP Feed		VSEP Permeate		VSEP Concentrate	
			Target Species	Full Suite	Target Species	Full Suite	Target Species	Full Suite	Target Species	Full Suite	Target Species	Full Suite	Target Species	Full Suite	Target Species	Full Suite
Day 1	Lead Nitrate		2/day		2/day		2/day		2/day							
Day 2	Lead Nitrate		2/day		2/day		2/day		2/day							
Day 3		Lead Nitrate		1/day	2/day	1/day	2/day	1/day	2/day	1/day						
Day 4		Lead Nitrate			2/day		2/day		2/day							
Day 5		Sodium Selenite			2/day		2/day		2/day							
Day 6												1/day		1/day		1/day
Day 7		Sodium Selenite		1/day	2/day	1/day	2/day	1/day	2/day	1/day						
Day 8												1/day		1/day		1/day
Day 9	Sodium Selenite		2/day		2/day		2/day		2/day							
Day 10	Sodium Selenite		2/day		2/day		2/day		2/day							
Day 11		Sodium Selenate			2/day		2/day		2/day							
Day 12												1/day		1/day		1/day
Day 13		Sodium Selenate			2/day		2/day		2/day							
Day 14												1/day		1/day		1/day
Day 15	Sodium Selenate		2/day		2/day		2/day		2/day							
Day 16	Sodium Selenate		2/day		2/day		2/day		2/day							
Day 17		Cobalt Chloride, Zinc Sulfate, Nickel Chloride, Sodium Arsenite		1/day	2/day	1/day	2/day	1/day	2/day	1/day						
Day 18		Cobalt Chloride, Zinc Sulfate, Nickel Chloride, Sodium Arsenite			2/day		2/day		2/day							
Day 19	Cobalt Chloride, Zinc Sulfate, Nickel Chloride, Sodium Arsenite		2/day		2/day		2/day		2/day							
Day 20	Cobalt Chloride, Zinc Sulfate, Nickel Chloride, Sodium Arsenite		2/day		2/day	1/day	2/day	1/day	2/day	1/day						
Day 21		Copper Sulfate			2/day		2/day		2/day							
Day 22		Copper Sulfate			2/day		2/day		2/day							
Day 23	Copper Sulfate		2/day		2/day		2/day		2/day							
Day 24	Copper Sulfate		2/day	1/day	2/day	1/day	2/day	1/day	2/day	1/day						

Table 2 **Dosing and Sampling Frequency for the Dow Membrane**

	Dose Location and Metal Salt to Add	*Sample Locations and Names*													
	At NF inlet	**Feed Tank Effluent**		**Pretreated Effluent**		**NF Permeate**		**NF Concentrate**		**VSEP Feed**		**VSEP Permeate**		**VSEP Concentrate**	
		Target Species List	**Full Suite List**	**Target Species List**	**Full Suite List**	**Target Species List**	**Full Suite List**	**Target Species List**	**Full Suite List**	**Target Species List**	**Full Suite List**	**Target Species List**	**Full Suite List**	**Target Species List**	**Full Suite List**
Day 1	**Lead Nitrate**		DOW-Feed-Tank-Day1-#1, DOW-Feed-Tank-Day1-#2		DOW-Pretrtd-Eff-Day1-#1, DOW-Pretrtd-Eff-Day1-#2		DOW-NF-Perm-Day1-#1, DOW-NF-Perm-Day1-#2		DOW-NF-Conc-Day1-#1, DOW-NF-Conc-Day1-#2						
Day 2											DOW-VSEP-Feed-Day2-#1		DOW-VSEP-Perm-Day2-#2		DOW-VSEP-Conc-Day2-#2
Day 3	**Lead Nitrate**	DOW-Feed-Tank-Day3-#1, DOW-Feed-Tank-Day3-#2		DOW-Pretrtd-Eff-Day3-#1, DOW-Pretrtd-Eff-Day3-#2		DOW-NF-Perm-Day3-#1, DOW-NF-Perm-Day3-#2		DOW-NF-Conc-Day3-#1, DOW-NF-Conc-Day3-#2							
Day 4											DOW-VSEP-Feed-Day4-#1		DOW-VSEP-Perm-Day4-#2		DOW-VSEP-Conc-Day4-#2
Day 5	**Sodium Selenite**		DOW-Feed-Tank-Day5-#1, DOW-Feed-Tank-Day5-#2		DOW-Pretrtd-Eff-Day5-#1, DOW-Pretrtd-Eff-Day5-#2		DOW-NF-Perm-Day5-#1, DOW-NF-Perm-Day5-#2		DOW-NF-Conc-Day5-#1, DOW-NF-Conc-Day5-#2						
Day 6											DOW-VSEP-Feed-Day6-#1		DOW-VSEP-Perm-Day6-#2		DOW-VSEP-Conc-Day6-#2
Day 7	**Sodium Selenite**	DOW-Feed-Tank-Day7-#1, DOW-Feed-Tank-Day7-#2,		DOW-Pretrtd-Eff-Day7-#1, DOW-Pretrtd-Eff-Day7-#2,		DOW-NF-Perm-Day7-#1, DOW-NF-Perm-Day7-#2,		DOW-NF-Conc-Day7-#1, DOW-NF-Conc-Day7-#2							
Day 8											DOW-VSEP-Feed-Day8-#1		DOW-VSEP-Perm-Day8-#2		DOW-VSEP-Conc-Day8-#2
Day 9	**Sodium Selenate**		DOW-Feed-Tank-Day9-#1, DOW-Feed-Tank-Day9-#2		DOW-Pretrtd-Eff-Day9-#1, DOW-Pretrtd-Eff-Day9-#2		DOW-NF-Perm-Day9-#1, DOW-NF-Perm-Day9-#2		DOW-NF-Conc-Day9-#1, DOW-NF-Conc-Day9-#2						
Day 10											DOW-VSEP-Feed-Day10-#1		DOW-VSEP-Perm-Day10-#2		DOW-VSEP-Conc-Day10-#2
Day 11	**Sodium Selenate**	DOW-Feed-Tank-Day11-#1, DOW-Feed-Tank-Day11-#2,		DOW-Pretrtd-Eff-Day11-#1, DOW-Pretrtd-Eff-Day11-#2,		DOW-NF-Perm-Day11-#1, DOW-NF-Perm-Day11-#2		DOW-NF-Conc-Day11-#1, DOW-NF-Conc-Day11-#2							
Day 12											DOW-VSEP-Feed-Day12-#1		DOW-VSEP-Perm-Day12-#2		DOW-VSEP-Conc-Day12-#2
Day 13	**Cobalt Chloride, Zinc Sulfate, Nickel Chloride, Sodium Arsenite**		DOW-Feed-Tank-Day13-#1, DOW-Feed-Tank-Day13-#2		DOW-Pretrtd-Eff-Day13-#1, DOW-Pretrtd-Eff-Day13-#2		DOW-NF-Perm-Day13-#1, DOW-NF-Perm-Day13-#2		DOW-NF-Conc-Day13-#1, DOW-NF-Conc-Day13-#2						
Day 14											DOW-VSEP-Feed-Day14-#1		DOW-VSEP-Perm-Day14-#2		DOW-VSEP-Conc-Day14-#2
Day 15	**Cobalt Chloride, Zinc Sulfate, Nickel Chloride, Sodium Arsenite**	DOW-Feed-Tank-Day15-#1, DOW-Feed-Tank-Day15-#2		DOW-Pretrtd-Eff-Day15-#1, DOW-Pretrtd-Eff-Day15-#2		DOW-NF-Perm-Day15-#1, DOW-NF-Perm-Day15-#2		DOW-NF-Conc-Day15-#1, DOW-NF-Conc-Day15-#2							
Day 16											DOW-VSEP-Feed-Day16-#1		DOW-VSEP-Perm-Day16-#2		DOW-VSEP-Conc-Day16-#2
Day 17	**Copper Sulfate**		DOW-Feed-Tank-Day17-#1, DOW-Feed-Tank-Day17-#2		DOW-Pretrtd-Eff-Day17-#1, DOW-Pretrtd-Eff-Day17-#2		DOW-NF-Perm-Day17-#1, DOW-NF-Perm-Day17-#2		DOW-NF-Conc-Day17-#1, DOW-NF-Conc-Day17-#2						
Day 18											DOW-VSEP-Feed-Day18-#1		DOW-VSEP-Perm-Day18-#2		DOW-VSEP-Conc-Day18-#2
Day 19	**Copper Sulfate**	DOW-Feed-Tank-Day19-#1, DOW-Feed-Tank-Day19-#2		DOW-Pretrtd-Eff-Day19-#1, DOW-Pretrtd-Eff-Day19-#2		DOW-NF-Perm-Day19-#1, DOW-NF-Perm-Day19-#2		DOW-NF-Conc-Day19-#1, DOW-NF-Conc-Day19-#2							
Day 20											DOW-VSEP-Feed-Day20-#1		DOW-VSEP-Perm-Day20-#2		DOW-VSEP-Conc-Day20-#2

Appendix B

WWTF Chemical Precipitation Bench Testing

resourceful. naturally.
engineering and environmental consultants
BARR

Memorandum

To: Project File
From: Todd DeJournett
Subject: MS WWTF Chemical Precipitation Bench Testing
Date: August 14, 2014
Project: 23690C08

This memo summarizes the objectives and approach for chemical precipitation bench testing using VSEP concentrate from the nanofiltration pilot-test.

Previous Work

Barr previously completed a series of bench tests using VSEP concentrate from the tailings basin RO pilot system. This testing focused on the optimal pH for removal of metals via the HDS process, possible interference from antiscalants, reaction times required, settling times required, and efficiency of the gypsum precipitation process for sulfate removal.

The previous work had some limitations, however, including:

- The metal spike solution tested included selenite, which had been used to measure selenium rejection in the metal-spiked RO pilot-test. While selenite is a worst-case scenario for selenium removal via a membrane (i.e. it is less rejected than selenate), it is a best-case scenario for selenium removal via chemical precipitation (i.e. selenite is better adsorbed than selenate). Additionally, based on the anticipated redox of the water, selenate is the more likely state of selenium in the water.

- Like selenium, the oxidized form of antimony is not well removed via chemical precipitation. Antimony was below detection limits in the concentrate used for the previous bench testing work.

- The iron sludge used in the previous bench test was only subjected to one exchange of water volume. GoldPHREEQC modeling suggests that, as the HDS sludge is exposed to multiple volumes of water during sludge recycle, and is loaded with metals adsorbed from the feed water, cobalt removal efficiency may be lower than desired.

- The gypsum precipitation process resulted in higher-than-expected aluminum concentrations in the treated water. The aluminum likely originated from the lime that was used for the test, but may have been biased higher yet by the means of preparation of the gypsum seed sludge. It is possible that the aluminum-bearing mineral ettringite may have formed in the seed sludge, then subsequently dissolved upon contact of the seed sludge with the feed water.

Objectives

This proposed work seeks to address the limitations described in the preceding section. The objectives of this proposed bench testing are”

- To evaluate the removal of metals, particularly selenium (as selenate) and cobalt, via the HDS process over several volume exchanges.
- To evaluate the addition of ferrous sulfate (in lieu of ferric sulfate) as a means to enhance selenium removal across the HDS process.
- To evaluate the gypsum precipitation process in the following ways
- Use of gypsum seed sludge precipitated from feed water, rather than lab water
- Optimization of pH to maximize removal of sulfate and minimize residual aluminum
- Evaluation of the removal of metals, particularly cobalt and selenium (as selenate) in the gypsum precipitation process
- To evaluate the addition of metal scavenger in the recarbonation step as a means to polish residual cobalt.

Materials

The materials required for this test include:

- Phipps and Bird Jar Testing Apparatus
- 1000-mL glass beakers
- Sample of VSEP reject – 6 x 2.5 gallon cubitainers
- Freshly-Precipitated Ferric Sludge – 10%
- Freshly-prepared lime slurry (10% wt:wt)
- Freshly-precipitated gypsum slurry
- Stopwatch
- 3x Filter funnels and 0.45-micron filter papers
- Hand vacuum pump

- Benchtop water quality meter (pH, ORP, temperature)
- Glass pipettes and autopipetter
- Micropiopetter and pipette tips
- Sample containers:
    - Dissolved metals
    - Total alkalinity, sulfate
- Baking Soda

Protocol – HDS Testing

Prior to beginning this test, it will be necessary to prepare a number of materials, including

- Lime Milk – 10%
- Iron oxyhydroxide sludge
- Metals stock solutions

Preparation of Lime Milk

Add 100 g of hydrated lime to 1 L of DI water in a beaker and mix well. The solution will be a slurry and will settle on standing, so it must be well-mixed when used. Transfer the solution to a plastic bottle and label with the date to store when not in use.

Preparation of Iron Oxyhydroxide Sludge

Place an aliquot (4 gallons) of VSEP concentrate in a 5-gallon bucket, mix on a stir plate and aerate with the aquarium bubbler.

Add 20 g of ferrous sulfate to the aliquot and adjust pH to 8 with lime milk. Cover the bucket with a lid, continue to mix and aerate overnight.

The next morning, measure solution pH and adjust to 8 with more lime milk if necessary. If the pH of the solution continues to drop, it may be necessary to mix the solution longer with periodic additions of lime milk to maintain pH 8.

Once solution pH is stable, shut off the mixer and observe settling. After solids are settled, decant the supernatant to a separate bucket using a peristaltic pump. Dispose of the supernatant via the mop sink.

Transfer the settled sludge to a cubitainer, label, and courier to Braun Intertec for centrifugation and subsequent iron/percent solids analysis. Braun will return a centrifuged (thickened) sludge aliquot and associated iron/solids content.

Preparation of Metals Stock Solutions

One previously-prepared stock solution (Solution #3, lead) can be re-used for this test (Table 1). New stock solutions required for this test are:

- Solution 1a – Cobalt, Copper, Nickel
- Solution 1b – Arsenic, selenium, antimony
- Solution 2 – Zinc

Table 1 Metals Addition Stock Solution and Target Concentrations

		Metal Salt Formula	Salt Formula Wt, g/mol	Metal Stock Concentration (mg/L)	Mass Salt in 250 mL DI Water, mg	90th Percentile Concentration (mg/L)	Volume Of Stock Solution to Add (ml of stock/ /Liter of Water)
Solution #1a	Cobalt	$CoCl_2*6H_2O$	238	117	117	1.17	10
Solution #1a	Copper	$CuSO_4*5H_2O$	250	525	512	5.25	10
Solution #1a	Nickel	$NiCl_2*6H_2O$	238	2100	2,118	21.0	10
Solution #1b	Arsenic	Na_3AsO_4	207	8.2	57	.082	1
Solution #1b	Selenium	Na_2SeO_4	189	10.5	63	0.105	1
Solution #1b	Antimony	K_2SbO_3	263	326	598	1.5	1
Solution #2	Zinc	$ZnSO_4*7H_2O$	288	1800	1,994	18.1	10
Solution #3	Lead	$Pb(NO_3)_2$	331	100		0.405	4

Using the digital scale, weigh the appropriate amount of cobalt, copper and nickel salts into a 250-mL volumetric flask. Bring the solution volume to 250 mL using DI water. Add a stir bar and stir the solution to dissolve the salts. If the solution appears cloudy, add sulfuric acid dropwise to dissolve any solids. After the solution is mixed and solids are dissolved, transfer the solution to a labeled media bottle, cap, and store inside secondary containment.

Using the digital scale, weigh the appropriate amount of arsenic, selenium, and antimony salts into a 250-mL volumetric flask. Bring the solution volume to 250 mL using DI water. Add a stir bar and stir the solution to dissolve the salts. If the solution appears cloudy, make note of this but do not add any acid to dissolve any solids. After the solution is mixed, transfer to a labeled media bottle, cap, and store inside secondary containment.

Using the digital scale, weigh the appropriate amount of zinc salt into a 250-mL volumetric flask. Bring the solution volume to 250 mL using DI water. Add a stir bar and stir the solution to dissolve the salt. If the solution appears cloudy, add sulfuric acid dropwise to dissolve any solids. After the solution is mixed and solids are dissolved, transfer the solution to a labeled media bottle, cap, and store inside secondary containment.

Execution of the test

Prior to beginning the test, collect samples of raw water for the parameters in Table 2.

Table 2 Parameters for Raw Water Analysis

Dissolved Metals	Ca, Mg, Na, K
Anions	Sulfate, chloride, carbonate alkalinity, bicarbonate alkalinity
General Parameters	Total Dissolved Solids

Using four clean 1-L glass beakers, prepare treatments as described in Table 3:

Table 3 Treatment Preparations - HDS

Jar Number	pH	Iron Solids Content	FeSO4 Spike, mg
HDS 1	8	0.2%	0
HDS 2	8	0.2%	700
HDS 3	9.5	0.1%	0
HDS 4	9.5	0.1%	700

Pre-weigh aliquots of ferrous sulfate powder prior to beginning the test.

Prepare the jars described above by placing the appropriate volume of iron sludge into each beaker, and bring the volume to 1 L with VSEP concentrate. Rapid- mix the beakers with the Phipps and Bird jar tester. Spike each beaker with the appropriate volume of metals spike solution, then add the ferrous sulfate aliquots.

Bring the solution pH to the target value using lime milk. Mix the beakers for 45 minutes, then settle the sludge. Using a 250-mL pipette and autopipettor, decant the supernatant from each jar into separate beakers. Place a 250 mL sample of the supernatant into an unpreserved jar. Filter a 250-mL sample of the supernatant and place in a nitric-preserved jar for dissolved metals analysis.

Refill each jar with fresh VSEP concentrate, spike with an appropriate volume of metals solution and ferrous sulfate, and bring the pH to the target value. After 45 minutes of reaction time, settle, decant and sample the supernatant. Repeat this process four times.

On the COC, specify analysis of the first and last volume exchanges, and hold the intermediate samples. Lab analyses are summarized in Table 4.

Table 4 Lab Analysis Summary

Container	Parameters
Nitric Preserved	Dissolved As, Cu, Co, Sb, Se, Ni, Pb, Mg, Fe
Unpreserved	Sulfate, carbonate alkalinity, bicarbonate alkalinity

Protocol – Sulfate Precipitation Jar Test

Prior to beginning this test, it will be necessary to prepare the following materials:

- Lime milk (previously described)
- Gypsum sludge

Preparation of Gypsum Sludge

Place 4 gallons of VSEP concentrate into a 5 gallon bucket and mix on a stir plate. Bring the pH of the concentrate to 12.5 using lime milk. Mix the solution for two hours, then settle and decant the supernatant. The sludge should be heavy and easily settleable. Neutralize the supernatant with sulfuric acid and dispose of in the mop sink.

Place the resulting sludge in a sealed container. Dry an aliquot of the sludge at 105C to determine the solids content.

Test Execution

Using six clean 1-L beakers, prepare the treatments described in Table 5.

Table 5 Treatment Preparations – Sulfate Precipitation

Jar Number	Solids Content	pH	Solution 1a Spike, mL	Solution 1b Spike	Alum Spike, mg
GYP-1	1%	11.5	10	1	1,300
GYP-2	1%	11.8	10	1	1,300
GYP-3	1%	12	10	1	1,300
GYP-4	1%	12.5	10	1	1,300
GYP-5	1%	12	10	1	0
GYP-6	1%	12.5	10	1	0

Place the sludge in the beakers, then bring the volume to 1 L using VSEP concentrate. Spike with the appropriate amount of metals solution and/or alum and bring the pH to the target setpoint using lime milk. Mix the beakers for 45 minutes, then settle the sludge and decant using a 250-mL pipette. Place a 250-mL aliquot of supernatant in an unpreserved sample bottle, and filter a 250-mL sample and place in a nitric-preserved sample bottle.

Analytes for this test are in Table 6.

Table 6 Analytes

Sample Container	Parameters
Nitric Preserved	Dissolved Ca, Mg, Al, Se, Sb, As, Cu, Co, Ni,
Unpreserved	Sulfate, carbonate alkalinity,

Scavenger Test

Water will be treated via lime/gypsum precipitation (pH 12.5), settled, decanted, then spiked with Solution 1a. The pH will then be adjusted using CO2 as described in Table 7 below prior to addition of metal scavenger:

Table 7 pH Adjustments

Jar	pH Setpoint	Solution 1a Spike, mL	Scavenger Dose, ppm
SCAV-1	10.5	1	0
SCAV-2	10.5	1	5
SCAV-3	10	1	0
SCAV-4	10	1	5
SCAV-5	9	1	0
SCAV-6	9	1	5

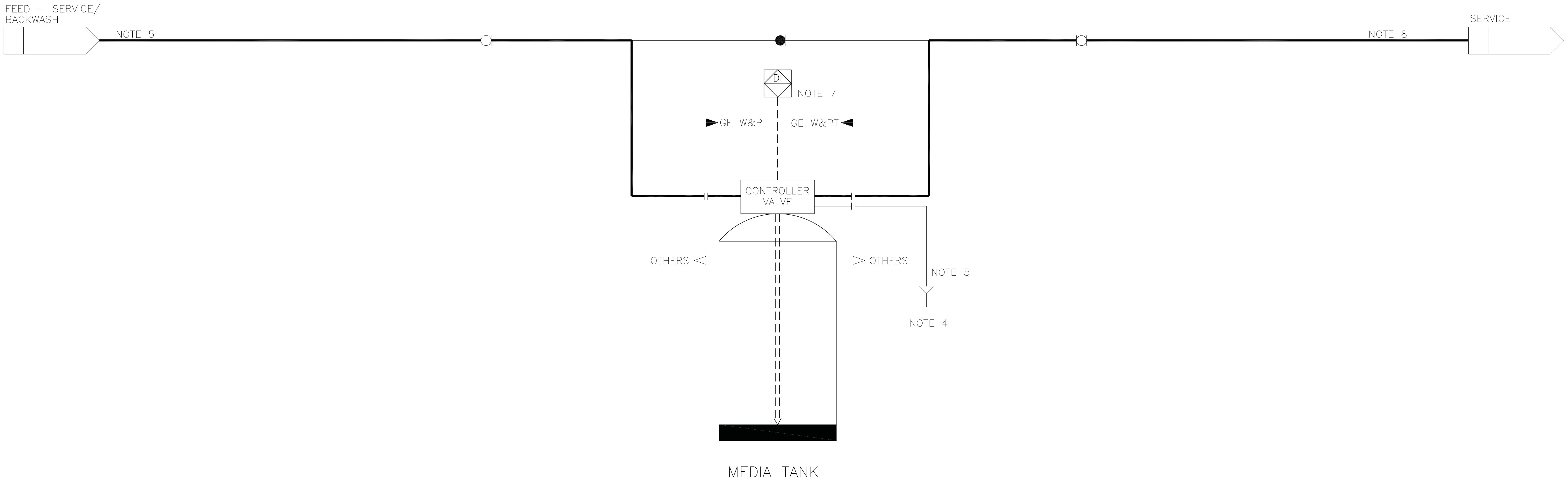
After addition of the scavenger, mix the water for 10 minutes, then settle and decant the supernatant. Filter 250 mL of supernatant and place in a nitric-preserved jar. Table 8 summarizes the analyte list for these samples.

Table 8 Summary of Analytes

Container	Parameters
Nitric Preserved	Dissolved Cu, Ni, Co

Appendix C

GE Pilot System Information



SYSTEM INFORMATION (EACH)				
TANK SIZE (IN.);	SERVICE (GPM): NOTE 5	BACKWASH(GPM): NOTE 5	INLET/OUTLET CONNECTIONS SIZE (IN):	DRAIN CONNECTION SIZE (IN):
10	1.5–5	6	1.0 SPG	0.75 MPT
14	3–9	10	1.0 SPG	0.75 MPT
21	6–18	25	2.0 SPG	1.5 SPG
30	15–45	50	2.0 SPG	2.0 MPT
36	20–60	75	2.0 SPG	2.5 MPT

NOTE:

1. MANUAL VALVES AND PIPING IN CUSTOMER SCOPE OF SUPPLY.
2. WATER PRESSURE 25 PSI MINIMUM AND 125 PSI MAXIMUM.
3. A 120 VOLT ELECTRICAL OUTLET SHOULD BE PROVIDED WITHIN 10 FEET OF EQUIPMENT.
4. REFER TO INSTALLATION MANUAL FOR INSTALLATION INSTRUCTION. TO MEET SANITARY REQUIREMENTS, THE DRAIN LINE MUST BE PIPED TO AN OPEN DRAIN WHERE FLOW (DURING REGENERATION) CAN BE OBSERVED AND AN AIR GAP CAN BE MAINTAINED IN ACCORDANCE WITH LOCAL PLUMBING CODES.
5. FEED LINE AND DRAIN LINE SHALL BE SIZED FOR BACKWASH FLOW.
6. MEDIA SHIPPED LOOSE AND LOADED ON SITE BY CUSTOMER.
7. CONTROLLER IS PROVIDED WITH SWITCH FOR EQUIPMENT LOCKOUT DURING REGENERATION.
8. NO AUTOMATIC UNFILTERED WATER BYPASS DURING REGENERATION
9. REFERENCE P&ID LEGEND PAGE: 1301227

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	13308	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
.X ± ±
.XX ±
.XXX ±
FRAC
±

DRAWN BY GRK	DATE 28Jun07
CHECKED BY RLD	DATE 21Sep07
APPROVED BY PWG	DATE 21Sep07
APPROVED BY	DATE

GE
Water & Process Technologies
GLOBAL HEADQUARTERS : TREVOSE, PA USA +1–215–355–3300 WWW.GEWATER.COM

CLIENT/JOB

FILE

DWG DESCRIPTION
PIPING & INSTRUMENTATION DIAGRAM
CARBON, FRP, SINGLE

MATERIAL/BOM NO.

SIZE	DRAWING NO.	REV
D	1303222	A

PROJECT

SCALE NONE
SHEET 1 OF 1

P/N 1161662–RGP01

Inversand Company
SINCE 1925
226 Atlantic Avenue, P.O. 650 • Clayton, NJ 08312
Phone 856-881-2345 Fax 856-881-6859
Email: info@inversand.com • www.inversand.com

GREENSANDPLUS™ TECHNICAL DATA

GREENSANDplus™

Performance Media for Water Filtration

Removes iron, manganese, hydrogen sulfide, arsenic and radium.

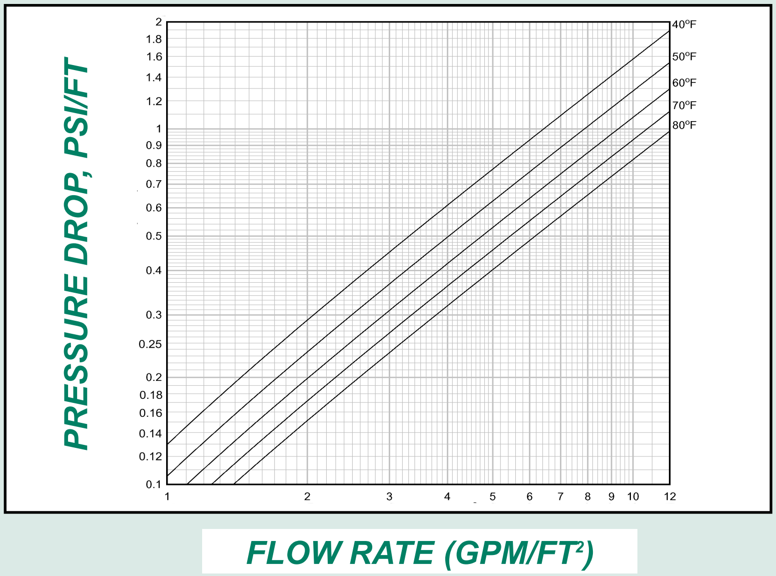
GreensandPlus™ is a black filter media used for removing soluble iron, manganese, hydrogen sulfide, arsenic and radium from groundwater supplies.

The manganese dioxide coated surface of GreensandPlus acts as a catalyst in the oxidation reduction reaction of iron and manganese.

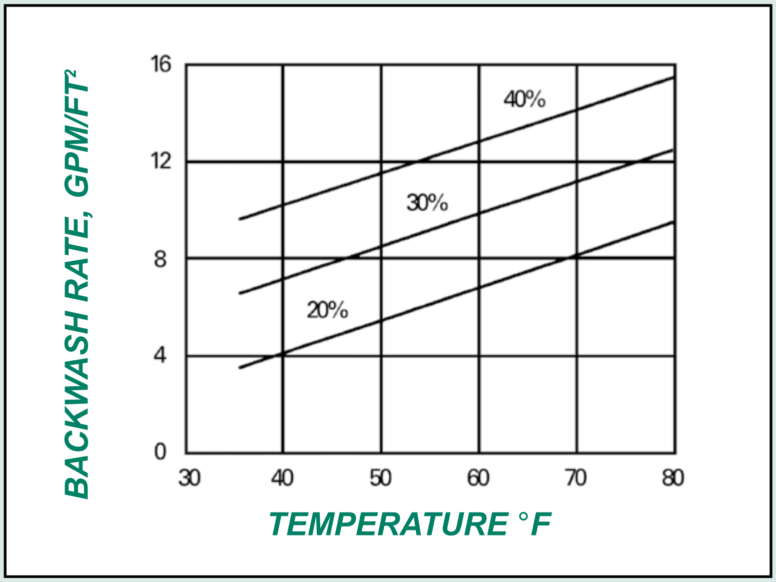
The silica sand core of GreensandPlus allows it to withstand waters that are low in silica, TDS and hardness without breakdown.

GreensandPlus is effective at higher operating temperatures and higher differential pressures than standard manganese greensand. Tolerance to higher differential pressure can provide for longer run times between backwashes and a greater margin of safety.

GREENSANDPLUS PRESSURE DROP (CLEAN BED)



BED EXPANSION DURING BACKWASHING



Systems may be designed using either vertical or horizontal pressure filters, as well as gravity filters.

GreensandPlus is a proven technology for iron, manganese, hydrogen sulfide, arsenic and radium removal. Unlike other media, there is no need for extensive preconditioning of filter media or lengthy startup periods during which required water quality may not be met.

GreensandPlus is an exact replacement for manganese greensand. It can be used in CO or IR applications and requires no changes in backwash rate or times or chemical feeds.

GreensandPlus has the WQA Gold Seal Certification for compliance with NSF/ANSI 61. Packaging is available in 1/2 cubic foot bags or 1 metric ton (2,205 lbs) bulk sacks.

PHYSICAL CHARACTERISTICS

Physical Form
Black, nodular granules shipped in a dry form

Apparent Density
88 pounds per cubic foot net (1410.26 kg/m3)

Shipping Weight
90 pounds per cubic foot gross (1442.31 kg/m3)

Specific Gravity
Approximately 2.4

Porosity
Approximately 0.45

Screen Grading (dry)
18 X 60 mesh

Effective Size
0.30 to 0.35 mm

Uniformity Coefficient
Less than 1.60

pH Range
6.2-8.5 (see General Notes)

Maximum Temperature
No limit

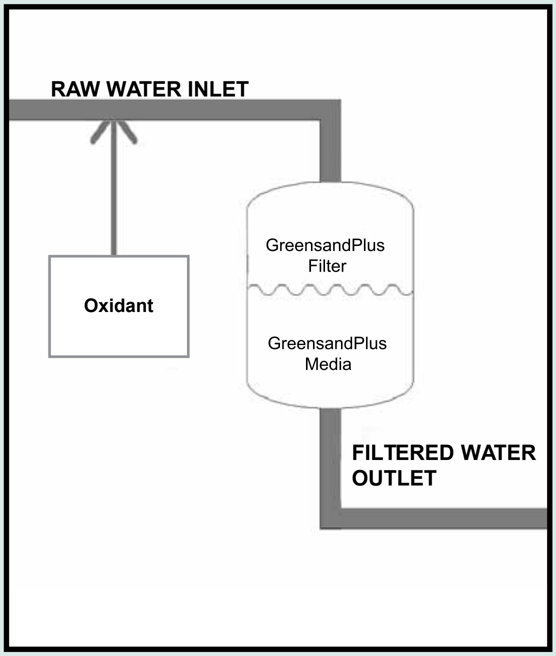
Backwash Rate
Minimum 12 gpm/sq. ft. at 55ºF
(29.4 m/hr @ 12.78*C) (see expansion chart)

Service Flow Rate
2 – 12 gpm/sq. ft. (4.9m/hr - 29.4 m/hr)

Minimum Bed Depth
15 inches (381 mm) of each media for dual media beds or 30 inches minimum (762 mm) of GreensandPlus alone.

METHOD OF OPERATION CO

GreensandPlus: Catalytic Oxidation (CO)



Catalytic Oxidation (CO) operation is recommended in applications where iron removal is the main objective in well waters with or without the presence of manganese. This method involves the feeding of a predetermined amount of chlorine (Cl_2) or other strong oxidant directly to the raw water before the GreensandPlus Filter.

Chlorine should be fed at least 10-20 seconds upstream of the filter, or as far upstream of the filter as possible to insure adequate contact time. A free chlorine residual carried through the filter will maintain GreensandPlus in a continuously regenerated condition.

For operation using chlorine, the demand can be estimated as follows:

$$\text{mg/L } Cl_2 = (1 \times \text{mg/L Fe}) + (3 \times \text{mg/L Mn}) + (6\times \text{mg/L } H_2S) + (8 \times \text{mg/L } NH_3)$$

SUGGESTED OPERATING CONDITIONS

Bed Type

Dual media; anthracite 15-18 in. (381 mm-457 mm) and GreensandPlus 15-24 in. (381 mm - 610 mm)

Capacity

700-1200 grains of oxidized iron and manganese/sq.ft. of bed area based on oxidant demand and operation to iron break through or dp limitations.

Backwash

Sufficient rate using treated water to produce 40% bed expansion until waste water is clear, or for 10 minutes, whichever occurs first.

Air/Water Scour

Optional using 0.8-2.0 cfm/sq. ft. (15 m/hr -37 m/hr) with a simultaneous treated water backwash at 4.0-4.5 gpm/sq. ft. (9.8 m/hr - 11.03 m/hr)

Raw Water Rinse

At normal service flow rate for 3 minutes or until effluent is acceptable.

Flow Rate

Recommended flow rates with CO operation are 2-12 gpm/sq. ft. (4.9 m/hr - 29.4 m/hr). High concentrations of iron and manganese usually require lower flow rates for equivalent run lengths. Higher flow rates can be considered with low concentrations of iron and manganese. For optimizing design parameters, pilot plant testing is recommended.The run length between backwashes can be estimated as follows:

What is the run length for a water containing 1.7 mg/L iron and 0.3 mg/L manganese at a 4 gpm/sq. ft. service rate:

Contaminant loading
= (1 x mg/L Fe) + (2 x mg/L Mn)
= (1 x 1.7) + (2 x 0.3)
= (2.3 mg/L or 2.3/17.1 = 0.13 grains/gal. (gpg)

At 1,200 grains / sq. ft. loading ÷ 0.13 gpg = 9,230 gal./sq. ft.

At 4 gpm / sq. ft. service rate 9,230/4 = 2,307 min.

The backwash frequency is approximately every 32-38 hours of actual operation.

The Intermittent regeneration (IR) operation is available for certain applications. Contact your Inversand representative for additional information.

GENERAL NOTES

pH

Raw waters having natural pH of 6.2 or above can be filtered through GreensandPlus without pH correction. Raw waters with a pH lower than 6.2 should be pH-corrected to 6.5-6.8 before filtration. Additional alkali should be added following the filters if a pH higher than 6.5-6.8 is desired in the treated water. This prevents the possible adverse reaction and formation of a colloidal precipitate that sometimes occurs with iron and alkali at a pH above 6.8.

Initial Conditioning of GreensandPlus

GreensandPlus media must be backwashed prior to adding the anthracite cap. The GreensandPlus backwash rate must be a minimum of 12 gpm/sq. ft. @ 55 °F.

This initial backwash could last for up to 60 minutes to thoroughly remove the fine dust. After backwashing is complete, the GreensandPlus must be conditioned. Mix 0.5 gal. (1.9 L) of 6% household bleach or

Initial Conditioning of GreensandPlus

0.2 gal (0.75 L) of 12% sodium hypochlorite for every 1 cu. ft. (28.3 L cu. m) of GreensandPlus into 6.5 gallons (25 L) of water.

Drain the filter enough to add the diluted chlorine mix. Apply the diluted chlorine to the filter being sure to allow the solution to contact the GreensandPlus media. Let soak for a minimum of 4 hours, then rinse to waste until the “free” chlorine residual is less than 0.2 mg/L. The GreensandPlus is now ready for service.

REFERENCES

USA

American Water Company, CA
San Jacinto, CA
City of Tallahassee, FL
Adedge Technologies, Inc., Buford, GA
City of Mason City, IL
City of Goshen, IN
City of Hutchinson, KS
City of Burlington, MA
Dedham Water Co., MA
Raynham Center, MA
Northbrook Farms, MD
Sykesville, MD
Tonka Equipment Company, Plymouth, MN
City of New Bern, NC
Onslow County, NC
Hungerford & Terry, Inc., Clayton, NJ
Fort Dix, NJ
Jackson Twsp. MUA, NJ

Radium and Arsenic Removal Using GreensandPlus

The GreensandPlus CO process has been found to be successful in removing radium and arsenic from well water. This occurs via adsorption onto the manganese and/or iron precipitates that are formed. For radium removal, soluble manganese must be present in or added to the raw water for removal to occur. Arsenic removal requires iron to be present in or added to the raw water to accomplish removal. Pilot plant testing is recommended in either case.

USA

Churchill County, NV
Suffolk County Water Authority, NY
City of Urbana, OH
Roberts Filter Group, Darby, PA

International

Watergroup, Saskatoon, SK Canada
BI Pure Water, Surrey, BC Canada
Sydney, Nova Scotia, Canada
PT Besflo Prima, Jakarta, Indonesia
Eurotrol, Milanese, Italy
Gargon Industrial, Mexico City, Mexico
Filtration Tech, Auckland, New Zealand
Alamo Water Poland, Izabelin, Poland
Aquatrol Company, Moscow, Russia
Impulse Group, St. Petersburg, Russia
Brenntag Nordic, Taby, Sweden
Nema Kimya, Istanbul, Turkey
Minh Tam, Ho Chi Minh City, Vietnam

The manufacturing of GreensandPlus is an ongoing, 24/7 process to ensure the highest quality water treatment media.

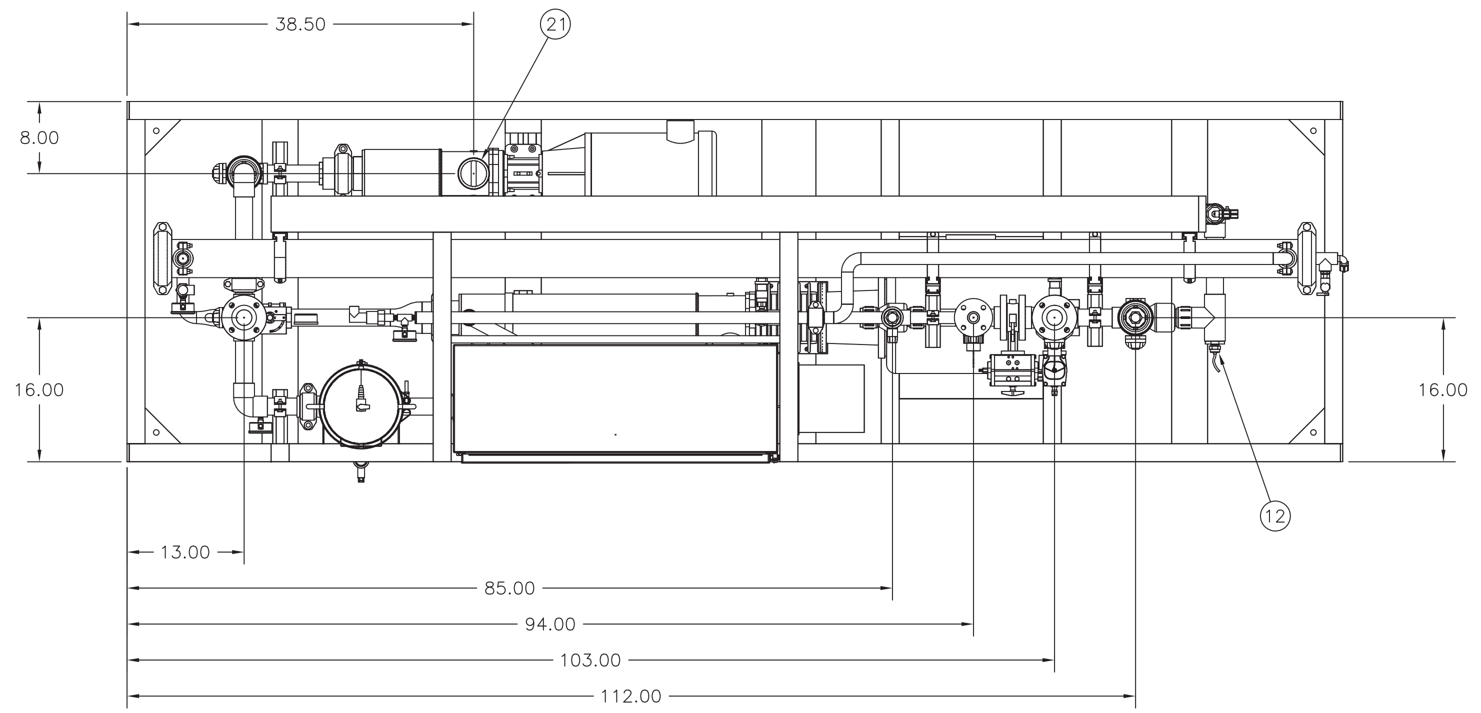
Distributed by:

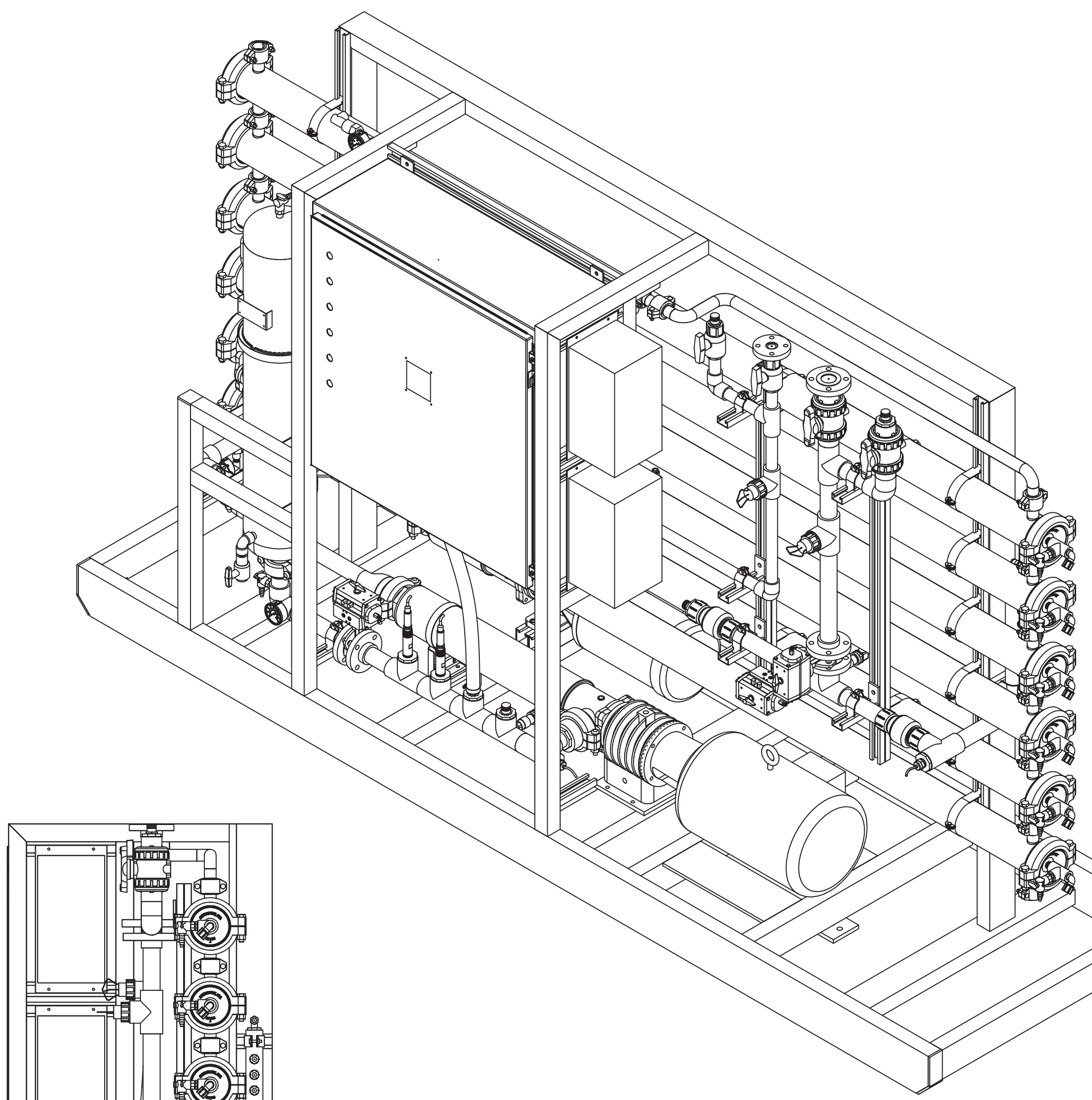
Inversand Company
SINCE 1926
226 Atlantic Avenue • P.O. Box 650
Clayton, NJ 08312 USA
T: 856-881-2345 • F: 856-881-6859
E:info@inversand.com •**www.inversand.com**

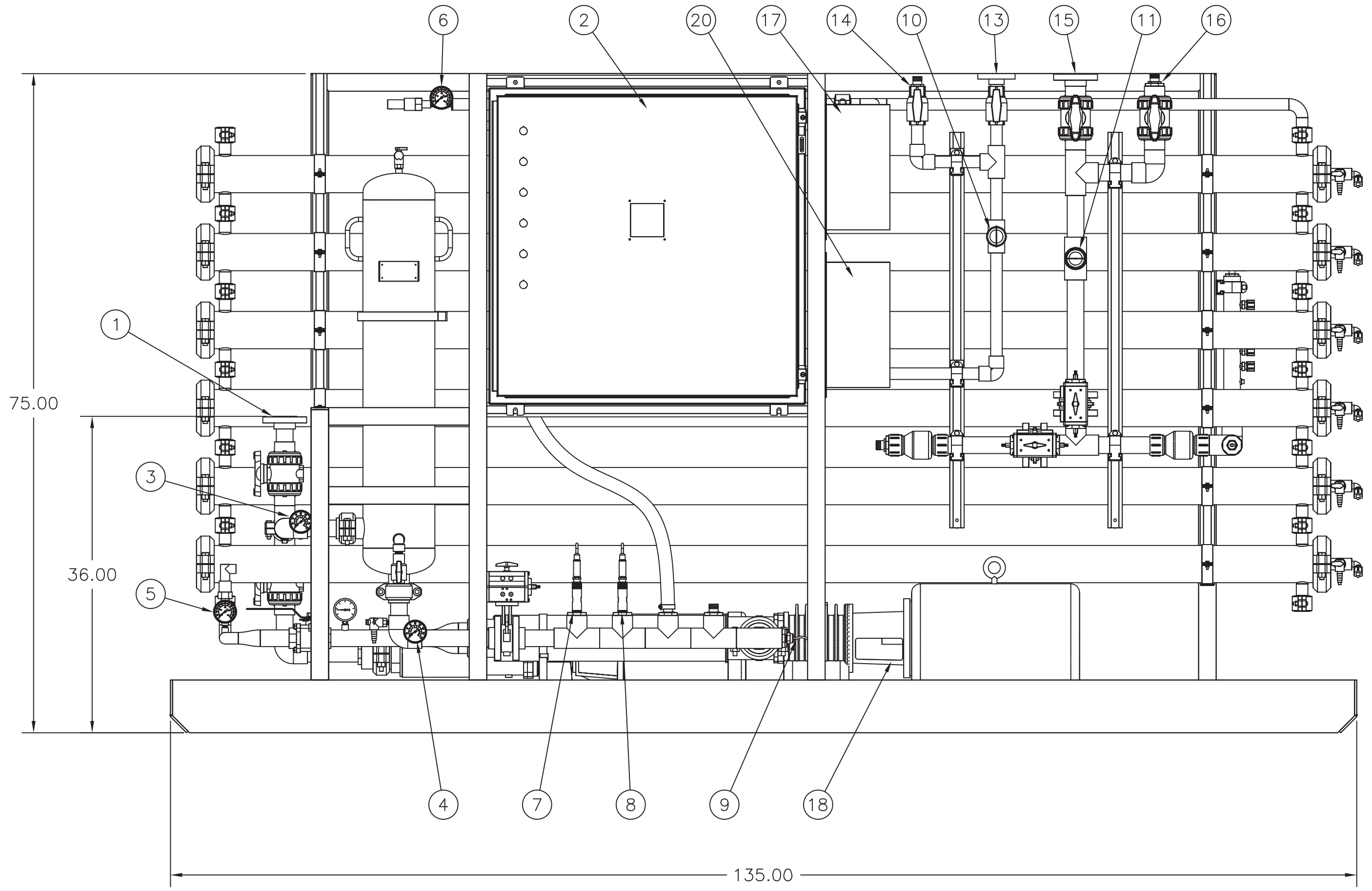
C USA

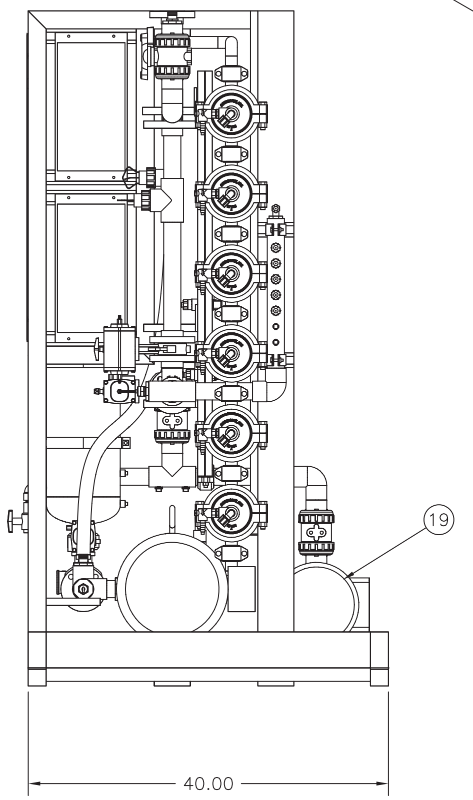
REVISION HISTORY

REV	ZONE	DESCRIPTION	ECO	DWN	DATE	APVD
A	–	INITIAL RELEASE	–	–	–	–









LEGEND

1. INLET, 1.50" FLANGE
2. ELECTRICAL ASSEMBLY
3. PRE–FILTER PRESSURE GAUGE, 1–160 PSIG
4. POST–FILTER PRESSURE GAUGE, 1–160 PSIG
5. PRIMARY PRESSURE GAUGE/TRANSMITTER, 1–600 PSIG
6. FINAL PRESSURE GAUGE/TRANSMITTER, 1–600 PSIG
7. INLET ORP, THORNTON 770MAX
8. INLET pH, THORNTON 770MAX
9. INLET CONDUCTIVITY, THORNTON 770MAX
10. CONCENTRATE FLOWMETER, THORNTON 770MAX
11. PERMEATE FLOWMETER, THORNTON 770MAX
12. PERMEATE CONDUCTIVITY, THORNTON 770MAX
13. CONCENTRATE OUTLET, 1.00" FLANGE
14. CONCENTRATE OUTLET CIP, 1.00" HOSEBARB
15. PERMEATE OUTLET, 1.50" FLANGE
16. PERMEATE OUTLET CIP, 1.00" HOSEBARB
17. RO MOTOR STARTER ASSEMBLY
18. RO PUMP AND MOTOR, SS5512KZA W/ 15 HP, TEFC
19. CIP PUMP AND MOTOR, SS5503G W/ 5 HP, TEFC
20. CIP MOTOR STARTER ASSEMBLY
21. CIP INLET, 3.00" VICTAULIC

NOTICE ON REPRODUCTIONS

MATERIAL SEE BOM	TOLERANCES UNLESS NOTED FRAC ± DECIMALS .X ± .XX ± .50 .XXX ± ANGLES ± 1°		
FINISH			
ORDER NO.	DWN PDT	DATE 18Jan05	
CUSTOMER	CHKD BRB	DATE 19Jan05	
CUSTOMER LOC.	APVD JSS	DATE 17Jan05	
DO NOT SCALE	APVD	DATE	

GE Osmonics
GE Water Technologies
5951 CLEARWATER DRIVE, MINNETONKA, MN 55343–8995 (952) 933–2277
WWW.GEWATER.COM

TITLE
DWG, RO, PES–18
PALL PILOT SYSTEM

SIZE		DWG NO/PN	REV
D	THIRD ANGLE	2300026A–951	A
SCALE 3/32	FILE TYPE ACR2004	SHEET 1 OF 1	

GE
Water & Process Technologies

HL Series

Water Softening NF Elements

The H-Series proprietary thin-film nanofiltration membrane elements are characterized by an approximate molecular weight cut-off of 150-300 daltons for uncharged organic molecules. Divalent and multivalent ion rejection is dependent upon feed concentration and composition.

HL Nanofiltration Elements are used for water softening, color removal, and reduction of THM formation potential.

Table 1: Element Specification

Membrane	H-Series, Thin-film membrane (TFM*)

Model	Average permeate flow gpd (m3/day)[1,2]	Average MgSO4 rejection [1,2]	Minimum MgSO4 rejection [1,2]
HL2540FM	780 (3.0)	98.0%	95.0%
HL2540TM	780 (3.0)	98.0%	95.0%
HL4040FM	2,400 (9.1)	98.0%	95.0%
HL4040TM	2,400 (9.1)	98.0%	95.0%
HL8040F 365	10,800 (40.9)	98.0%	95.0%
HL8040F-400	11,500 (43.5)	98.0%	95.0%
HL8040N	10,100 (38.2)	97.5%	95.0%

[1] Average salt rejection after 24 hours operation. Individual flow rate may vary +25%/-15%.

[2] Testing conditions: 2,000ppm MgSO4 solution at 110psi (760kPa) operating pressure, 77°F, pH7.5 and 15% recovery.

Model	Active area ft^2 (m^2)	Outer wrap	Part number
HL2540FM	27 (2.5)	Fiberglass	1207230
HL2540TM	27 (2.5)	Tape	1207231
HL4040FM	89 (8.2)	Fiberglass	1207236
HL4040TM	89 (8.2)	Tape	1220990
HL8040F 365	365 (33.9)	Fiberglass	1266702
HL8040F-400	400 (37.2)	Fiberglass	1207240
HL8040N	350 (32.5)	Net	1231793

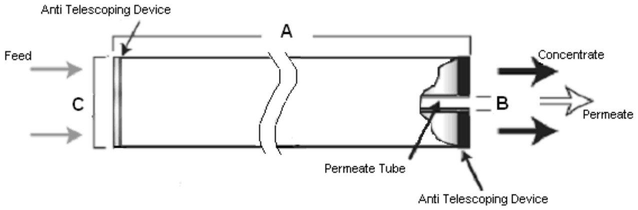


Figure 1: Element Dimensions Diagram (Female)

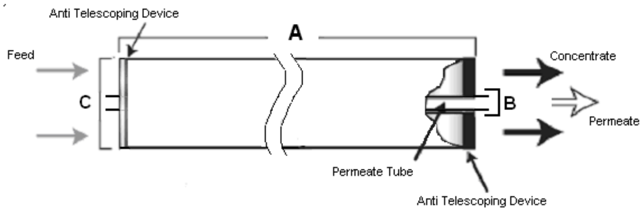


Figure 2: Element Dimensions Diagram (Male)

a product of
ecomagination℠

Table 2: Dimensions and Weight

Model[1]	Dimensions, inches (cm)			Boxed
	A	B[2]	C[3]	Weight lbs (kg)
HL2540FM	40.0 (101.6)	0.75 (1.90) OD	2.4 (6.1)	5 (2.3)
HL2540TM	40.0 (101.6)	0.75 (1.90) OD	2.4 (6.1)	5 (2.3)
HL4040FM	40.0 (101.6)	0.75 (1.90) OD	3.9 (9.9)	8 (3.5)
HL4040TM	40.0 (101.6)	0.75 (1.90) OD	3.9 (9.9)	8 (3.5)
HL8040F 365	40.0 (101.6)	1.125 (2.86)	7.9 (20.1)	32 (14.5)
HL8040F-400	40.0 (101.6)	1.125 (2.86)	7.9 (20.1)	32 (14.5)
HL8040N	40.0 (101.6)	1.125 (2.86)	7.9 (20.1)	32 (14.5)

[1] These elements are dried then bagged before shipping.

[2] Internal diameter unless specified OD (outside diameter).

[3] The element diameter (dimension C) is designed for optimum performance in GE Water & Process Technologies pressure vessels. Other pressure vessel dimension and tolerance may result in excessive bypass and loss of capacity

Table 3: Operating and CIP parameters

Typical Operating Pressure	70-300psi (483-2,069kPa)
Typical Operating Flux	10-20GFD (15-35LMH)
Maximum Operating Pressure	Tape elements: 450psi (3,103kPa) Other outer wrap: 600psi (4,140kPa)
Maximum Temperature	Continuous operation: 122°F (50°C) Clean In Place (CIP): 104°F (40°C)
pH Range	Optimum rejection: 6.0-7.0, Continuous operation: 3.0-9.0, Clean In Place (CIP): 2.0-10.5
Maximum Pressure Drop	Over an element: 12psi (83kPa) Per housing: 50psi (345kPa)
Chlorine Tolerance	1,000+ ppm-hours, dechlorination recommended
Feedwater	NTU < 1 SDI < 5

Product Information

FILMTEC™ Membranes

FILMTEC NF270 Nanofiltration Elements for Commercial Systems

Features

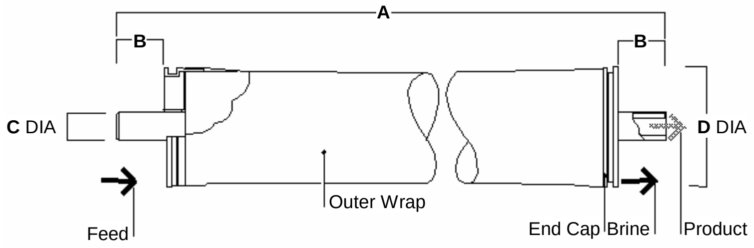
The FILMTEC™ NF270 membrane elements are ideal for removing a high percentage of TOC and THM precursors with medium to high salt passage and medium hardness passage. The FILMTEC NF270 membrane is an ideal choice for surface water and ground water where good organic removal is desired with partial softening.

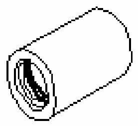
Product Specifications

Product	Part Number	Active Area ft² (m²)	Applied Pressure psig (bar)	Permeate Flow Rate gpd (m³/d)	Stabilized Salt Rejection (%)
NF270-2540	149986	28 (2.6)	70 (4.8)	850 (3.2)	>97.0
NF270-4040	149987	82 (7.6)	70 (4.8)	2,500 (9.5)	>97.0

1. Permeate flow and salt rejection based on the following test conditions: 2,000 ppm $MgSO_4$, 77°F (25°C) and 15% recovery at the pressure specified above.
2. Permeate flows for individual NF270-2540 elements may vary by -20% / +30%. NF270-4040 individual elements may vary -15% / +50%.
3. Developmental products available for sale.

Figure 1




FilmTec sells coupler part number 89055 for use in multiple element housings. Each coupler includes two 2-210 EPR o-rings, FilmTec part number 89255.

Product	Dimensions – Inches (mm) A	B	C	D
NF270-2540	40.0 (1,016)	1.19 (30)	0.75 (19)	2.4 (61)
NF270-4040	40.0 (1,016)	1.05 (27)	0.75 (19)	3.9 (99)

1. Refer to FilmTec Design Guidelines for multiple-element systems.
2. NF270-2540 has a tape outer wrap. NF270-4040 has a fiberglass outer wrap.

1 inch = 25.4 mm

Operating Limits

• Membrane Type	Polyamide Thin-Film Composite
• Maximum Operating Temperature	113°F (45°C)
• Maximum Operating Pressure	600 psi (41 bar)
• Maximum Feed Flow Rate - 4040 elements	16 gpm (3.6 m³/hr)
- 2540 elements	6 gpm (1.4 m³/hr)
• Maximum Pressure Drop - tape wrapped	13 psig (0.9 bar)
- fiberglassed	15 psig (1.0 bar)
• pH Range, Continuous Operation[a]	2 - 11
• pH Range, Short-Term Cleaning (30 min.)[b]	1 - 12
• Maximum Feed Silt Density Index	SDI 5
• Free Chlorine Tolerance[c]	< 0.1 ppm

[a] Maximum temperature for continuous operation above pH 10 is 95°F (35°C).

[b] Refer to Cleaning Guidelines in specification sheet 609-23010 for NF90.

[c] Under certain conditions, the presence of free chlorine and other oxidizing agents will cause premature membrane failure. Since oxidation damage is not covered under warranty, FilmTec recommends removing residual free chlorine by pretreatment prior to membrane exposure. Please refer to technical bulletin 609-22010 for more information.

Important Information

Proper start-up of reverse osmosis water treatment systems is essential to prepare the membranes for operating service and to prevent membrane damage due to overfeeding or hydraulic shock. Following the proper start-up sequence also helps ensure that system operating parameters conform to design specifications so that system water quality and productivity goals can be achieved.

Before initiating system start-up procedures, membrane pretreatment, loading of the membrane elements, instrument calibration and other system checks should be completed.

Please refer to the application information literature entitled “Start-Up Sequence” (Form No. 609-02077) for more information.

Operation Guidelines

Avoid any abrupt pressure or cross-flow variations on the spiral elements during start-up, shutdown, cleaning or other sequences to prevent possible membrane damage. During start-up, a gradual change from a standstill to operating state is recommended as follows:

- Feed pressure should be increased gradually over a 30-60 second time frame.
- Cross-flow velocity at set operating point should be achieved gradually over 15-20 seconds.
- Permeate obtained from first hour of operation should be discarded.

General Information

- Keep elements moist at all times after initial wetting.
- If operating limits and guidelines given in this bulletin are not strictly followed, the limited warranty will be null and void.
- To prevent biological growth during prolonged system shutdowns, it is recommended that membrane elements be immersed in a preservative solution.
- The customer is fully responsible for the effects of incompatible chemicals and lubricants on elements.
- Maximum pressure drop across an entire pressure vessel (housing) is 30 psi (2.1 bar).
- Avoid static permeate-side backpressure at all times.

FILMTEC™ Membranes

For more information about FILMTEC membranes, call the Dow Liquid Separations business:

North America:	1-800-447-4369
Latin America:	(+55) 11-5188-9222
Europe:	(+32) 3-450-2240
Pacific:	+60 3 7958 3392
Japan:	+813 5460 2100
China:	+86 21 2301 9000

http://www.filmtec.com

Notice: The use of this product in and of itself does not necessarily guarantee the removal of cysts and pathogens from water. Effective cyst and pathogen reduction is dependent on the complete system design and on the operation and maintenance of the system.

Appendix D

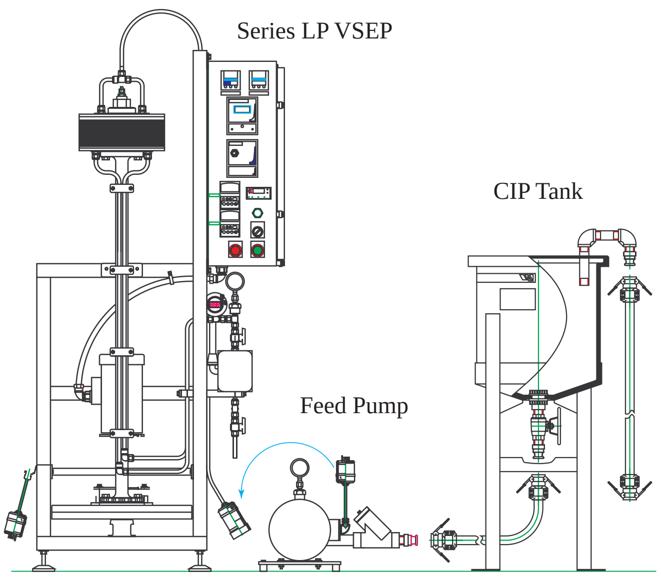
New Logic Research VSEP Pilot Unit Information

Series LP Specifications 06/01/03

VSEP - Vibratory Shear Enhanced Process

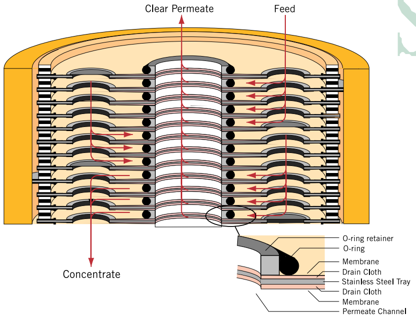
Description:

The V✧SEP Filtration System incorporates the patented Vibrating Membrane Filtration Technology. The key ingredient that comes from the vibrational oscillation is highly focused shear energy at the membrane surface. The combination of this plus pressure creates a non-fouling, high yielding, and efficient way of filtration for previously difficult separation applications. Throughputs of up to 225,000 GPD per module, (based on 150 GFD) are possible with a footprint of only 16 SF (1.5 m2). Torsional vibration created by an induced wobble in an opposing mass creates the necessary shear at the membrane.



Series LP V✧SEP Equipment Set Up

Filter Pack Cross Section



Series LP

The pilot scale VSEP unit is known as the *Series L/P*. This unit is inter-convertible between pilot (P), and laboratory modes (L). In the laboratory L mode, the system acts as a *Series L* with 0.4785 ft^2 of membrane area. However, in pilot P mode, with the addition of a small membrane stack, the membrane area is 16.44 ft^2. For most Microfiltration and Ultrafiltration applications, the Series L/P will filter between 62.5 and 125 gallons per hour (236-473 liters per hour). For Nanofiltration and RO applications, the system will filter approximately 25 to 94 gallons per hour (95-356 liters per hour). These ranges will vary according to feed material, pressure, temperature, and membrane selection.

Specifications:

1] Filter Pack

Membrane:	Reverse Osmosis-Microfiltration
Membrane Area:	16.8 square ft. (1.5 m2)
Max. Temperature:	up to 284 ^{O}F (140ºC)
Allowable Ph Range:	1-14
Elastomers (O-rings):	EPDM,(Options for Buna, Viton)
Wetted Steel Trays:	304 .018 Gauge Stainless Steel

2] Piping

Maximum Pressure:	600 psi
Process Piping:	1/2” 316L Stainless Steel
Clean in Place Tank:	15 Gallon Polyethylene
Flow Control Valves:	Parker 12Z-PR4-VT-SS

3] Vibration System

Motor:	Baldor, 2HP, 3525 RPM
Speed Controller:	“ABB” ACS400501635
Maximum Decibels:	65

4] Electrical Specifications:

Power Supply Voltage:	240VAC 3 Phase 50/60Hz
Full Load Amp Rating:	30 Amps
Normal Load Amps:	9-26 Amps
Pressure Sensors:	Wika 0-600 Analog Gauge

5] Feed Pump Specifications:

Feed Pump Type:	Hydra-Cell M-10MRSEHHC
Power Supply Voltage:	240VAC 3 Phase 50/60Hz
Motor:	Baldor, 5HP, 1725 RPM, TEFC
Pressure Relief:	Wanner Bypass C22ADBESSEF

6] Pre-Screen Bag Filter:

Filter Housing Type:	316 SS Y-Strainer
Filter Size:	100 Mesh
Capacity:	10 GPM Each

7] Operating Site Conditions:

Equipment Rating:	NEMA 4, Indoor/Outdoor
Ambient Temperature:	5 - 37℃
Storage Temperature:	2 - 70℃ (Protect from Freezing)
Relative Humidity:	<95%, non-condensing
Elevation:	3300 ft max without derating

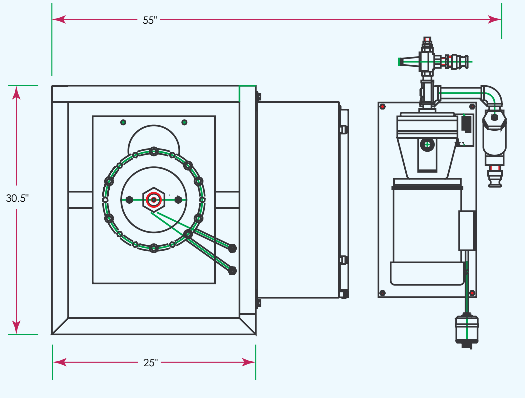
8] Instrumentation:

Temperature:	Ashcroft Digital Thermometer
pH:	Oakton Model EW-27011-11
Conductivity:	Myron L Company Model 758

VSEP Applications:

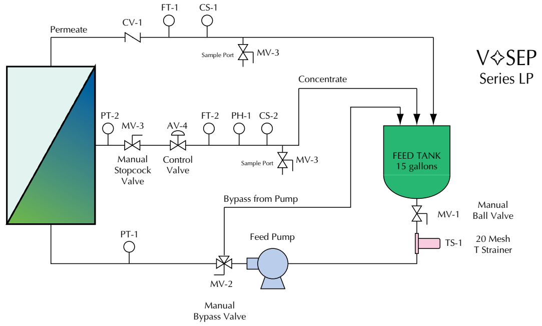
- Ultrapure Water
- Industrial Wastewater
- Chemical Processing
- Mineral Slurry Dewatering
- Glycol Recovery
- Waste Oil Recycling
- Phosphate Clarification
- Pulp & Paper Closed Loop
- Water Recycling
- Mining
- Oil Production & Processing
- Ethanol Production
- Polymer & Pigment Diafiltration
- Latex Concentration
- Laundry Wastewater Recycling
- Scrubber Blowdown

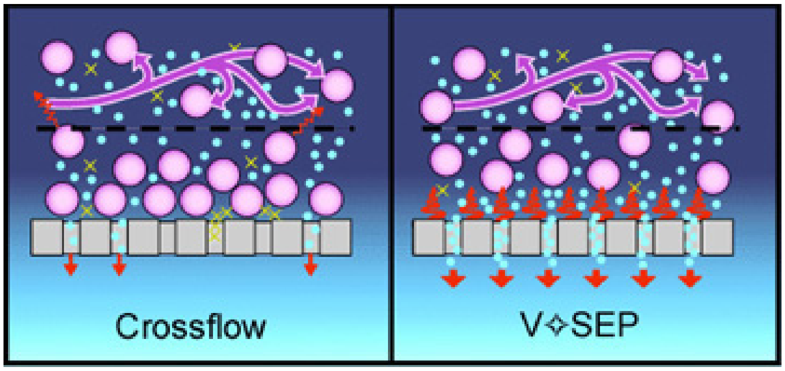
Footprint:



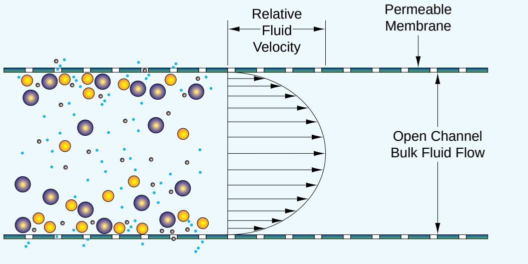
VSEP Series LP Footprint Drawing
(Tank not Shown)

Typical Simplified Flow Diagram:

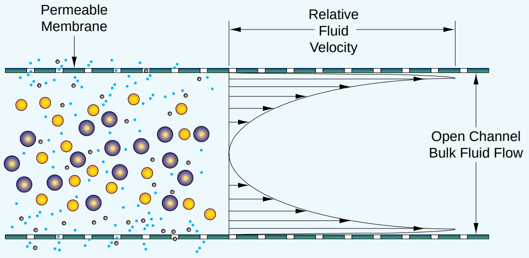




Tangential Flow Pattern in Crossflow Membrane Systems



Tangential Flow Pattern in Vibratory V✧SEP Membrane Systems



NEW LOGIC'S FILTRATION SYSTEM
MEMBRANES THAT CAN DO THIS ....

- ✔ Discriminating Molecular Separation
- ✔ Create a high solids concentrate in a **single pass**
- ✔ Separate any Liquid / Solid stream that flows
- ✔ Recovery of valuable chemical products
- ✔ Reduce operating costs and plant size
- ✔ Replace expensive, traditional processes*

(*Flocculation, Sedimentation, Vacuum Filtration, Centrifugation, Evaporation, Etc.)

New Logic Research
1295 67th Street, Emeryville, CA 94608
1-800-BUY VSEP
510-655-7305 tel
510-655-7307 fax

For more information, visit our website:

www.vsep.com

NLR doc 300-40

Appendix E

New Logic Research VSEP WWTF Permeate Quality Projections

		Year 1 NF Concentrate		Year 1 Chemical Precipitation Effluent		Year 5 NF Concentrate		Year 5 Chemical Precipitation Effluent		Year 14 NF Concentrate		Year 14Chemical Precipitation Effluent	
		Feed	Permeate	Feed	Permeate	Feed	Permeate	Feed	Permeate	Feed	Permeate	Feed	Permeate
Flow Rate	Peak, GPM	120	90	120	90	220	165	210	157.5	440	330	300	225
90th Percentile Summer Ave	GPM	120	90	120	90	220	165	205	153.75	304	228	435	326.25
Ag	mg/L	0.00056	0.000022	0.00006	0.000002	0.00094	0.000038	0.00003	0.000001	0.00089	0.000036	0.00029	0.000012
Al	mg/L	0.0067	0.000043	1.59116	0.010183	0.00799	0.000051	1.57528	0.010082	0.00795	0.000051	1.71661	0.010986
As	mg/L	0.21843	0.075227	0	0	0.35097	0.120874	0	0	0.38757	0.133479	0	0
B	mg/L	0.37169	0.436116	0.63368	0.743518	0.44682	0.524269	0.85336	1.001276	0.08705	0.102139	0.52754	0.618980
Ba	mg/L	0.11973	0.007487	0.00553	0.000346	0.08859	0.005540	0.00514	0.000321	0.0686	0.004290	0.00253	0.000158
Be	mg/L	0.00155	0.001860	0	0	0.00188	0.002256	0	0	0.00181	0.002172	0	0
Ca	mg/L	653.74	69.73	698.22	74.48	1290.04	137.60	612.25	65.31	2431.02	259.31	430.87	45.96
Cd	mg/L	0.03	0.000776	0	0	0.04	0.001035	0	0	0.08	0.002069	0	0
Cl	mg/L	75.59	65.51	639.59	554.31	348.13	301.71	326.85	283.27	206.67	179.11	368.42	319.30
Co	mg/L	1.43076	0.031858	0.00037	0.000008	1.81876	0.040498	0.00105	0.000023	5.30012	0.118016	0.06894	0.001535
Cr	mg/L	0.02109	0.002250	0.0015	0.000160	0.03007	0.003207	0.00386	0.000412	0.03691	0.003937	0.00383	0.000409
Cu	mg/L	8.7867	0.108955	0.00014	0.000002	9.8497	0.122136	0.0003	0.000004	20.42663	0.253290	0.00287	0.000036
F	mg/L	6.5743	3.944580	1.79997	1.079982	5.77522	3.465132	1.75103	1.050618	5.37649	3.225894	2.08524	1.251144
Fe	mg/L	0.64036	0.025614	0.00019	0.000008	0.79364	0.031746	0.00023	0.000009	0.76991	0.030796	0.0001	0.000004
K	mg/L	62.6	23.370667	89.88	33.56	85.73	32.01	113.96	42.55	122.96	45.91	332.05	123.97
Mg	mg/L	397.48	95.40	0	0	827.55	198.61	0	0	1064.2	255.41	0	0
Mn	mg/L	1.63	0.413	3.48	0.88	2.12	0.54	12.89	3.27	6.22	1.58	26.97	6.83
Na	mg/L	336.37	112.12	573.49	191.16	341.49	113.83	582.27	194.09	654.25	218.08	1229.02	409.67
Ni	mg/L	16.24	4.20	0	0	20.19	5.22	0	0	86.71	22.43	0.1	0.026
Pb	mg/L	0.00901	0.000240	0	0	0.03712	0.000990	0	0	0.0283	0.000755	0	0.000000
Sb	mg/L	0.19441	0.010369	0.21938	0.011700	0.24855	0.013256	0.6511	0.034725	0.27352	0.014588	1.25811	0.067099
Se	mg/L	0.03011	0.002810	0.0361	0.003369	0.06766	0.006315	0.13036	0.012167	0.28772	0.026854	0.30036	0.028034
SiO2	mg/L	252.07	23.53	14.53	1.36	253.72	23.68	22.57	2.11	255.54	23.85	77.14	7.20
SO4	mg/L	1211.63	177.71	1510.09	221.48	4599.15	674.54	1482.45	217.43	8767.42	1285.89	2022.43	296.62
Tl	mg/L	0.00055	0.000029	0.00144	0.000077	0.00094	0.000050	0.00245	0.000131	0.00079	0.000042	0.00576	0.000307
V	mg/L	0.03872	0.005163	0	0	0.04651	0.006201	0	0	0.04595	0.006127	0	0
Zn	mg/L	2.31801	0.123627	0.0002	0.000011	2.89048	0.154159	0.00046	0.000025	3.94669	0.210490	0.00386	0.000206
Alkalinity	mg/L	2883.46	1614.737600	1229.37	688.447200	3874.37	2169.65	1422.49	796.59	4557.11	2551.98	2164.83	1212.30
pH	Std units	6.01	5.96	6.02	5.97	6	5.96	6.01	5.96	6.01	5.96	6.02	5.979

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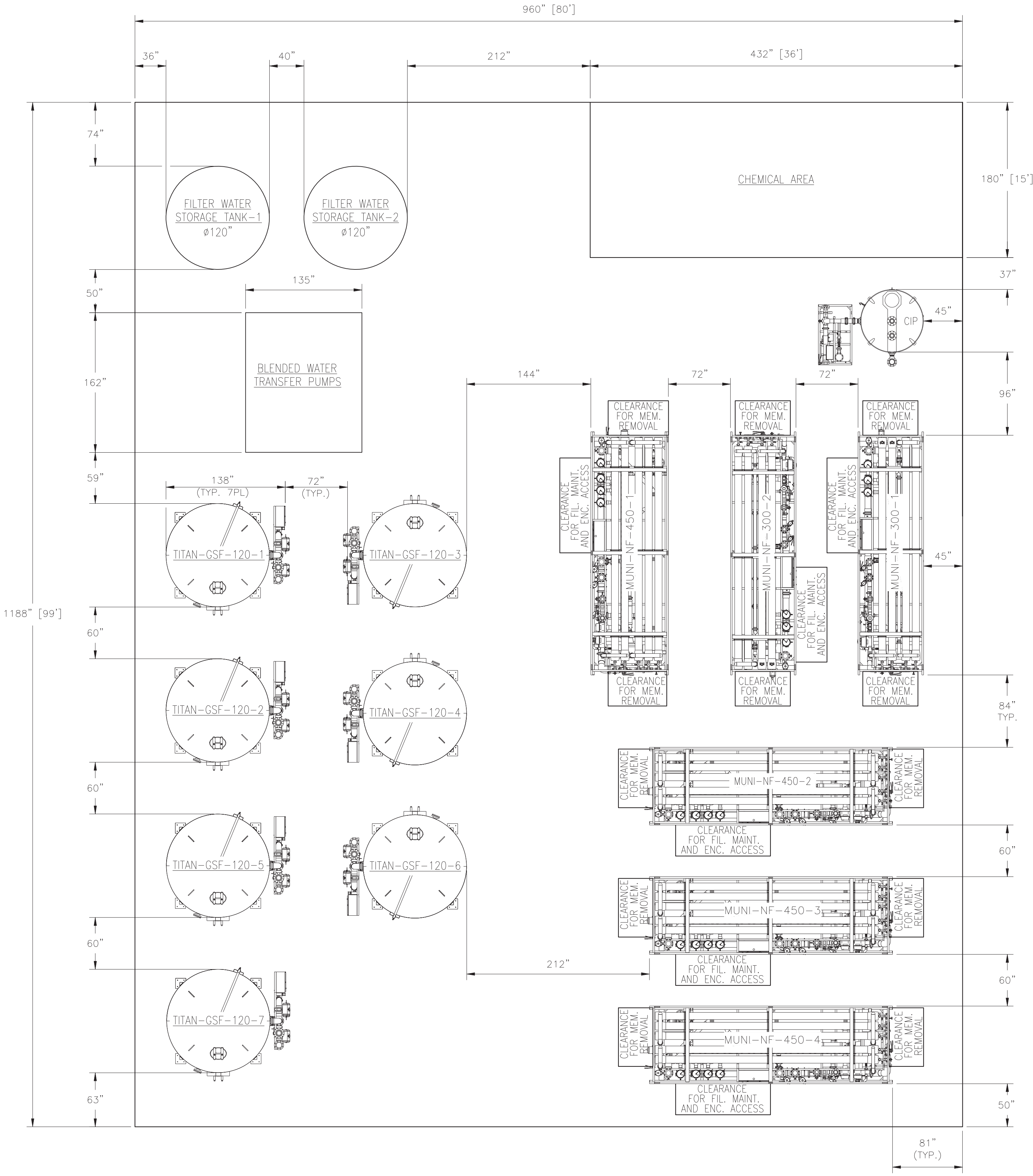
*The reduction of metals is based on projections from historical data and can vary depending on feed quality, recovery, membrane condition, and operating variables. The above is only provided as an estimate actual rejection may vary.

mgalimberti@vsep.com

Attachment F

Tailings Basin Seepage Treatment Train Vendor Data

Tailings Basin Seepage Treatment Train GE Membranes, 1/8



GE Water & Process Technologies

REFERENCE ONLY DO NOT USE FOR CONSTRUCTION

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE		EVN		03APR13	

TOLERANCES UNLESS NOTED
DECIMALS .X ± .XX ± .XXX ±
ANGLES ± FRAC ±
DIMENSIONS IN INCHES DO NOT SCALE
THIRD ANGLE

DRAWN BY EVN	DATE 03APR13
CHECKED BY	DATE
APPROVED BY	DATE
APPROVED BY	DATE

GE
Water & Process Technologies
GLOBAL HEADQUARTERS : TREVOSE, PA USA +1-215-355-3300 WWW.GEWATER.COM

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CLIENT/JOB
POLYMET MINING WWTF PROJECT
BARR ENGINEERING, MINNESOTA,

FILE AUTOCAD

TITLE
PRELIMINARY
EQUIPMENT LAYOUT

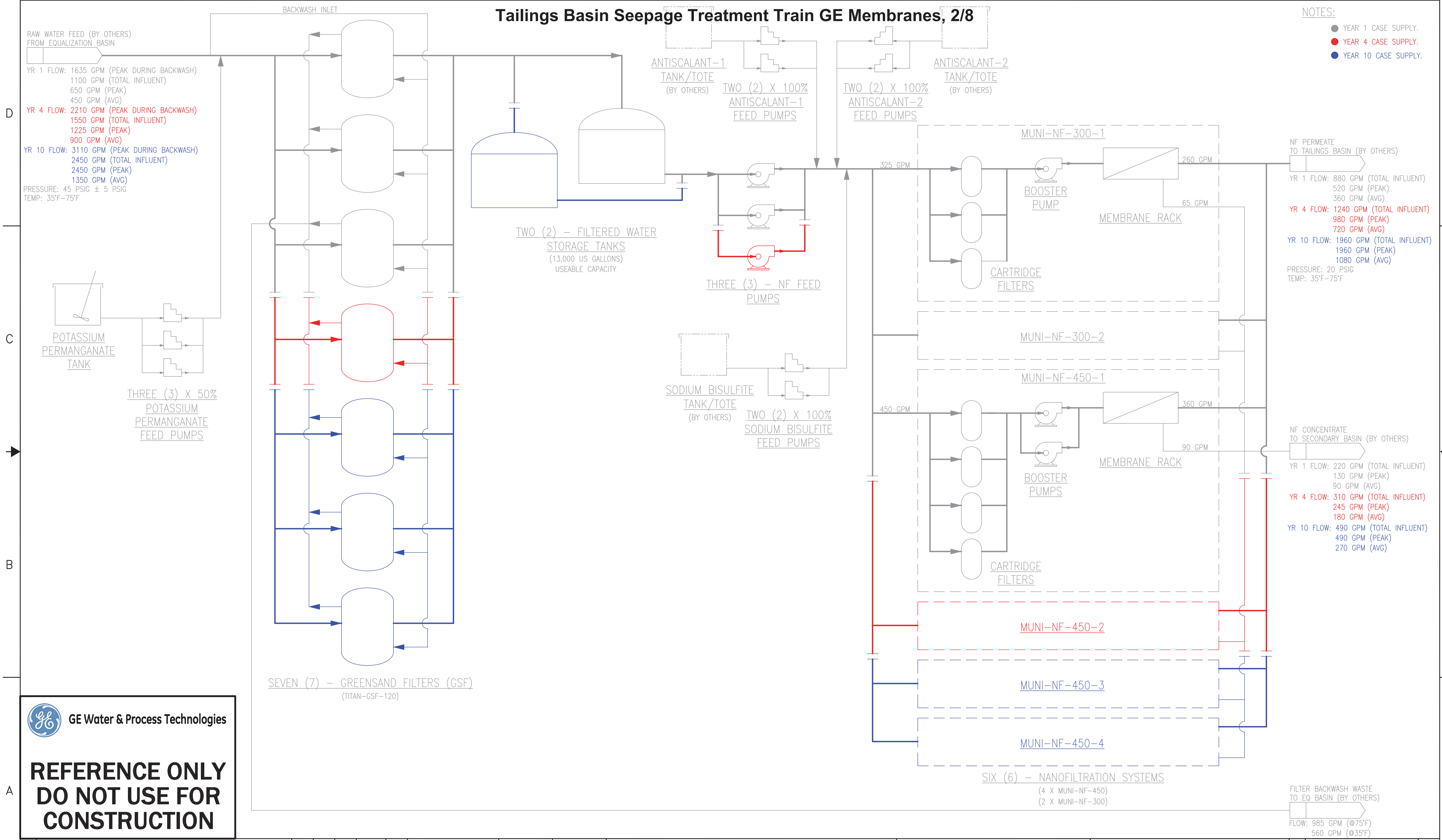
MATERIAL

SIZE	DRAWING NO.	REV
D	792240-AG-01	A1

PROJECT 792240
SCALE 1:75
SHEET 1 OF 1

P/N 1161662-RHP01

Tailings Basin Seepage Treatment Train GE Membranes, 2/8



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REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE		LVN		03APR13	

TOLERANCES UNLESS NOTED
DECIMALS
.X ±
.XX ±
.XXX ±
ANGLES
±
FRAC
±

DIMENSIONS IN INCHES
DO NOT SCALE

THIRD ANGLE

DRAWN BY MSK	DATE 02APR13
CHECKED BY	DATE
APPROVED BY	DATE
APPROVED BY	DATE

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CLIENT/JOB
POLYMET MINING WWTF PROJECT
BARR ENGINEERING, MINNESOTA,

FILE AUTOCAD

TITLE
PRELIMINARY
PROCESS FLOW DIAGRAM

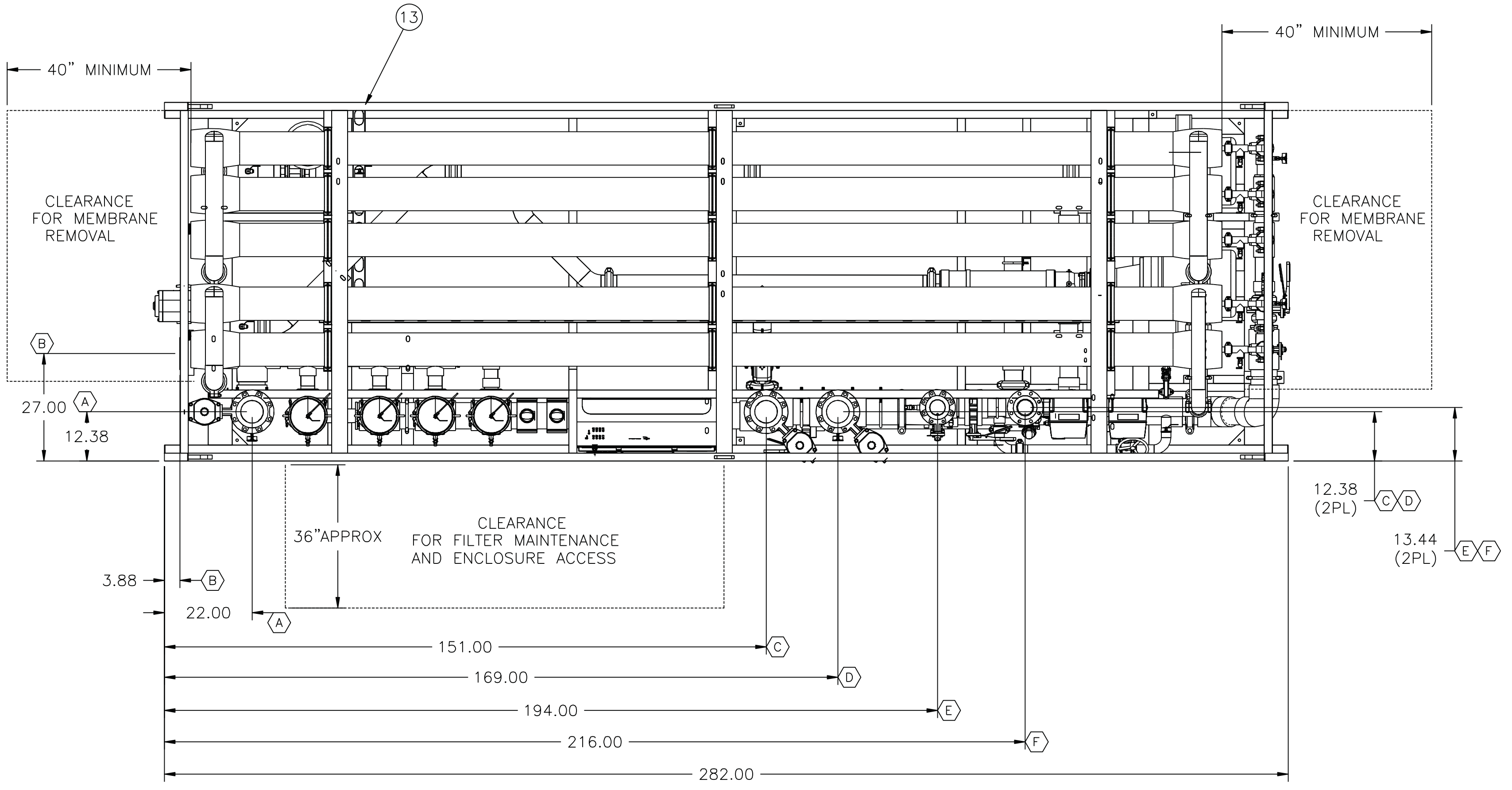
MATERIAL

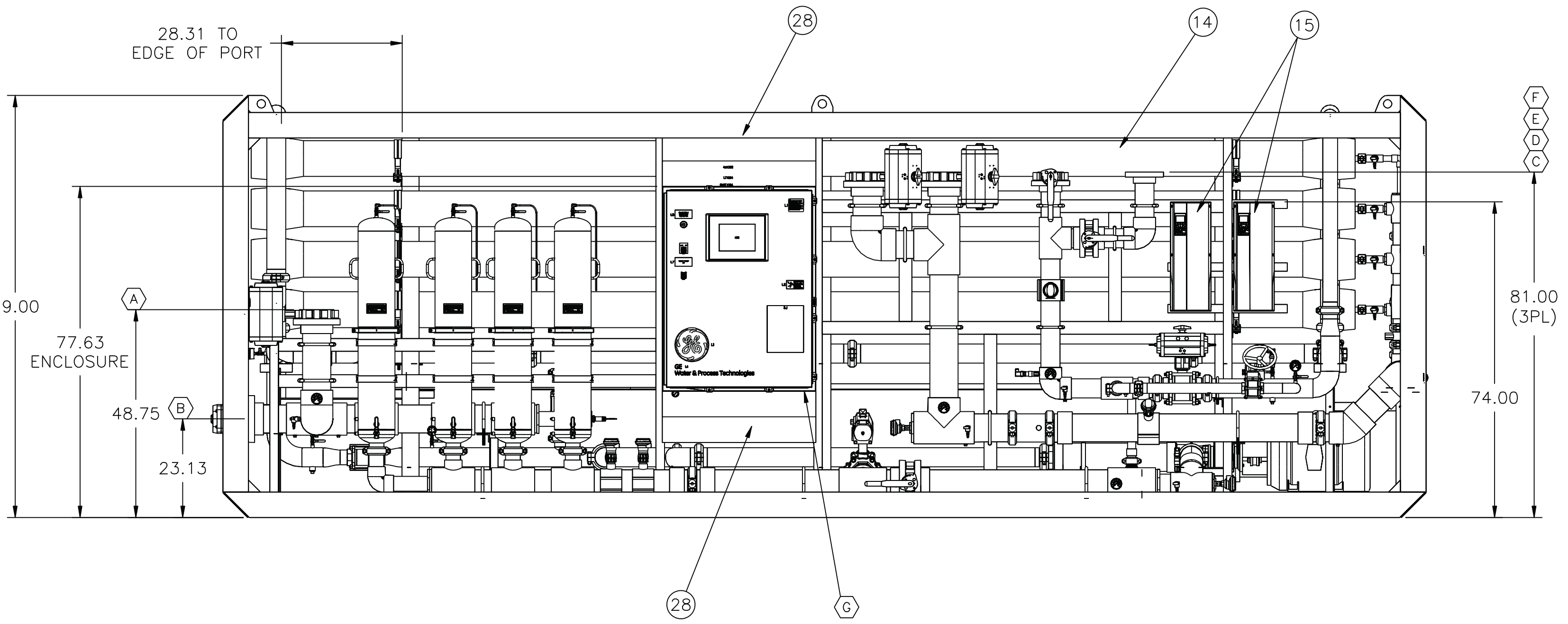
SIZE D
DRAWING NO. 792240–AM–01
REV A3
PROJECT 792240
SCALE NONE
SHEET 1 OF 1

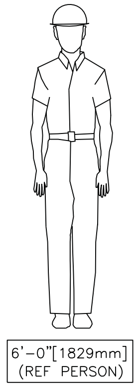
P/N 1161662–RHP01

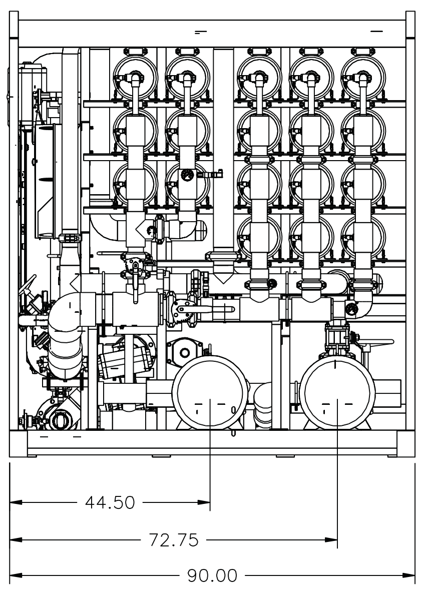
PART NUMBER	DESCRIPTION
3051902	RO,MUNI-450,480/3/60

Tailings Basin Seepage Treatment Train GE Membranes, 3/8









NOTES:

1. CONNECTION TABLE

ITEM	DESCRIPTION	MATERIAL	TYPE	SIZE
A	INLET	PVC	150# FLANGE	6.00
B	INLET CIP	PVC	150# FLANGE	6.00
C	PERMEATE OUTLET	PVC	150# FLANGE	6.00
D	PERMEATE CIP OUTLET	PVC	150# FLANGE	6.00
E	CONCENTRATE OUTLET	PVC	150# FLANGE	4.00
F	CONCENTRATE CIP OUTLET	PVC	150# FLANGE	4.00
G	COMPRESSED AIR INLET	ZINC	FNPT	0.25

2. SHIPPING WEIGHT APPROX – 21,650 LB/[9,825 Kg].
3. OPERATING WEIGHT APPROX – 27,020 LB/[12,260 Kg].
4. PLUMBING RUN \ EQUIPMENT TABLE:

FIND NO.	PART NUMBER	QTY.	DESCRIPTION	U/M
1	1115055	1	PLUG,PIPE,MPT,316,SQH,0.25,3000LB	EA
2	1115698	1	NIPPLE,MPT,316,0.25XCLS	EA
3	1144776	1	FTG-SENSOR,FLOW,PVC,6.00	EA
4	1156020	1	PLUG,M.CPLG,PVC,1.50	EA
5	1202086	1	PLUG,M.CPLG,316,1.00	EA
6	1225625	1	PUMP,TF,AS40405KZE,40HP,TEFC	EA
7	1226020	1	VALVE-BALL,FPT,316,0.25",1PC,FLO	EA
8	1268176	2	VALVE-BTFLY,NYLON,6.00,MANUAL,LUGGED	EA
9	1268181	2	VALVE-BTFLY,NYLON,6.00,A/S,LUGGED,BRAY	EA
10	3013257	1	TRANS-PRESS,DIN,316SS,0-500PSIG,4-20,GE	EA
11	3020604	2	STARTER,ABB,COMBO,IEC,460VAC,40HP,N4 PL	EA
12	3034594	1	SENSOR,ORP,SIGNET,3-2725-6,3-2750-2	EA
13	3035326	3	DUCT,WIRE,3.00,VENTED,CS,3M,PAINTED	EA
14	3035340	18	HSG,SH-6/823,FRP,32VIC,4P,WAVE,450,V,COD	EA
15	3042688	2	VFD,GE,AF-650GP,40HP,N4,460VAC,3PH	EA
16	3051915	1	PLMB-INLET,PVC,6.00,MUNI-450	EA
17	3051916	1	PLMB-PERM,PVC,6.00,MUNI-450	EA
18	3051917	1	PLMB-CONC LP,PVC,4.00,MUNI-450	EA
19	3051918	1	PLMB-CONC HP,316,4.00,3PC,MUNI-450	EA
20	3051919	1	PLMB-PUMP DISCH,316,4.00,6PC,MUNI-450	EA
21	3051930	1	PLMB-RECY,316,1.50,MUNI-450	EA
22	3051931	1	PLMB-CONC B1,316,4.00,2PC,MUNI-450	EA
23	3051932	1	PLMB-INLET B2,316,4.00,6PC,MUNI-450	EA
24	3051933	1	FRAME,CS,282LX90WX99H,MUNI-450	EA
25	3052830	1	PUMP,TF,AS40405KZE,40HP,TEFC,F2	EA
26	3053053	1	ENCL-MACH,MUNI-RO,AB,120VAC,60HZ,RIO	EA
27	3053054	1	ENCL-MACH,MUNI-RO,AB,120VAC,60HZ,CP	EA
28	3053193	2	ENCL-HOOD-PNTD,CS,MUNI100-450	EA
29	3053483	2	SPOOL-OPTIONAL,316,4.00,MUNI,MANUAL	EA
30	3053484	2	SPOOL-OPTIONAL,316,4.00,MUNI,AUTOMATIC	EA

5. ALL DIMENSIONS IN INCHES.
6. REFERENCE – PIPING AND INSTRUMENTATION DIAGRAM: 1308275

◆7 OPTIONAL EQUIPMENT. REFERENCE BILL OF MATERIAL FOR CUSTOMER SPECIFIC OPTIONS.

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	14334	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
.X ± ±
.XX ± 0.50 FRAC
.XXX ± ±
DIMENSIONS IN INCHES
DO NOT SCALE
THIRD ANGLE

DRAWN BY	JWA	DATE 17MAY10
CHECKED BY	JSS	DATE 16Nov10
APPROVED BY	BRB	DATE 16Nov10
APPROVED BY		DATE

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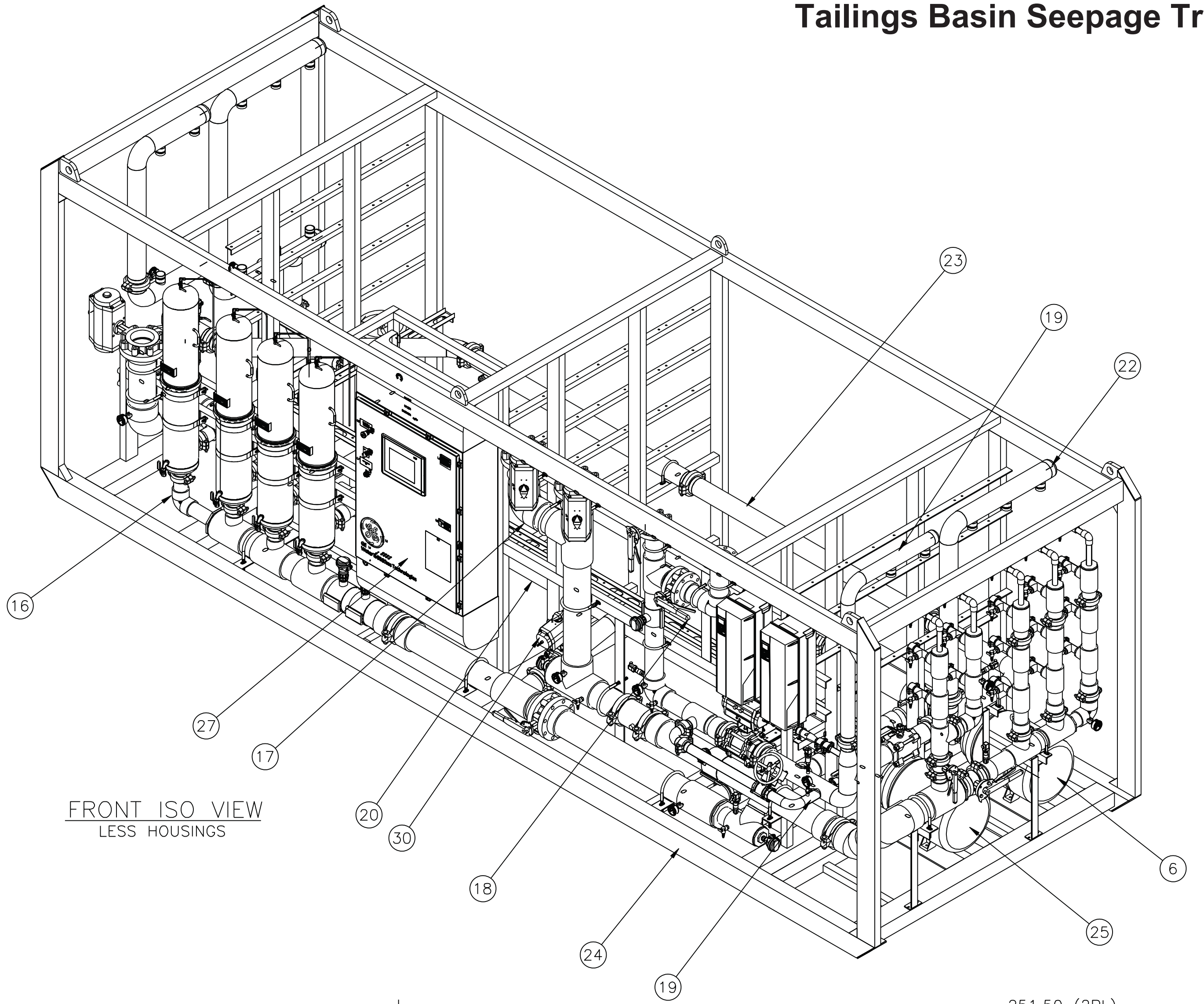
CLIENT/JOB
FILE ACR2007

TITLE
GA,RO,MUNI-450,
480/3/60
MATERIAL SEE BOM

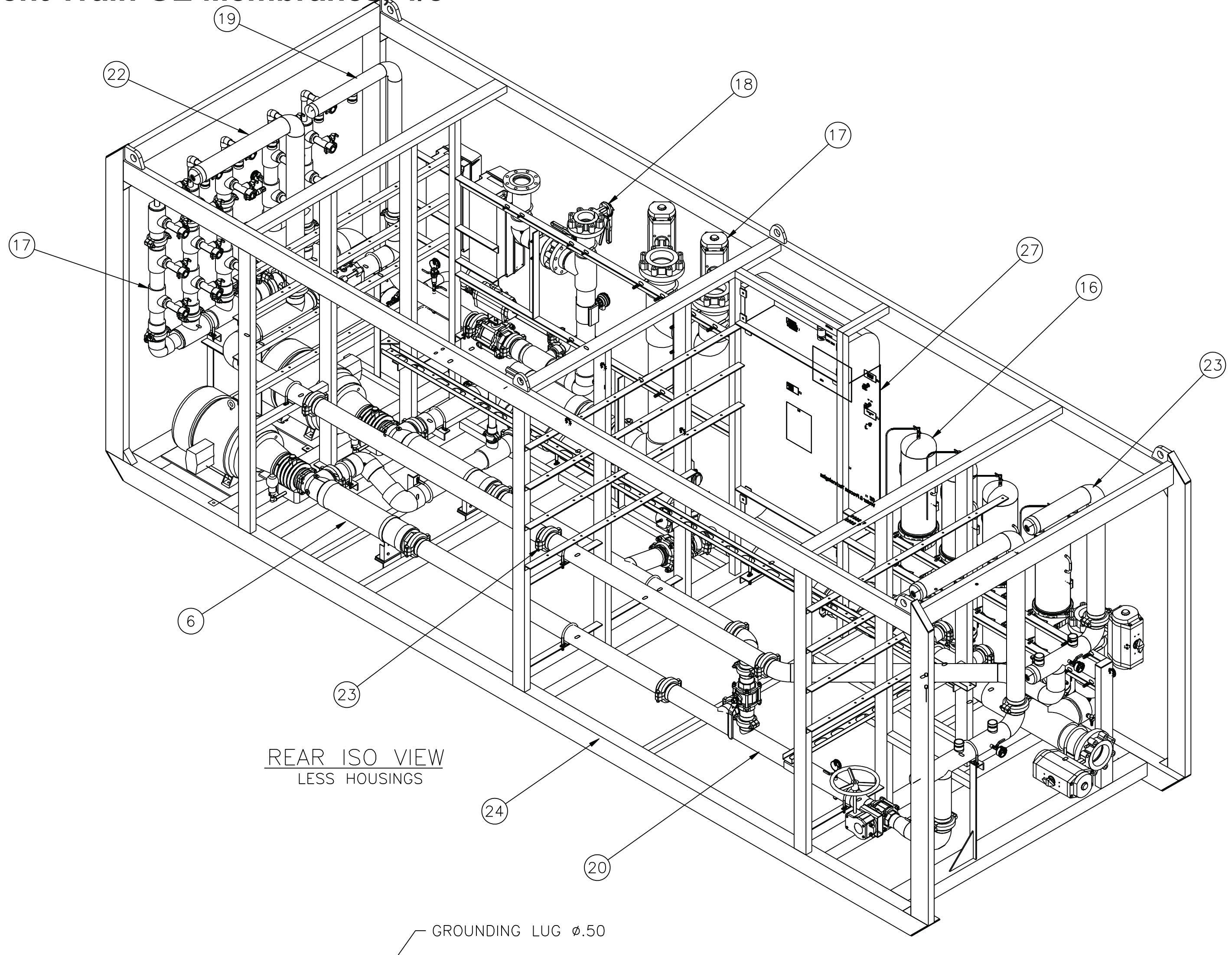
SIZE D
DRAWING NO. 1308274
REV A
PROJECT
SCALE 3:64
SHEET 1 OF 3

P/N 1161662-RHP01

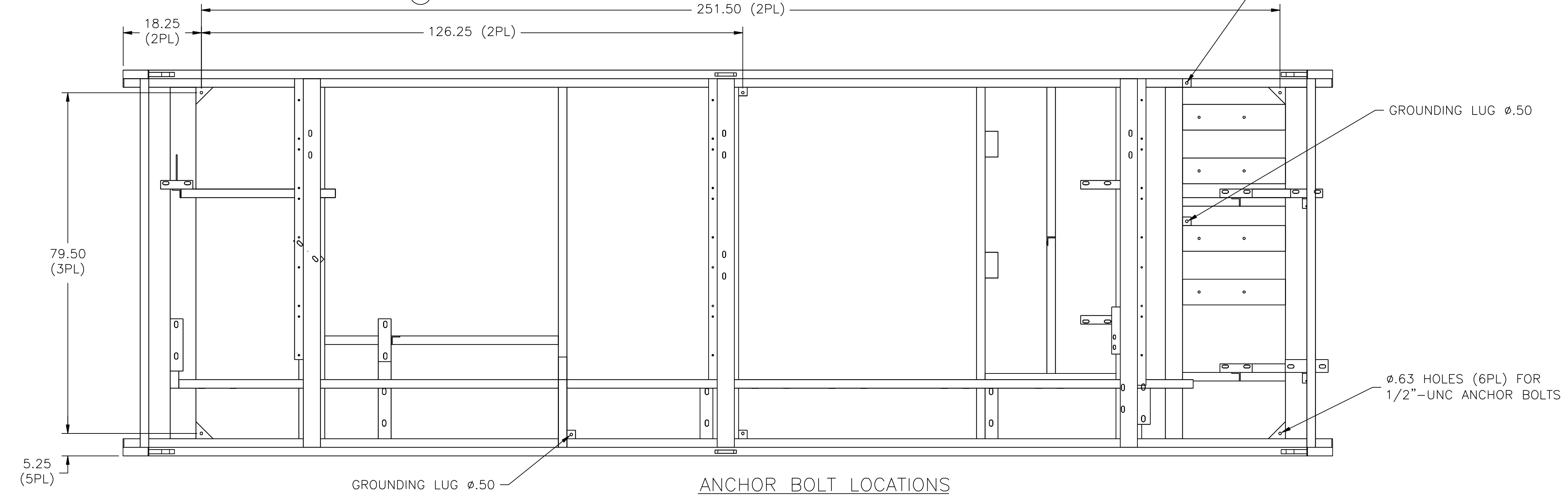
Tailings Basin Seepage Treatment Train GE Membranes, 4/8



FRONT ISO VIEW
LESS HOUSINGS



REAR ISO VIEW
LESS HOUSINGS



ANCHOR BOLT LOCATIONS

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	14334	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
.X ± ±
.XX ± FRAC
.XXX ± ±
DIMENSIONS IN INCHES
DO NOT SCALE
THIRD ANGLE

DRAWN BY	JWA	DATE	17MAY10
CHECKED BY	JSS	DATE	16Nov10
APPROVED BY	BRB	DATE	16Nov10
APPROVED BY		DATE	

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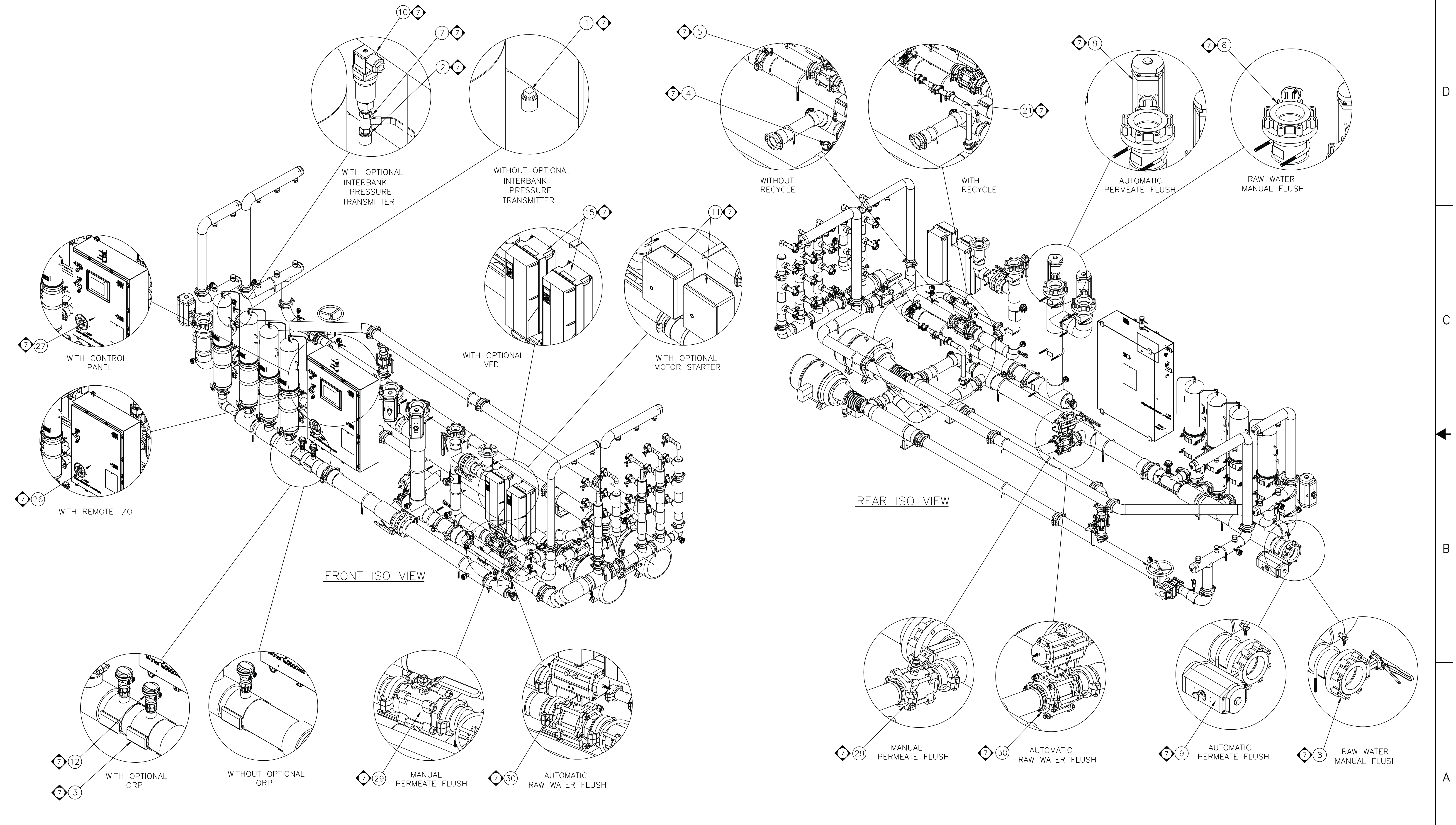
CLIENT/JOB
FILE ACR2007

TITLE
GA,RO,MUNI-450,
480/3/60
MATERIAL SEE BOM

SIZE D
DRAWING NO. 1308274
REV A
PROJECT
SCALE 1:16
SHEET 2 OF 3

P/N 1161662-RHP01

Tailings Basin Seepage Treatment Train GE Membranes, 5/8



REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	14334	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
.X ± ±
.XX ± FRAC
.XXX ± ±

DIMENSIONS IN INCHES DO NOT SCALE
THIRD ANGLE

DRAWN BY JWA	DATE 17MAY10
CHECKED BY JSS	DATE 16Nov10
APPROVED BY BRB	DATE 16Nov10
APPROVED BY	DATE

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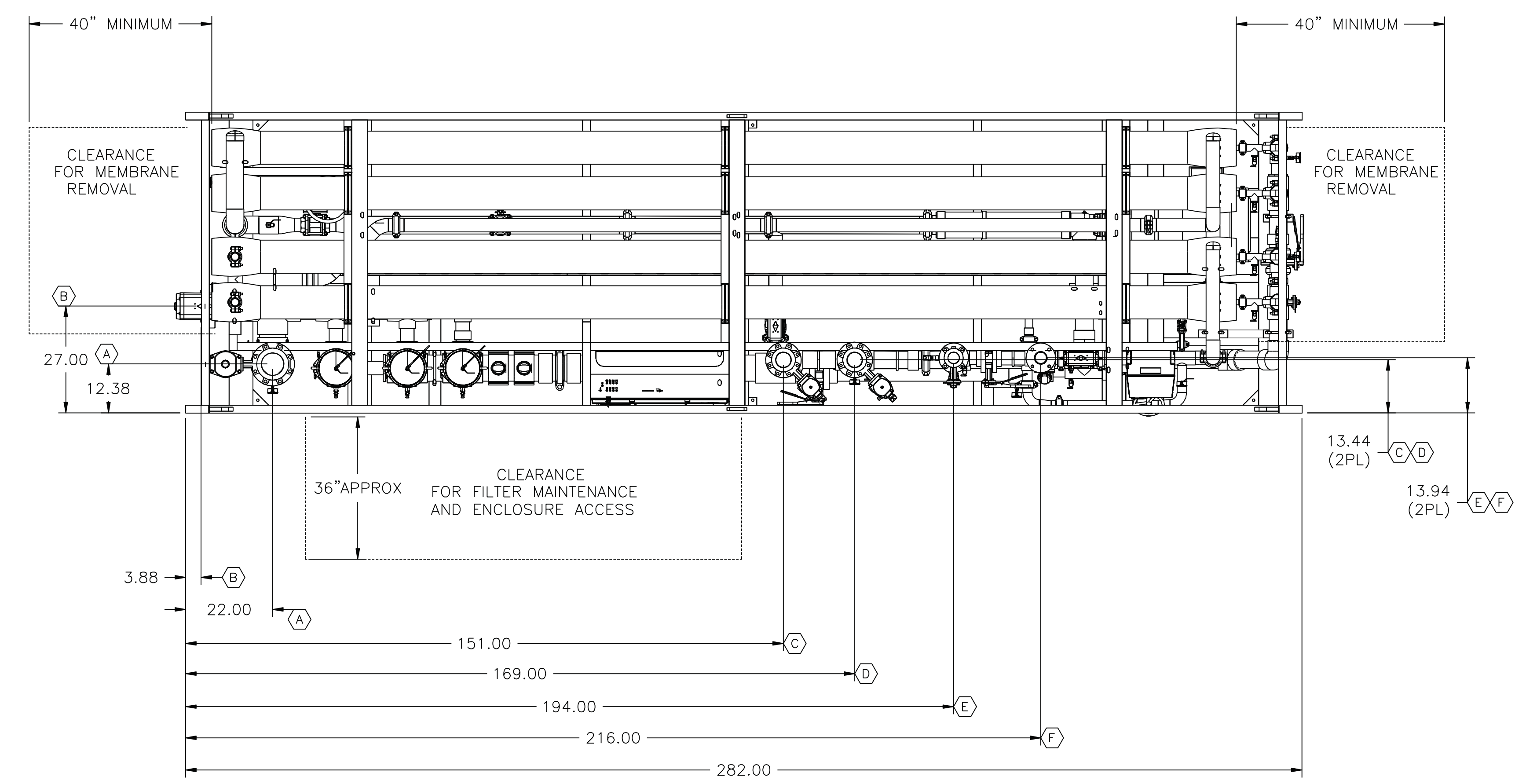
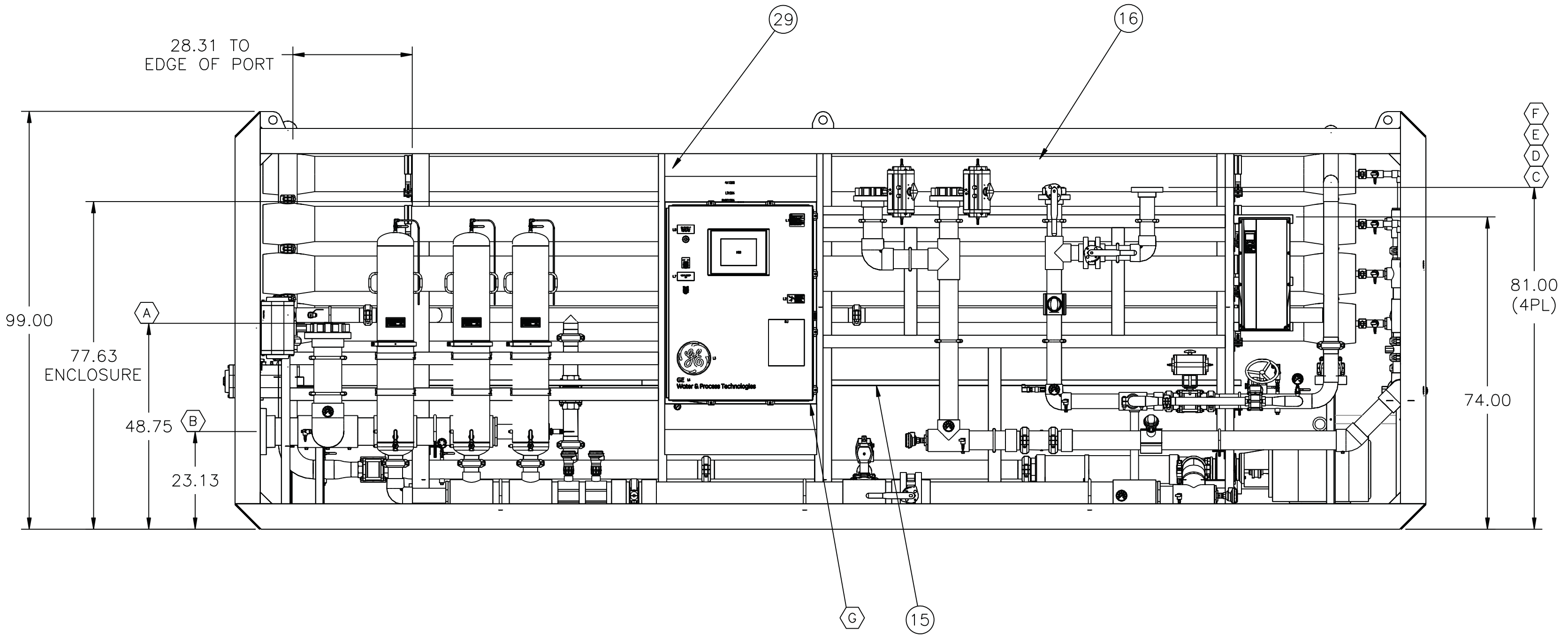
CLIENT/JOB
FILE ACR2007
TITLE GA,RO,MUNI–450, 480/3/60
MATERIAL SEE BOM
SIZE D
DRAWING NO. 1308274
REV A
PROJECT
SCALE NONE
SHEET 3 OF 3

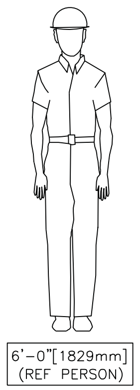
P/N 1161662–RHP01

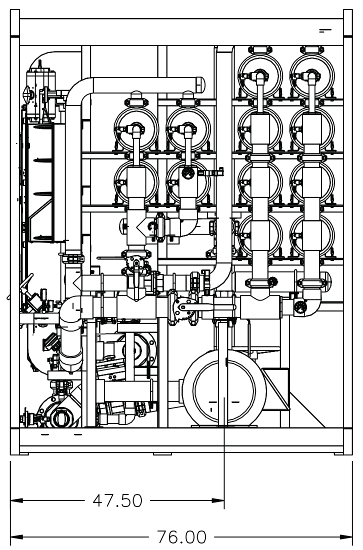
PART NUMBER	DESCRIPTION
3051903	GA,RO,MUNI-300,480/3/60

Tailings Basin Seepage Treatment Train GE Membranes, 6/8









NOTES:

1. CONNECTION TABLE

ITEM	DESCRIPTION	MATERIAL	TYPE	SIZE
A	INLET	PVC	150# FLANGE	6.00
B	INLET CIP	PVC	150# FLANGE	6.00
C	PERMEATE OUTLET	PVC	150# FLANGE	4.00
D	PERMEATE CIP OUTLET	PVC	150# FLANGE	4.00
E	CONCENTRATE OUTLET	PVC	150# FLANGE	4.00
F	CONCENTRATE CIP OUTLET	PVC	150# FLANGE	4.00
G	COMPRESSED AIR INLET	ZINC	FNPT	0.25

2. SHIPPING WEIGHT – 12,500 LB/[5,670 Kg].
3. OPERATING WEIGHT – 23,650 LB/[10,727 Kg].
4. PLUMBING RUN \ EQUIPMENT TABLE:

FIND NO.	PART NUMBER	QTY.	DESCRIPTION	U/M
1	1115055	1	PLUG,PIPE,MPT,316,SQH,0.25,3000LB	EA
2	1115698	1	NIPPLE,MPT,316,0.25XCLS	EA
3	1144776	1	FTG–SENSOR,FLOW,PVC,6.00	EA
4	1161642	1	PLUG,M.CPLG,316,1.5	EA
5	1202086	1	PLUG,M.CPLG,316,1.00	EA
6	1225627	1	PUMP,TF,AS40406KZE,50HP,TEFC	EA
7	1226020	1	VALVE–BALL,FPT,316,0.25",1PC,FLO	EA
8	1268175	1	VALVE–BTFLY,NYLON,4.00,MANUAL,LUGGED	EA
9	1268176	1	VALVE–BTFLY,NYLON,6.00,MANUAL,LUGGED	EA
10	1268180	1	VALVE–BTFLY,NYLON,4.00,A/S,LUGGED,BRAY	EA
11	1268181	1	VALVE–BTFLY,NYLON,6.00,A/S,LUGGED,BRAY	EA
12	3013257	1	TRANS–PRESS,DIN,316SS,0–500PSIG,4–20,GE	EA
13	3020605	1	STARTER,ABB,COMBO,IEC,460VAC,50HP,N4 PL	EA
14	3034594	1	SENSOR,ORP,SIGNET,3–2725–6,3–2750–2	EA
15	3035326	2	DUCT,WIRE,3.00,VENTED,CS,3M,PAINTED	EA
16	3035340	12	HSG,SH–6/823,FRP,32VIC,4P,WAVE,450,V,COD	EA
17	3051935	1	PLMB–INLET,PVC,6.00,MUNI–300	EA
18	3051936	1	PLMB–PERM,PVC,4.00,MUNI–300	EA
19	3051937	1	PLMB–CONC LP,PVC,3.00,MUNI–300	EA
20	3051938	1	PLMB–CONC HP,316,3.00,3PC,MUNI–300	EA
21	3051939	1	PLMB–PUMP DISCH,316,4.00,4PC,MUNI–300	EA
22	3051940	1	PLMB–RECY,316/PVC,1.50,MUNI–300	EA
23	3051941	1	PLMB–CONC B1,316,3.00,MUNI–300	EA
24	3051942	1	PLMB–INLET B2,316,3.00,5PC,MUNI–300	EA
25	3051943	1	FRAME,CS,282LX76WX99H,MUNI–300	EA
26	3052306	1	VFD,GE,AF–650GP,50HP,N4,460VAC,3PH	EA
27	3053053	1	ENCL–MACH,MUNI–RO,AB,120VAC,60HZ,RIO	EA
28	3053054	1	ENCL–MACH,MUNI–RO,AB,120VAC,60HZ,CP	EA
29	3053193	2	ENCL–HOOD–PNTD,CS,MUNI100–450	EA
30	3053485	2	SPOOL–OPTIONAL,316,3.00,MUNI,MANUAL	EA
31	3053486	2	SPOOL–OPTIONAL,316,3.00,MUNI,AUTOMATIC	EA

5. ALL DIMENSIONS IN INCHES.
6. REFERENCE – PIPING AND INSTRUMENTATION DIAGRAM: 1308280

7 OPTIONAL EQUIPMENT. REFERENCE BILL OF MATERIAL FOR CUSTOMER SPECIFIC OPTIONS.

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	14334	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS .X ± .XX ± .XXX ±
ANGLES ± FRAC ±

DIMENSIONS IN INCHES DO NOT SCALE

THIRD ANGLE

DRAWN BY JWA	DATE 19MAY10
CHECKED BY JSS	DATE 17Nov10
APPROVED BY BRB	DATE 17Nov10
APPROVED BY	DATE

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CLIENT/JOB

FILE ACR2007

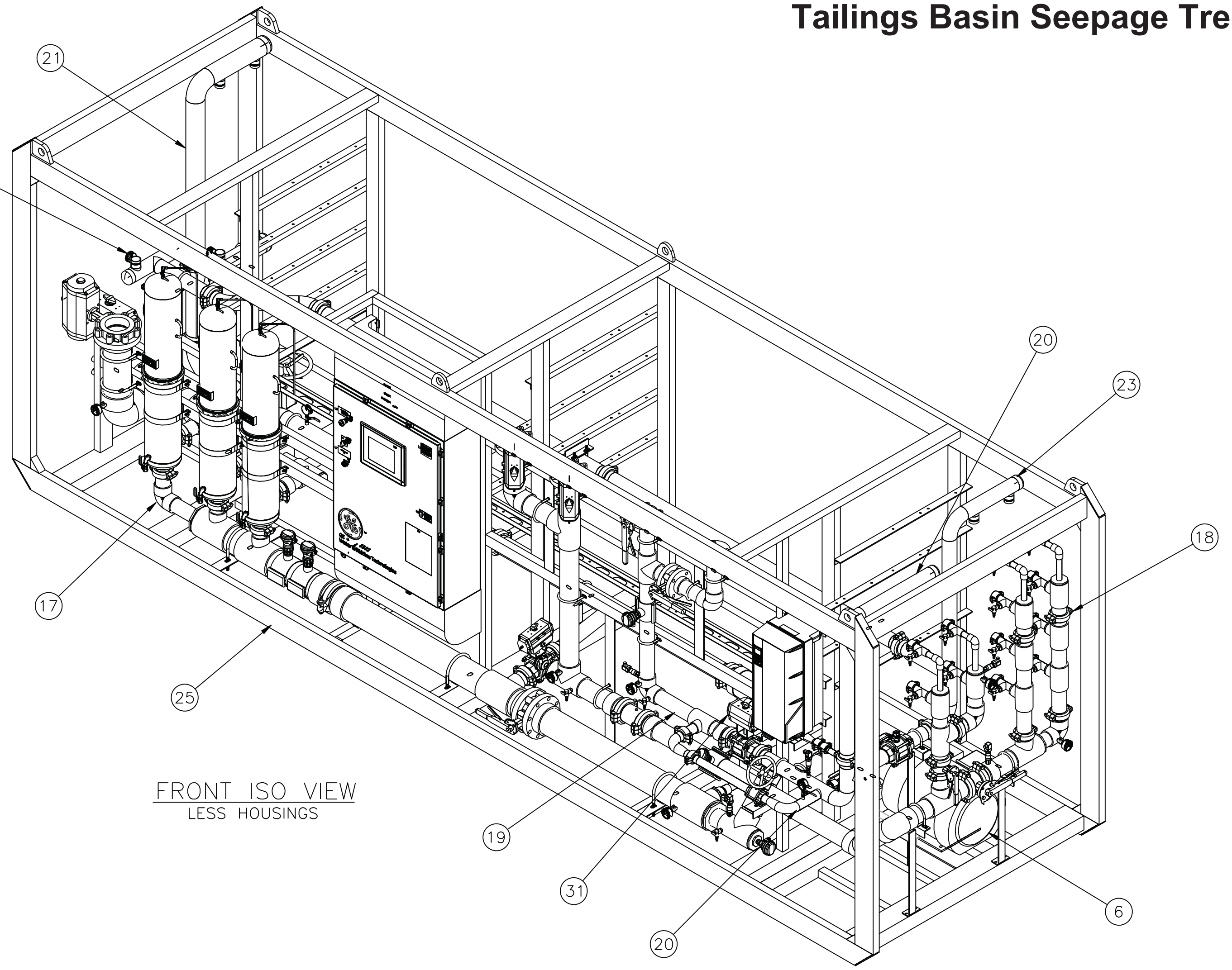
TITLE GA,RO,MUNI–300, 480/3/60

MATERIAL SEE BOM

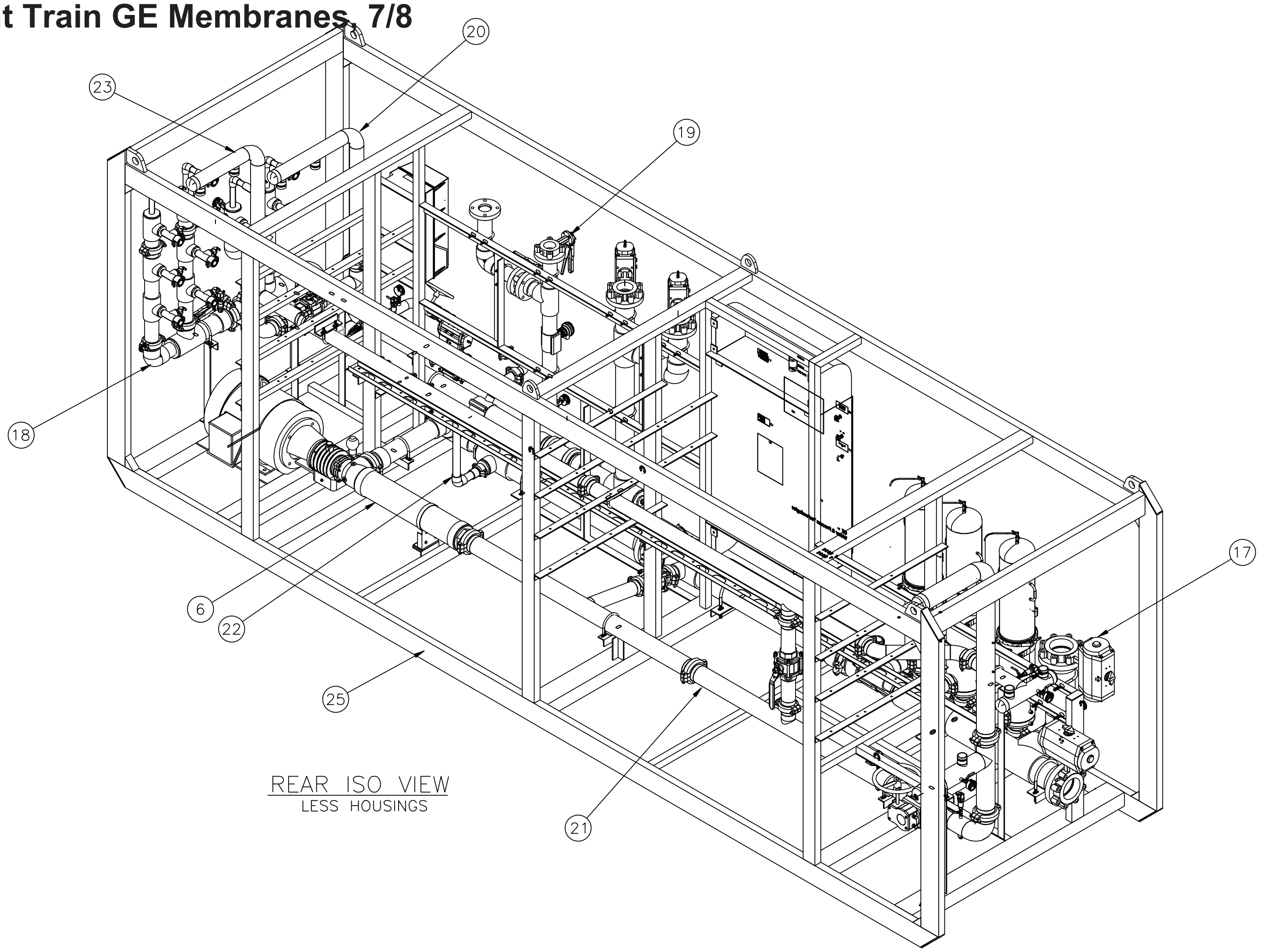
SIZE D
DRAWING NO. 1308279
REV A
PROJECT
SCALE 3:64
SHEET 1 OF 3

P/N 1161662–RHP01

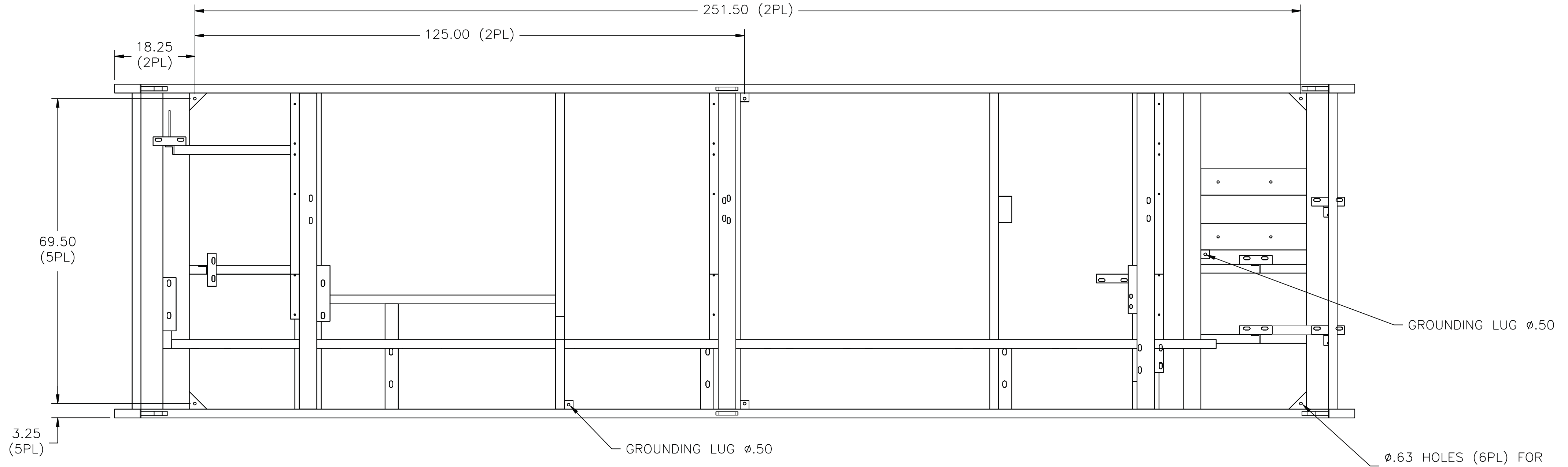
Tailings Basin Seepage Treatment Train GE Membranes, 7/8



FRONT ISO VIEW
LESS HOUSINGS



REAR ISO VIEW
LESS HOUSINGS



ANCHOR BOLT LOCATIONS

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	14334	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
.X ± ±
.XX ± FRAC
.XXX ± ±
DIMENSIONS IN INCHES
DO NOT SCALE
THIRD ANGLE

DRAWN BY	JWA	DATE 19MAY10
CHECKED BY	JSS	DATE 17Nov10
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APPROVED BY		DATE

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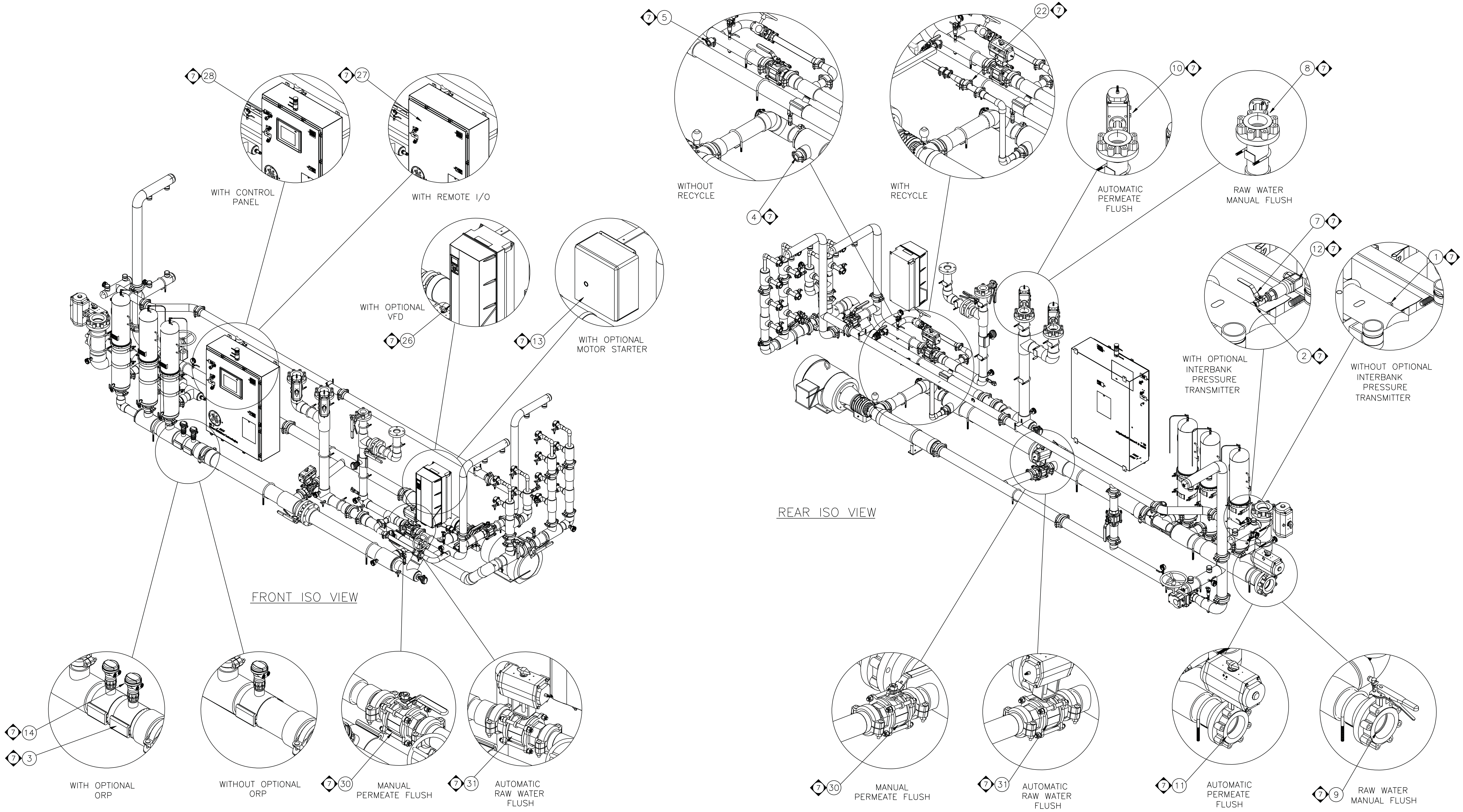
CLIENT/JOB	
FILE	ACR2007
TITLE	GA,RO,MUNI–300, 480/3/60
MATERIAL	SEE BOM
SIZE	D
DRAWING NO.	1308279
REV	A
PROJECT	
SCALE	1:16
SHEET	2 OF 3

P/N 1161662–RHP01

Tailings Basin Seepage Treatment Train GE Membranes, 8/8



REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	14334	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
.X ± ±
.XX ± FRAC
.XXX ± ±
DIMENSIONS IN INCHES
DO NOT SCALE
THIRD ANGLE

DRAWN BY	JWA	DATE	19MAY10
CHECKED BY	JSS	DATE	17Nov10
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CLIENT/JOB
FILE ACR2007
TITLE
GA,RO,MUNI–300,
480/3/60
MATERIAL SEE BOM
SIZE D
DRAWING NO. 1308279
REV A
PROJECT
SCALE NONE
SHEET 3 OF 3

P/N 1161662–RHP01

Tailings Basin Seepage Treatment Train GE Membrane Projections, 1/24

Plant Site Projections with Muni-NF-400 Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			702.8	702.8	
pH		7		6.55	6.73	
Cations						
Ca	mg/L	37.2		11.13	17.87	2.7528
Mg	mg/L	64.9		3.64	7.03	3.3748
Na	mg/L	61.6		20.62	31.85	26.1184
K	mg/L	8.6		2.88	4.45	3.526
Ba	mg/L	0.172		0.05	0.08	0.01118
Fe	mg/L	0.0209		0	0.01	
Mn	mg/L	0.0392		0.01	0.01	0.0008624
Anions						
SO4	mg/L	196		8.95	17.22	1.96
Cl	mg/L	19.5	39.58	3.53	6.91	17.667
F	mg/L	3.57		0.41	0.76	
B	mg/L	0.262		0.26	0.26	
SiO2	mg/L	54		53.88	53.92	40.986
Total Alk	mg/L as CaCO3	236				
	mg/L as HCO3	287.92		92.65	144.98	
Metals						
Ag	ug/L	0.105		0.035	0.054	
Al	ug/L	13.1		0.735	1.419	
As	ug/L	0.0301		0.001	0.001	0.0001806
Be	ug/L	0.226		0.013	0.024	
Cd	ug/L	0.125		0.007	0.014	
Co	ug/L	0.0443		0.002	0.005	0.0000443
Cr	ug/L	0.518		0.029	0.056	
Cu	ug/L	0.816				0.050592
Ni	ug/L	2.17		0.122	0.235	0.00434
Pb	ug/L	0.119		0.007	0.013	0.000714
Sb	ug/L	0.78		0.044	0.084	
Se	ug/L	0.515		0.024	0.045	0.00412
Tl	ug/L	0.141		0.008	0.015	
V	ug/L	3.85		0.216	0.417	
Zn	ug/L	0.246		0.014	0.027	0.003936

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTP Plant site, equipment = 2xMuniNF1MGD [20x10(6M) with Muni-NF-400 elements], Only one system running for 703 gpm flow

Tailings Basin Seepage Treatment Train GE Membrane Projections, 2/24

Feedwater ions balanced with either Na or Cl as appropriate

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Mg, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Tailings Basin Seepage Treatment Train GE Membrane Projections, 3/24

Plant Site Projections with Muni-NF-400 Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			781.3	781.3	
pH		7		6.65	6.81	
Cations						
Ca	mg/L	82.7		3.34	6.57	6.1198
Mg	mg/L	96.9		4.07	7.85	5.0388
Na	mg/L	69.3	88.13	33.74	46.72	29.3832
K	mg/L	14.5		5.6	8.36	5.945
Ba	mg/L	0.0461		0	0	0.0029965
Fe	mg/L	0.0838		0	0.01	
Mn	mg/L	0.135		0.01	0.01	0.00297
Anions						
SO4	mg/L	618		25.53	49.65	6.18
Cl	mg/L	22.9		16.49	19.37	20.7474
F	mg/L	1.97		1.43	1.67	
B	mg/L	0.263		0.26	0.26	
SiO2	mg/L	54		53.89	53.95	40.986
Total Alk	mg/L as CaCO3	135				
	mg/L as HCO3	164.7		63.5	94.61	
Metals						
Ag	ug/L	0.289		0.141	0.195	
Al	ug/L	12.1		0.508	0.980	
As	ug/L	0.099		0.002	0.002	0.000594
Be	ug/L	0.409		0.017	0.033	
Cd	ug/L	0.75		0.032	0.061	
Co	ug/L	0.315		0.013	0.026	0.000315
Cr	ug/L	3.41		0.143	0.276	
Cu	ug/L	13.6				0.8432
Ni	ug/L	33.3		1.399	2.698	0.0666
Pb	ug/L	1.21		0.051	0.098	0.00726
Sb	ug/L	5.7		0.239	0.462	
Se	ug/L	1.6		0.066	0.129	0.0128
Tl	ug/L	0.212		0.009	0.017	
V	ug/L	5.81		0.244	0.471	
Zn	ug/L	1.09		0.046	0.088	0.01744

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTP Plant site, equipment = 2xMuniNF1MGD [20x10(6M) with Muni-NF-400 elements]
Feedwater ions balanced with either Na or Cl as appropriate

Tailings Basin Seepage Treatment Train GE Membrane Projections, 4/24

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Mg, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Tailings Basin Seepage Treatment Train GE Membrane Projections, 5/24

Plant Site Projections with Muni-NF-400 Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			781.3	781.3	
pH		7		6.64	6.8	
Cations						
Ca	mg/L	84.2		3.4	6.68	6.2308
Mg	mg/L	90.7		3.81	7.34	4.7164
Na	mg/L	68.3		28.73	39.14	28.9592
K	mg/L	16.8		6.36	9.54	6.888
Ba	mg/L	0.032		0	0	0.00208
Fe	mg/L	0.0735		0	0.01	
Mn	mg/L	0.137		0.01	0.01	0.003014
Anions						
SO4	mg/L	580		23.99	46.54	5.8
Cl	mg/L	23.8	24.5	17.49	20.62	21.5628
F	mg/L	1.7		1.22	1.43	
B	mg/L	0.233		0.23	0.23	
SiO2	mg/L	54		53.89	53.95	40.986
Total Alk	mg/L as CaCO3	111				
	mg/L as HCO3	135.42		51.18	76.66	
Metals						
Ag	ug/L	0.291		0.122	0.167	
Al	ug/L	10.8		0.454	0.874	
As	ug/L	0.128		0.003	0.003	0.000768
Be	ug/L	0.428		0.018	0.035	
Cd	ug/L	0.95		0.040	0.077	
Co	ug/L	0.335		0.014	0.027	0.000335
Cr	ug/L	4.67		0.196	0.378	
Cu	ug/L	19.2				1.1904
Ni	ug/L	36.8		1.546	2.978	0.0736
Pb	ug/L	2.01		0.084	0.163	0.01206
Sb	ug/L	6.29		0.264	0.509	
Se	ug/L	1.79		0.074	0.144	0.01432
Tl	ug/L	0.211		0.009	0.017	
V	ug/L	6.83		0.287	0.553	
Zn	ug/L	1.43		0.060	0.116	0.02288

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTP Plant site, equipment = 3xMuniNF 1MGD [20x10(6M) with Muni-NF-400 elements] + 1xMuniNF450 [12x6(6M) with Muni-NF-400 elements]

Tailings Basin Seepage Treatment Train GE Membrane Projections, 6/24

Feedwater ions balanced with either Na or Cl as appropriate

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Mg, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Tailings Basin Seepage Treatment Train GE Membrane Projections, 7/24

Plant Site Projections with Muni-NF-400 Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			1638.5	1638.5	
pH		7		6.72	6.86	
Cations						
Ca	mg/L	85.7		17.12	30.63	6.3418
Mg	mg/L	82.6		5.49	10.64	4.2952
Na	mg/L	65.6		41.76	51.07	27.8144
K	mg/L	20		9.58	13.3	8.2
Ba	mg/L	0.0252		0.01	0.01	0.001638
Fe	mg/L	0.0285		0.01	0.01	
Mn	mg/L	0.124		0.03	0.05	0.002728
Anions						
SO4	mg/L	319		20.85	40.42	3.19
Cl	mg/L	23.2	205.8	69.35	98.7	21.0192
F	mg/L	1.33		1.06	1.18	
B	mg/L	0.206		0.21	0.21	
SiO2	mg/L	54		53.93	53.97	40.986
Total Alk	mg/L as CaCO3	96.5				
	mg/L as HCO3	117.73		56.31	78.05	
Metals						
Ag	ug/L	0.21		0.134	0.163	
Al	ug/L	9.48		0.630	1.221	
As	ug/L	0.17		0.003	0.003	0.00102
Be	ug/L	0.411		0.027	0.053	
Cd	ug/L	1.19		0.079	0.153	
Co	ug/L	0.366		0.024	0.047	0.000366
Cr	ug/L	5.73		0.381	0.738	
Cu	ug/L	23.2				1.4384
Ni	ug/L	44.7		2.971	5.758	0.0894
Pb	ug/L	3.17		0.211	0.408	0.01902
Sb	ug/L	7.6		0.505	0.979	
Se	ug/L	1.86		0.122	0.236	0.01488
Tl	ug/L	0.165		0.011	0.021	
V	ug/L	7.57		0.503	0.975	
Zn	ug/L	1.9		0.126	0.245	0.0304

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTP Plant site, equipment = 3xMuniNF 1MGD [20x10(6M) with Muni-NF-400 elements] + 1xMuniNF450 [12x6(6M) with Muni-NF-400 elements]

Tailings Basin Seepage Treatment Train GE Membrane Projections, 8/24

Feedwater ions balanced with either Na or Cl as appropriate
This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.
Arsenic is assumed to be in oxidized form
Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Mg, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Tailings Basin Seepage Treatment Train GE Membrane Projections, 9/24

Plant Site Projections with Muni-NF-400 Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			1855.6	1855.6	
pH		7		6.72	6.9	
Cations						
Ca	mg/L	160		14.78	27.69	11.84
Mg	mg/L	14.9		0.88	1.7	0.7748
Na	mg/L	10.1		7.59	8.75	4.2824
K	mg/L	29.5		21.87	25.39	12.095
Ba	mg/L	0.025		0.01	0.01	0.001625
Fe	mg/L	2.24		0.52	0.88	
Mn	mg/L	0.853		0.2	0.33	0.018766
Anions						
SO4	mg/L	340		19.48	38.22	3.4
Cl	mg/L	0.366	121.29	46.51	63.43	0.331596
F	mg/L	0.0119		0.01	0.01	
B	mg/L	0.218		0.22	0.22	
SiO2	mg/L	54		53.92	53.97	40.986
Total Alk	mg/L as CaCO3	0.776				
	mg/L as HCO3	0.94672		0.42	0.56	
Metals						
Ag	ug/L	0.198		0.149	0.172	
Al	ug/L	10.8		0.638	1.232	
As	ug/L	43.4		0.868	0.868	0.2604
Be	ug/L	0.451		0.027	0.051	
Cd	ug/L	2.23		0.132	0.254	
Co	ug/L	38.7		2.286	4.415	0.0387
Cr	ug/L	0.419		0.025	0.048	
Cu	ug/L	507				31.434
Ni	ug/L	56.4		3.331	6.435	0.1128
Pb	ug/L	51.2		3.024	5.842	0.3072
Sb	ug/L	12.2		0.721	1.392	
Se	ug/L	3.32		0.190	0.373	0.02656
Tl	ug/L	0.184		0.011	0.021	
V	ug/L	0.201		0.012	0.023	
Zn	ug/L	163		9.627	18.597	2.608

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTP Plant site, equipment = 3xMuniNF 1MGD [20x10(6M) with Muni-NF-400 elements] + 1xMuniNF450 [12x6(6M) with Muni-NF-400 elements]

Tailings Basin Seepage Treatment Train GE Membrane Projections, 10/24

Feedwater ions balanced with either Na or Cl as appropriate

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Mg, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Tailings Basin Seepage Treatment Train GE Membrane Projections, 11/24

Plant Site Projections with Muni-NF-400 Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			1414.9	1414.9	
pH		7		6.81	6.96	
Cations						
Ca	mg/L	274		32.72	60.81	20.276
Mg	mg/L	14.8		0.94	1.83	0.7696
Na	mg/L	14.7		11.8	13.18	6.2328
K	mg/L	36.7		29.26	32.82	15.047
Ba	mg/L	0.0196		0	0.01	0.001274
Fe	mg/L	0.52		0.12	0.2	
Mn	mg/L	0.773		0.17	0.3	0.017006
Anions						
SO4	mg/L	410		25.46	50.18	4.1
Cl	mg/L	0.459	282.61	86.78	126.4	0.415854
F	mg/L	0.0137		0.01	0.01	
B	mg/L	0.116		0.12	0.12	
SiO2	mg/L	54		53.93	53.97	40.986
Total Alk	mg/L as CaCO3	0.41				
	mg/L as HCO3	0.5002		0.26	0.3	
Metals						
Ag	ug/L	0.177		0.142	0.159	
Al	ug/L	4.86		0.309	0.601	
As	ug/L	64.1		1.282	1.282	0.3846
Be	ug/L	0.374		0.024	0.046	
Cd	ug/L	3.81		0.242	0.471	
Co	ug/L	72.1		4.579	8.915	0.0721
Cr	ug/L	0.443		0.028	0.055	
Cu	ug/L	572				35.464
Ni	ug/L	96.6		6.135	11.944	0.1932
Pb	ug/L	64.4		4.090	7.963	0.3864
Sb	ug/L	19.6		1.245	2.424	
Se	ug/L	5.73		0.356	0.701	0.04584
Tl	ug/L	0.176		0.011	0.022	
V	ug/L	0.205		0.013	0.025	
Zn	ug/L	254		16.132	31.407	4.064

Assumptions:

Projections made via Winflows v3.2.1, with Database 3.06

Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively

WWTP Plant site, equipment = 3xMuniNF 1MGD [20x10(6M) with Muni-NF-400 elements] + 1xMuniNF450 [12x6(6M) with Muni-NF-400 elements], but with MuniNF450 off given 1415 gpm flow

Tailings Basin Seepage Treatment Train GE Membrane Projections, 12/24

Feedwater ions balanced with either Na or Cl as appropriate

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Mg, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Tailings Basin Seepage Treatment Train GE Membrane Projections, 13/24

Plant Site Projections with AG8040F400 RO Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			702.8	702.8	
pH		7		5.02	5.33	
Cations						
Ca	mg/L	37.2		0.23	0.57	0.20832
Mg	mg/L	64.9		0.33	0.79	0.2596
Na	mg/L	61.6		0.48	1.2	1.4784
K	mg/L	8.6		0.07	0.17	0.49536
Ba	mg/L	0.172		0	0	0.0004128
Fe	mg/L	0.0209		0	0	
Mn	mg/L	0.0392		0	0	
Anions						
SO4	mg/L	196		0.85	2.02	0.3136
Cl	mg/L	19.5	39.58	0.29	0.72	0.348304
F	mg/L	3.57		0.03	0.07	0.062832
B	mg/L	0.262		0.11	0.16	
SiO2	mg/L	54	34.75	0.26	0.65	0.3024
Total Alk	mg/L as CaCO3	236				
	mg/L as HCO3	287.92		2.64	5.42	
Metals						
Ag	ug/L	0.105		0.001	0.002	
Al	ug/L	13.1		0.081	0.201	
As	ug/L	0.0301		0.001	0.001	0.0043043
Be	ug/L	0.226		0.001	0.003	
Cd	ug/L	0.125		0.001	0.002	
Co	ug/L	0.0443		0.000	0.001	0.0000443
Cr	ug/L	0.518		0.003	0.008	
Cu	ug/L	0.816				0.001632
Ni	ug/L	2.17		0.013	0.033	0.002387
Pb	ug/L	0.119		0.001	0.002	0.0001071
Sb	ug/L	0.78		0.005	0.012	
Se	ug/L	0.515		0.002	0.005	0.01545
Tl	ug/L	0.141		0.001	0.002	
V	ug/L	3.85		0.024	0.059	
Zn	ug/L	0.246		0.002	0.004	0.0008118

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTP Plant site, equipment = 2xMuniRO1MGD [20x10(6M) with AG8040F400 elements], Only one system running for 703 gpm flow

Tailings Basin Seepage Treatment Train GE Membrane Projections, 14/24

Feedwater ions balanced with either Na or Cl as appropriate

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Ca, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Tailings Basin Seepage Treatment Train GE Membrane Projections, 15/24

Plant Site Projections with AG8040F400 RO Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			781.3	781.3	
pH		7		5.28	5.63	
Cations						
Ca	mg/L	82.7		0.59	1.46	0.46312
Mg	mg/L	96.9		0.71	1.73	0.3876
Na	mg/L	69.3	88.14	1.12	2.83	1.6632
K	mg/L	14.5		0.2	0.52	0.8352
Ba	mg/L	0.0461		0	0	0.00011064
Fe	mg/L	0.0838		0	0	
Mn	mg/L	0.135		0	0	
Anions						
SO4	mg/L	618		4.46	10.99	0.9888
Cl	mg/L	22.9		0.33	0.84	0
F	mg/L	1.97		0.03	0.07	0.034672
B	mg/L	0.263		0.14	0.2	
SiO2	mg/L	54	34.75	0.45	1.15	0.3024
Total Alk	mg/L as CaCO3	135				
	mg/L as HCO3	164.7		2.62	5.97	
Metals						
Ag	ug/L	0.289		0.005	0.012	
Al	ug/L	12.1		0.086	0.214	
As	ug/L	0.099		0.002	0.002	0.014157
Be	ug/L	0.409		0.003	0.007	
Cd	ug/L	0.75		0.005	0.013	
Co	ug/L	0.315		0.002	0.006	0.000315
Cr	ug/L	3.41		0.024	0.060	
Cu	ug/L	13.6				0.0272
Ni	ug/L	33.3		0.238	0.588	0.03663
Pb	ug/L	1.21		0.009	0.021	0.001089
Sb	ug/L	5.7		0.041	0.101	
Se	ug/L	1.6		0.012	0.028	0.048
Tl	ug/L	0.212		0.002	0.004	
V	ug/L	5.81		0.041	0.103	
Zn	ug/L	1.09		0.008	0.019	0.003597

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTP Plant site, equipment = 2xMuniRO-1MGD [20x10(6M) with AG8040F400 elements]
Feedwater ions balanced with either Na or Cl as appropriate

Tailings Basin Seepage Treatment Train GE Membrane Projections, 16/24

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Ca, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Tailings Basin Seepage Treatment Train GE Membrane Projections, 17/24

Plant Site Projections with AG8040F400 RO Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			781.3	781.3	
pH		7		5.29	5.63	
Cations						
Ca	mg/L	84.2		0.6	1.48	0.47152
Mg	mg/L	90.7		0.66	1.62	0.3628
Na	mg/L	68.3		0.89	2.26	1.6392
K	mg/L	16.8		0.23	0.59	0.96768
Ba	mg/L	0.032		0	0	7.68E-05
Fe	mg/L	0.0735		0	0	
Mn	mg/L	0.137		0	0	
Anions						
SO4	mg/L	580		4.18	10.29	0.928
Cl	mg/L	23.8	24.5	0.35	0.89	0.2156
F	mg/L	1.7		0.03	0.06	0.02992
B	mg/L	0.233		0.13	0.18	
SiO2	mg/L	54	34.75	0.45	1.15	0.3024
Total Alk	mg/L as CaCO3	111				
	mg/L as HCO3	135.42		2.2	4.9	
Metals						
Ag	ug/L	0.291		0.004	0.010	
Al	ug/L	10.8		0.077	0.190	
As	ug/L	0.128		0.003	0.003	0.018304
Be	ug/L	0.428		0.003	0.008	
Cd	ug/L	0.95		0.007	0.017	
Co	ug/L	0.335		0.002	0.006	0.000335
Cr	ug/L	4.67		0.033	0.082	
Cu	ug/L	19.2				0.0384
Ni	ug/L	36.8		0.262	0.647	0.04048
Pb	ug/L	2.01		0.014	0.035	0.001809
Sb	ug/L	6.29		0.045	0.111	
Se	ug/L	1.79		0.013	0.032	0.0537
Tl	ug/L	0.211		0.002	0.004	
V	ug/L	6.83		0.049	0.120	
Zn	ug/L	1.43		0.010	0.025	0.004719

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTP Plant site, equipment = 3xMuniRO 1MGD [20x10(6M) with AG8040F400 elements] + 1xMuniRO450 [12x6(6M) with AG8040F400 elements]

Tailings Basin Seepage Treatment Train GE Membrane Projections, 18/24

Feedwater ions balanced with either Na or Cl as appropriate

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Ca, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Tailings Basin Seepage Treatment Train GE Membrane Projections, 19/24

Plant Site Projections with AG8040F400 RO Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			1638.5	1638.5	
pH		7		5.25	5.57	
Cations						
Ca	mg/L	85.7		1.01	2.56	0.47992
Mg	mg/L	82.6		0.53	1.31	0.3304
Na	mg/L	65.6		0.79	2	1.5744
K	mg/L	20		0.24	0.61	1.152
Ba	mg/L	0.0252		0	0	6.048E-05
Fe	mg/L	0.0285		0	0	
Mn	mg/L	0.124		0	0	
Anions						
SO4	mg/L	319		2.03	4.94	0.5104
Cl	mg/L	23.2	205.8	2.44	6.18	1.81104
F	mg/L	1.33		0.02	0.04	0.023408
B	mg/L	0.206		0.1	0.15	
SiO2	mg/L	54	34.75	0.39	0.99	0.3024
Total Alk	mg/L as CaCO3	96.5				
	mg/L as HCO3	117.73		1.75	3.72	
Metals						
Ag	ug/L	0.21		0.003	0.006	
Al	ug/L	9.48		0.112	0.283	
As	ug/L	0.17		0.003	0.003	0.02431
Be	ug/L	0.411		0.005	0.012	
Cd	ug/L	1.19		0.014	0.036	
Co	ug/L	0.366		0.004	0.011	0.000366
Cr	ug/L	5.73		0.068	0.171	
Cu	ug/L	23.2				0.0464
Ni	ug/L	44.7		0.527	1.335	0.04917
Pb	ug/L	3.17		0.037	0.095	0.002853
Sb	ug/L	7.6		0.090	0.227	
Se	ug/L	1.86		0.012	0.029	0.0558
Tl	ug/L	0.165		0.002	0.005	
V	ug/L	7.57		0.089	0.226	
Zn	ug/L	1.9		0.022	0.057	0.00627

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTP Plant site, equipment = 3xMuniRO 1MGD [20x10(6M) with AG8040F400 elements] + 1xMuniRO450 [12x6(6M) with AG8040F400 elements]

Tailings Basin Seepage Treatment Train GE Membrane Projections, 20/24

Feedwater ions balanced with either Na or Cl as appropriate

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Ca, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Tailings Basin Seepage Treatment Train GE Membrane Projections, 21/24

Plant Site Projections with AG8040F400 RO Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			1855.6	1855.6	
pH		7		6	6.06	
Cations						
Ca	mg/L	160		1.07	2.66	0.896
Mg	mg/L	14.9		0.08	0.2	0.0596
Na	mg/L	10.1		0.1	0.26	0.2424
K	mg/L	29.5		0.3	0.76	1.6992
Ba	mg/L	0.025		0	0	6E-05
Fe	mg/L	2.24		0.02	0.06	
Mn	mg/L	0.853		0.01	0.02	
Anions						
SO4	mg/L	340		1.88	4.6	0.544
Cl	mg/L	0.366	121.29	1.23	3.09	1.067352
F	mg/L	0.0119		0	0	0.00020944
B	mg/L	0.218		0.1	0.15	
SiO2	mg/L	54	34.75	0.34	0.88	0.3024
Total Alk	mg/L as CaCO3	0.776				
	mg/L as HCO3	0.94672		0.07	0.08	
Metals						
Ag	ug/L	0.198		0.002	0.005	
Al	ug/L	10.8		0.072	0.180	
As	ug/L	43.4		0.868	0.868	6.2062
Be	ug/L	0.451		0.003	0.007	
Cd	ug/L	2.23		0.015	0.037	
Co	ug/L	38.7		0.259	0.643	0.0387
Cr	ug/L	0.419		0.003	0.007	
Cu	ug/L	507				1.014
Ni	ug/L	56.4		0.377	0.938	0.06204
Pb	ug/L	51.2		0.342	0.851	0.04608
Sb	ug/L	12.2		0.082	0.203	
Se	ug/L	3.32		0.018	0.045	0.0996
Tl	ug/L	0.184		0.001	0.003	
V	ug/L	0.201		0.001	0.003	
Zn	ug/L	163		1.090	2.710	0.5379

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values,
WWTP Plant site, equipment = 3xMuniRO 1MGD [20x10(6M) with AG8040F400 elements] + 1xMuniRO450 [12x6(6M) with AG8040F400 elements]
Feedwater ions balanced with either Na or Cl as appropriate

Tailings Basin Seepage Treatment Train GE Membrane Projections, 22/24

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Ca, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Tailings Basin Seepage Treatment Train GE Membrane Projections, 23/24

Plant Site Projections with AG8040F400 RO Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			1414.9	1414.9	
pH		7		6.15	6.22	
Cations						
Ca	mg/L	274		2.39	5.99	1.5344
Mg	mg/L	14.8		0.09	0.22	0.0592
Na	mg/L	14.7		0.18	0.45	0.3528
K	mg/L	36.7		0.44	1.11	2.11392
Ba	mg/L	0.0196		0	0	4.704E-05
Fe	mg/L	0.52		0.01	0.02	
Mn	mg/L	0.773		0.01	0.02	
Anions						
SO4	mg/L	410		2.47	6.07	0.656
Cl	mg/L	0.459	282.61	3.36	8.5	2.486968
F	mg/L	0.0137		0	0	0.00024112
B	mg/L	0.116		0.06	0.08	
SiO2	mg/L	54	34.75	0.38	0.96	0.3024
Total Alk	mg/L as CaCO3	0.41				
	mg/L as HCO3	0.5002		0.05	0.05	
Metals						
Ag	ug/L	0.177		0.002	0.005	
Al	ug/L	4.86		0.042	0.106	
As	ug/L	64.1		1.282	1.282	9.1663
Be	ug/L	0.374		0.003	0.008	
Cd	ug/L	3.81		0.033	0.083	
Co	ug/L	72.1		0.629	1.576	0.0721
Cr	ug/L	0.443		0.004	0.010	
Cu	ug/L	572				1.144
Ni	ug/L	96.6		0.843	2.112	0.10626
Pb	ug/L	64.4		0.562	1.408	0.05796
Sb	ug/L	19.6		0.171	0.428	
Se	ug/L	5.73		0.035	0.085	0.1719
Tl	ug/L	0.176		0.002	0.004	
V	ug/L	0.205		0.002	0.004	
Zn	ug/L	254		2.216	5.553	0.8382

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTP Plant site, equipment = 3xMuniRO 1MGD [20x10(6M) with AG8040F400 elements] + 1xMuniRO450 [12x6(6M) with AG8040F400 elements]

Tailings Basin Seepage Treatment Train GE Membrane Projections, 24/24

Feedwater ions balanced with either Na or Cl as appropriate

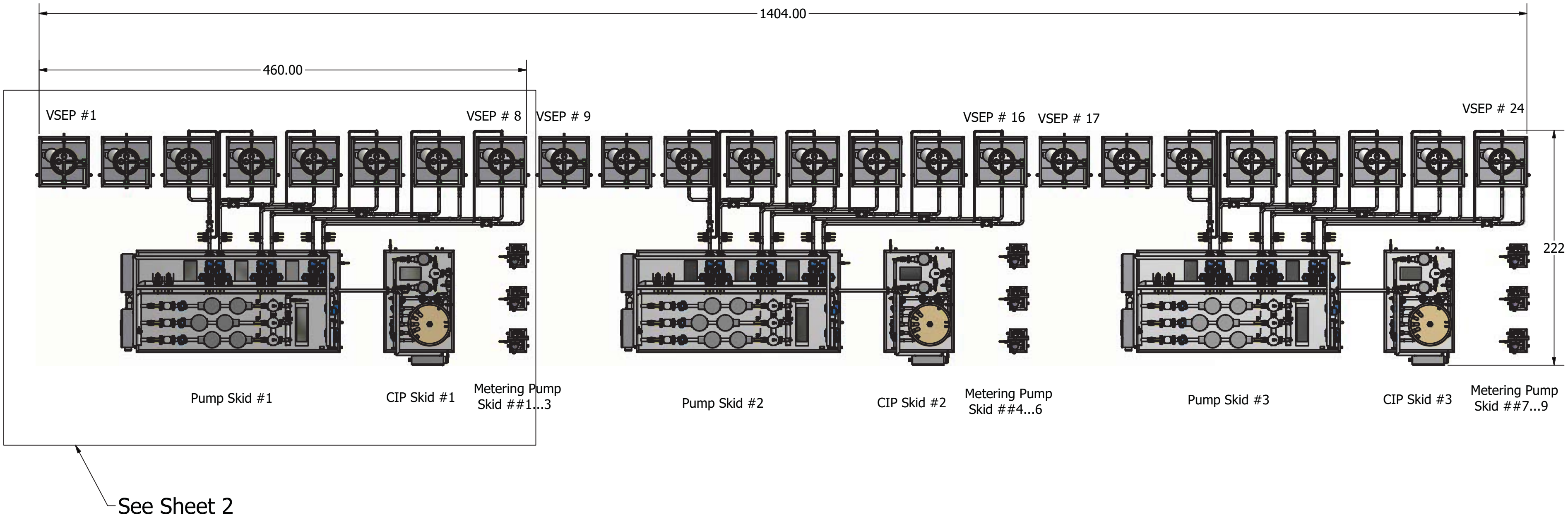
This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Ca, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Tailings Basin Seepage Treatment Train NLR VSEP, 1/2

TOP VIEW



NOTES:
1. New Logic Research confidential material.
2. All dimensions are shown in inches.
3. Preliminary, for references only.

DRAWN F. Rubin 11/7/2013
CHECKED M. Ayers
QA
MFG
APPROVED G. Johnson

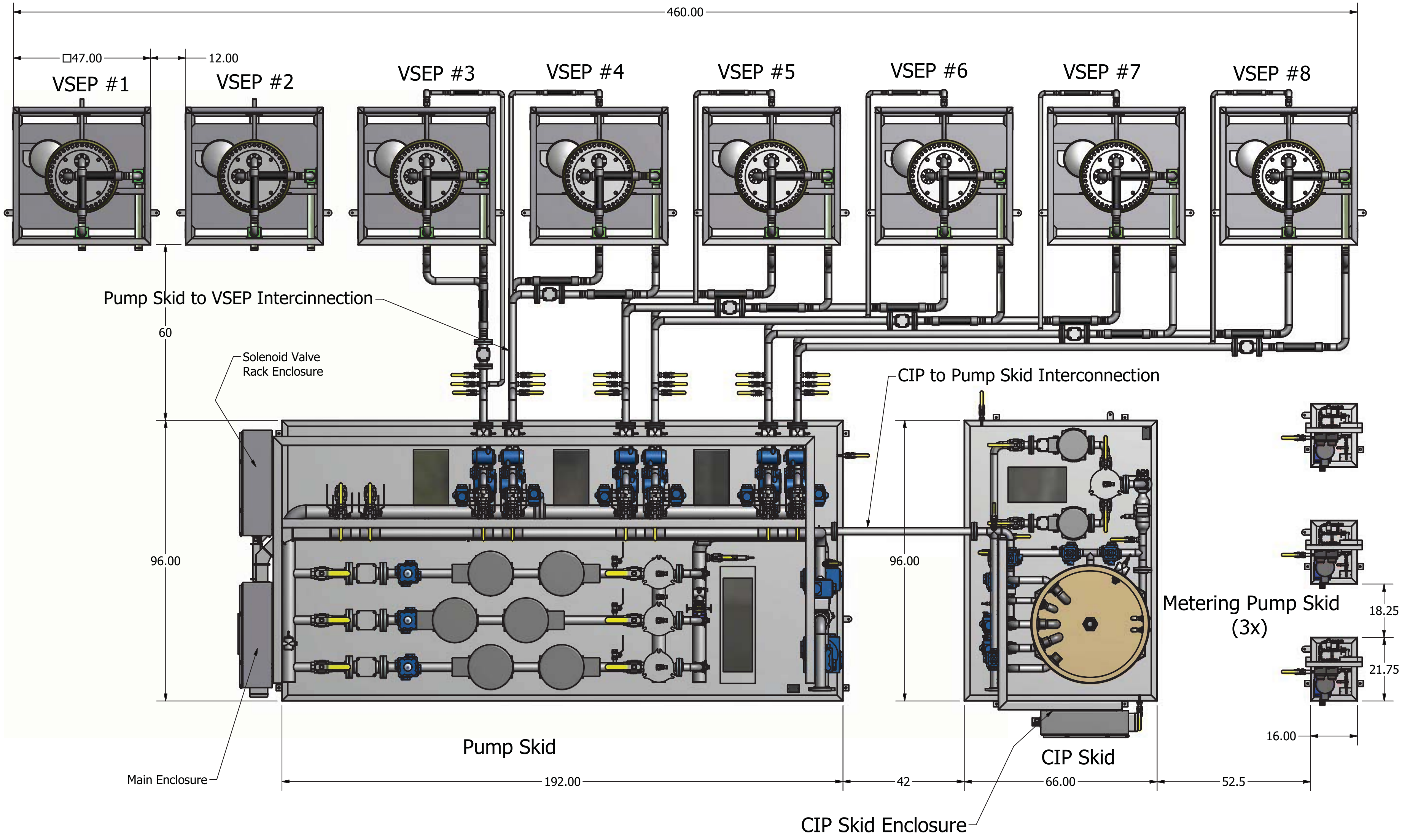
NEW LOGIC RESEARCH

TITLE
SYSTEM EQUIPMENT LAYOUT

SIZE C
DWG NO PMM-000
REV B
SCALE
SHEET 1 OF 2

Tailings Basin Seepage Treatment Train NLR VSEP, 2/2

TOP VIEW



NOTES:
1. New Logic Research confidential material.
2. All dimensions are shown in inches.
3. Preliminary, for references only.

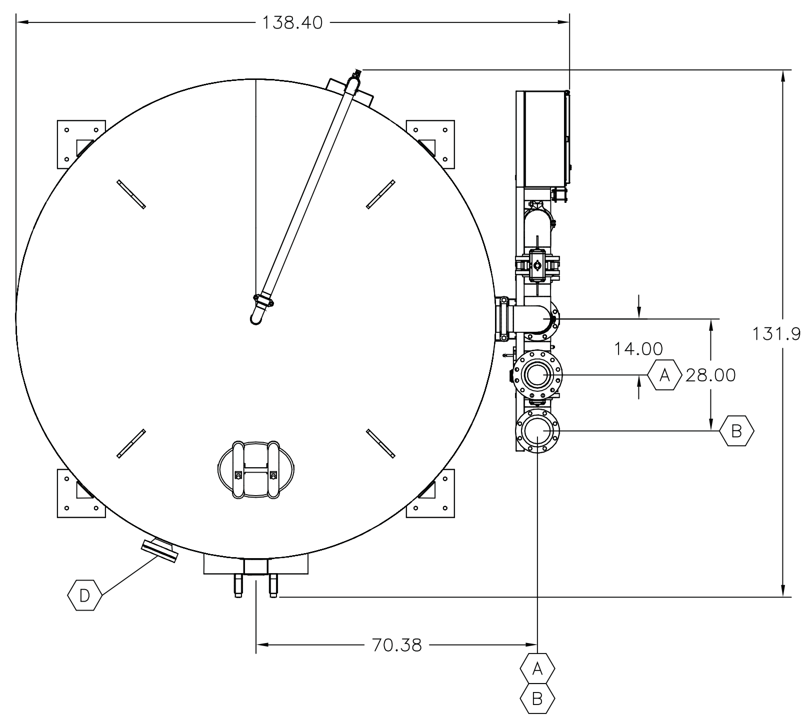
DRAWN F. Rubin 11/7/2013
CHECKED M. Ayers
QA
MFG
APPROVED G. Johnson

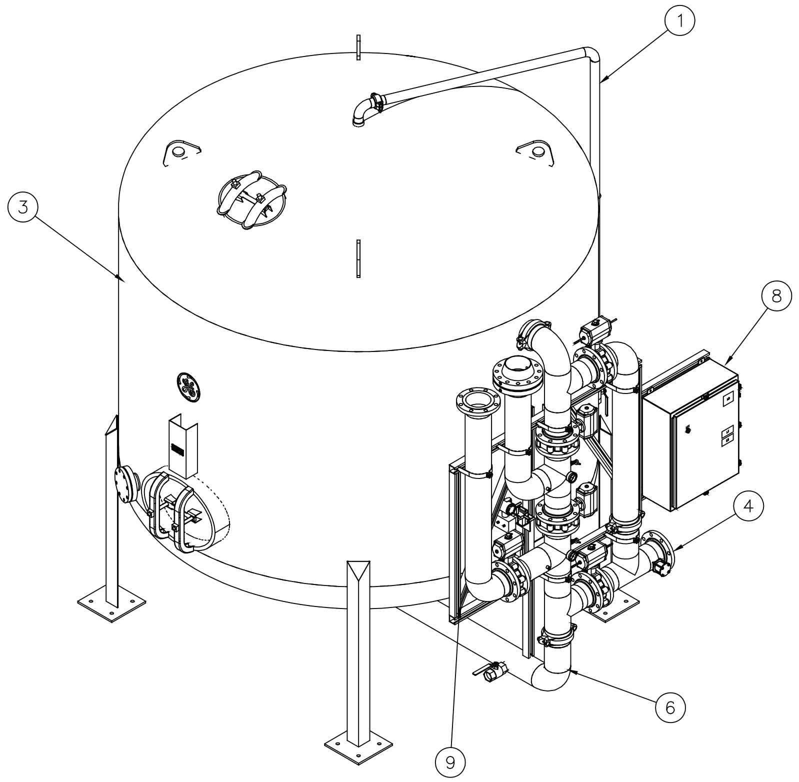
NEW LOGIC RESEARCH

TITLE
SYSTEM EQUIPMENT LAYOUT

SIZE C
DWG NO PMM-000
REV B
SCALE
SHEET 2 OF 2

Tailings Basin Seepage Treatment Train GE GSF, 1/1





NOTES:

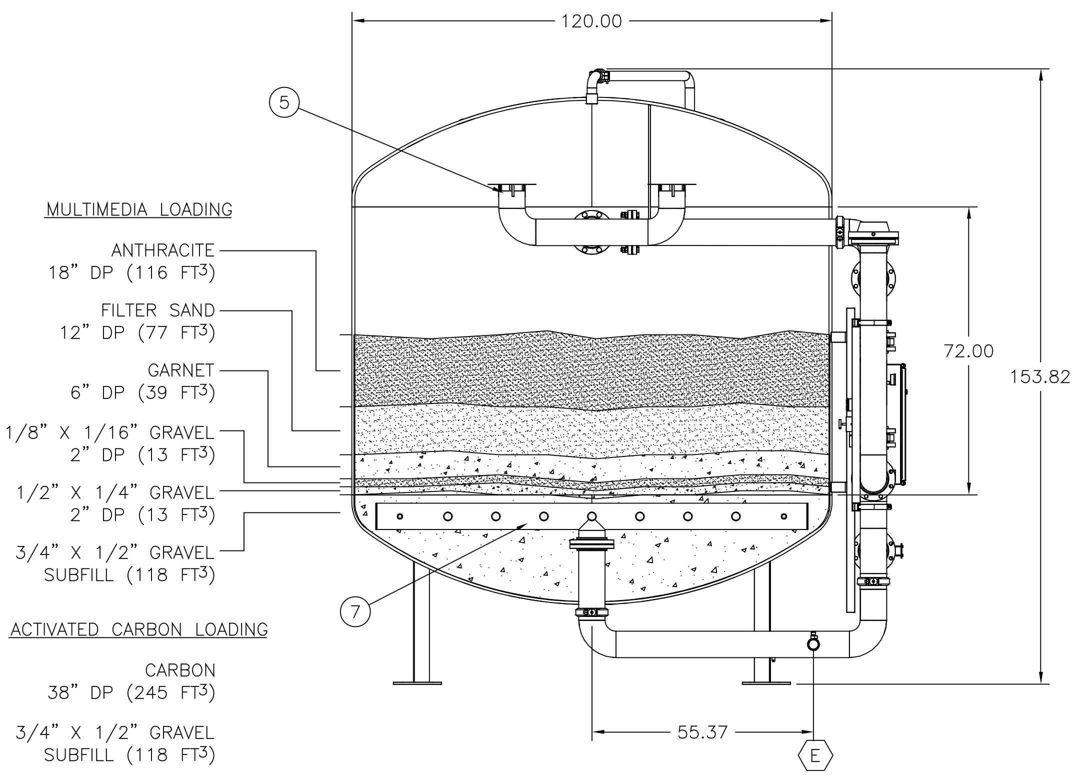
1. CONNECTION TABLE

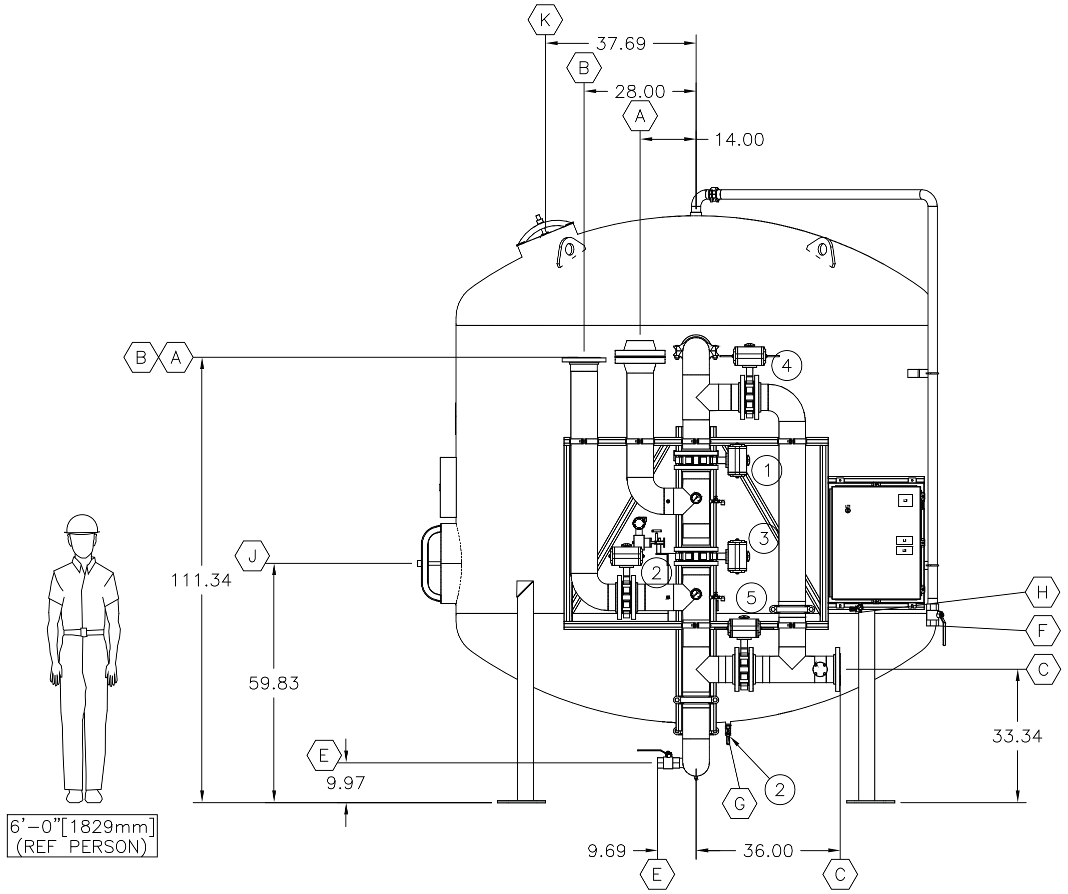
ITEM	DESCRIPTION	MATERIAL	TYPE	SIZE
A	SERVICE INLET	316SS	150# FLANGE	6.00"
B	SERVICE OUTLET	316SS	150# FLANGE	6.00"
C	DRAIN	316SS	150# FLANGE	6.00"
D	MEDIA REMOVAL PORT	CS	150# FLANGE	4.00"
E	PRIMARY TANK DRAIN	316SS	FPT	2.00"
F	TANK VENT	316SS	FPT	2.00"
G	SECONDARY TANK DRAIN	316SS	FPT	0.75"
H	AIR INLET	ZINC	FPT	0.25"
J	MANWAY W/EPDM GASKET	CS	CRAB	18"X24"
K	MANWAY W/EPDM GASKET	CS	CRAB	14"X18"

2. DRY WEIGHT: M120 – 43,075 LB/[19,580 Kg.]
C120 – 29,4500 LB/[13,386 Kg.]
3. OPERATING WEIGHT: M120 – 63,625 LB/[28,920 Kg.]
C120 – 57,805 LB/[26,275 Kg.]
4. PLUMBING RUN \ EQUIPMENT TABLE:

FIND NO.	PART NUMBER	QTY.	DESCRIPTION	U/M
1	1220617	1	PLMB,VENT,MM,316,2.00	EA
2	1228727	1	PLMB,DRAIN,MM,316,0.75	EA
3	3023818	1	TANK,FILTER,CS,120" DIA X 72"	EA
4	3024397	1	PLMB, FACE ASSY,MM/AC,316,6.00	EA
5	3024458	1	PLMB,DIST,UPPER,4P,316,6.00	EA
6	3024461	1	PLMB,LWR PLMB,MM/AC–120,316,6.00"	EA
7	3024565	1	PLMB,LWR DISTRIB,MM/AC–120,316,6.0	EA
8	3024784	1	ENCL–MACH,MM/AC,TITAN	EA
9	3024899	1	BRACKET,FACE PLMB,CS,3–6,24X30 ENCL	EA

5. ALL DIMENSIONS IN INCHES.
6. REFERENCE – PROCESS AND INSTRUMENTATION DIAGRAM : 1303306





VALVE NUMBER	DESCRIPTION
1	SERVICE INLET VALVE
2	SERVICE OUTLET VALVE
3	BACKWASH INLET VALVE
4	BACKWASH OUTLET VALVE
5	RINSE OUTLET VALVE

FILTER FUNCTION	VALVES OPEN
SERVICE	1,2
BACKWASH	3,4
SETTLE	---
RINSE	1,5

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	13332	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS .X ± 3.0 .XX ± 1.00 .XXX ± 0.500
ANGLES ± 1°
FRAC ± N/A

DRAWN BY DJS	DATE	17Aug07
CHECKED BY RLD	DATE	3Dec07
APPROVED BY PWG	DATE	3Dec07
APPROVED BY	DATE	

GE
Water & Process Technologies
GLOBAL HEADQUARTERS : TREVOSE, PA USA +1-215-355-3300 WWW.GEWATER.COM

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CLIENT/JOB

FILE ACR2007

DWG DESCRIPTION
GENERAL ARRANGEMENT
FLT–MM/AC,120X72,CS/SS,RIO,60

MATERIAL/BOM NO. 3023939

SIZE	DRAWING NO.	REV
D	1303397	A

PROJECT

SCALE 1/2"=1'–0" SHEET 1 OF 1

P/N 1161662–RGP01

TOMCO$_2$ SYSTEMS

Industrial Equipment

Applications Equipment

Carbon Dioxide Water Bath Vaporizer

6,000 lb./hr. Capacity Water Bath Vaporizer
With Optional Dual Water Pumps

FEATURES

- ASME coded heat exchanger
- Low water supply protection
- Low discharge CO_2 temperature protection
- Pressure safety relief protection for CO_2 and water
- Optional dual or single water pump assemblies with factory installed water piping
- Discharge CO_2 temperature based on supplied water temperature and flow rate from customer
- Unit is equipped based on customer's water conditions

Available sizes from 2,000 pounds CO_2 capacity to 12,000 pounds CO_2 capacity.

Pressure build option is available
Larger units available upon request

TOMCO$_2$ SYSTEMS

Industrial Equipment

Applications Equipment

Carbon Dioxide Vapor Heater

The TOMCO$_2$ Systems' carbon dioxide vapor heater is used to increase the temperature of carbon dioxide vapor from an average storage temperature of 0°F (-17.8° C) to the desired temperature level. Prevents such problems as regulator freeze-up and condensation on pipe lines.

FEATURES

- Heat transfer tube and heating elements pressure cast in common platen for maximum efficiency
- Designed to NEMA 12 standards
- Overheat protection
- Adjustable temperature control
- Stainless steel mounting brackets

SPECIFICATIONS

1/2" (1.27 cm) MPT and outlet connections

Allowable working pressure:
1000 psig

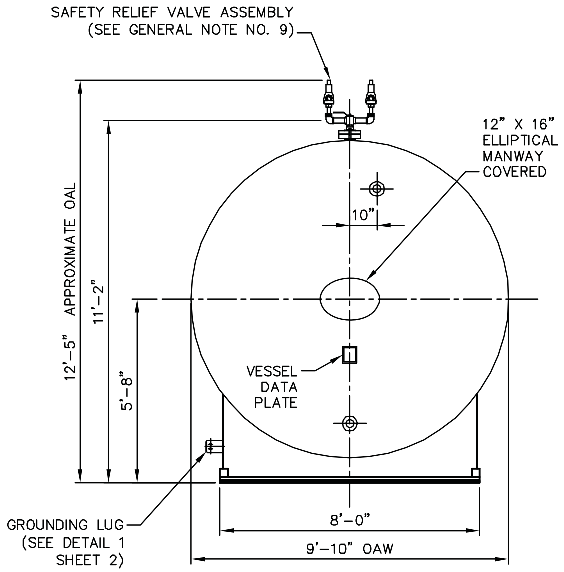
Flow Rate:
720 lbs./hr. @ 70°F (327 kg/hr @ 21°C)

Electrical Characteristics:
230/460V, 60Hz. Single Phase

Model	Nominal Capacity	Wattage	Dimensions	Weight*
CVH-4	720 lbs./hr. @ 70° F.T.D 327 kg/hr	4,000	14" x 8.5" x 12" high 35.5 cm x 21.6 cm x 30 cm	47 lbs. 21 kg
CVH-8	1,500 lbs./hr. @ 70° F.T.D 681 kg/hr	8,000	20" x 9" x 16" high 50.8 cm x 22.8 cm x 40.6 cm	84 lbs. 38 kg
VH-6000	6,000 lbs./hr. @ 70° F.T.D 2,726 kg/hr	30,000	22" x 33" x 37" high 55.9 cm x 84 cm x 94 cm	305 lbs. 138 kg

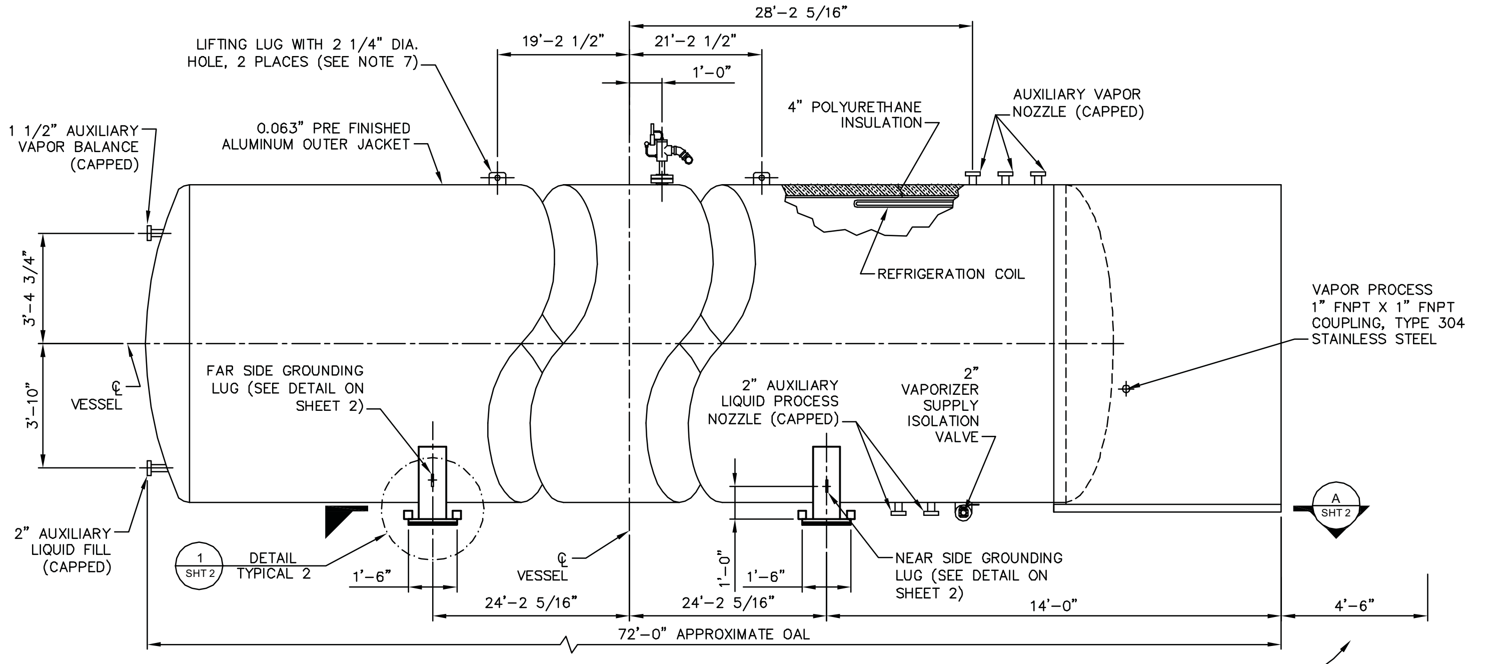
Published weights include equipment only. Shipping crate(s) are not included.

Tailings Basin Seepage Treatment Train TomCO2 Carbon Dioxide Feed, 3/4



REAR ELEVATION

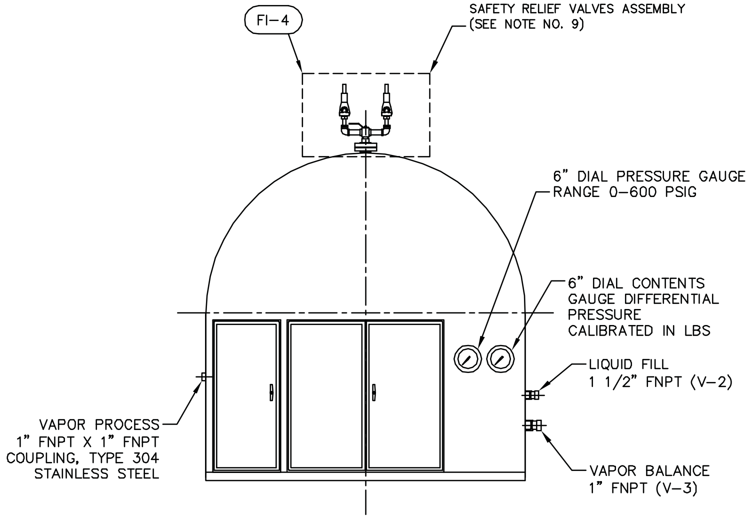
SCALE: NONE



MODEL WT-120C LIQUID CO2 STORAGE TANK ID NO. T-8700
GENERAL ARRANGEMENT

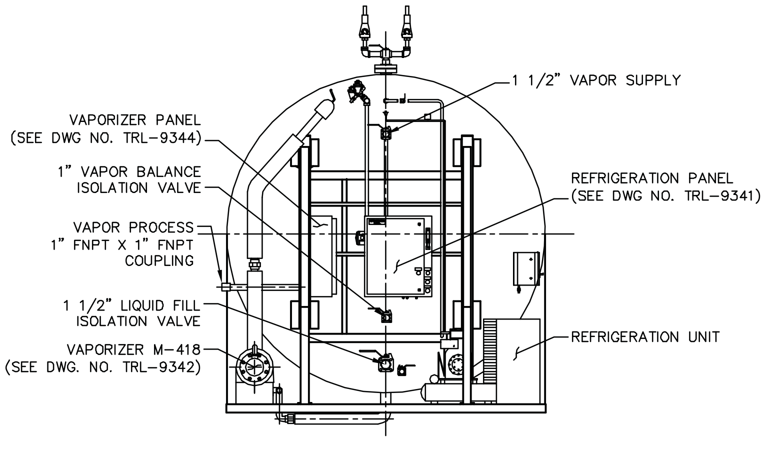
SCALE: NONE

3'-0" MINIMUM CLEARANCE REQUIRED FOR ACCESS AND DOOR OPENING AND 4'-6" FOR VAPORIZER HEATING ELEMENT REMOVAL



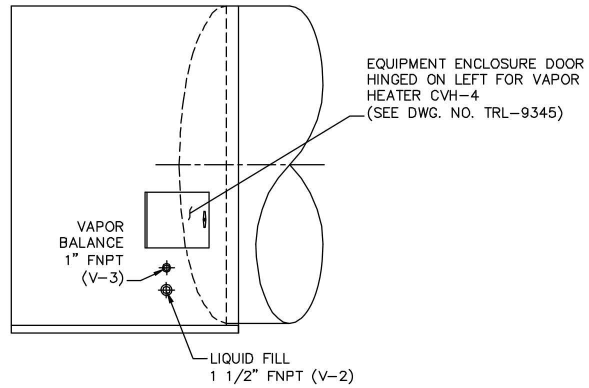
FRONT ELEVATION

SCALE: NONE



FRONT ELEVATION
WITH DOOR REMOVED

SCALE: NONE



RIGHT SIDE VIEW

SCALE: NONE

NOTE:

- SEE GENERAL AND INSTALLATION NOTES ON SHEET 3 THIS DWG

DWG. FILE NAME: 120C-Ton-GA-A.DWG

A	DWG FOR PROPOSAL INFO AND DESIGN REFERENCE	03/11/13	NHP
NO.	DESCRIPTION	DATE	BY
ORIGINAL/REVISIONS			

REFERENCE DRAWING

"CONFIDENTIAL-TRADE SECRETS"

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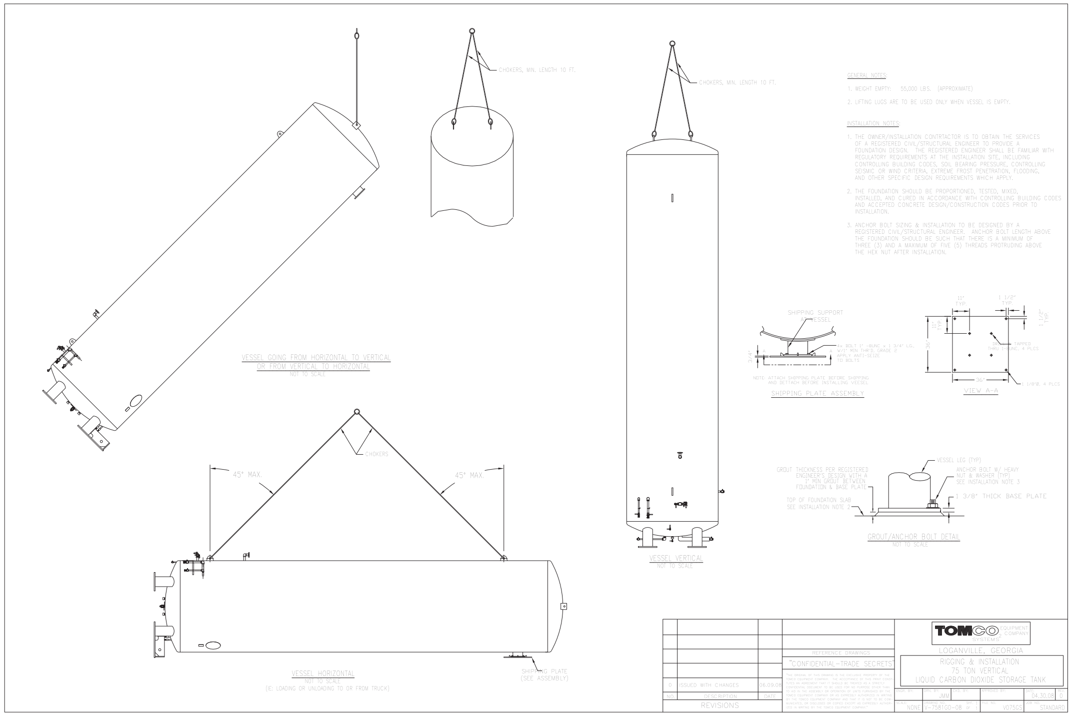
TOMCO2 EQUIPMENT COMPANY SYSTEMS
LOGANVILLE, GEORGIA

TOMCO2 MODEL WT-120C
LIQUID CO2 STORAGE TANK
GENERAL ARRANGEMENT
FOR PROPOSAL & DESIGN REFERENCE

DRAWN BY: TEC/NP
SCALE: AS NOTED
CHECKED BY: NHP
DATE: 03/11/2013
JOB NO. GB031113-1
SHEET 1 OF 3
120C-TON-GA

Tailings Basin Seepage Treatment Train TomCO2 Carbon Dioxide Feed, 4/4



GENERAL NOTES:

1. WEIGHT EMPTY: 55,000 LBS. (APPROXIMATE)
2. LIFTING LUGS ARE TO BE USED ONLY WHEN VESSEL IS EMPTY.

INSTALLATION NOTES:

1. THE OWNER/INSTALLATION CONTRTACTOR IS TO OBTAIN THE SERVICES OF A REGISTERED CIVIL/STRUCTURAL ENGINEER TO PROVIDE A FOUNDATION DESIGN. THE REGISTERED ENGINEER SHALL BE FAMILIAR WITH REGULATORY REQUIREMENTS AT THE INSTALLATION SITE, INCLUDING CONTROLLING BUILDING CODES, SOIL BEARING PRESSURE, CONTROLLING SEISMIC OR WIND CRITERIA, EXTREME FROST PENETRATION, FLOODING, AND OTHER SPECIFIC DESIGN REQUIREMENTS WHICH APPLY.
2. THE FOUNDATION SHOULD BE PROPORTIONED, TESTED, MIXED, INSTALLED, AND CURED IN ACCORDANCE WITH CONTROLLING BUILDING CODES AND ACCEPTED CONCRETE DESIGN/CONSTRUCTION CODES PRIOR TO INSTALLATION.
3. ANCHOR BOLT SIZING & INSTALLATION TO BE DESIGNED BY A REGISTERED CIVIL/STRUCTURAL ENGINEER. ANCHOR BOLT LENGTH ABOVE THE FOUNDATION SHOULD BE SUCH THAT THERE IS A MINIMUM OF THREE (3) AND A MAXIMUM OF FIVE (5) THREADS PROTRUDING ABOVE THE HEX NUT AFTER INSTALLATION.

NO.	DESCRIPTION	DATE
0	ISSUED WITH CHANGES	06.09.08

REVISIONS

REFERENCE DRAWINGS

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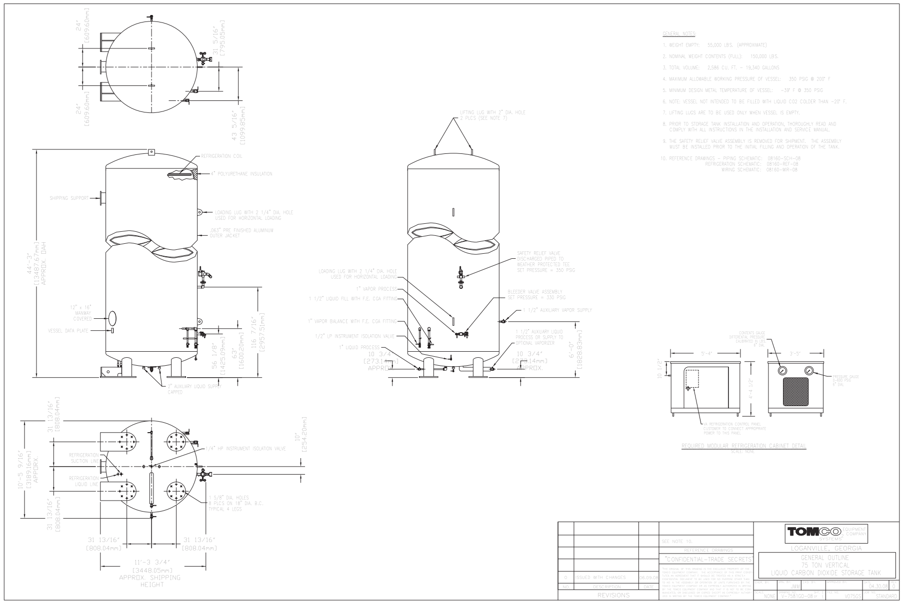
TOMCO2 SYSTEMS EQUIPMENT COMPANY
LOGANVILLE, GEORGIA

RIGGING & INSTALLATION
75 TON VERTICAL
LIQUID CARBON DIOXIDE STORAGE TANK

ENGR. BY:
DRN. BY: JMM
CKD. BY:
APPROVED BY:
DATE: 04.30.08
REV. 0
SCALE: NONE
DRAWING NO. V-7581GO-08
SHT. 1 OF 1
FILE NO. V075GS
JOB NO. STANDARD



GENERAL NOTES:

1. WEIGHT EMPTY: 55,000 LBS. (APPROXIMATE)
2. NOMINAL WEIGHT CONTENTS (FULL): 150,000 LBS.
3. TOTAL VOLUME: 2,586 CU. FT. - 19,340 GALLONS
4. MAXIMUM ALLOWABLE WORKING PRESSURE OF VESSEL: 350 PSIG @ 200° F
5. MINIMUM DESIGN METAL TEMPERATURE OF VESSEL: -39° F @ 350 PSIG
6. NOTE: VESSEL NOT INTENDED TO BE FILLED WITH LIQUID CO2 COLDER THAN -20° F.
7. LIFTING LUGS ARE TO BE USED ONLY WHEN VESSEL IS EMPTY.
8. PRIOR TO STORAGE TANK INSTALLATION AND OPERATION, THOROUGHLY READ AND COMPLY WITH ALL INSTRUCTIONS IN THE INSTALLATION AND SERVICE MANUAL.
9. THE SAFETY RELIEF VALVE ASSEMBLY IS REMOVED FOR SHIPMENT. THE ASSEMBLY MUST BE INSTALLED PRIOR TO THE INITIAL FILLING AND OPERATION OF THE TANK.
10. REFERENCE DRAWINGS - PIPING SCHEMATIC: 08160-SCH-08
REFRIGERATION SCHEMATIC: 08160-REF-08
WIRING SCHEMATIC: 08160-WIR-08

NO.	DESCRIPTION	DATE
0	ISSUED WITH CHANGES	06.09.08

REVISIONS

SEE NOTE 10.

REFERENCE DRAWINGS

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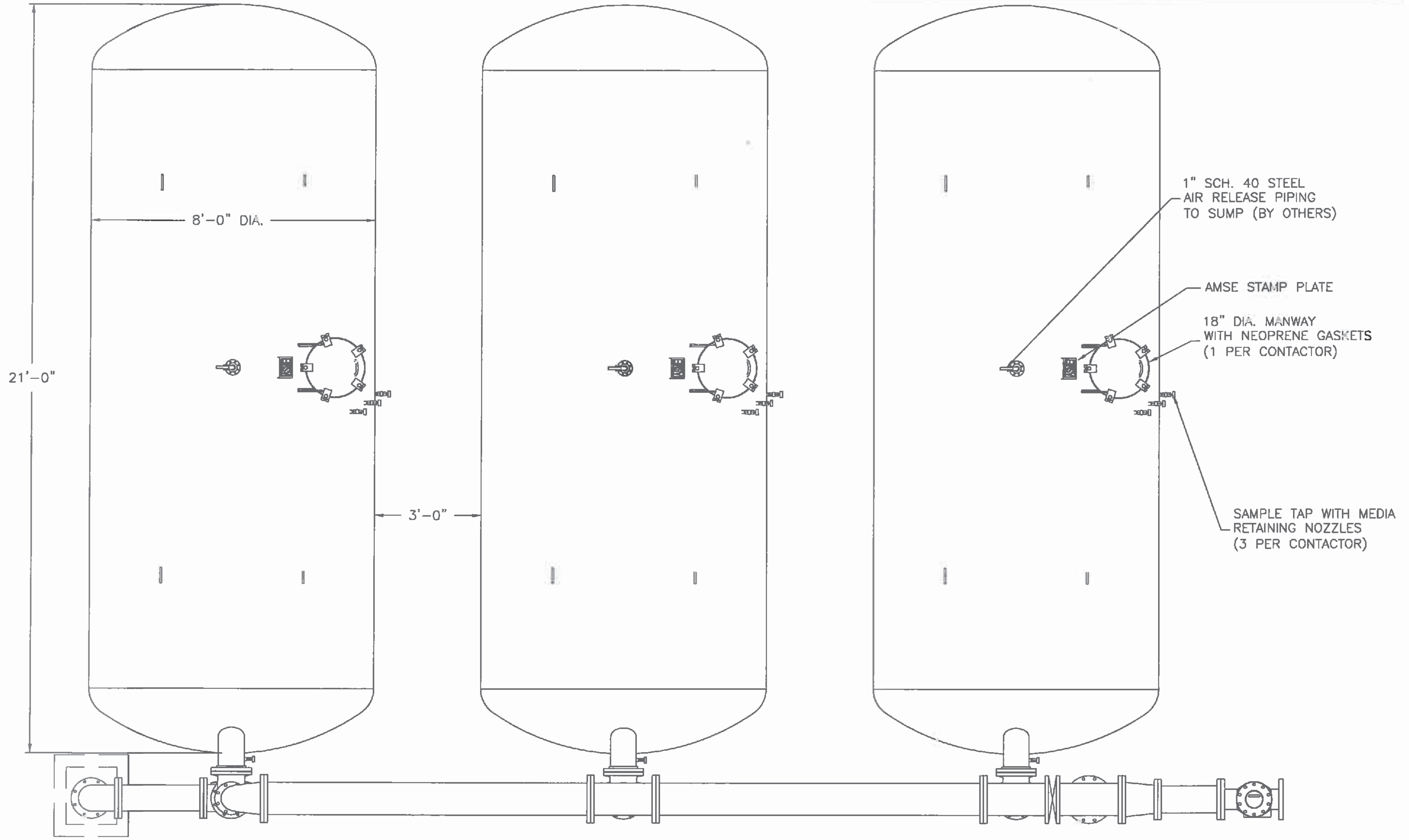
TOMCO2 SYSTEMS EQUIPMENT COMPANY
LOGANVILLE, GEORGIA

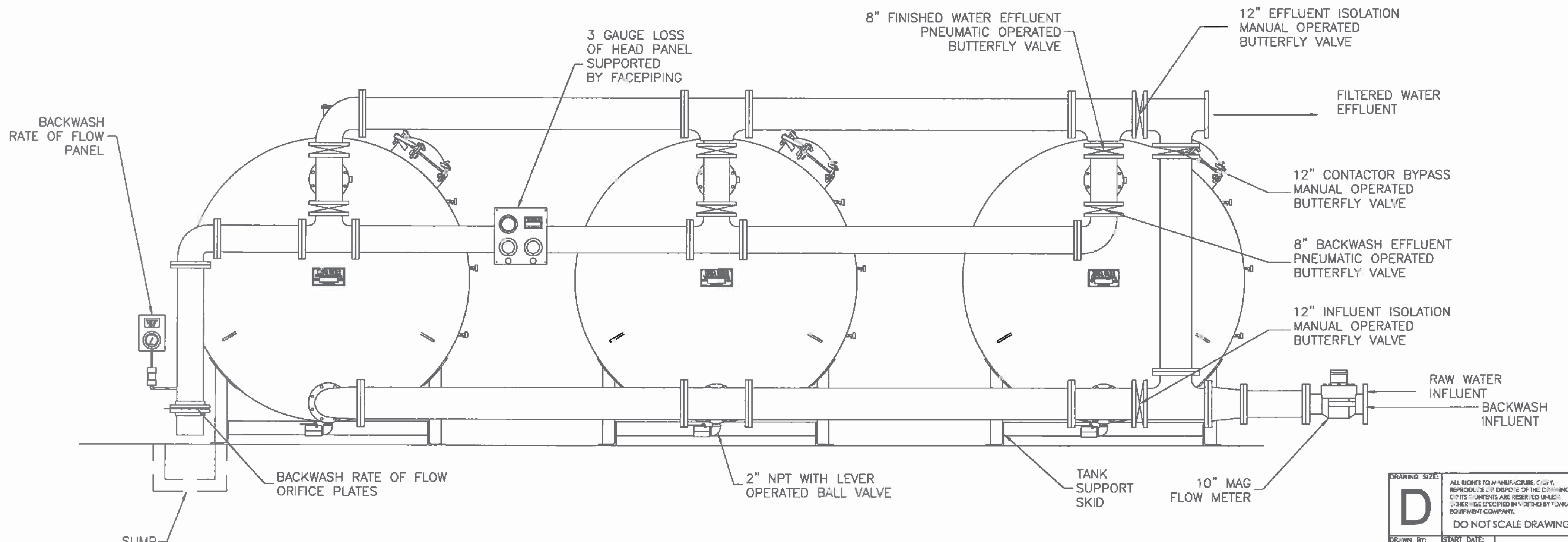
GENERAL OUTLINE
75 TON VERTICAL
LIQUID CARBON DIOXIDE STORAGE TANK

ENGR. BY:
DRN. BY: JMM
CKD. BY:
APPROVED BY:
DATE: 04.30.08
REV. 0
SCALE: NONE
DRAWING NO. V-7581GO-08
SHT. 1 OF 1
FILE NO. V075GS
JOB NO. STANDARD

Tailings Basin Seepage Treatment Train Tonka Limestone Contractor, 1/5



PLAN VIEW



FRONT ELEVATION

SPECIFICATIONS:

NUMBER OF CONTACTORS:
(3) THREE (CURRENT)
(3) THREE (FUTURE)

NUMBER OF CELLS:
(1) ONE CELL

CONTACTOR AREA:
155 SQ. FT./CONTACTOR

CONTACTOR RATE:
467 GPM (3.0 GPM/SQ. FT.) PER CONTACTOR

SUPPORT GRAVELS:

3" –	3/4" x 1/2"	GRADED GRAVEL
3" –	1/2" x 1/4"	GRADED GRAVEL
3" –	1/4" x 1/8"	GRADED GRAVEL
3" –	0.8–1.2mm TORPEDO SAND	

CONTACTOR MEDIA:
48" CALCITE

CONSTRUCTION:
8'–0" DIA. x 21'–0" OVERALL LENGTH
WORKING PRESSURE – 50 PSIG
HYDROSTATIC TEST – 65 PSIG
BUILT TO ASME CODE AND STAMPED ACCORDINGLY

NOTES:

(1) ALL DIMENSIONS SHOWN ARE SUBJECT TO NORMAL CONSTRUCTION TOLERANCES FOR FABRICATION OF THIS SIZE.

(2) FACEPIPING MUST BE ADEQUATELY SUPPORTED INDEPENDENT OF EQUIPMENT SHOWN. PIPE SUPPORTS NOT SUPPLIED BY TONKA.

FINAL VALVE AND PIPING CONFIGURATION TO BE DEFINED BY ENGINEER AFTER REVIEW

DRAWING SIZE: D

DO NOT SCALE DRAWING

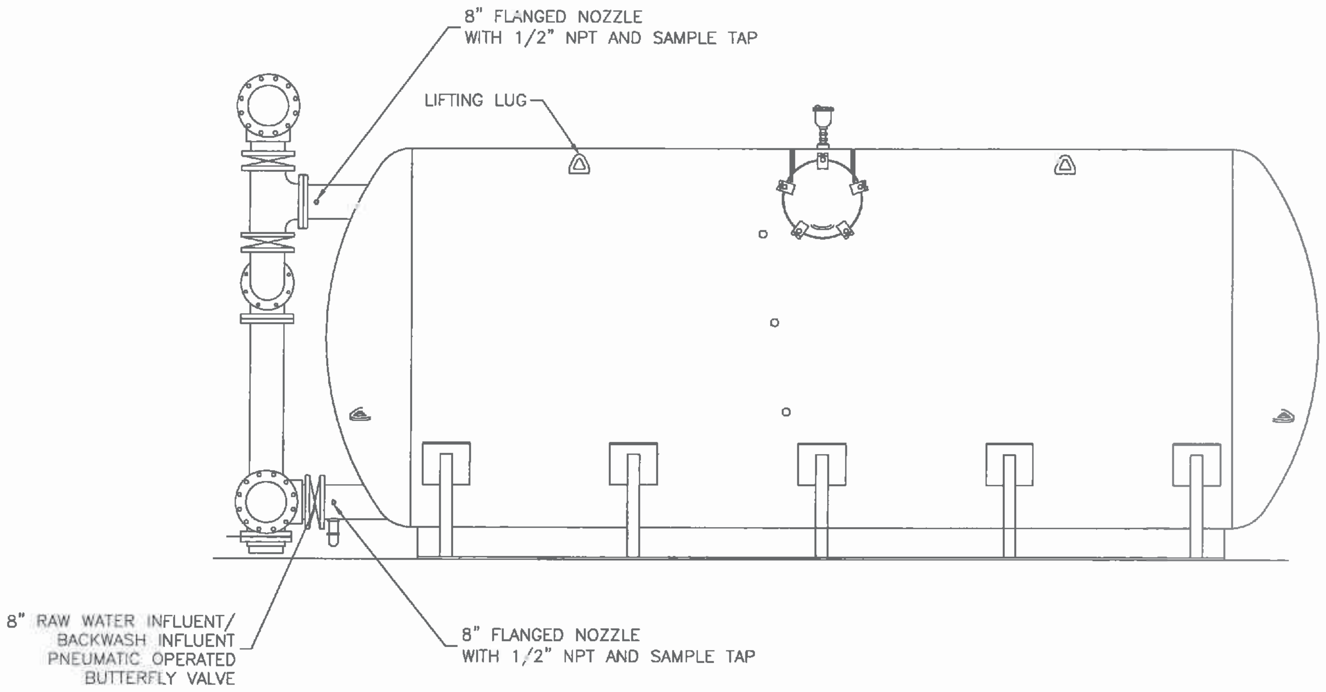
TONKAWATER
Trusted systems. Resourceful thinking.

13305 WATERTOWER CIRCLE
PLYMOUTH, MN 55441
(763) 559-2837
www.tonkawater.com

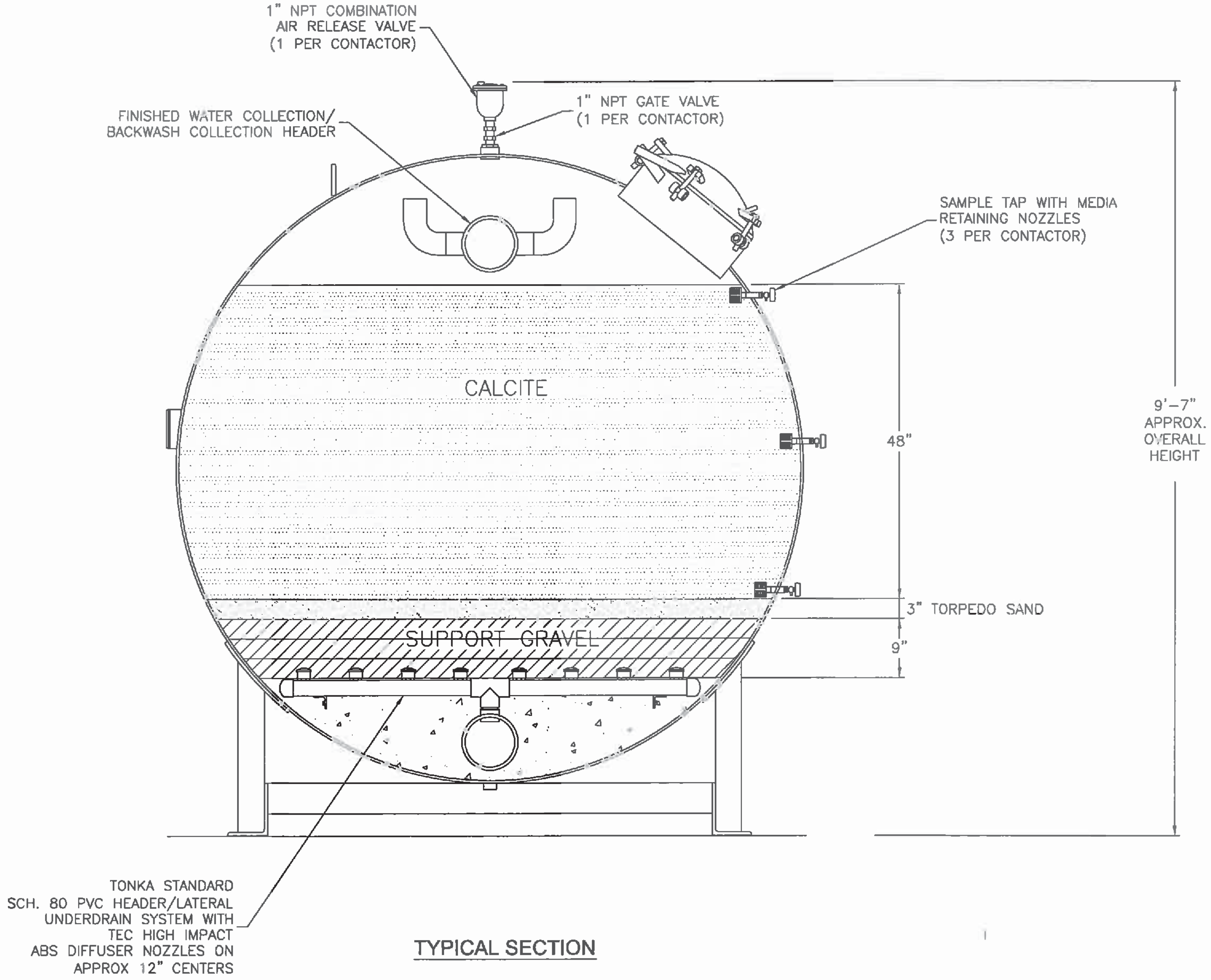
DRAWN BY: MRR
START DATE: 11/04/2013
PROJECT MGR: MTM
DWG. SCALE: NONE
APPR. BY:
APPR. DATE:

LIMESTONE CONTACTOR
8'-0" DIA. X 21'-0" LONG
PROPOSAL DRAWING
POLY MET MINING–HOYT LAKES, MN

SHEET NUMBER: 1 OF 3
REV: 0
DRAWING NUMBER: 00063648
PROJECT NUMBER: 00000



RIGHT ELEVATION



TYPICAL SECTION

DRAWING SIZE:
D

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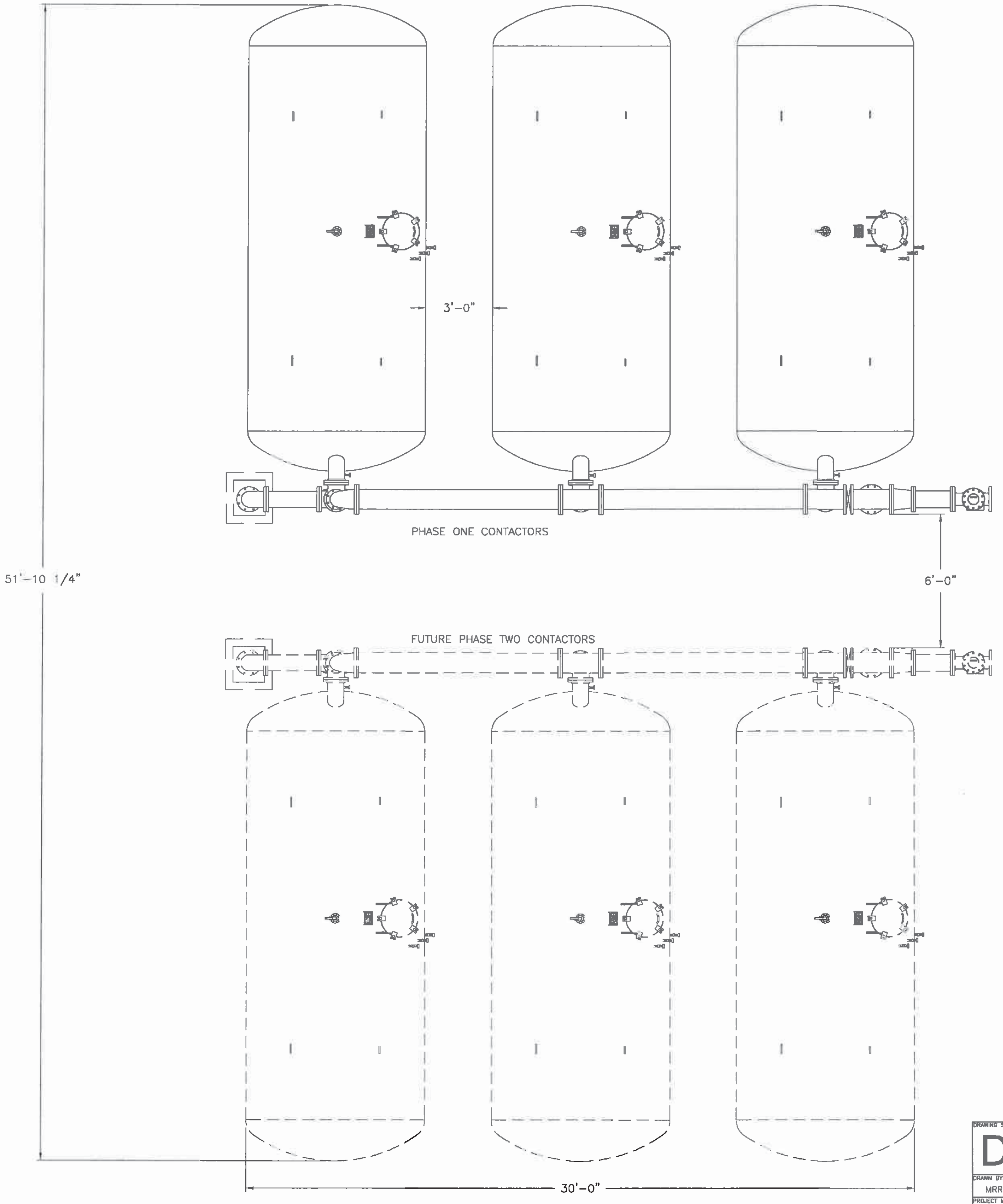
(763) 559-2837
www.tonkawater.com

DRAWN BY: MRR
START DATE: 11/04/2013
PROJECT MGR: NTM
DWG. SCALE: NONE
APPR. BY:
APPR. DATE:

LIMESTONE CONTACTOR
8'-0" DIA. X 21'-0" LONG
PROPOSAL DRAWING
POLY MET MINING–HOYT LAKES, MN

SHEET NUMBER: 2 OF 3
REV: 0
DRAWING NUMBER: 00063648
PROJECT NUMBER: 00000



PROPOSED PLANT LAYOUT

DRAWING SIZE: D

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DRAWN BY: MRR
START DATE: 11/04/2013
PROJECT MGR: MTM
DWG. SCALE: NONE
APPR. BY:
APPR. DATE:

LIMESTONE CONTACTOR
8'-0" DIA. X 21'-0" LONG
PROPOSAL DRAWING
POLY MET MINING–HOYT LAKES, MN

SHEET NUMBER: 3 OF 3
REV: 0
DRAWING NUMBER: 00063648
PROJECT NUMBER: 00000

Tailings Basin Seepage Treatment Train Tonka Limestone Contractor, 4/5

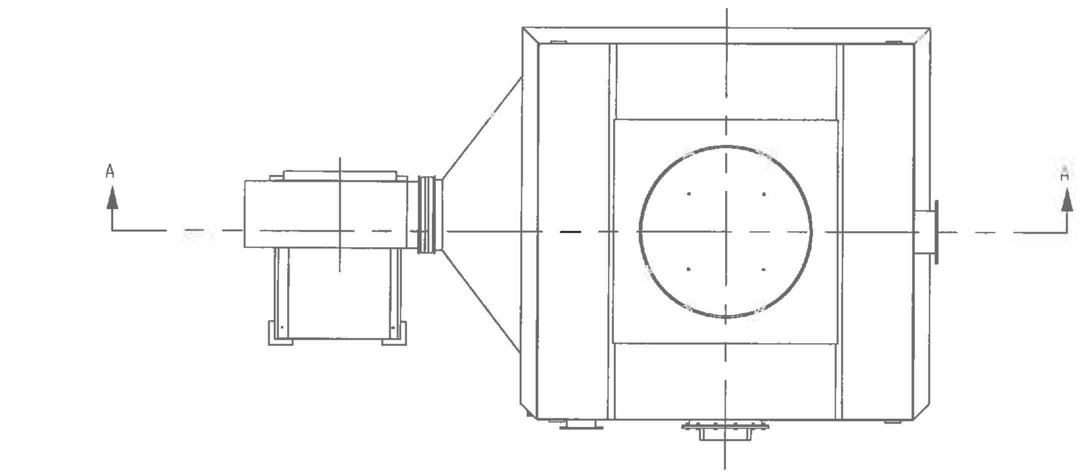
VOC DEGASIFIER SPECIFICATION:

TANK SIZE:
6'-0" SQ.

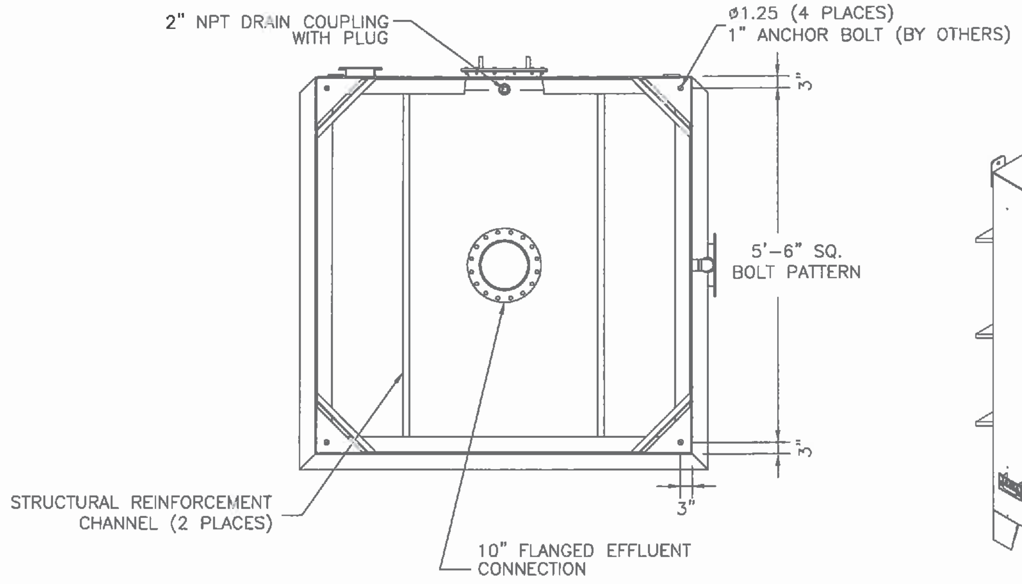
WATER FLOW RATE:
DESIGN FLOW 700 GPM/VOC

BLOWER AIR FLOW RATE:
2800 CFM @ 1/2" S.P.

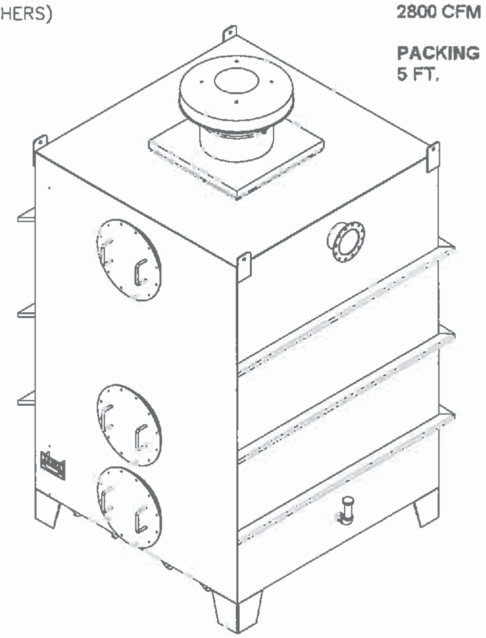
PACKING DEPTH:
5 FT.



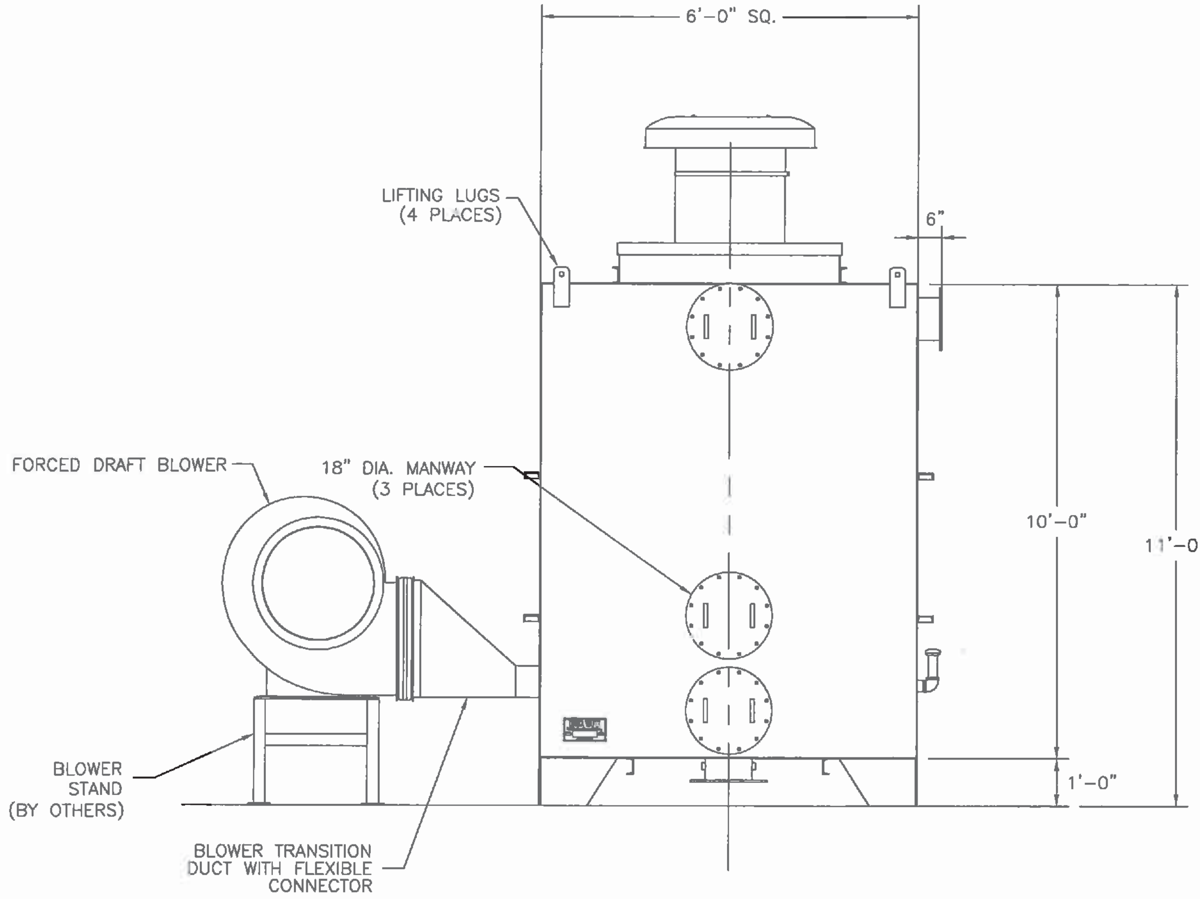
PLAN VIEW



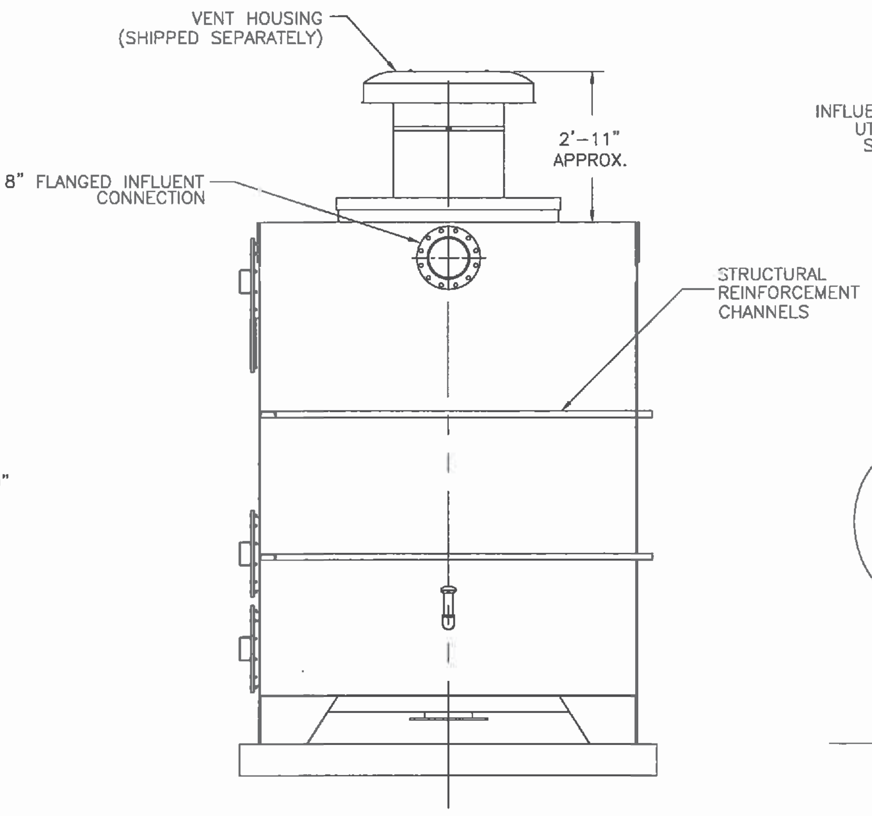
BOTTOM VIEW



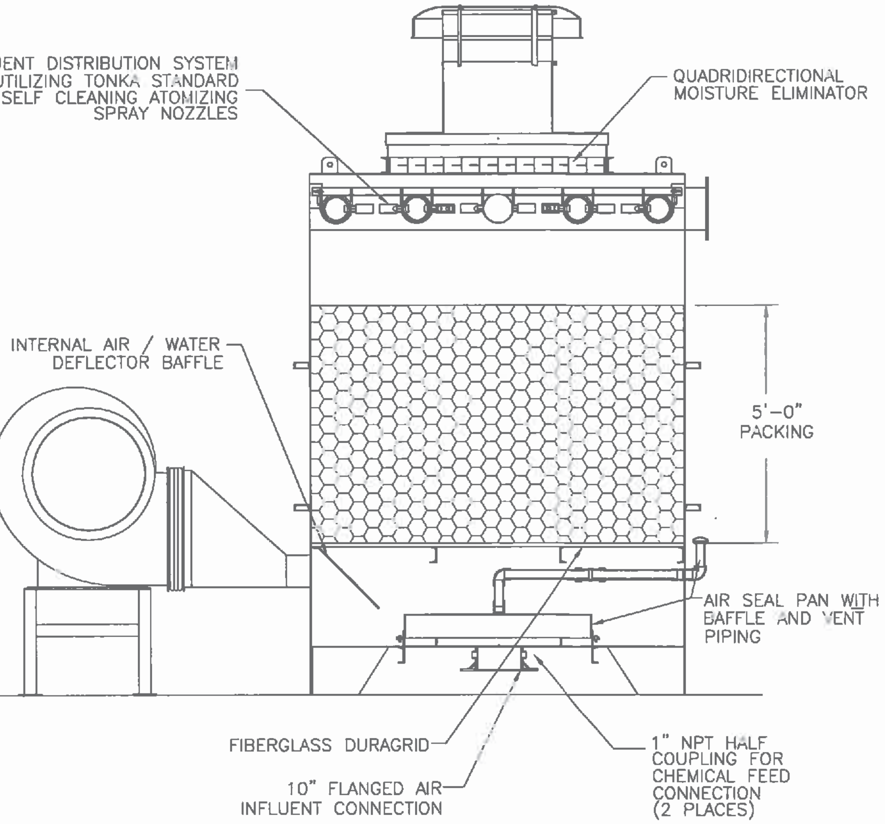
ISOMETRIC VIEW



FRONT ELEVATION



RIGHT SIDE ELEVATION



SECTION A-A

DRAWING SIZE:			
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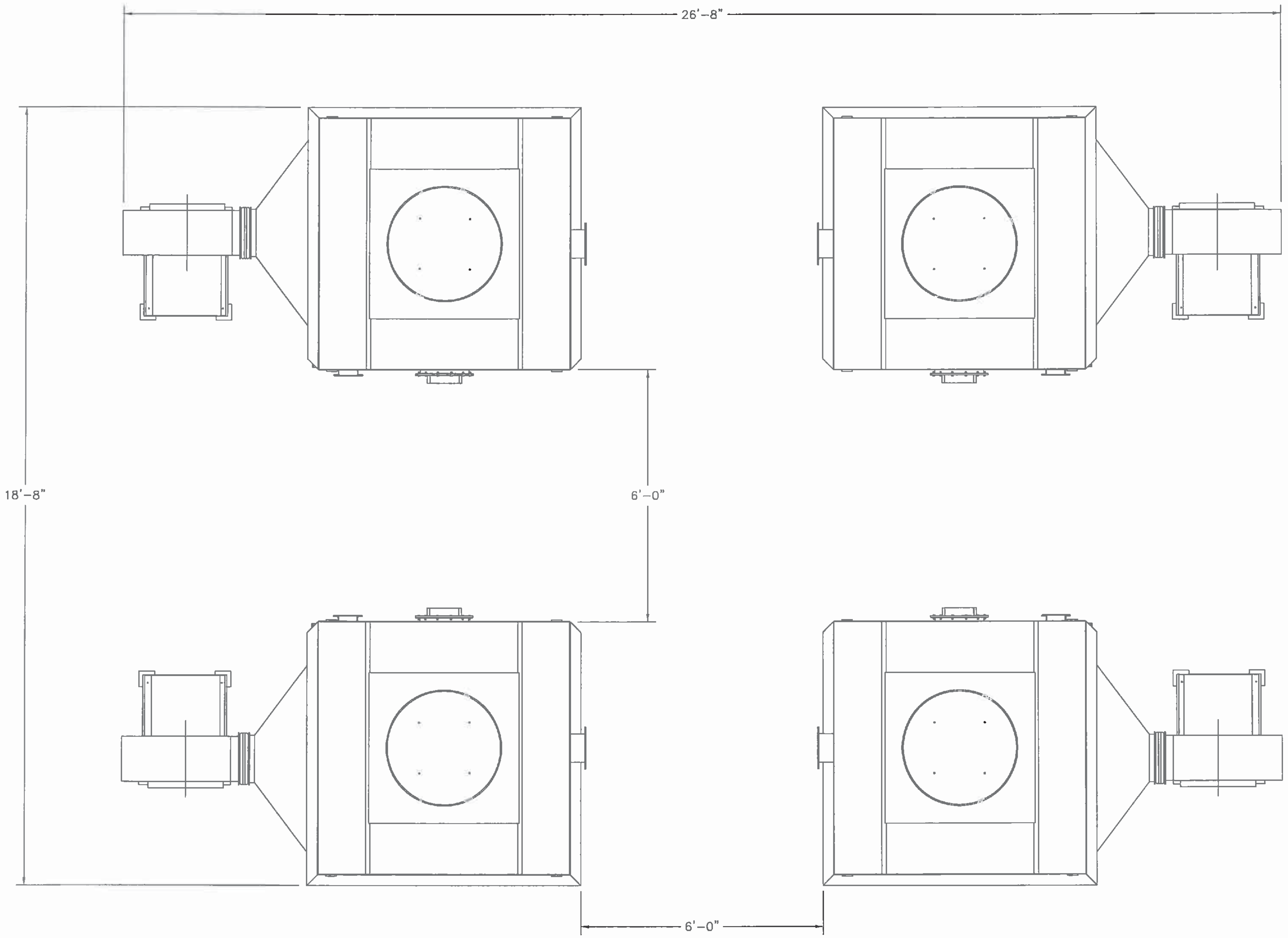
DRAWN BY: MRR	START DATE: 11/04/2013	VOC DEGASIFIER 6'-0" SQ. PROPOSAL DRAWING POLY MET MINING–HOYT LAKES, MN	SHEET NUMBER: 1 OF 2	REV: 0	PROJECT NUMBER: 00000
PROJECT MGR: MTM	DWG. SCALE: NONE		DRAWING NUMBER: 00063635		
APPR. BY:	APPR. DATE:				



PROPOSED PLANT LAYOUT

DRAWING SIZE:
D

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DRAWN BY: MRR
START DATE: 11/04/2013
PROJECT MGR: MTM
DWG. SCALE: NONE
APPR. BY:
APPR. DATE:

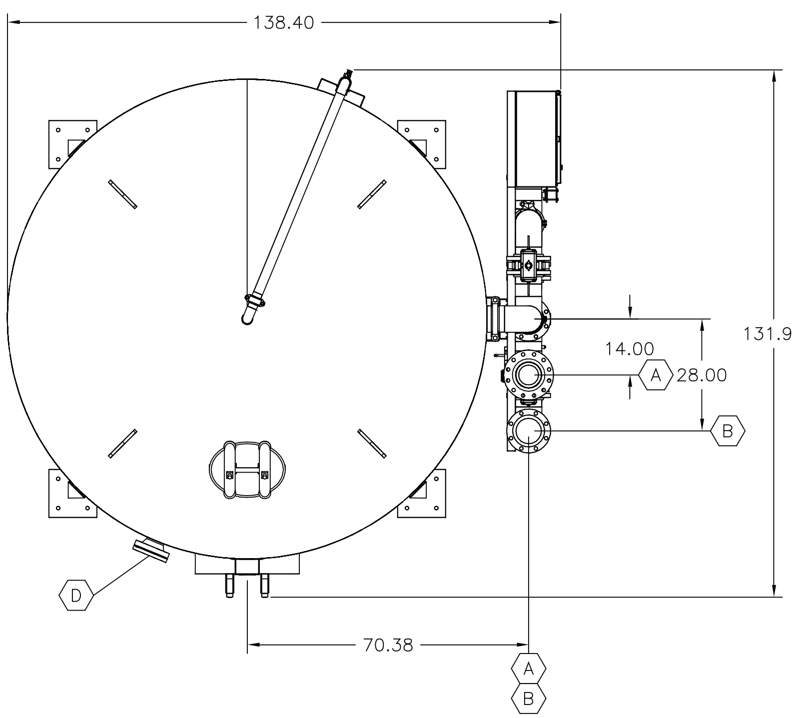
VOC DEGASIFIER
6'-0" SQ.
PROPOSAL DRAWING
POLY MET MINING–HOYT LAKES, MN

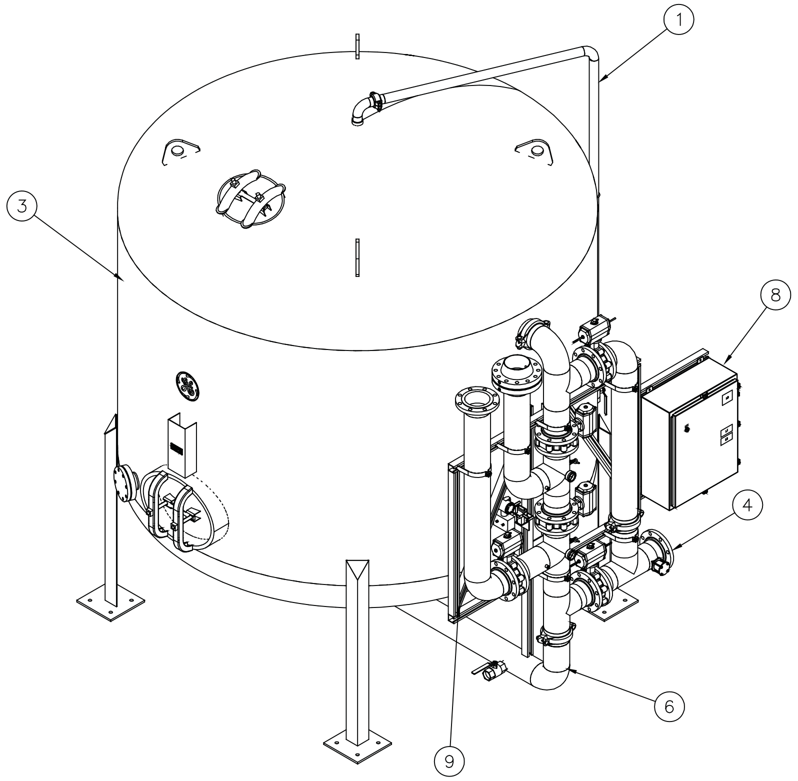
SHEET NUMBER: 2 OF 2
REV: 0
DRAWING NUMBER: 00063635
PROJECT NUMBER: 00000

Attachment G

Mine Water Treatment Trains Vendor Data

Mine Water Treatment Trains GE GSF, 1/1





NOTES:

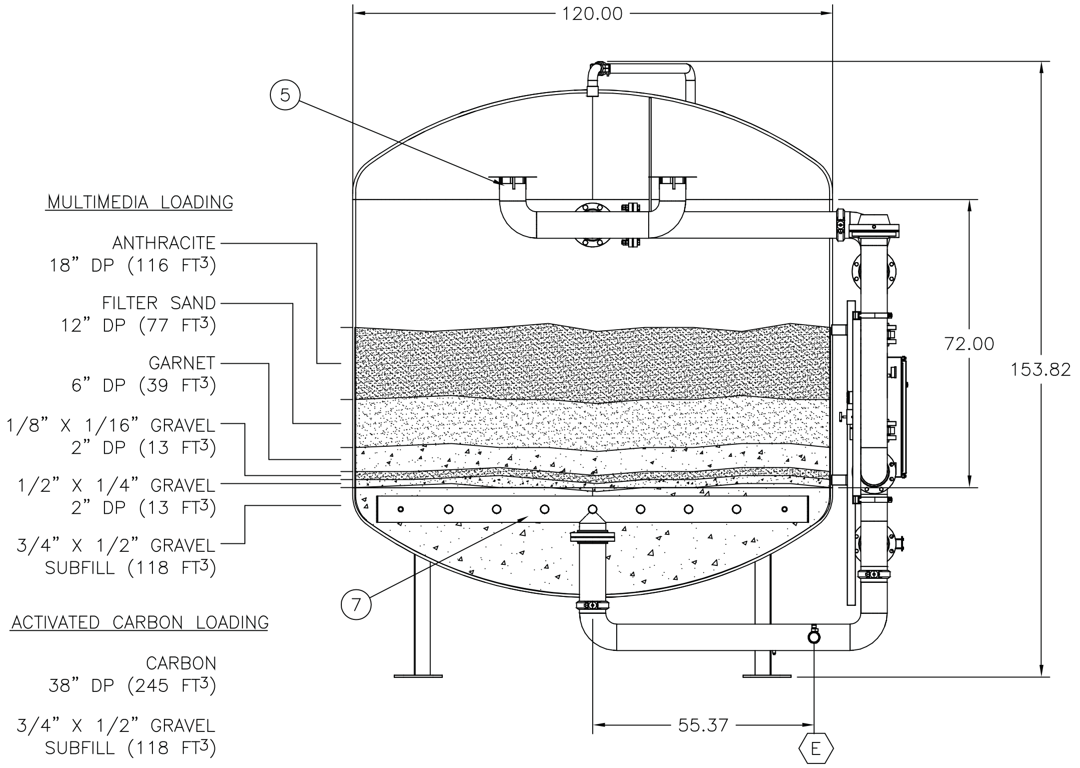
1. CONNECTION TABLE

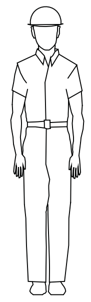
ITEM	DESCRIPTION	MATERIAL	TYPE	SIZE
A	SERVICE INLET	316SS	150# FLANGE	6.00"
B	SERVICE OUTLET	316SS	150# FLANGE	6.00"
C	DRAIN	316SS	150# FLANGE	6.00"
D	MEDIA REMOVAL PORT	CS	150# FLANGE	4.00"
E	PRIMARY TANK DRAIN	316SS	FPT	2.00"
F	TANK VENT	316SS	FPT	2.00"
G	SECONDARY TANK DRAIN	316SS	FPT	0.75"
H	AIR INLET	ZINC	FPT	0.25"
J	MANWAY W/EPDM GASKET	CS	CRAB	18"X24"
K	MANWAY W/EPDM GASKET	CS	CRAB	14"X18"

2. DRY WEIGHT: M120 – 43,075 LB/[19,580 Kg.]
C120 – 29,4500 LB/[13,386 Kg.]
3. OPERATING WEIGHT: M120 – 63,625 LB/[28,920 Kg.]
C120 – 57,805 LB/[26,275 Kg.]
4. PLUMBING RUN \ EQUIPMENT TABLE:

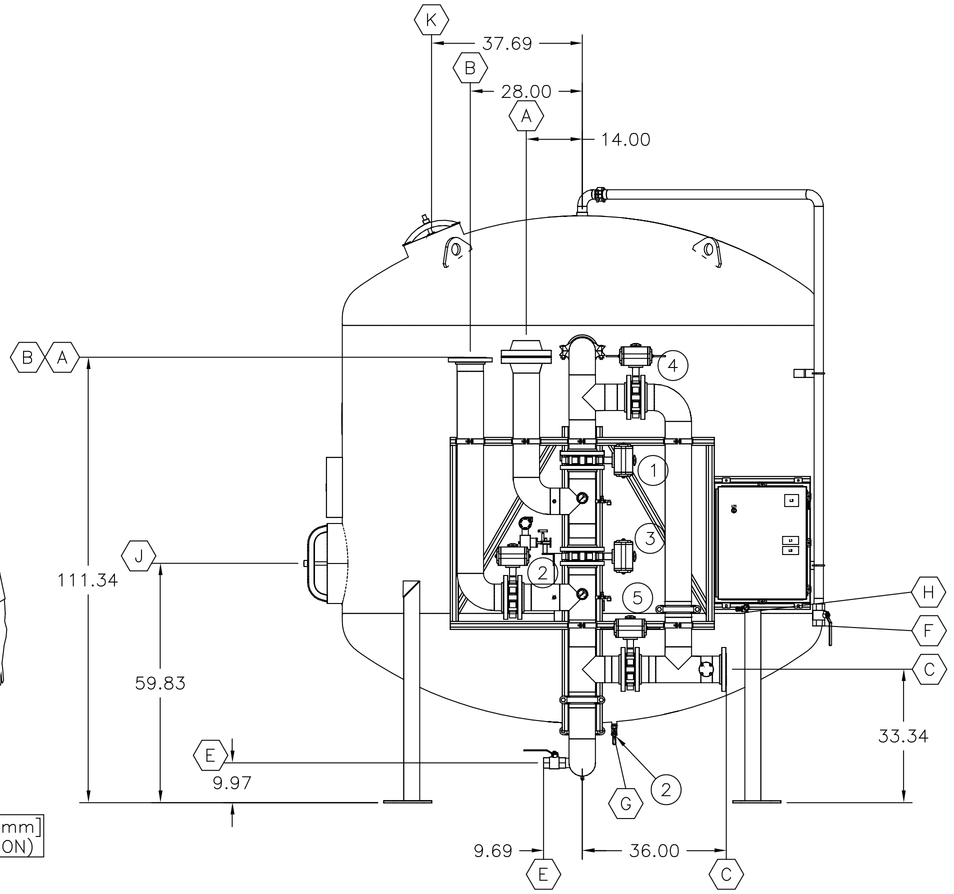
FIND NO.	PART NUMBER	QTY.	DESCRIPTION	U/M
1	1220617	1	PLMB,VENT,MM,316,2.00	EA
2	1228727	1	PLMB,DRAIN,MM,316,0.75	EA
3	3023818	1	TANK,FILTER,CS,120" DIA X 72"	EA
4	3024397	1	PLMB, FACE ASSY,MM/AC,316,6.00	EA
5	3024458	1	PLMB,DIST,UPPER,4P,316,6.00	EA
6	3024461	1	PLMB,LWR PLMB,MM/AC–120,316,6.00"	EA
7	3024565	1	PLMB,LWR DISTRIB,MM/AC–120,316,6.0	EA
8	3024784	1	ENCL–MACH,MM/AC,TITAN	EA
9	3024899	1	BRACKET,FACE PLMB,CS,3–6,24X30 ENCL	EA

5. ALL DIMENSIONS IN INCHES.
6. REFERENCE – PROCESS AND INSTRUMENTATION DIAGRAM : 1303306





6'-0"[1829mm]
(REF PERSON)



VALVE NUMBER	DESCRIPTION
①	SERVICE INLET VALVE
②	SERVICE OUTLET VALVE
③	BACKWASH INLET VALVE
④	BACKWASH OUTLET VALVE
⑤	RINSE OUTLET VALVE

FILTER FUNCTION	VALVES OPEN
SERVICE	1,2
BACKWASH	3,4
SETTLE	---
RINSE	1,5

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	13332	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
.X ± 3.0 ± 1°
.XX ± 1.00
.XXX ± 0.500
FRAC
± N/A

DRAWN BY	DJS	DATE 17Aug07
CHECKED BY	RLD	DATE 3Dec07
APPROVED BY	PWG	DATE 3Dec07
APPROVED BY		DATE

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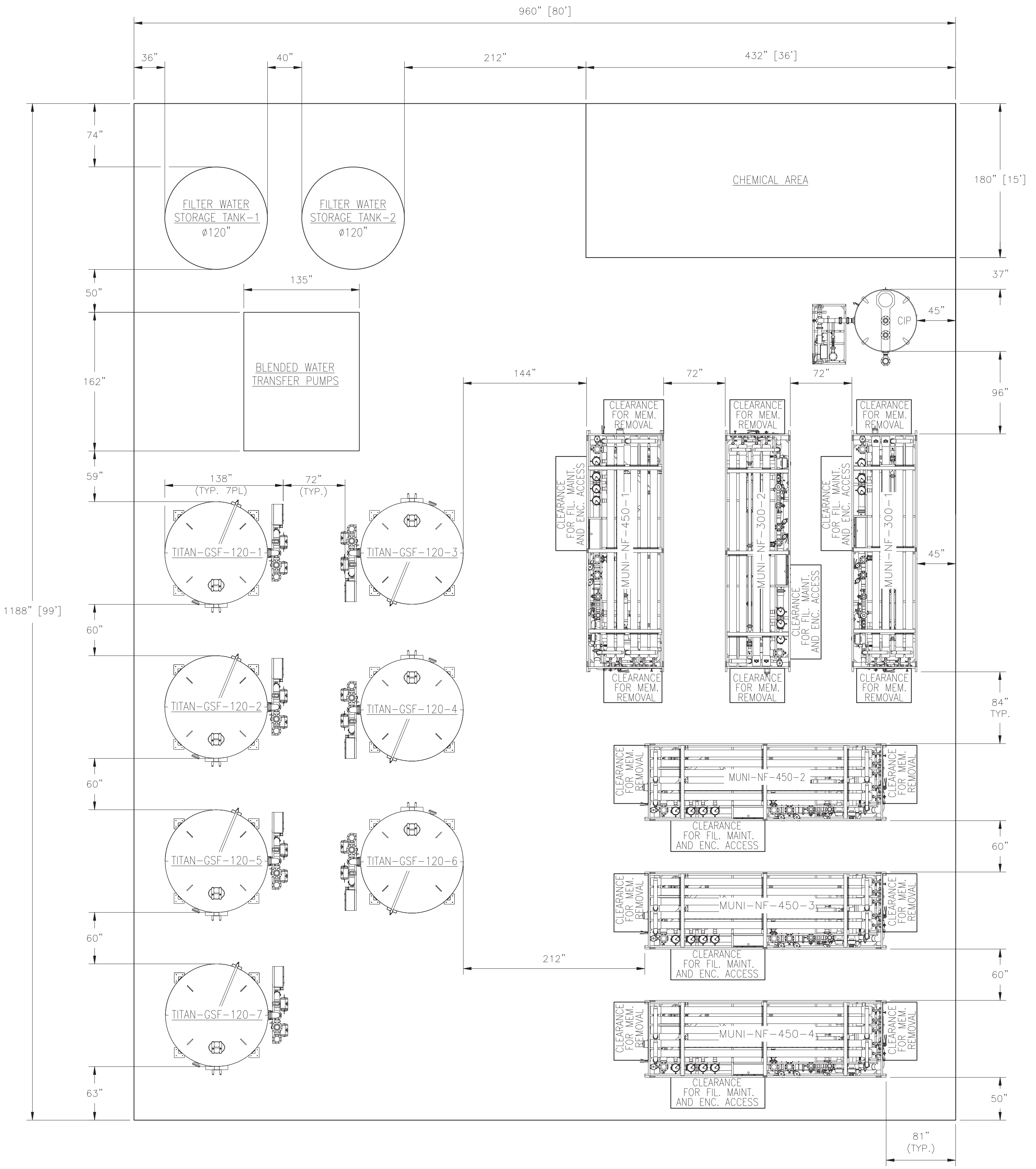
CLIENT/JOB
FILE ACR2007

DWG DESCRIPTION
GENERAL ARRANGEMENT
FLT–MM/AC,120X72,CS/SS,RIO,60
MATERIAL/BOM NO. 3023939

SIZE D
DRAWING NO. 1303397
REV A
PROJECT
SCALE 1/2"=1'–0"
SHEET 1 OF 1

P/N 1161662–RGP01

Mine Water Treatment Trains GE Membranes, 1/8



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CONSTRUCTION

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE		EVN		03APR13	

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
.X ± ±
.XX ± FRAC
.XXX ± ±

DIMENSIONS IN INCHES
DO NOT SCALE

THIRD ANGLE

DRAWN BY EVN	DATE 03APR13
CHECKED BY	DATE
APPROVED BY	DATE
APPROVED BY	DATE

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CLIENT/JOB
POLYMET MINING WWTF PROJECT
BARR ENGINEERING, MINNESOTA,

TITLE
PRELIMINARY
EQUIPMENT LAYOUT

FILE AUTOCAD

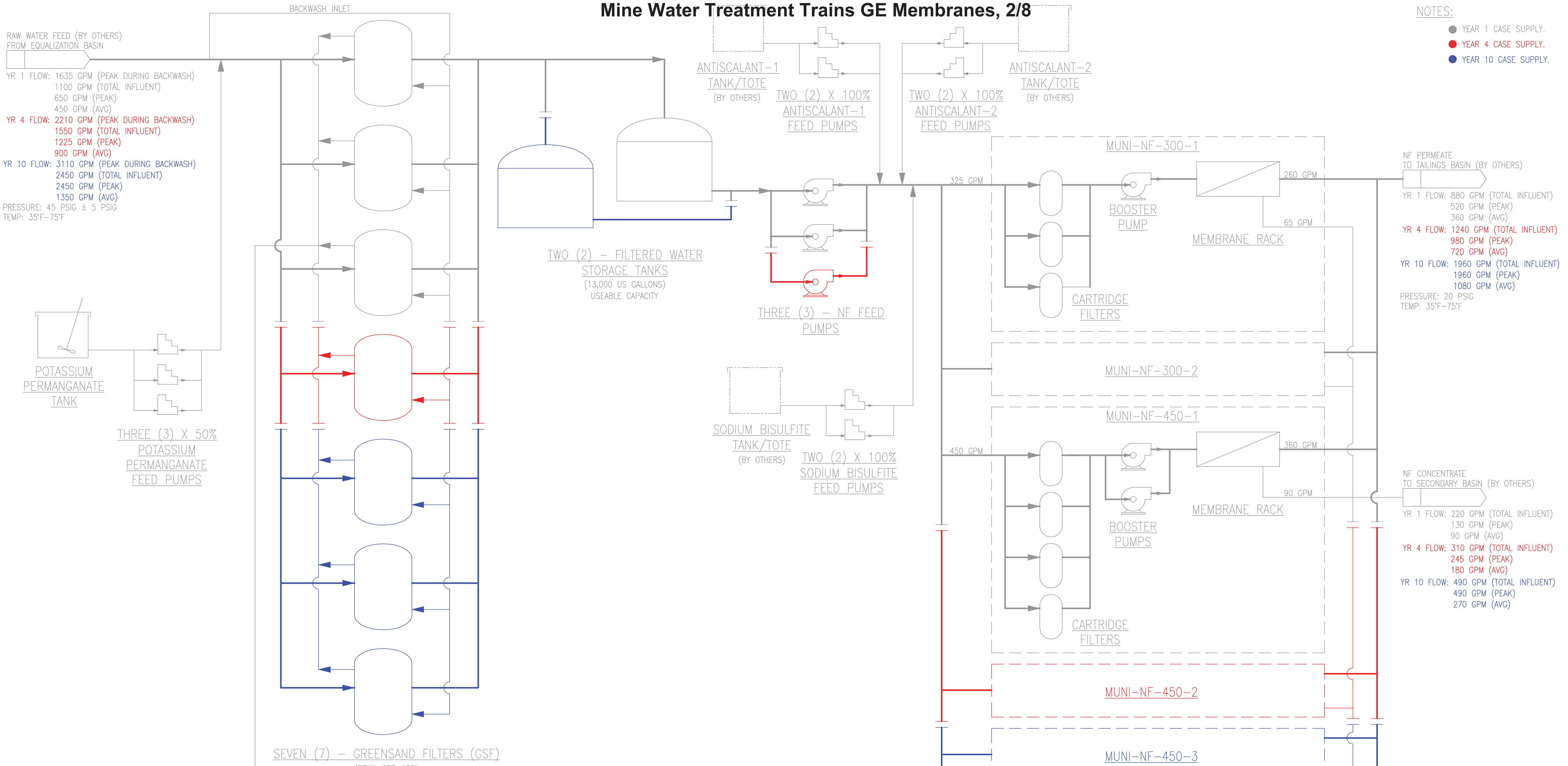
MATERIAL

SIZE	DRAWING NO.	REV
D	792240–AG–01	A1

PROJECT 792240
SCALE 1:75
SHEET 1 OF 1

P/N 1161662–RHP01

Mine Water Treatment Trains GE Membranes, 2/8



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CONSTRUCTION**

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE		LVN		03APR13	

TOLERANCES UNLESS NOTED
DECIMALS .X ± .XX ± .XXX ±
ANGLES ± FRAC ±
DIMENSIONS IN INCHES
DO NOT SCALE
THIRD ANGLE

DRAWN BY MSK DATE 02APR13
CHECKED BY DATE
APPROVED BY DATE
APPROVED BY DATE

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CLIENT/JOB
POLYMET MINING WWTF PROJECT
BARR ENGINEERING, MINNESOTA,

FILE AUTOCAD

TITLE
PRELIMINARY
PROCESS FLOW DIAGRAM

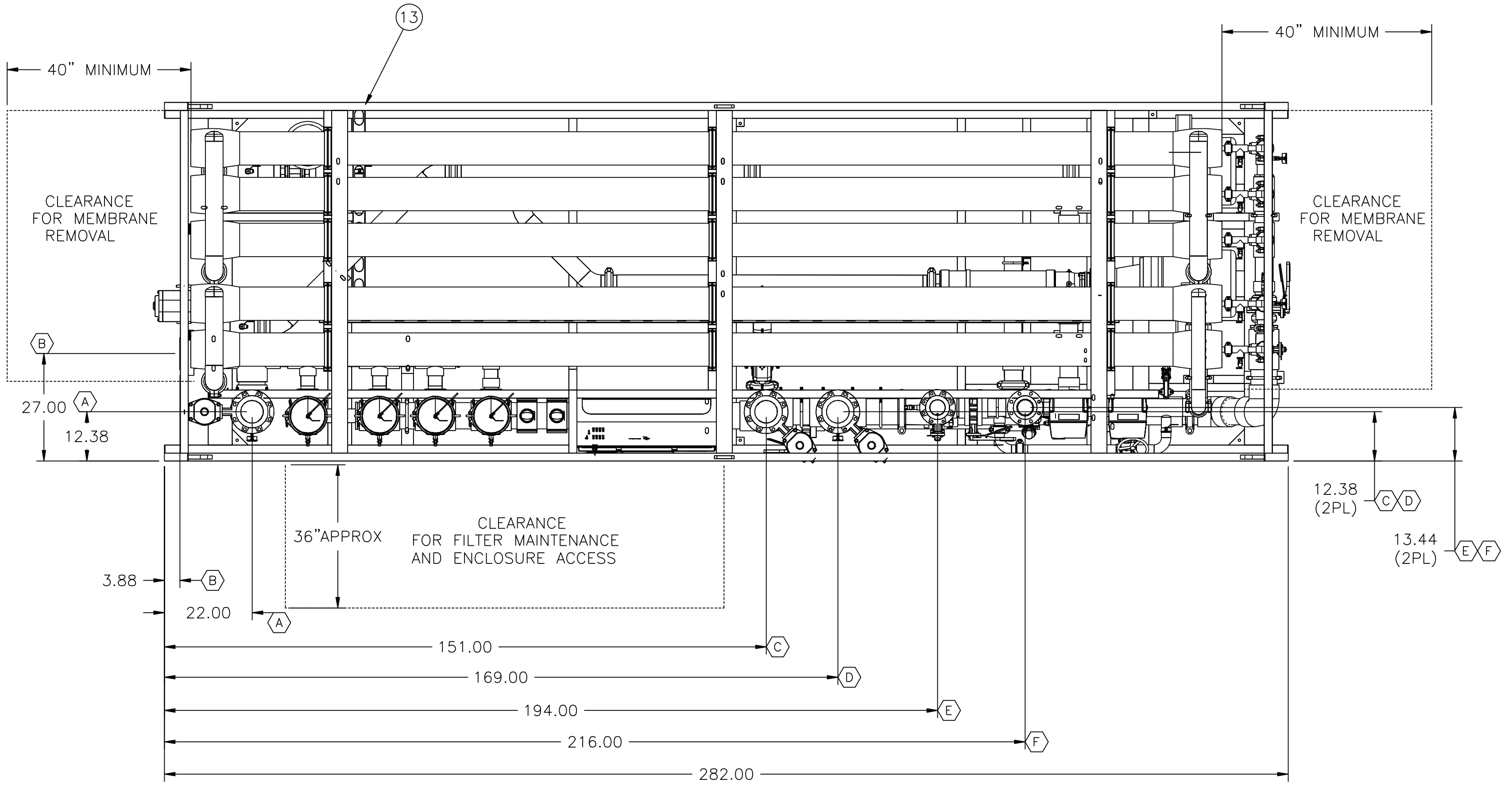
MATERIAL

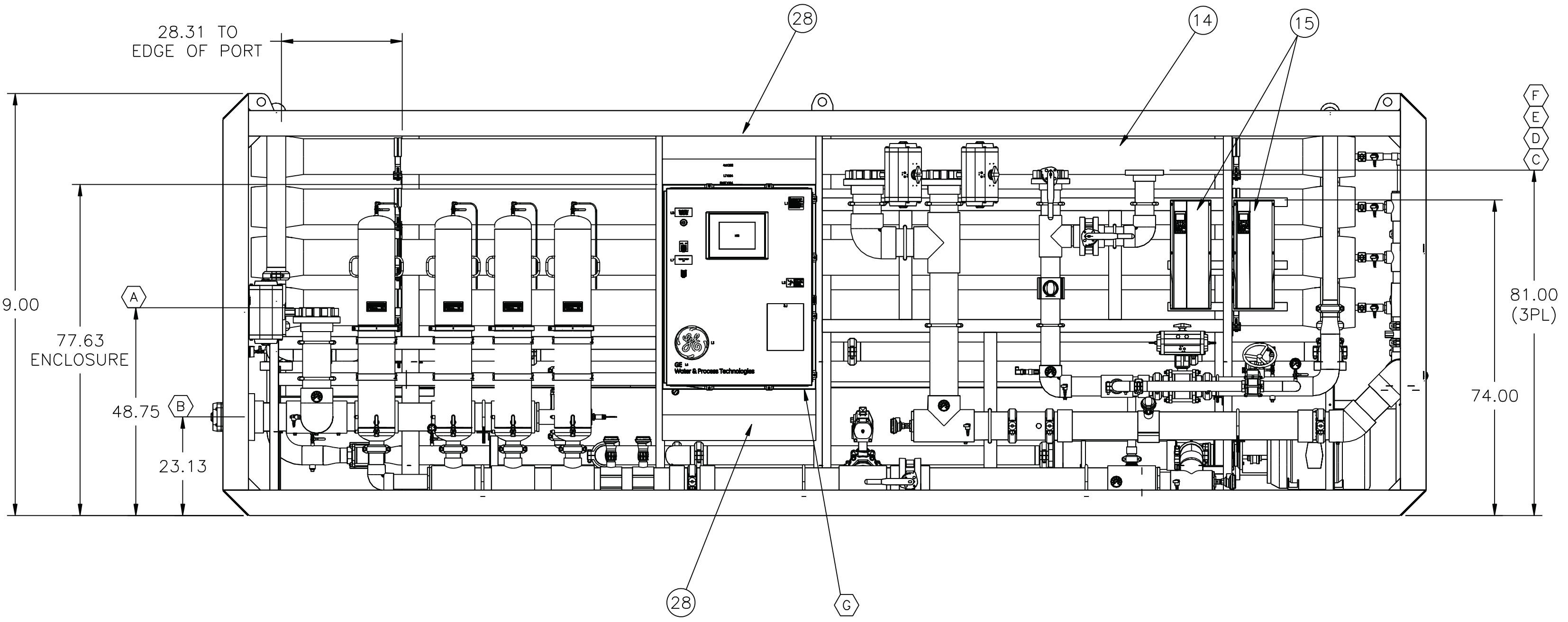
SIZE D
DRAWING NO. 792240–AM–01
REV A3
PROJECT 792240
SCALE NONE
SHEET 1 OF 1

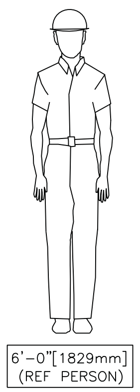
P/N 1161662–RHP01

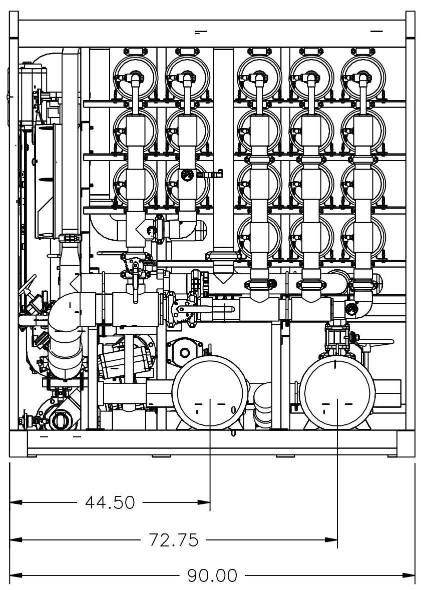
PART NUMBER	DESCRIPTION
3051902	RO,MUNI-450,480/3/60

Mine Water Treatment Trains GE Membranes, 3/8









NOTES:

1. CONNECTION TABLE

ITEM	DESCRIPTION	MATERIAL	TYPE	SIZE
A	INLET	PVC	150# FLANGE	6.00
B	INLET CIP	PVC	150# FLANGE	6.00
C	PERMEATE OUTLET	PVC	150# FLANGE	6.00
D	PERMEATE CIP OUTLET	PVC	150# FLANGE	6.00
E	CONCENTRATE OUTLET	PVC	150# FLANGE	4.00
F	CONCENTRATE CIP OUTLET	PVC	150# FLANGE	4.00
G	COMPRESSED AIR INLET	ZINC	FNPT	0.25

2. SHIPPING WEIGHT APPROX – 21,650 LB/[9,825 Kg].
3. OPERATING WEIGHT APPROX – 27,020 LB/[12,260 Kg].
4. PLUMBING RUN \ EQUIPMENT TABLE:

FIND NO.	PART NUMBER	QTY.	DESCRIPTION	U/M
1	1115055	1	PLUG,PIPE,MPT,316,SQH,0.25,3000LB	EA
2	1115698	1	NIPPLE,MPT,316,0.25XCLS	EA
3	1144776	1	FTG-SENSOR,FLOW,PVC,6.00	EA
4	1156020	1	PLUG,M.CPLG,PVC,1.50	EA
5	1202086	1	PLUG,M.CPLG,316,1.00	EA
6	1225625	1	PUMP,TF,AS40405KZE,40HP,TEFC	EA
7	1226020	1	VALVE-BALL,FPT,316,0.25",1PC,FLO	EA
8	1268176	2	VALVE-BTFLY,NYLON,6.00,MANUAL,LUGGED	EA
9	1268181	2	VALVE-BTFLY,NYLON,6.00,A/S,LUGGED,BRAY	EA
10	3013257	1	TRANS-PRESS,DIN,316SS,0-500PSIG,4-20,GE	EA
11	3020604	2	STARTER,ABB,COMBO,IEC,460VAC,40HP,N4 PL	EA
12	3034594	1	SENSOR,ORP,SIGNET,3-2725-6,3-2750-2	EA
13	3035326	3	DUCT,WIRE,3.00,VENTED,CS,3M,PAINTED	EA
14	3035340	18	HSG,SH-6/823,FRP,32VIC,4P,WAVE,450,V,COD	EA
15	3042688	2	VFD,GE,AF-650GP,40HP,N4,460VAC,3PH	EA
16	3051915	1	PLMB-INLET,PVC,6.00,MUNI-450	EA
17	3051916	1	PLMB-PERM,PVC,6.00,MUNI-450	EA
18	3051917	1	PLMB-CONC LP,PVC,4.00,MUNI-450	EA
19	3051918	1	PLMB-CONC HP,316,4.00,3PC,MUNI-450	EA
20	3051919	1	PLMB-PUMP DISCH,316,4.00,6PC,MUNI-450	EA
21	3051930	1	PLMB-RECY,316,1.50,MUNI-450	EA
22	3051931	1	PLMB-CONC B1,316,4.00,2PC,MUNI-450	EA
23	3051932	1	PLMB-INLET B2,316,4.00,6PC,MUNI-450	EA
24	3051933	1	FRAME,CS,282LX90WX99H,MUNI-450	EA
25	3052830	1	PUMP,TF,AS40405KZE,40HP,TEFC,F2	EA
26	3053053	1	ENCL-MACH,MUNI-RO,AB,120VAC,60HZ,RIO	EA
27	3053054	1	ENCL-MACH,MUNI-RO,AB,120VAC,60HZ,CP	EA
28	3053193	2	ENCL-HOOD-PNTD,CS,MUNI100-450	EA
29	3053483	2	SPOOL-OPTIONAL,316,4.00,MUNI,MANUAL	EA
30	3053484	2	SPOOL-OPTIONAL,316,4.00,MUNI,AUTOMATIC	EA

5. ALL DIMENSIONS IN INCHES.
6. REFERENCE – PIPING AND INSTRUMENTATION DIAGRAM: 1308275

7 OPTIONAL EQUIPMENT. REFERENCE BILL OF MATERIAL FOR CUSTOMER SPECIFIC OPTIONS.

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	14334	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS .X ± .XX ± 0.50 .XXX ±
ANGLES ± FRAC ±
DIMENSIONS IN INCHES DO NOT SCALE
THIRD ANGLE

DRAWN BY	JWA	DATE	17MAY10
CHECKED BY	JSS	DATE	16Nov10
APPROVED BY	BRB	DATE	16Nov10
APPROVED BY		DATE	

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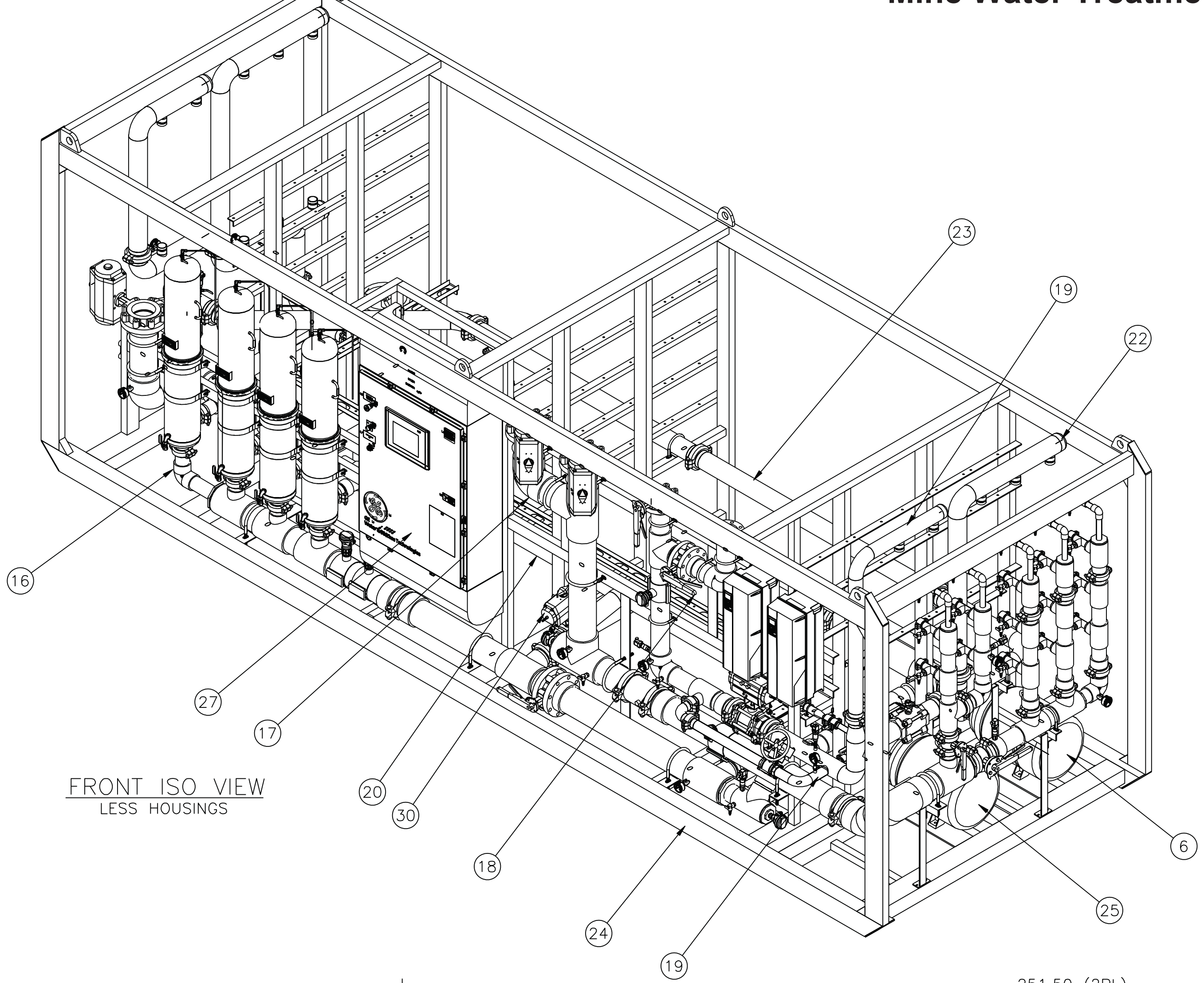
CLIENT/JOB
FILE ACR2007

TITLE
GA,RO,MUNI-450,
480/3/60
MATERIAL SEE BOM

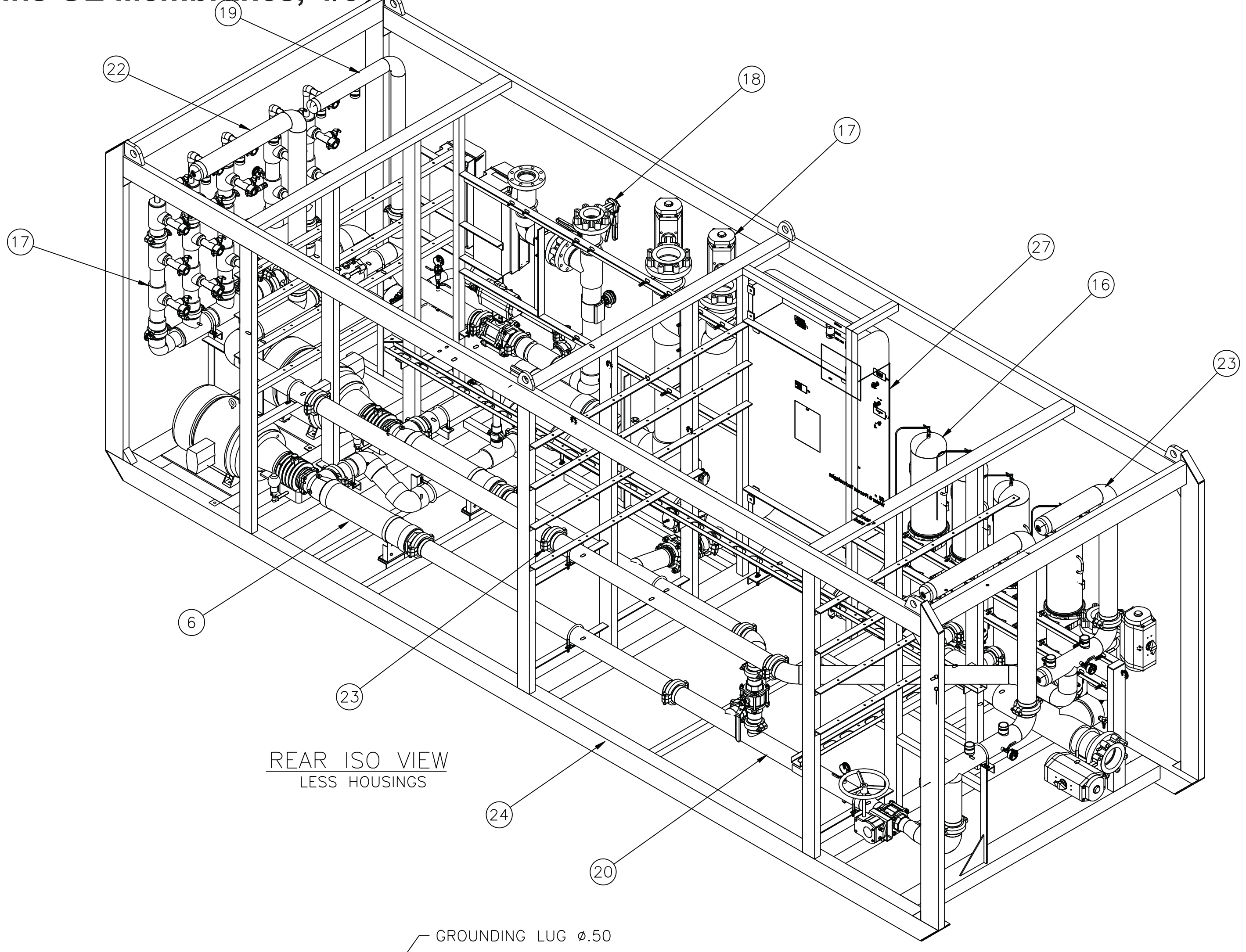
SIZE D
DRAWING NO. 1308274
REV A
PROJECT
SCALE 3:64
SHEET 1 OF 3

P/N 1161662-RHP01

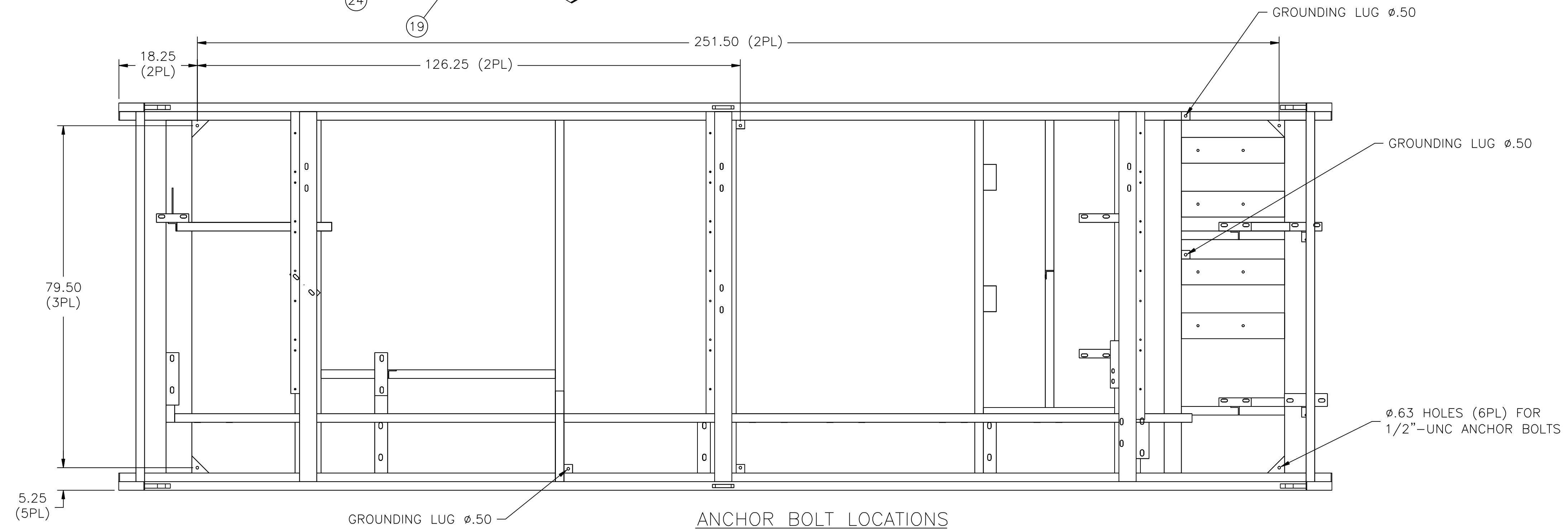
Mine Water Treatment Trains GE Membranes, 4/8



FRONT ISO VIEW
LESS HOUSINGS



REAR ISO VIEW
LESS HOUSINGS



ANCHOR BOLT LOCATIONS

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	14334	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS .X ± .XX ± .XXX ±
ANGLES ± FRAC ±

DIMENSIONS IN INCHES
DO NOT SCALE

THIRD ANGLE

DRAWN BY JWA — DATE 17MAY10
CHECKED BY JSS — DATE 16Nov10
APPROVED BY BRB — DATE 16Nov10
APPROVED BY — DATE

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CLIENT/JOB
FILE ACR2007

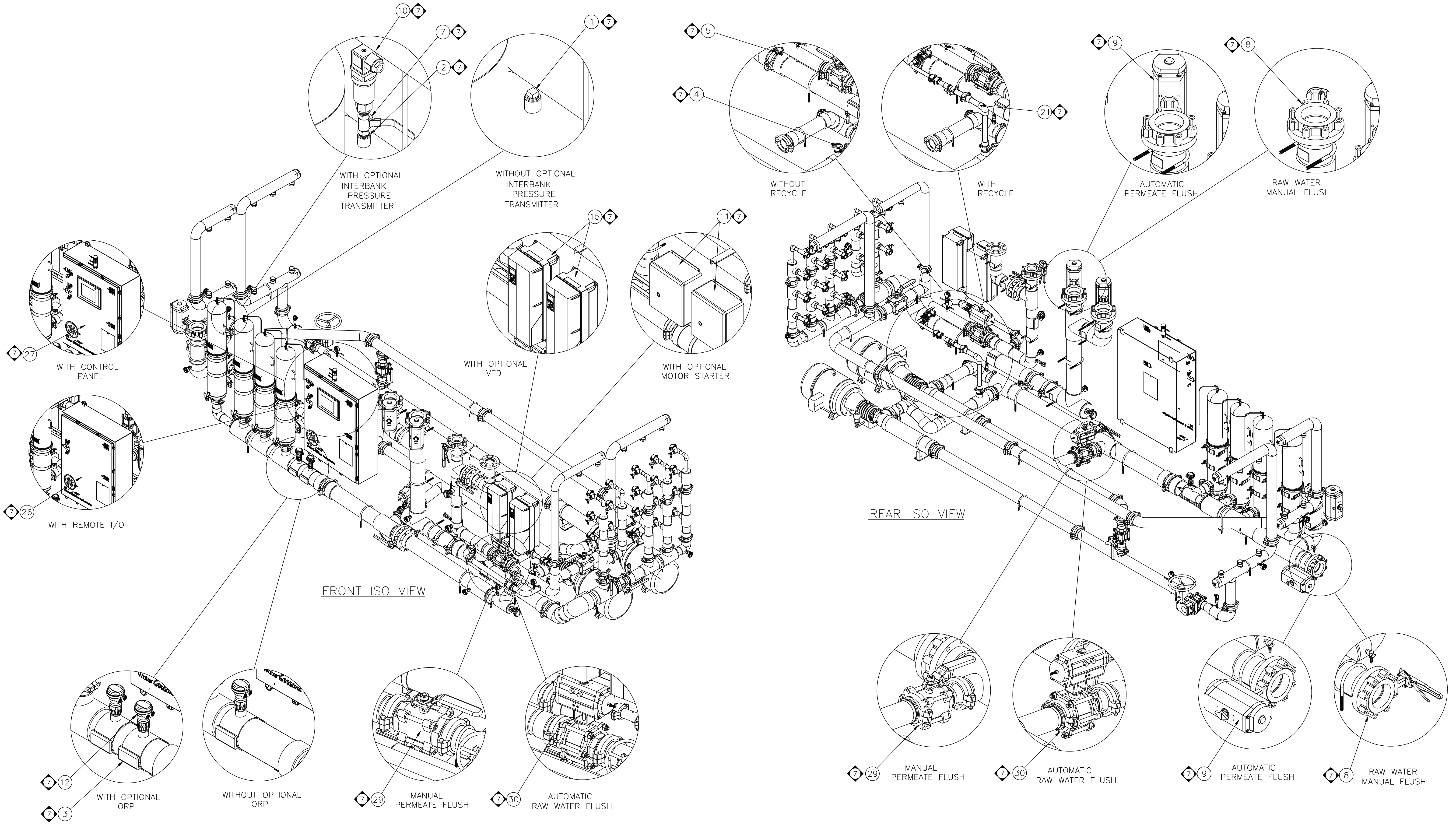
TITLE
GA,RO,MUNI–450,
480/3/60

MATERIAL SEE BOM

SIZE D
DRAWING NO. 1308274
REV A
PROJECT
SCALE 1:16
SHEET 2 OF 3

P/N 1161662-RHP01

Mine Water Treatment Trains GE Membranes, 5/8



REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	14334	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
.X ± ±
.XX ± FRAC
.XXX ± ±

DIMENSIONS IN INCHES DO NOT SCALE

THIRD ANGLE

DRAWN BY JWA	DATE 17MAY10
CHECKED BY JSS	DATE 16Nov10
APPROVED BY BRB	DATE 16Nov10
APPROVED BY	DATE

GE
Water & Process Technologies
GLOBAL HEADQUARTERS : TREVOSE, PA USA +1-215-355-3300 WWW.GEWATER.COM

CLIENT/JOB

FILE ACR2007

TITLE GA,RO,MUNI–450, 480/3/60

MATERIAL SEE BOM

SIZE D

DRAWING NO. 1308274

REV A

PROJECT

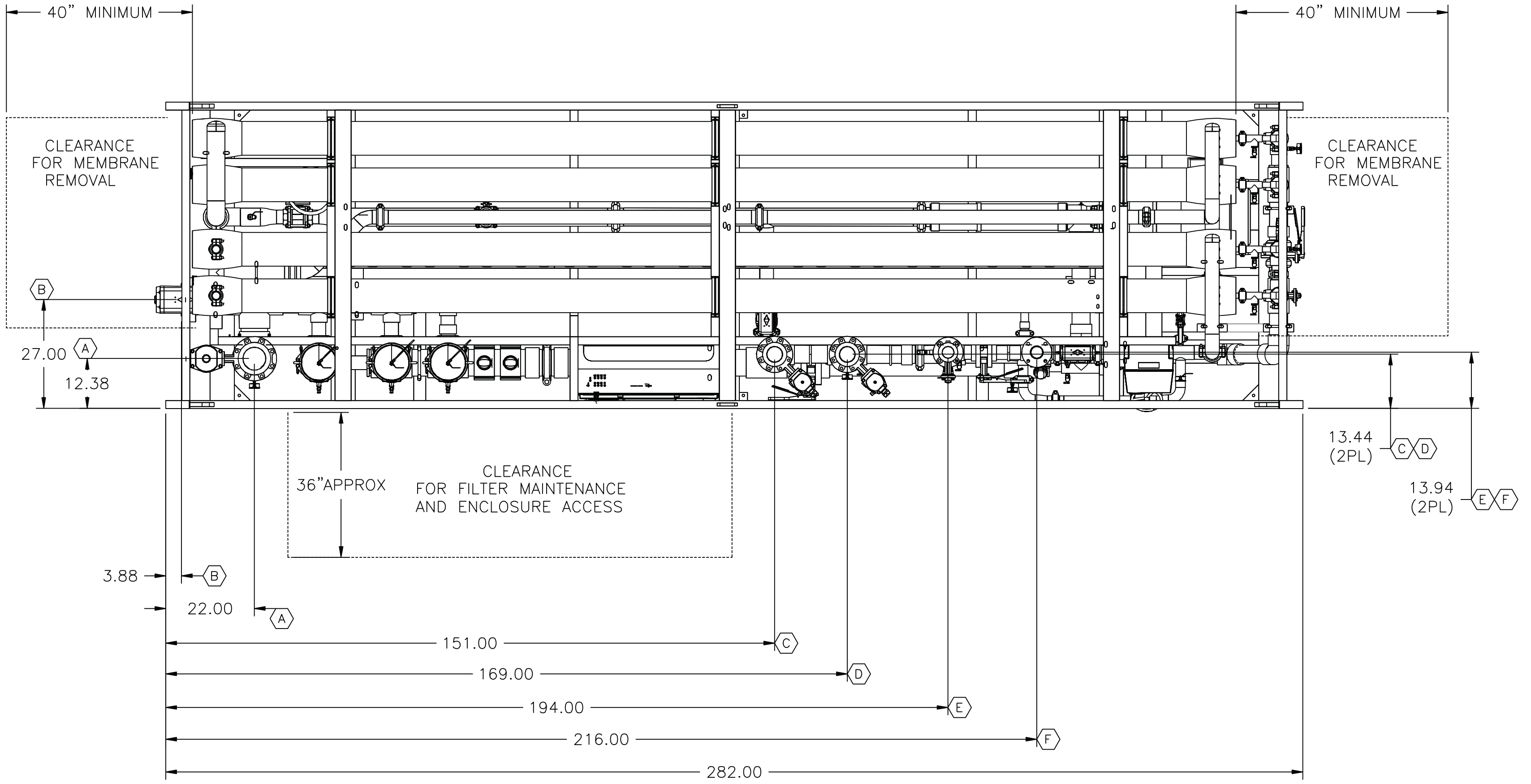
SCALE NONE

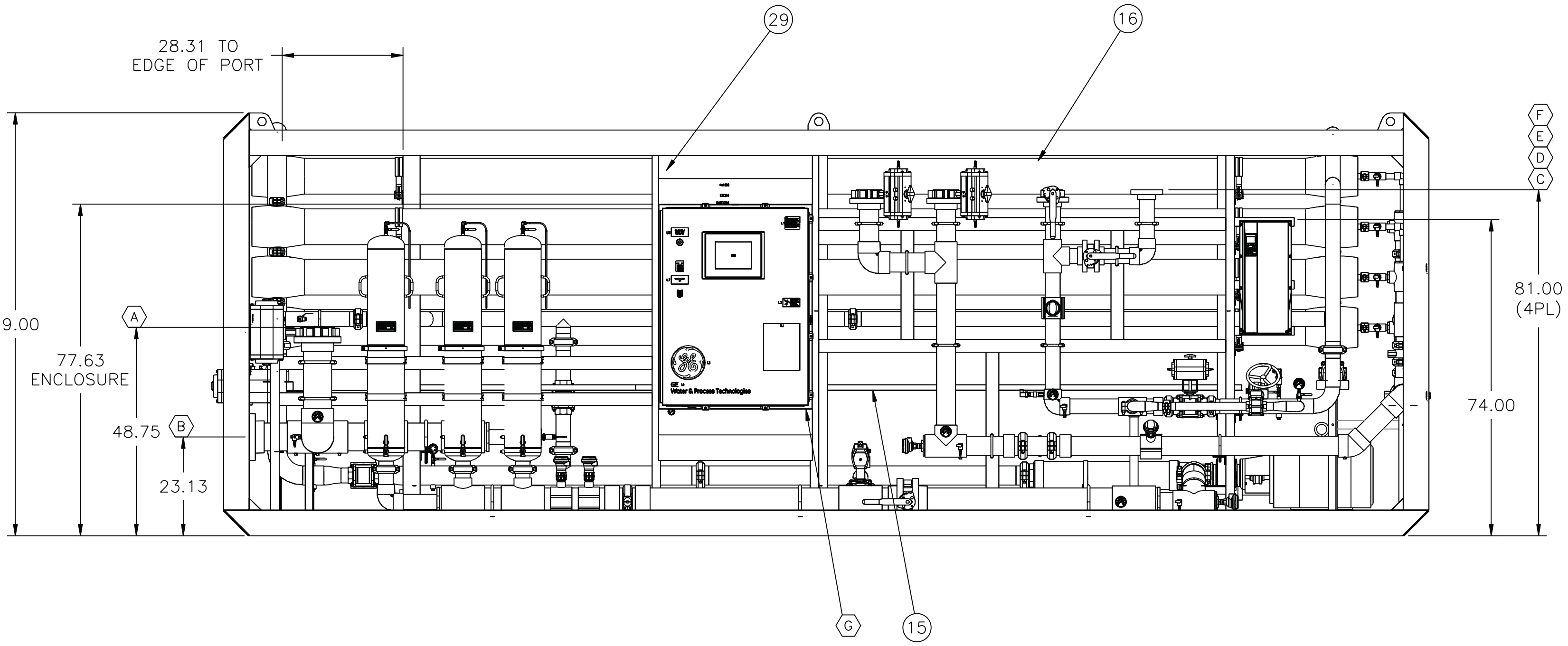
SHEET 3 OF 3

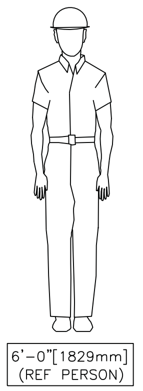
P/N 1161662–RHP01

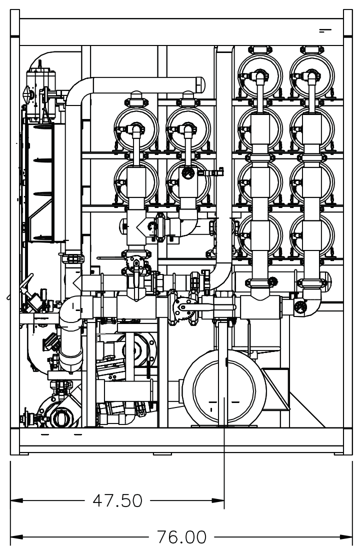
PART NUMBER	DESCRIPTION
3051903	GA,RO,MUNI-300,480/3/60

Mine Water Treatment Trains GE Membranes, 6/8






6'-0"[1829mm] (REF PERSON)



NOTES:

1. CONNECTION TABLE

ITEM	DESCRIPTION	MATERIAL	TYPE	SIZE
A	INLET	PVC	150# FLANGE	6.00
B	INLET CIP	PVC	150# FLANGE	6.00
C	PERMEATE OUTLET	PVC	150# FLANGE	4.00
D	PERMEATE CIP OUTLET	PVC	150# FLANGE	4.00
E	CONCENTRATE OUTLET	PVC	150# FLANGE	4.00
F	CONCENTRATE CIP OUTLET	PVC	150# FLANGE	4.00
G	COMPRESSED AIR INLET	ZINC	FNPT	0.25

2. SHIPPING WEIGHT – 12,500 LB/[5,670 Kg].
3. OPERATING WEIGHT – 23,650 LB/[10,727 Kg].
4. PLUMBING RUN \ EQUIPMENT TABLE:

FIND NO.	PART NUMBER	QTY.	DESCRIPTION	U/M
1	1115055	1	PLUG,PIPE,MPT,316,SQH,0.25,3000LB	EA
2	1115698	1	NIPPLE,MPT,316,0.25XCLS	EA
3	1144776	1	FTG–SENSOR,FLOW,PVC,6.00	EA
4	1161642	1	PLUG,M.CPLG,316,1.5	EA
5	1202086	1	PLUG,M.CPLG,316,1.00	EA
6	1225627	1	PUMP,TF,AS40406KZE,50HP,TEFC	EA
7	1226020	1	VALVE–BALL,FPT,316,0.25",1PC,FLO	EA
8	1268175	1	VALVE–BTFLY,NYLON,4.00,MANUAL,LUGGED	EA
9	1268176	1	VALVE–BTFLY,NYLON,6.00,MANUAL,LUGGED	EA
10	1268180	1	VALVE–BTFLY,NYLON,4.00,A/S,LUGGED,BRAY	EA
11	1268181	1	VALVE–BTFLY,NYLON,6.00,A/S,LUGGED,BRAY	EA
12	3013257	1	TRANS–PRESS,DIN,316SS,0–500PSIG,4–20,GE	EA
13	3020605	1	STARTER,ABB,COMBO,IEC,460VAC,50HP,N4 PL	EA
14	3034594	1	SENSOR,ORP,SIGNET,3–2725–6,3–2750–2	EA
15	3035326	2	DUCT,WIRE,3.00,VENTED,CS,3M,PAINTED	EA
16	3035340	12	HSG,SH–6/823,FRP,32VIC,4P,WAVE,450,V,COD	EA
17	3051935	1	PLMB–INLET,PVC,6.00,MUNI–300	EA
18	3051936	1	PLMB–PERM,PVC,4.00,MUNI–300	EA
19	3051937	1	PLMB–CONC LP,PVC,3.00,MUNI–300	EA
20	3051938	1	PLMB–CONC HP,316,3.00,3PC,MUNI–300	EA
21	3051939	1	PLMB–PUMP DISCH,316,4.00,4PC,MUNI–300	EA
22	3051940	1	PLMB–RECY,316/PVC,1.50,MUNI–300	EA
23	3051941	1	PLMB–CONC B1,316,3.00,MUNI–300	EA
24	3051942	1	PLMB–INLET B2,316,3.00,5PC,MUNI–300	EA
25	3051943	1	FRAME,CS,282LX76WX99H,MUNI–300	EA
26	3052306	1	VFD,GE,AF–650GP,50HP,N4,460VAC,3PH	EA
27	3053053	1	ENCL–MACH,MUNI–RO,AB,120VAC,60HZ,RIO	EA
28	3053054	1	ENCL–MACH,MUNI–RO,AB,120VAC,60HZ,CP	EA
29	3053193	2	ENCL–HOOD–PNTD,CS,MUNI100–450	EA
30	3053485	2	SPOOL–OPTIONAL,316,3.00,MUNI,MANUAL	EA
31	3053486	2	SPOOL–OPTIONAL,316,3.00,MUNI,AUTOMATIC	EA

5. ALL DIMENSIONS IN INCHES.
6. REFERENCE – PIPING AND INSTRUMENTATION DIAGRAM: 1308280

7 OPTIONAL EQUIPMENT. REFERENCE BILL OF MATERIAL FOR CUSTOMER SPECIFIC OPTIONS.

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	14334	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS .X ± .XX ± .XXX ±
ANGLES ± FRAC ±
DIMENSIONS IN INCHES DO NOT SCALE
THIRD ANGLE

DRAWN BY JWA	DATE 19MAY10
CHECKED BY JSS	DATE 17Nov10
APPROVED BY BRB	DATE 17Nov10
APPROVED BY	DATE

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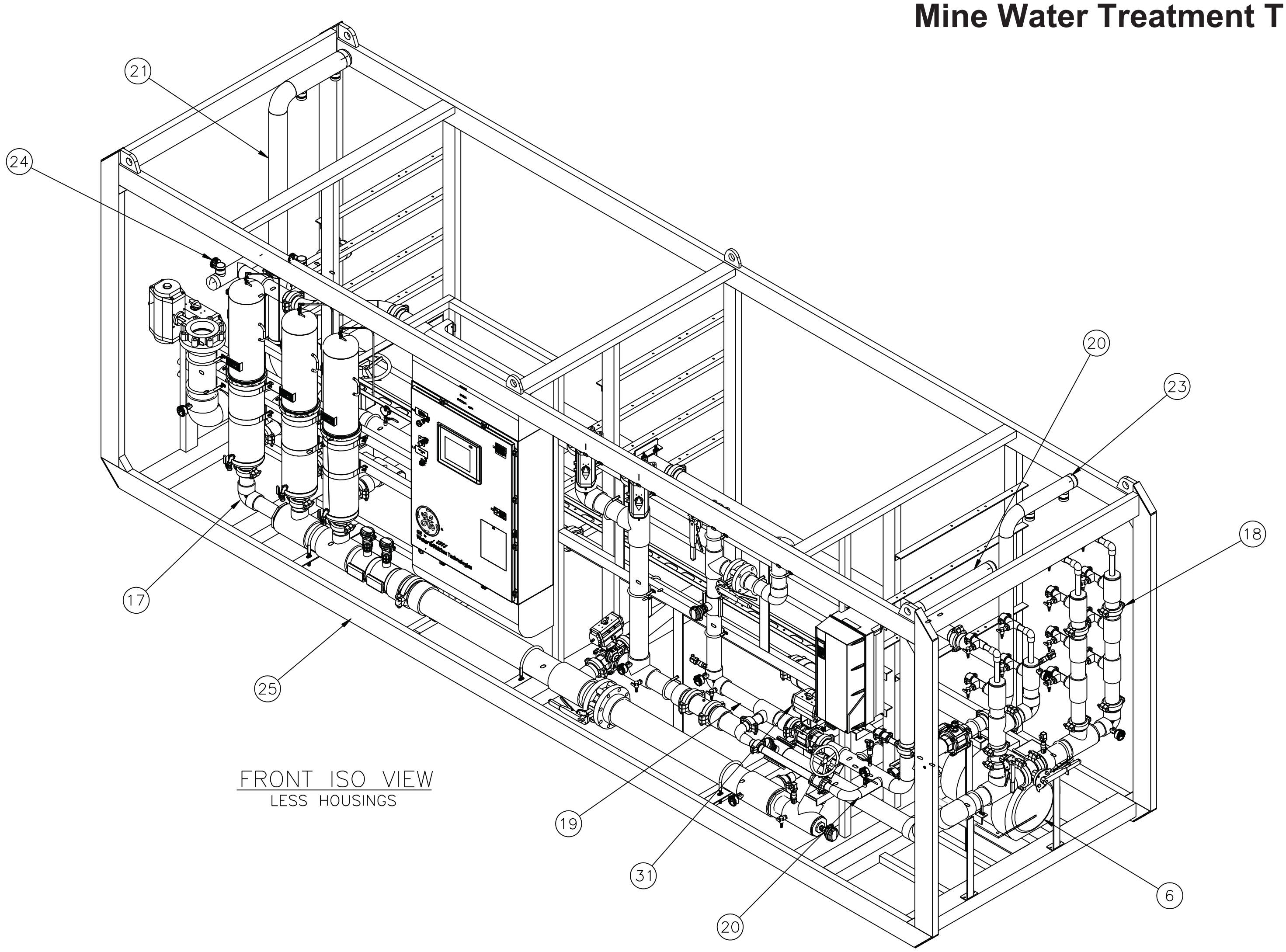
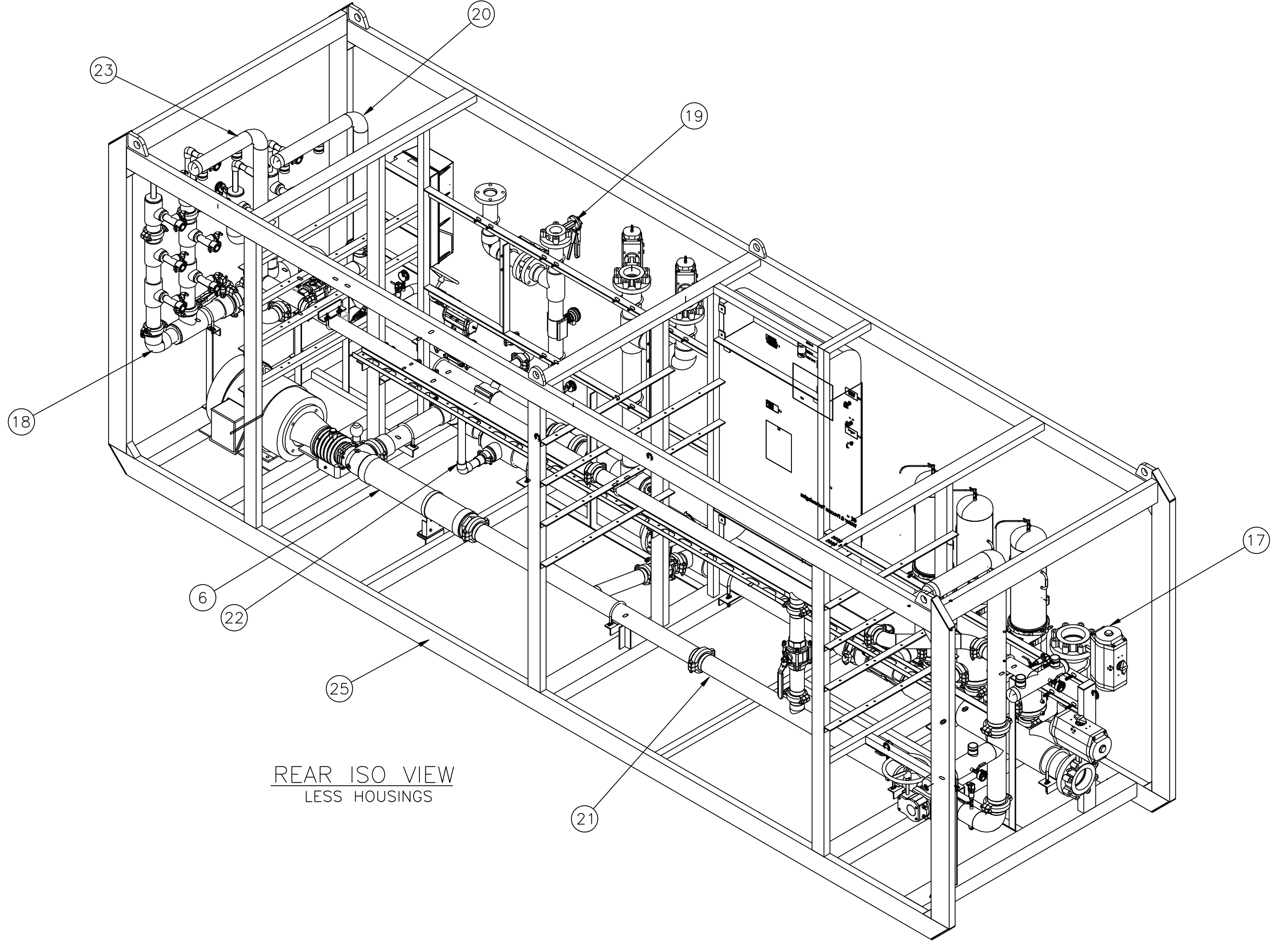
CLIENT/JOB
FILE ACR2007
TITLE GA,RO,MUNI–300, 480/3/60
MATERIAL SEE BOM
SIZE D
DRAWING NO. 1308279
REV A
PROJECT
SCALE 3:64
SHEET 1 OF 3

P/N 1161662–RHP01

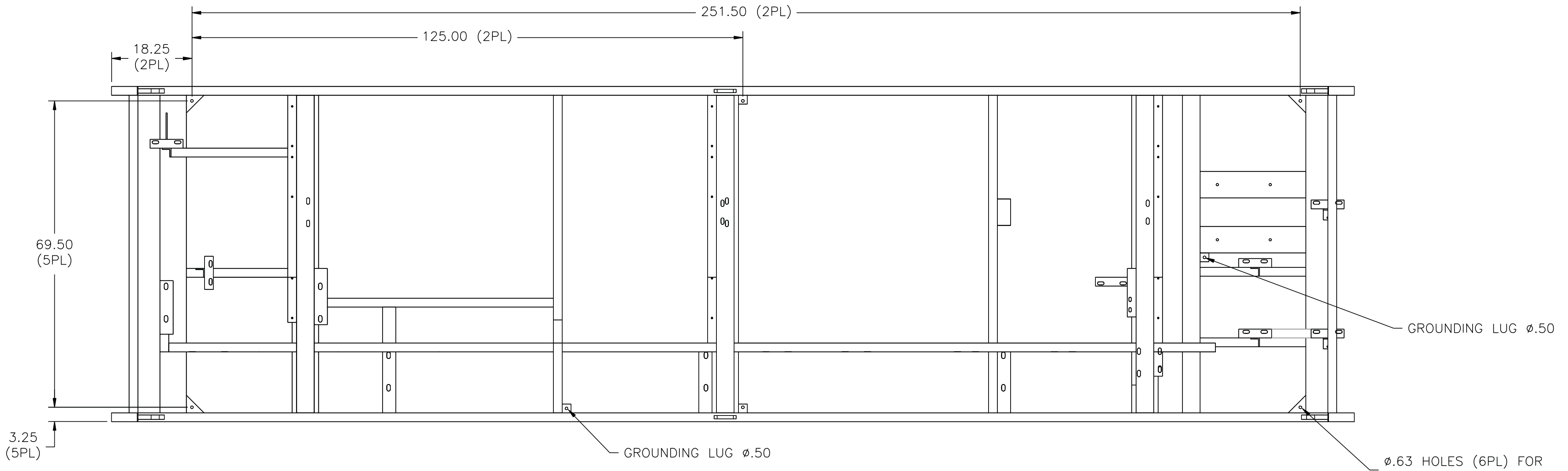
Mine Water Treatment Trains GE Membranes, 7/8



FRONT ISO VIEW
LESS HOUSINGS



REAR ISO VIEW
LESS HOUSINGS



ANCHOR BOLT LOCATIONS

REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	14334	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS .X ± .XX ± .XXX ±
ANGLES ±
FRAC ±
DIMENSIONS IN INCHES
DO NOT SCALE
THIRD ANGLE

DRAWN BY	JWA	DATE 19MAY10
CHECKED BY	JSS	DATE 17Nov10
APPROVED BY	BRB	DATE 17Nov10
APPROVED BY		DATE

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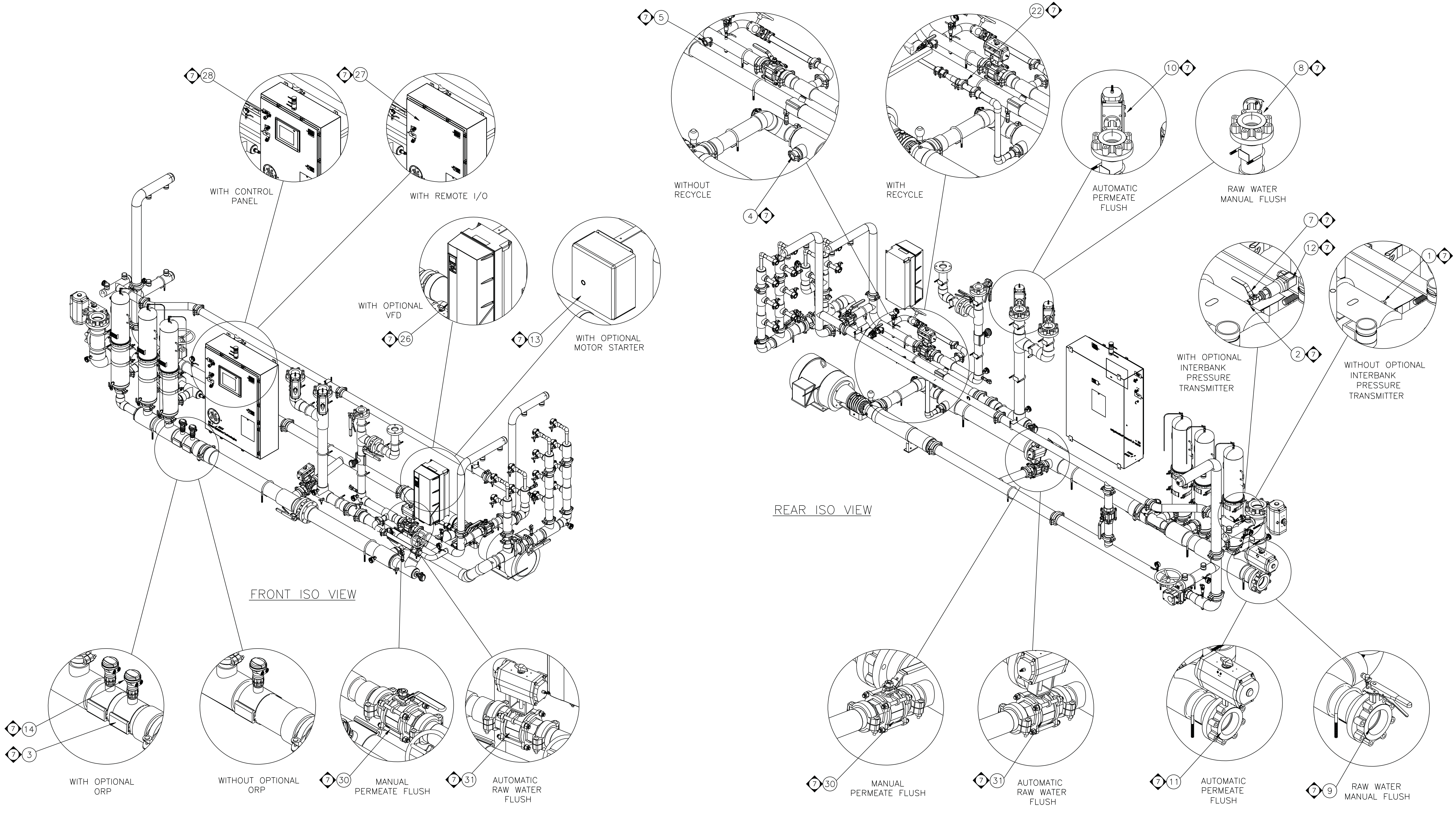
CLIENT/JOB
FILE ACR2007
TITLE GA,RO,MUNI-300, 480/3/60
MATERIAL SEE BOM
SIZE D
DRAWING NO. 1308279
REV A
PROJECT
SCALE 1:16
SHEET 2 OF 3

P/N 1161662-RHP01

Mine Water Treatment Trains GE Membranes, 8/8



REV	DESCRIPTION	ECO	DWN	APVD	DATE	CHKD
A	INITIAL RELEASE	14334	–	–	–	–

TOLERANCES UNLESS NOTED
DECIMALS ANGLES
.X ± ±
.XX ± FRAC
.XXX ± ±

DIMENSIONS IN INCHES
DO NOT SCALE

THIRD ANGLE

DRAWN BY	JWA	DATE 19MAY10
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CLIENT/JOB

FILE ACR2007

TITLE
GA,RO,MUNI–300,
480/3/60

MATERIAL SEE BOM

SIZE D
DRAWING NO. 1308279
REV A
PROJECT
SCALE NONE
SHEET 3 OF 3

P/N 1161662–RHP01

Mine Water Treatment Trains GE Membrane Projections, 1/10

Mine Site Projections with Muni-NF-400 Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			880	880	
pH		7		6.69	6.84	
Cations						
Ca	mg/L	191		27.17	50.83	14.134
Mg	mg/L	68.7		3.46	6.71	3.5724
Na	mg/L	80.8		60.79	69.84	34.2592
K	mg/L	24		10.46	14.97	9.84
Ba	mg/L	0.0319		0.01	0.01	0.0020735
Fe	mg/L	0.00157		0	0	
Mn	mg/L	0.0242		0	0.01	0.0005324
Anions						
SO4	mg/L	294		14.76	28.68	2.94
Cl	mg/L	137	439.82	137.31	191.44	124.122
F	mg/L	1.68		1.29	1.46	
B	mg/L	0.0742		0.07	0.07	
SiO2	mg/L	54		53.91	53.96	40.986
Total Alk	mg/L as CaCO3	35				
	mg/L as HCO3	42.7		18.59	26.54	
Metals						
Ag	ug/L	0.112		0.084	0.097	
Al	ug/L	1.36		0.068	0.133	
As	ug/L	17.9		0.358	0.358	0.1074
Be	ug/L	0.319		0.016	0.031	
Cd	ug/L	6.89		0.347	0.673	
Co	ug/L	5.16		0.260	0.504	0.00516
Cr	ug/L	0.542		0.027	0.053	
Cu	ug/L	142				8.804
Ni	ug/L	488		24.578	47.663	0.976
Pb	ug/L	0.216		0.011	0.021	0.001296
Sb	ug/L	36.5		1.838	3.565	
Se	ug/L	5.65		0.284	0.551	0.0452
Tl	ug/L	0.127		0.006	0.012	
V	ug/L	8		0.403	0.781	
Zn	ug/L	633		31.880	61.826	10.128

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06

Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTF Mine site, equipment = 2xMuniNF300 [8x4(6M) with Muni-NF-400 elements] + 1xMuniNF450 [12x6(6M) with Muni-NF-400 elements]

Mine Water Treatment Trains GE Membrane Projections, 2/10

Feedwater ions balanced with either Na or Cl as appropriate

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Mg, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Mine Water Treatment Trains GE Membrane Projections, 3/10

Mine Site Projections with Muni-NF-400 Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			1240	1240	
pH		7		6.77	6.89	
Cations						
Ca	mg/L	285		33.58	64.07	21.09
Mg	mg/L	121		6.21	12.16	6.292
Na	mg/L	100		79.06	88.66	42.4
K	mg/L	23.8		11.94	16.31	9.758
Ba	mg/L	0.0256		0	0.01	0.001664
Fe	mg/L	0.00184		0	0	
Mn	mg/L	0.0215		0	0.01	0.000473
Anions						
SO4	mg/L	604		30.78	60.48	6.04
Cl	mg/L	53.2	556.26	171.34	233.95	48.1992
F	mg/L	0.998		0.81	0.9	
B	mg/L	0.0843		0.08	0.08	
SiO2	mg/L	54		53.92	53.97	40.986
Total Alk	mg/L as CaCO3	41.4				
	mg/L as HCO3	50.508		25.3	34.47	
Metals						
Ag	ug/L	0.179		0.142	0.159	
Al	ug/L	1.59		0.082	0.160	
As	ug/L	24.4		0.488	0.488	0.1464
Be	ug/L	0.375		0.019	0.038	
Cd	ug/L	6.91		0.355	0.694	
Co	ug/L	4.07		0.209	0.409	0.00407
Cr	ug/L	0.498		0.026	0.050	
Cu	ug/L	128				7.936
Ni	ug/L	467		23.968	46.932	0.934
Pb	ug/L	0.704		0.036	0.071	0.004224
Sb	ug/L	36.2		1.858	3.638	
Se	ug/L	10.5		0.535	1.051	0.084
Tl	ug/L	0.178		0.009	0.018	
V	ug/L	9.44		0.484	0.949	
Zn	ug/L	713		36.593	71.654	11.408

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTF Mine site, equipment = 2xMuniNF300 [8x4(6M) with Muni-NF-400 elements] + 2xMuniNF450 [12x6(6M) with Muni-NF-400 elements]

Mine Water Treatment Trains GE Membrane Projections, 4/10

Feedwater ions balanced with either Na or Cl as appropriate

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Mg, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Mine Water Treatment Trains GE Membrane Projections, 5/10

Mine Site Projections with Muni-NF-400 Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			1960	1960	
pH		7		6.73	6.87	
Cations						
Ca	mg/L	212		23.81	45.03	15.688
Mg	mg/L	91		4.69	9.12	4.732
Na	mg/L	79.3		59.63	68.35	33.6232
K	mg/L	17.9		8.41	11.75	7.339
Ba	mg/L	0.0281		0	0.01	0.0018265
Fe	mg/L	0.0019		0	0	
Mn	mg/L	0.0175		0	0.01	0.000385
Anions						
SO4	mg/L	526		26.8	52.42	5.26
Cl	mg/L	23.6	360.93	121.15	163.73	21.3816
F	mg/L	0.662		0.52	0.59	
B	mg/L	0.0729		0.07	0.09	
SiO2	mg/L	54		53.92	53.97	40.986
Total Alk	mg/L as CaCO3	40.5				
	mg/L as HCO3	49.41		23.16	32.31	
Metals						
Ag	ug/L	0.18		0.135	0.155	
Al	ug/L	1.58		0.081	0.158	
As	ug/L	17.2		0.344	0.344	0.1032
Be	ug/L	0.369		0.019	0.037	
Cd	ug/L	4.7		0.242	0.471	
Co	ug/L	2.79		0.144	0.280	0.00279
Cr	ug/L	0.368		0.019	0.037	
Cu	ug/L	89.6				5.5552
Ni	ug/L	340		17.523	34.075	0.68
Pb	ug/L	0.714		0.037	0.072	0.004284
Sb	ug/L	25.5		1.314	2.556	
Se	ug/L	6.86		0.350	0.684	0.05488
Tl	ug/L	0.172		0.009	0.017	
V	ug/L	9.32		0.480	0.934	
Zn	ug/L	519		26.748	52.014	8.304

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTF Mine site, equipment = 2xMuniNF300 [8x4(6M) with Muni-NF-400 elements] + 4xMuniNF450 [12x6(6M) with Muni-NF-400 elements]

Mine Water Treatment Trains GE Membrane Projections, 6/10

Feedwater ions balanced with either Na or Cl as appropriate

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Mg, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Mine Water Treatment Trains GE Membrane Projections, 7/10

Mine Site Projections with Muni-NF-400 Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			1960	1960	
pH		7		6.88	6.78	
Cations						
Ca	mg/L	561		28.4	57.07	41.514
Mg	mg/L	188		9.84	19.45	9.776
Na	mg/L	173		89.72	100.04	73.352
K	mg/L	45		30.61	36.58	18.45
Ba	mg/L	0.0167		0	0	0.0010855
Fe	mg/L	0.00187		0	0	
Mn	mg/L	0.112		0.01	0.01	0.002464
Anions						
SO4	mg/L	2240		114.42	228.94	22.4
Cl	mg/L	25.9	163.73	140.75	151.53	23.4654
F	mg/L	1.8		1.55	1.67	
B	mg/L	0.0892		0.09	0.09	
SiO2	mg/L	54		53.94	53.85	40.986
Total Alk	mg/L as CaCO3	39.9				
	mg/L as HCO3	48.678		29.18	37.01	
Metals						
Ag	ug/L	0.18		0.093	0.104	
Al	ug/L	1.59		0.083	0.164	
As	ug/L	27.3		0.546	0.546	0.1638
Be	ug/L	0.367		0.019	0.038	
Cd	ug/L	25.2		1.319	2.607	
Co	ug/L	24.5		1.282	2.535	0.0245
Cr	ug/L	0.852		0.045	0.088	
Cu	ug/L	462				28.644
Ni	ug/L	2600		136.085	268.989	5.2
Pb	ug/L	0.676		0.035	0.070	0.004056
Sb	ug/L	64.3		3.365	6.652	
Se	ug/L	43.4		2.217	4.436	0.3472
Tl	ug/L	0.166		0.009	0.017	
V	ug/L	9.26		0.485	0.958	
Zn	ug/L	1280		66.996	132.426	20.48

Assumptions:

Projections made via Winflows v3.2.1, with Database 3.06

Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively

WWTF Mine site, equipment = 2xMuniNF300 [8x4(6M) with Muni-NF-400 elements] + 4xMuniNF450 [12x6(6M) with Muni-NF-400 elements]

Mine Water Treatment Trains GE Membrane Projections, 8/10

Feedwater ions balanced with either Na or Cl as appropriate

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Mg, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Mine Water Treatment Trains GE Membrane Projections, 9/10

Mine Site Projections with Muni-NF-400 Membranes

		Feed	Adjusted Feed	Projected Permeate Quality		Based on Pilot Rejections
				Temp = 35F	Temp = 75F	
Permeate Flow	gpm			1960	1960	
pH		7		6.79	6.91	
Cations						
Ca	mg/L	321		32.15	61.82	23.754
Mg	mg/L	126		6.53	12.82	6.552
Na	mg/L	110		89.3	99.12	46.64
K	mg/L	29.8		15.5	20.89	12.218
Ba	mg/L	0.0245		0	0.01	0.0015925
Fe	mg/L	0.00175		0	0	
Mn	mg/L	0.0183		0	0.01	0.0004026
Anions						
SO4	mg/L	790		40.47	79.87	7.9
Cl	mg/L	14.5	517.42	180.69	236.98	13.137
F	mg/L	1.25		1.03	1.13	
B	mg/L	0.081		0.08	0.08	
SiO2	mg/L	54		53.93	53.97	40.986
Total Alk	mg/L as CaCO3	41.4				
	mg/L as HCO3	50.508		26.22	35.27	
Metals						
Ag	ug/L	0.154		0.125	0.139	
Al	ug/L	2.03		0.105	0.207	
As	ug/L	19.7		0.394	0.394	0.1182
Be	ug/L	0.346		0.018	0.035	
Cd	ug/L	4.69		0.243	0.477	
Co	ug/L	3.7		0.192	0.376	0.0037
Cr	ug/L	0.6		0.031	0.061	
Cu	ug/L	38				2.356
Ni	ug/L	562		29.126	57.181	1.124
Pb	ug/L	1.12		0.058	0.114	0.00672
Sb	ug/L	42.1		2.182	4.284	
Se	ug/L	16.3		0.835	1.648	0.1304
Tl	ug/L	0.128		0.007	0.013	
V	ug/L	8.87		0.460	0.902	
Zn	ug/L	260		13.475	26.454	4.16

Assumptions:
Projections made via Winflows v3.2.1, with Database 3.06
Membrane life = 3 years for all projections, with 5% and 7% annual change for A and B values, respectively
WWTF Mine site, equipment = 2xMuniNF300 [8x4(6M) with Muni-NF-400 elements] + 4xMuniNF450 [12x6(6M) with Muni-NF-400 elements]

Mine Water Treatment Trains GE Membrane Projections, 10/10

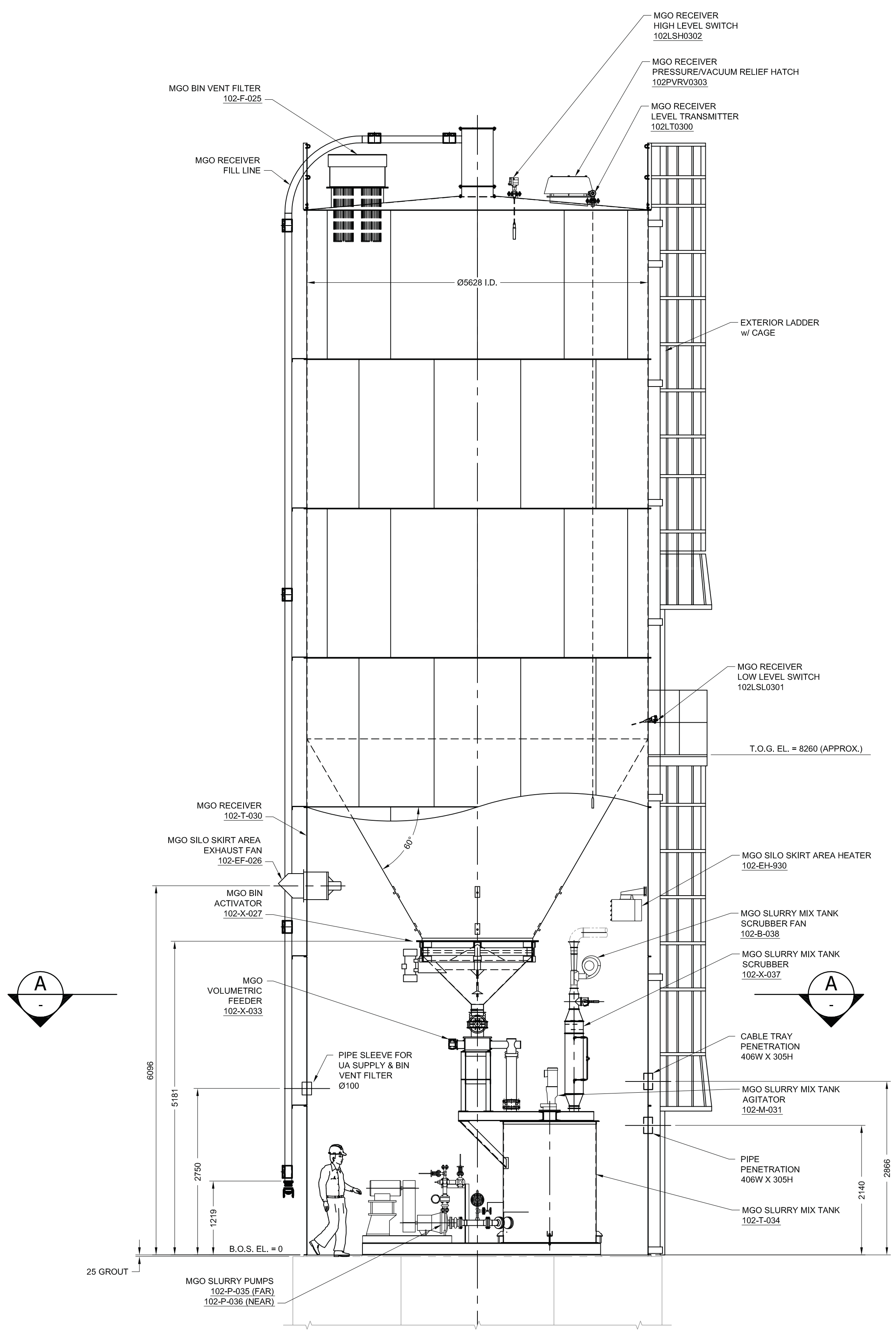
Feedwater ions balanced with either Na or Cl as appropriate

This design does not guarantee the same performance & is provided solely as a service. The data contained herein should be used with good engineering judgment.

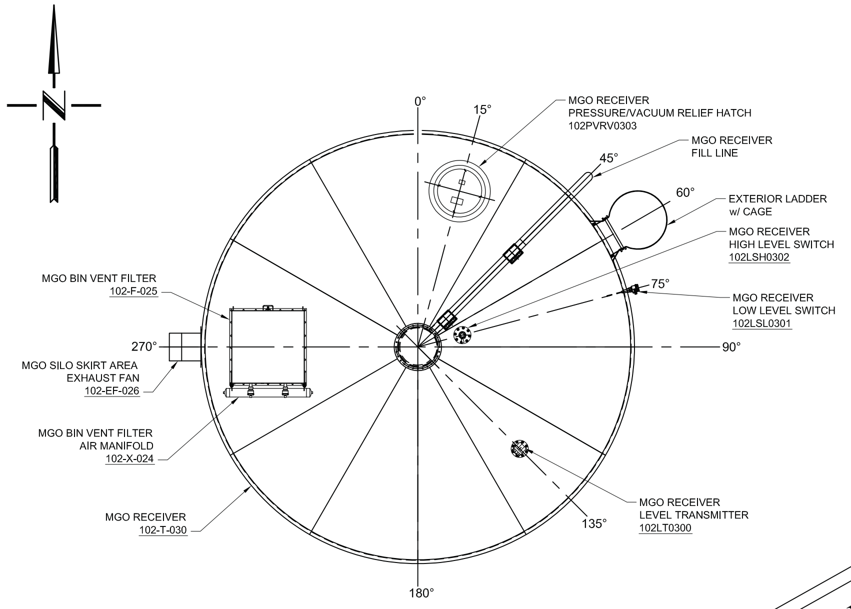
Arsenic is assumed to be in oxidized form

Metals rejection assumptions: collumn E&F: Al, Be, Cd, Co, Cr, Ni, Pb, SB, Tl, V, and Zn rejection similar to Mg, Ag rejection similar to Na, and Se rejection similar to SO4. Oxidized As at 98% rejection

Mine Water Treatment Trains Merrick Lime Feed, 1/2

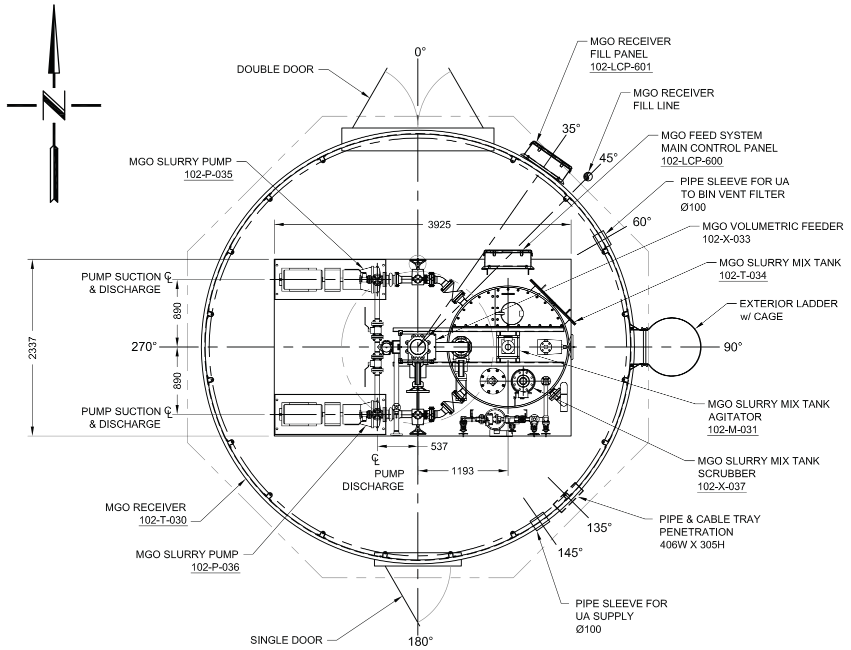


ELEVATION VIEW
(FOR TRUE ORIENTATION SEE PLAN AND SECTIONS)



PLAN VIEW

PRELIMINARY



SECTION A -

NOTES

REFERENCE DRAWINGS

REV	DATE	BY	CHK	ENG	APP	DESCRIPTION
0						FOR INFORMATION

STT
STANCO

PROJECT
MAGOX STORAGE AND FEED SYSTEM
TYPICAL

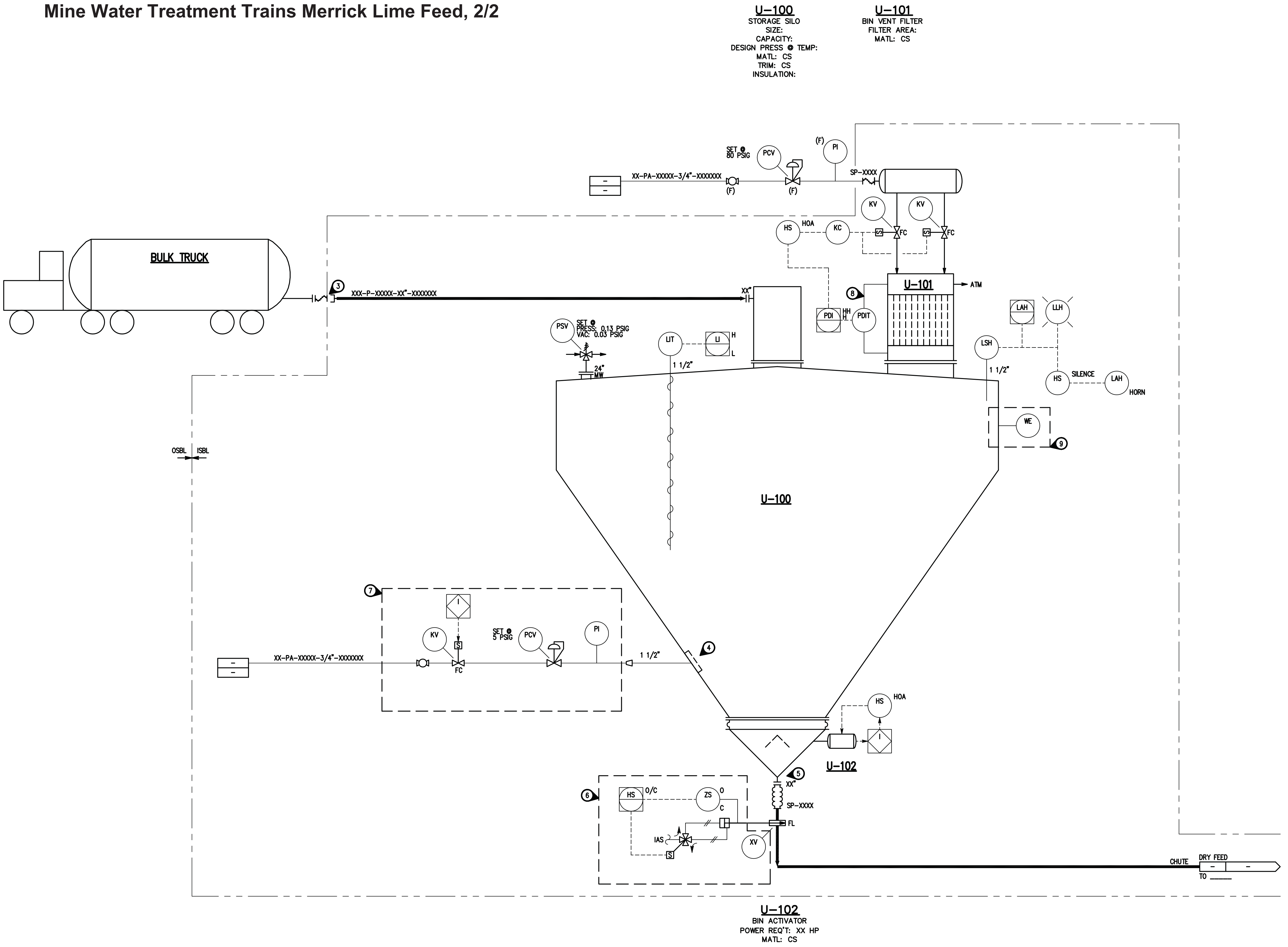
TITLE
PIPING & INSTRUMENTATION DIAGRAM
MAGOX STORAGE & FEED SYSTEM

- DO NOT SCALE -
USE DIMENSIONS ONLY

SIZE	PROJECT	DRAWING NO.	REV.
D	S13-1090	1090-1-ME-GA-001-1	0

SCALE 1:50
DWG. STATUS PRELIMINARY

Mine Water Treatment Trains Merrick Lime Feed, 2/2



NOTES

1. ALL INSTRUMENT TAGS PREFIXED BY "XX" UNLESS NOTED OTHERWISE.
2. (F) DENOTES ITEMS OUTSIDE BATTERY LIMITS SUPPLIED LOOSE BY STANCO.
3. LOADING STATION COUPLING LOCATED 4 FEET ABOVE GRADE ADJACENT TO SILO.
4. EIGHT (8) AERATION PADS SUPPLIED AND INSTALLED IN SILO CONE SECTION BY STANCO.
5. BIN ACTIVATOR EQUIPPED WITH INTEGRAL OUTLET MAINTENANCE GATE TO PERMIT MAINTENANCE OF DOWNSTREAM EQUIPMENT.
6. OPTIONAL PNEUMATIC ACTUATOR ON SILO ISOLATION GATE.
7. AERATION CONTROLS OPTIONAL FOR GRANULAR MATERIALS.
8. OPTIONAL DIFFERENTIAL PRESSURE TRANSMITTER, SWITCH, OR GAUGE.
9. OPTIONAL STRAIN GAUGE TYPE WEIGHT TRANSMITTER IN LIEU OF GUIDED RADAR LEVEL TRANSMITTER.

REFERENCE DRAWINGS

REV	DATE	BY	CHK	ENG	APP	DESCRIPTION
0		DV				FOR INFORMATION

STANCO

PROJECT
STANDARD DRAWING

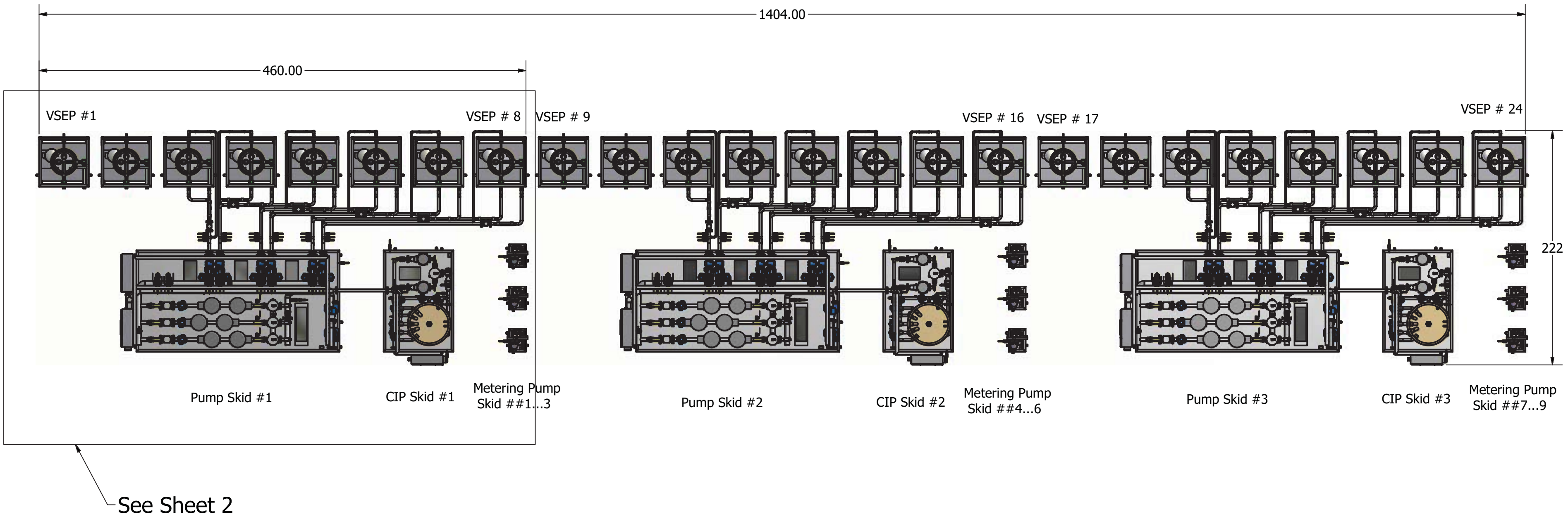
TITLE
PIPING & INSTRUMENTATION DIAGRAM
STORAGE SILO
BIN ACTIVATOR

SIZE: D
PROJECT:
DRAWING NO.: SD-000-0-P-120-1
REV.:
SCALE: NONE
DWG. STATUS: FOR INFORMATION

- DO NOT SCALE -
USE DIMENSIONS ONLY

Mine Water Treatment Trains NLR VSEP, 1/2

TOP VIEW

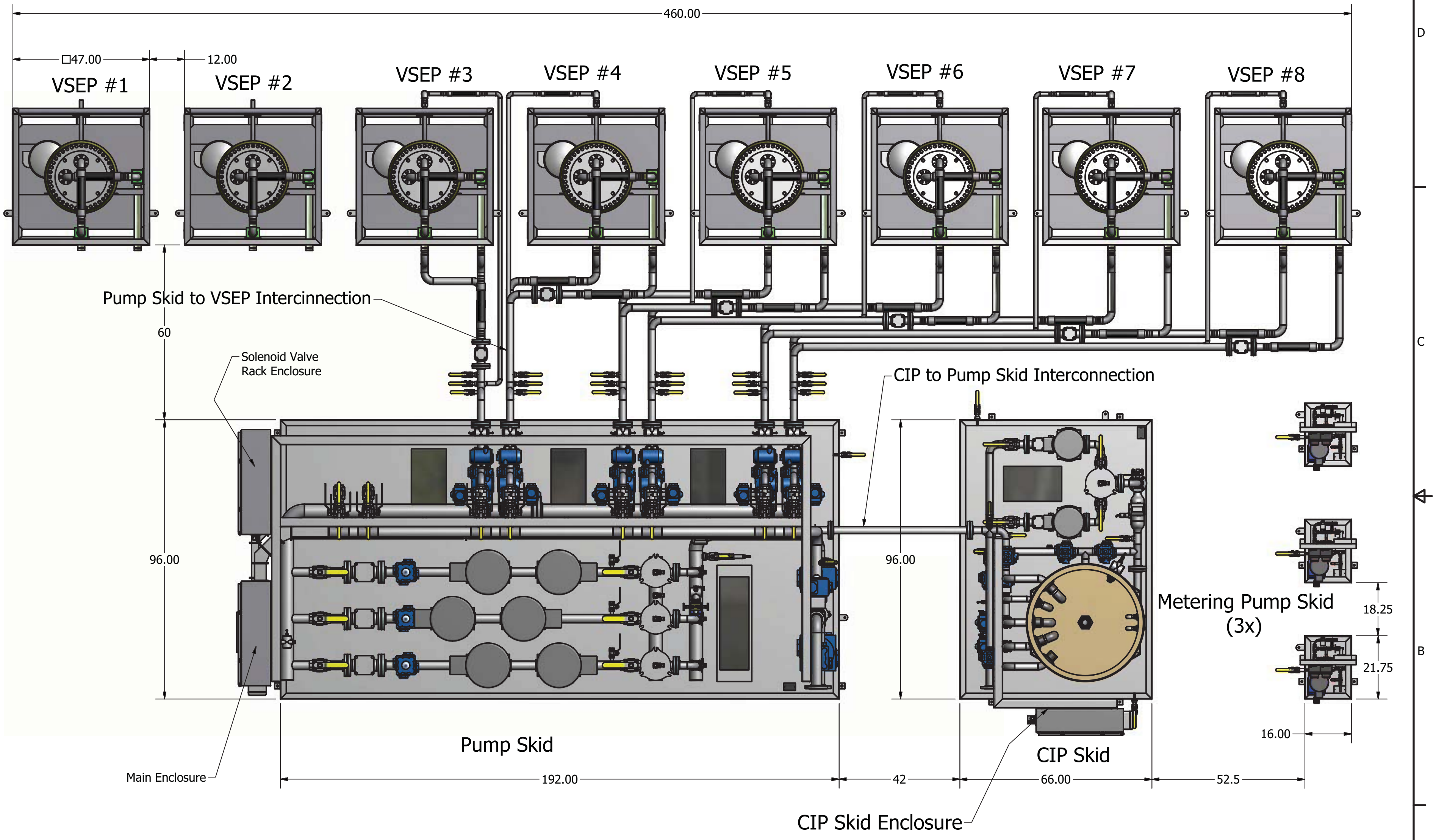


NOTES:
1. New Logic Research confidential material.
2. All dimensions are shown in inches.
3. Preliminary, for references only.

DRAWN F. Rubin	11/7/2013	NEW LOGIC RESEARCH
CHECKED M. Ayers		TITLE SYSTEM EQUIPMENT LAYOUT
QA		
MFG		
APPROVED G. Johnson		SIZE C
		DWG NO PMM-000
		REV B
		SCALE
		SHEET 1 OF 2

Mine Water Treatment Trains NLR VSEP, 2/2

TOP VIEW

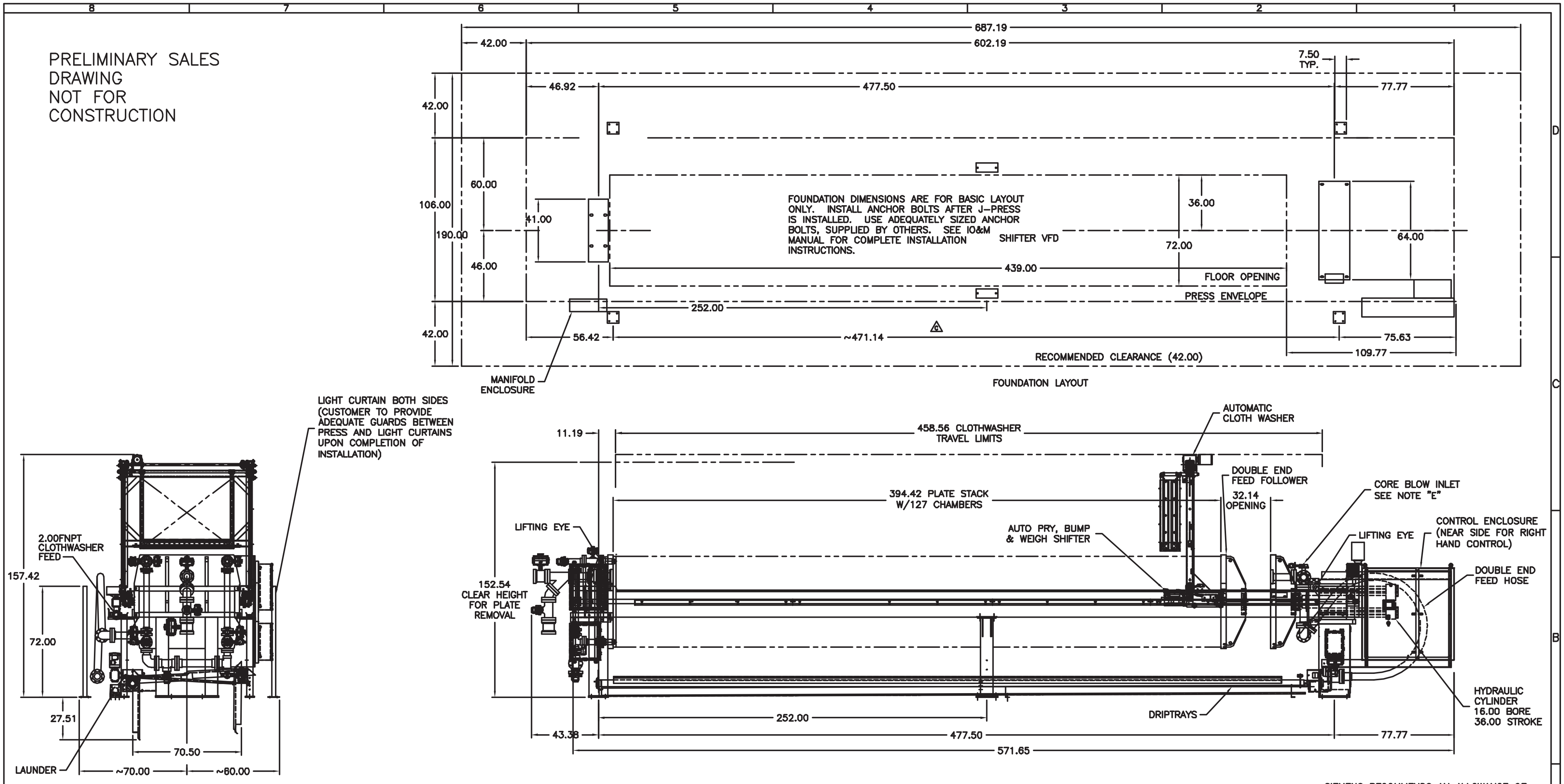


NOTES:
1. New Logic Research confidential material.
2. All dimensions are shown in inches.
3. Preliminary, for references only.

DRAWN F. Rubin	11/7/2013	NEW LOGIC RESEARCH		
CHECKED M. Ayers				
QA		TITLE SYSTEM EQUIPMENT LAYOUT		
MFG				
APPROVED G. Johnson				
		SIZE C	DWG NO PMM-000	REV B
		SCALE		SHEET 2 OF 2

Mine Water Treatment Trains Siemens Sludge Press, 1/1

PRELIMINARY SALES
DRAWING
NOT FOR
CONSTRUCTION



SIEMENS RECOMMENDS AN ALLOWANCE OF 42.00 [1667mm] AROUND THE PERIMETER OF THE J–PRESS FOR OPERATION AND MAINTENANCE PURPOSES

ALL PRESSES TO BE RIGHT HAND OPERATION, AS SHOWN.

DRAWING IS FOR REFERENCE ONLY.
SOME LINES MAY BE REMOVED FOR CLARITY.
ALL DIMENSIONS ARE ±1.00 [25.4mm]

PRESS LOADING WITH IDEAL INSTALLATION CONDITIONS*
TOTAL WEIGHT DRY (SHIP WEIGHT): 81,600 LB
TOTAL WEIGHT WITH CAKE: 101,600 LBS
@ CAKE WEIGHT: 80 LB/C.FT.
HEAD LEG WEIGHT:
CYLINDER LEG WEIGHT:
CENTER LEG WEIGHT (EACH):

MODEL NUMBER: 1500N32–127–250SYHC
SERIAL NUMBER:
PLATE SIZE/TYPE: 32mm/NON–GASKETED
PRESS CAPACITY: 250 C.FT.
FILTRATION AREA: 5089 FT²

THIRD ANGLE PROJECTION

ALL WELD SYMBOL DIMENSIONS ARE MINIMUM.
DIMENSIONS IN [mm] ARE MILLIMETERS.
DO NOT SCALE DRAWING.

DRAWN PER ASME Y14.5M
UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS ARE IN INCHES
AND TOLERANCES TO BE AS FOLLOWS.

FABRICATION	MACHINE
.XX ± .06	.XX ± .03
[X ± 2]	.XXX ± .005
< ± 2°	[X ± 1]
	[.X ± .1]
	< ± 1°

STD: BORDER–0106–22X34D BAR = 1" AT PLOT SCALE

REV	DESCRIPTION	DATE	DWN	CHKD	APVD	ECN
A	PRELIMINARY SALES DRAWING –	01NOV13	JDW	–	–	–

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DESIGNER: JDW DATE: 01NOV13
CHECKER: DATE:
ENGINEER: DATE:
MANAGER: DATE:
FILE: F008168GA
SCALE: NONE

TITLE: FILTER PRESS GENERAL ARRANGEMENT
1500C225
CLIENT: POLYMET MINING

SIEMENS WATER TECHNOLOGIES
HOLLAND, MICHIGAN USA
TEL: 616–772–9011

PROJECT	CODE	DRAWING	SHEET	REV
F008321		1301299GA	1 OF 1	A

Applications Equipment

Carbon Dioxide Water Bath Vaporizer

6,000 lb./hr. Capacity Water Bath Vaporizer
With Optional Dual Water Pumps

FEATURES

- ASME coded heat exchanger
- Low water supply protection
- Low discharge CO_2 temperature protection
- Pressure safety relief protection for CO_2 and water
- Optional dual or single water pump assemblies with factory installed water piping
- Discharge CO_2 temperature based on supplied water temperature and flow rate from customer
- Unit is equipped based on customer's water conditions

Available sizes from 2,000 pounds CO_2 capacity to 12,000 pounds CO_2 capacity.

Pressure build option is available
Larger units available upon request

TOMCO$_2$ SYSTEMS

Industrial Equipment

Applications Equipment

Carbon Dioxide Vapor Heater

The TOMCO$_2$ Systems' carbon dioxide vapor heater is used to increase the temperature of carbon dioxide vapor from an average storage temperature of 0°F (-17.8° C) to the desired temperature level. Prevents such problems as regulator freeze-up and condensation on pipe lines.

FEATURES

- Heat transfer tube and heating elements pressure cast in common platen for maximum efficiency
- Designed to NEMA 12 standards
- Overheat protection
- Adjustable temperature control
- Stainless steel mounting brackets

SPECIFICATIONS

1/2" (1.27 cm) MPT and outlet connections

Allowable working pressure:
1000 psig

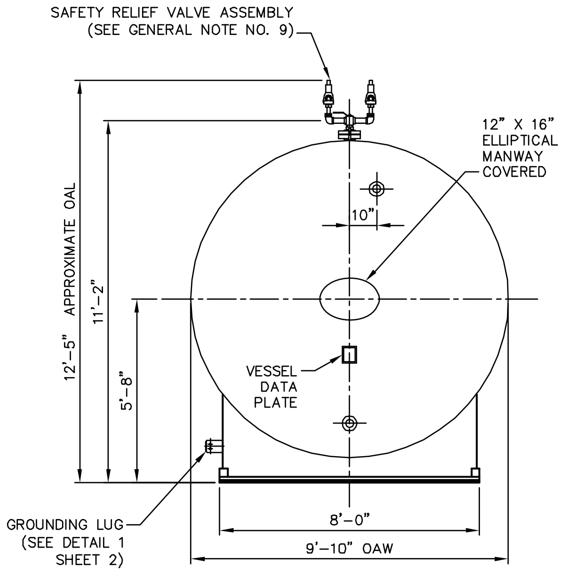
Flow Rate:
720 lbs./hr. @ 70°F (327 kg/hr @ 21°C)

Electrical Characteristics:
230/460V, 60Hz. Single Phase

Model	Nominal Capacity	Wattage	Dimensions	Weight*
CVH-4	720 lbs./hr. @ 70° F.T.D 327 kg/hr	4,000	14" x 8.5" x 12" high 35.5 cm x 21.6 cm x 30 cm	47 lbs. 21 kg
CVH-8	1,500 lbs./hr. @ 70° F.T.D 681 kg/hr	8,000	20" x 9" x 16" high 50.8 cm x 22.8 cm x 40.6 cm	84 lbs. 38 kg
VH-6000	6,000 lbs./hr. @ 70° F.T.D 2,726 kg/hr	30,000	22" x 33" x 37" high 55.9 cm x 84 cm x 94 cm	305 lbs. 138 kg

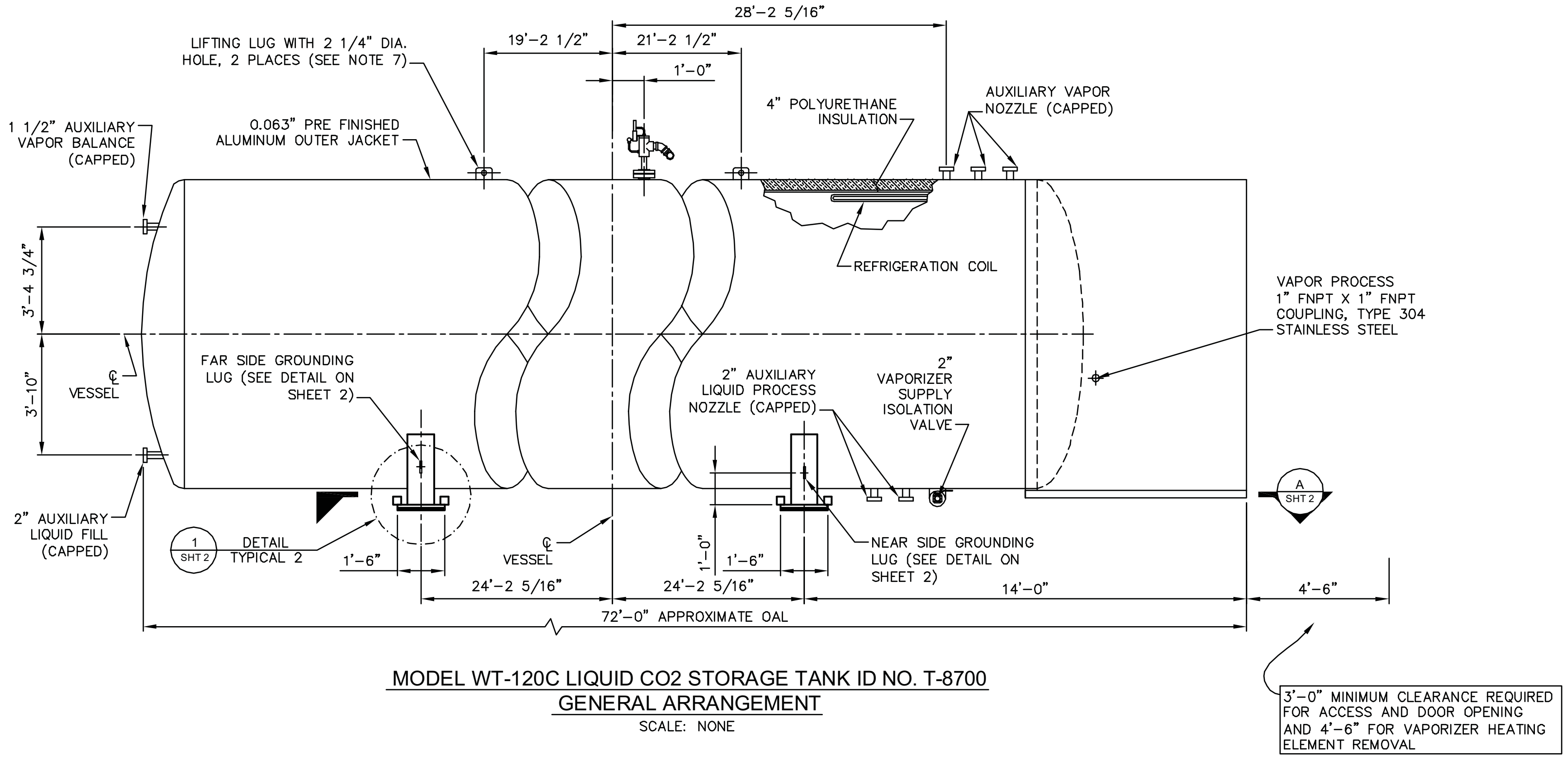
**Published weights include equipment only. Shipping crate(s) are not included.*

Mine Water Treatment Trains TomCO2 Carbon Dioxide Feed, 3/4



REAR ELEVATION

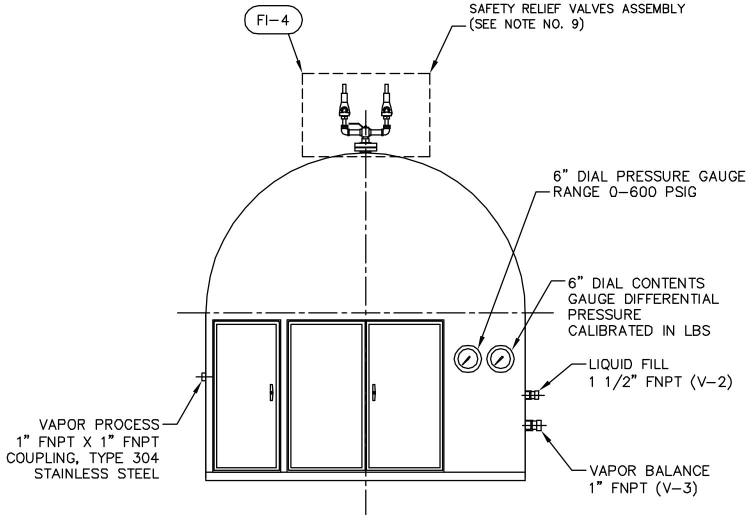
SCALE: NONE



MODEL WT-120C LIQUID CO2 STORAGE TANK ID NO. T-8700

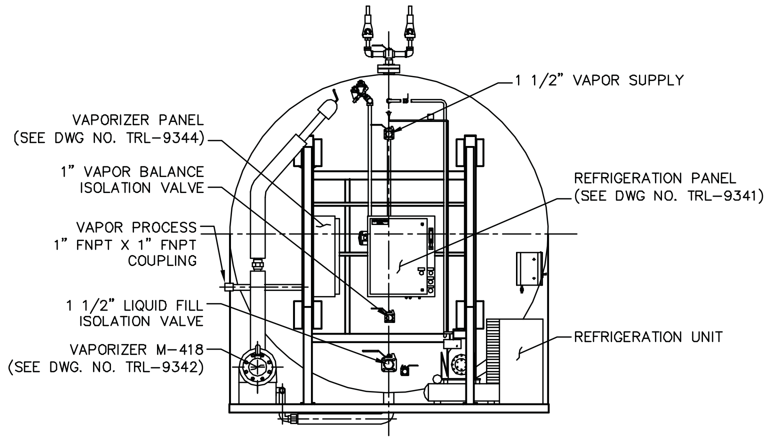
GENERAL ARRANGEMENT

SCALE: NONE



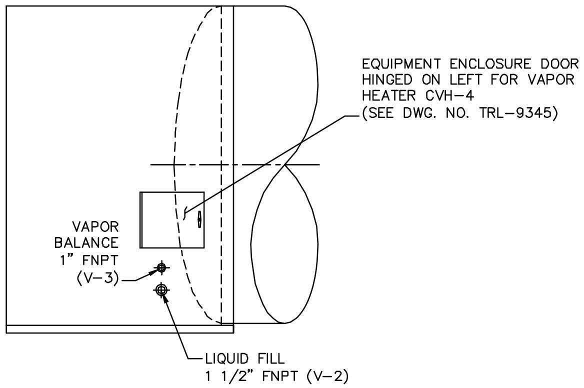
FRONT ELEVATION

SCALE: NONE



FRONT ELEVATION
WITH DOOR REMOVED

SCALE: NONE



RIGHT SIDE VIEW

SCALE: NONE

NOTE:

- SEE GENERAL AND INSTALLATION NOTES ON SHEET 3 THIS DWG

DWG. FILE NAME: 120C-Ton-GA-A.DWG

A	DWG FOR PROPOSAL INFO AND DESIGN REFERENCE	03/11/13	NHP
NO.	DESCRIPTION	DATE	BY

ORIGINAL/REVISIONS

REFERENCE DRAWING

"CONFIDENTIAL-TRADE SECRETS"

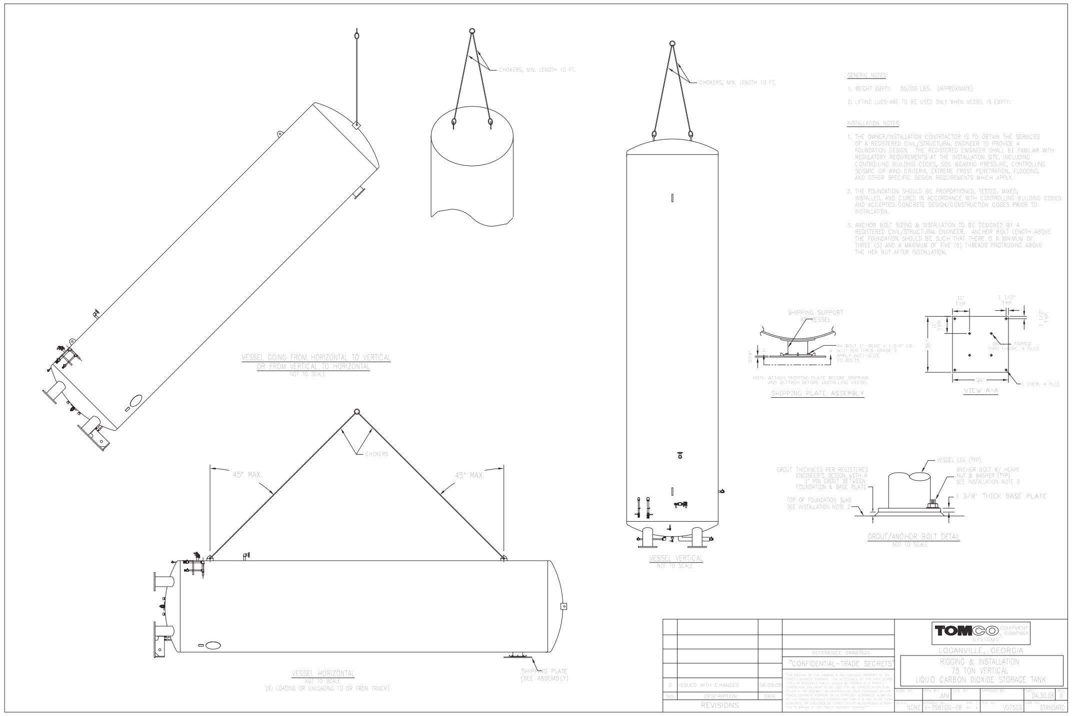
"THE ORIGINAL OF THIS DRAWING IS THE EXCLUSIVE PROPERTY OF THE TOMCO2 EQUIPMENT COMPANY. THE ACCEPTANCE OF THIS PRINT CONSTITUTES AN AGREEMENT THAT IT SHOULD BE TREATED AS A STRICTLY CONFIDENTIAL DOCUMENT TO BE USED FOR NO PURPOSE OTHER THAN TO AID IN THE ASSEMBLY, OR OPERATION OF UNITS FURNISHED BY THE TOMCO2 EQUIPMENT COMPANY, OR AS EXPRESSLY AUTHORIZED IN WRITING BY THE TOMCO2 EQUIPMENT COMPANY, AND THAT IT IS NOT BE COMMUNICATED, DISCLOSED, OR COPIED, EXCEPT AS EXPRESSLY AUTHORIZED IN WRITING BY THE TOMCO2 EQUIPMENT COMPANY"

TOMCO2 SYSTEMS EQUIPMENT COMPANY
LOGANVILLE, GEORGIA

TOMCO2 MODEL WT-120C
LIQUID CO2 STORAGE TANK
GENERAL ARRANGEMENT
FOR PROPOSAL & DESIGN REFERENCE

DRAWN BY: TEC/NP
SCALE: AS NOTED
CHECKED BY: NHP
DATE: 03/11/2013
JOB NO. GB031113-1
SHEET 1 OF 3
120C-TON-GA

Mine Water Treatment Trains TomCO2 Carbon Dioxide Feed, 4/4



GENERAL NOTES:

1. WEIGHT EMPTY: 55,000 LBS. (APPROXIMATE)
2. LIFTING LUGS ARE TO BE USED ONLY WHEN VESSEL IS EMPTY.

INSTALLATION NOTES:

1. THE OWNER/INSTALLATION CONTRTACTOR IS TO OBTAIN THE SERVICES OF A REGISTERED CIVIL/STRUCTURAL ENGINEER TO PROVIDE A FOUNDATION DESIGN. THE REGISTERED ENGINEER SHALL BE FAMILIAR WITH REGULATORY REQUIREMENTS AT THE INSTALLATION SITE, INCLUDING CONTROLLING BUILDING CODES, SOIL BEARING PRESSURE, CONTROLLING SEISMIC OR WIND CRITERIA, EXTREME FROST PENETRATION, FLOODING, AND OTHER SPECIFIC DESIGN REQUIREMENTS WHICH APPLY.
2. THE FOUNDATION SHOULD BE PROPORTIONED, TESTED, MIXED, INSTALLED, AND CURED IN ACCORDANCE WITH CONTROLLING BUILDING CODES AND ACCEPTED CONCRETE DESIGN/CONSTRUCTION CODES PRIOR TO INSTALLATION.
3. ANCHOR BOLT SIZING & INSTALLATION TO BE DESIGNED BY A REGISTERED CIVIL/STRUCTURAL ENGINEER. ANCHOR BOLT LENGTH ABOVE THE FOUNDATION SHOULD BE SUCH THAT THERE IS A MINIMUM OF THREE (3) AND A MAXIMUM OF FIVE (5) THREADS PROTRUDING ABOVE THE HEX NUT AFTER INSTALLATION.

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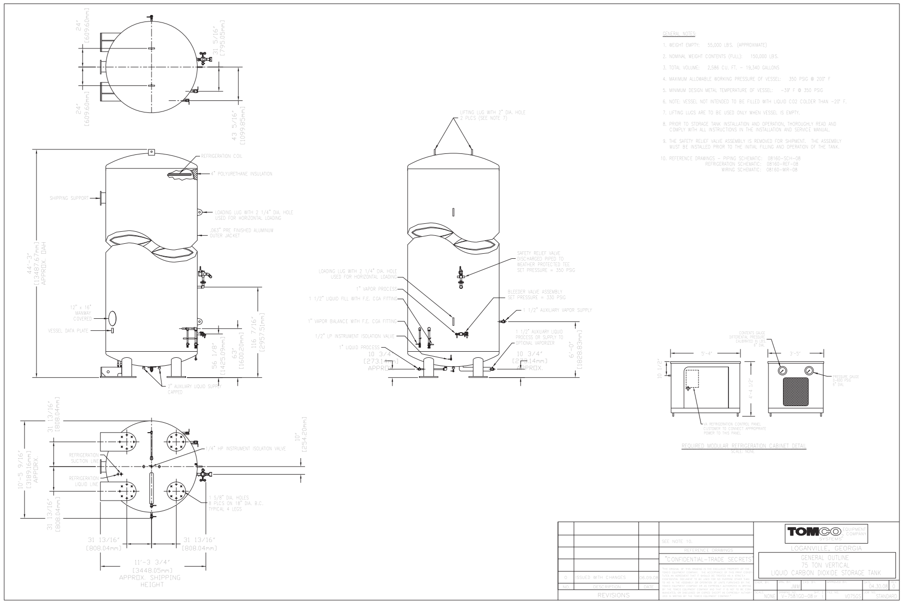

GENERAL NOTES:

1. WEIGHT EMPTY: 55,000 LBS. (APPROXIMATE)
2. NOMINAL WEIGHT CONTENTS (FULL): 150,000 LBS.
3. TOTAL VOLUME: 2,586 CU. FT. - 19,340 GALLONS
4. MAXIMUM ALLOWABLE WORKING PRESSURE OF VESSEL: 350 PSIG @ 200° F
5. MINIMUM DESIGN METAL TEMPERATURE OF VESSEL: -39° F @ 350 PSIG
6. NOTE: VESSEL NOT INTENDED TO BE FILLED WITH LIQUID CO2 COLDER THAN -20° F.
7. LIFTING LUGS ARE TO BE USED ONLY WHEN VESSEL IS EMPTY.
8. PRIOR TO STORAGE TANK INSTALLATION AND OPERATION, THOROUGHLY READ AND COMPLY WITH ALL INSTRUCTIONS IN THE INSTALLATION AND SERVICE MANUAL.
9. THE SAFETY RELIEF VALVE ASSEMBLY IS REMOVED FOR SHIPMENT. THE ASSEMBLY MUST BE INSTALLED PRIOR TO THE INITIAL FILLING AND OPERATION OF THE TANK.
10. REFERENCE DRAWINGS - PIPING SCHEMATIC: 08160-SCH-08
REFRIGERATION SCHEMATIC: 08160-REF-08
WIRING SCHEMATIC: 08160-WIR-08

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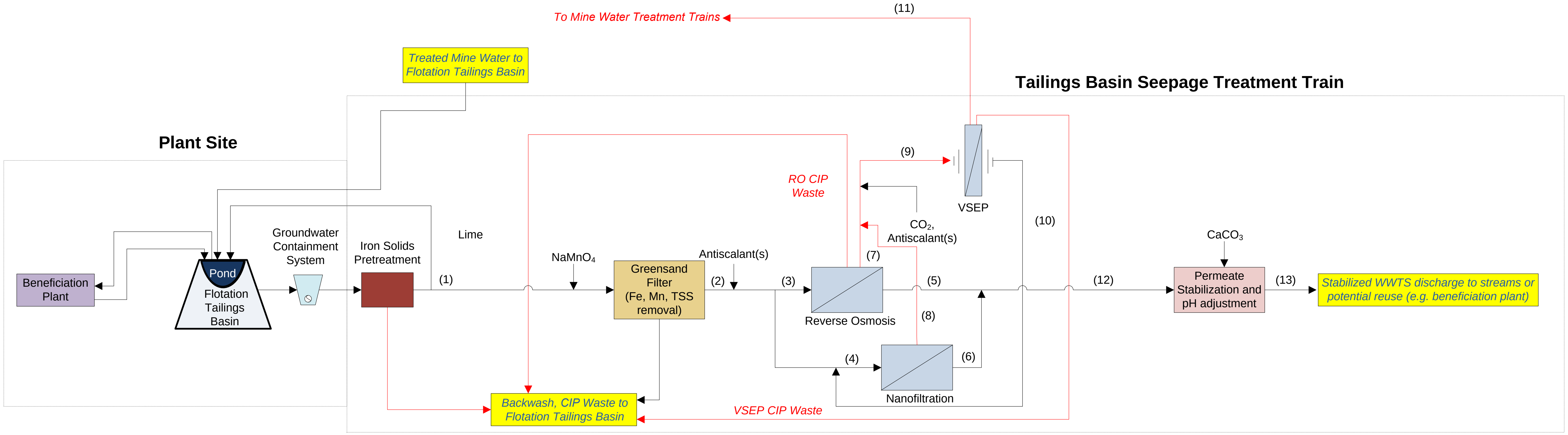
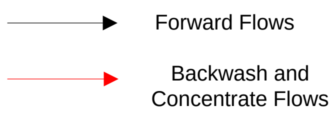
Attachment H

Tailings Basin Seepage Treatment Train Model Outputs





Item	Flow Name
1	Influent Seepage
2	Greensand Filter Effluent
3	RO Feed
4	NF Feed
5	RO Permeate
6	NF Permeate
7	RO Concentrate
8	NF Concentrate
9	RO/NF Concentrate with Acid
10	VSEP Permeate
11	VSEP Concentrate
12	Stabilization Influent
13	Stabilized Effluent

P:\Mpls\23 MN\69\2369862\WorkFiles\APA\Permitting\NPDES\Permit Applications\Volume III - WWTF-WWTP\Design and Operation Report\2017 version\Attachments\Attachments D and K figures

Large Figure 1
Tailings Basin Seepage Treatment
Overall Flow Sheet-Operations
NorthMet Project
PolyMet Mining Inc.
Hoyt Lakes, MN

Tailings Basin Seepage Treatment Train - Year 1 - P90 Annual Average Flows

Qualities and Quantities	Preliminary Water Quality Targets	(1) Influent Seepage	(2) Green Sand Effluent	(3) RO Feed	NF Rejection	(4) NF Feed	RO Rejection	(5) RO Permeate	VSEP Rejection	(6) NF Permeate	(7) RO Concentrate	(8) NF Concentrate	(9) NF/RO Concentrate w/CO2	(10) VSEP Permeate	(11) VSEP Concentrate	(12) Stabilization Influent	(13) Stabilized Effluent	System Mass Balance
Flow Rate, gpm		**1937**	**1840**	**1822**		**489**		**1366**		**391**	**455**	**98**	**553**	**470**	**83**	**1757**	**1757**	**N/A**
[Ag] [mg/L]	**0.001**	8.91E-05	8.91E-05	8.91E-05	66%	1.67E-05	99%	1.31E-06	96%	7.06E-06	3.54E-04	5.57E-05	3.01E-04	1.39E-05	1.96E-03	2.58E-06	2.58E-06	100.0%
[Al] [mg/L]	**0.125**	1.14E-02	1.14E-02	1.14E-02	93%	7.05E-04	99%	1.21E-04	99%	5.81E-05	4.54E-02	3.31E-03	3.80E-02	2.85E-04	2.55E-01	1.07E-04	1.07E-04	100.0%
[As] [mg/L]	**0.01**	3.71E-03	2.74E-05	2.74E-05	98%	9.90E-05	99%	4.74E-07	51%	1.98E-06	1.08E-04	4.90E-04	1.76E-04	1.02E-04	6.02E-04	8.08E-07	8.08E-07	100.0%
[B] [mg/L]	**0.5**	2.46E-01	2.46E-01	2.46E-01	21%	5.94E-01	61%	1.27E-01	15%	5.88E-01	6.07E-01	6.18E-01	6.09E-01	6.08E-01	6.18E-01	2.29E-01	2.29E-01	100.1%
[Ba] [mg/L]	**2**	1.72E-01	1.72E-01	1.72E-01	82%	4.91E-02	100%	0.00E+00	94%	1.13E-02	6.90E-01	2.01E-01	6.04E-01	4.43E-02	3.83E+00	2.51E-03	2.51E-03	100.0%
[Be] [mg/L]	**0.004**	1.61E-04	1.61E-04	1.61E-04	94%	2.51E-03	99%	1.50E-06	15%	2.04E-04	6.42E-04	1.18E-02	2.61E-03	2.60E-03	2.65E-03	4.64E-05	4.64E-05	100.2%
[C] [mg/L]		3.42E+02	3.42E+02	3.42E+02	49%	1.70E+03	99%	5.93E+00	40%	1.09E+03	1.36E+03	4.18E+03	2.76E+03	1.76E+03	6.75E+03	2.46E+02	2.97E+02	100.0%
[Ca] [mg/L]		3.76E+01	3.76E+01	3.76E+01	81%	1.78E+01	99%	4.01E-01	89%	4.30E+00	1.50E+02	7.24E+01	1.36E+02	1.71E+01	8.24E+02	1.27E+00	3.47E+01	100.1%
[Cd] [mg/L]	**0.0025**	1.04E-04	1.04E-04	1.04E-04	93%	1.43E-05	99%	1.25E-06	97%	1.19E-06	4.14E-04	6.68E-05	3.53E-04	1.07E-05	2.33E-03	1.24E-06	1.24E-06	100.0%
[Cl] [mg/L]	**230**	1.88E+01	1.88E+01	1.88E+01	9%	6.64E+01	99%	2.51E-01	13%	7.51E+01	7.47E+01	3.14E+01	6.71E+01	6.83E+01	6.05E+01	1.69E+01	1.69E+01	100.0%
[Co] [mg/L]	**0.005**	2.09E-03	3.24E-05	3.24E-05	97%	7.46E-06	99%	3.45E-07	95%	2.98E-07	1.29E-04	3.63E-05	1.13E-04	6.48E-06	7.25E-04	3.35E-07	3.35E-07	100.0%
[Cr] [mg/L]	**0.011**	4.52E-04	4.52E-04	4.52E-04	93%	2.17E-04	99%	4.81E-06	89%	1.79E-05	1.80E-03	1.02E-03	1.66E-03	2.08E-04	1.00E-02	7.72E-06	7.72E-06	100.0%
[Cu] [mg/L]	**0.0093**	8.10E-03	4.95E-04	4.95E-04	94%	8.36E-05	99%	6.60E-06	97%	6.47E-06	1.97E-03	3.94E-04	1.69E-03	6.74E-05	1.10E-02	6.57E-06	6.57E-06	100.0%
[F] [mg/L]	**2**	3.89E+00	3.89E+00	3.89E+00	87%	1.84E+01	99%	5.70E-02	40%	3.00E+00	1.55E+01	8.01E+01	2.69E+01	1.89E+01	7.27E+01	7.11E-01	7.11E-01	100.1%
[Fe] [mg/L]	**0.3**	1.23E+00	1.30E-02	1.30E-02	81%	2.51E-03	100%	0.00E+00	96%	5.98E-04	5.20E-02	1.02E-02	4.46E-02	2.10E-03	2.90E-01	1.33E-04	1.33E-04	100.0%
[K] [mg/L]		7.65E+00	7.65E+00	7.65E+00	59%	1.39E+01	99%	1.02E-01	63%	7.13E+00	3.04E+01	4.13E+01	3.23E+01	1.42E+01	1.37E+02	1.66E+00	1.66E+00	100.1%
[Mg] [mg/L]		6.40E+01	6.40E+01	6.40E+01	94%	7.68E+01	99%	5.11E-01	76%	5.66E+00	2.55E+02	3.63E+02	2.74E+02	7.73E+01	1.41E+03	1.65E+00	1.65E+00	100.1%
[Mn] [mg/L]	**0.05**	3.00E-01	4.74E-02	4.74E-02	89%	6.06E-02	100%	0.00E+00	75%	8.55E-03	1.90E-01	2.70E-01	2.04E-01	6.12E-02	1.03E+00	1.90E-03	1.90E-03	100.0%
[Na] [mg/L]		5.91E+01	5.91E+01	5.91E+01	58%	9.29E+01	99%	7.87E-01	67%	4.92E+01	2.35E+02	2.69E+02	2.41E+02	9.42E+01	1.09E+03	1.15E+01	1.15E+01	100.1%
[Ni] [mg/L]	**0.052**	1.16E+01	1.60E+00	1.60E+00	97%	3.29E-01	99%	1.71E-02	96%	1.40E-02	6.38E+00	1.60E+00	5.54E+00	2.80E-01	3.59E+01	1.64E-02	1.64E-02	100.0%
[Pb] [mg/L]	**0.0032**	1.10E-03	1.20E-04	1.20E-04	96%	1.68E-05	99%	1.44E-06	97%	7.77E-07	4.78E-04	8.13E-05	4.08E-04	1.28E-05	2.69E-03	1.29E-06	1.29E-06	100.0%
[Sb] [mg/L]	**0.031**	4.38E-04	4.38E-04	4.38E-04	94%	1.09E-04	99%	4.67E-06	95%	8.68E-06	1.75E-03	5.11E-04	1.53E-03	9.57E-05	9.80E-03	5.56E-06	5.56E-06	100.0%
[Se] [mg/L]	**0.005**	4.53E-04	4.53E-04	4.53E-04	97%	5.70E-05	100%	3.01E-06	98%	2.21E-06	1.81E-03	2.78E-04	1.54E-03	4.15E-05	1.02E-02	2.83E-06	2.83E-06	100.0%
[SiO2] [mg/L]		6.51E+01	6.51E+01	6.51E+01	22%	2.55E+01	99%	5.20E-01	91%	2.48E+01	2.60E+02	2.84E+01	2.19E+02	2.40E+01	1.34E+03	5.92E+00	5.92E+00	100.0%
[SO4] [mg/L]	**10**	1.68E+02	1.68E+02	1.68E+02	97%	1.14E+02	100%	1.12E+00	85%	4.57E+00	6.72E+02	5.56E+02	6.51E+02	1.12E+02	3.76E+03	1.89E+00	1.89E+00	100.1%
[Tl] [mg/L]	**0.00056**	1.48E-04	1.48E-04	1.48E-04	94%	3.63E-05	99%	1.58E-06	95%	2.95E-06	5.90E-04	1.71E-04	5.16E-04	3.19E-05	3.31E-03	1.88E-06	1.88E-06	100.0%
[V] [mg/L]		3.87E-03	3.87E-03	3.87E-03	93%	2.35E-03	99%	4.12E-05	87%	1.94E-04	1.54E-02	1.10E-02	1.46E-02	2.29E-03	8.59E-02	7.51E-05	7.51E-05	100.1%
[Zn] [mg/L]	**0.12**	1.05E-02	2.42E-04	2.42E-04	96%	6.00E-05	99%	2.90E-06	95%	3.07E-06	9.63E-04	2.89E-04	8.44E-04	5.28E-05	5.41E-03	2.94E-06	2.94E-06	100.0%
[Alkalinity] [mg/L] as CaCO3	**250**	2.85E+02	2.85E+02	2.85E+02	49%	7.10E+02	99%	4.94E+00	50%	4.54E+02	1.13E+03	1.74E+03	1.24E+03	7.27E+02	4.19E+03	1.05E+02	1.88E+02	111.8%
Hardness [mg/L]**	**100**	357.5	357.5	357.5	0%	360.9	0.0	3.1	0.0	34.0	1425.2	1676.0	1469.8	361.0	7871.1	10.0	93.5	N/A
[Ionic_Strength] [M]		0.014	0.014	0.014	0.000	0.019	0.000	0.000	0.000	0.008	0.049	0.058	0.051	0.019	0.20244	0.00181	0.00422	N/A
[Charge_pct_err]		2.193	0.142	0.142	0.000	-26.569	0.000	-14.127	0.000	-58.779	0.304	-6.193	-1.065	-27.211	15.37048	-56.19946	-28.71596	N/A
[pH] [std units]	**6.5-8.5**	7.9	8.0	8.0	0.0	6.3	0.0	8.0	0.0	6.3	7.9	6.2	6.3	6.3	6.6	6.3	6.8	N/A
mEQ-Na$^+$/mEQ-∑Cations	**0.6**	25%	26%	26%	0%	35%	0%	34%	0%	71%	26%	25%	26%	35%	23%	67%	21%	N/A
CO2 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	663.3	0.0	0.0	0.0	0.0	N/A
CO2 [kg/d]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2000.0	0.0	0.0	0.0	0.0	N/A
CaCO3 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	83.5	N/A
CaCO3 [kg/day]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	800.0	N/A

Temp 7.55 degrees C

181.94

****Calculated as the sum of Ca and Mg as CaCO3**

Tailings Basin Seepage Treatment Train - Year 1 - P90 Peak Flow

Qualities and Quantities	Preliminary Water Quality Targets	(1) Influent Seepage	(2) Green Sand Effluent	(3) RO Feed	NF Rejection	(4) NF Feed	RO Rejection	(5) RO Permeate	VSEP Rejection	(6) NF Permeate	(7) RO Concentrate	(8) NF Concentrate	(9) NF/RO Concentrate w/CO2	(10) VSEP Permeate	(11) VSEP Concentrate	(12) Stabilization Influent	(13) Stabilized Effluent	System Mass Balance
Flow Rate, gpm		**2000**	**1900**	**1881**		**504**		**1411**		**404**	**470**	**101**	**571**	**485**	**86**	**1814**	**1814**	**N/A**
[Ag] [mg/L]	**0.001**	8.91E-05	8.91E-05	8.91E-05	66%	1.68E-05	99%	1.31E-06	96%	7.07E-06	3.54E-04	5.58E-05	3.01E-04	1.39E-05	1.96E-03	2.58E-06	2.59E-06	100.0%
[Al] [mg/L]	**0.125**	1.14E-02	1.14E-02	1.14E-02	93%	7.05E-04	99%	1.21E-04	99%	5.81E-05	4.54E-02	3.31E-03	3.80E-02	2.86E-04	2.56E-01	1.07E-04	1.07E-04	100.0%
[As] [mg/L]	**0.01**	3.71E-03	2.74E-05	2.74E-05	98%	9.91E-05	99%	4.74E-07	51%	1.98E-06	1.08E-04	4.90E-04	1.76E-04	1.02E-04	6.03E-04	8.08E-07	8.08E-07	100.0%
[B] [mg/L]	**0.5**	2.46E-01	2.46E-01	2.46E-01	21%	5.94E-01	61%	1.27E-01	15%	5.88E-01	6.07E-01	6.19E-01	6.09E-01	6.08E-01	6.20E-01	2.29E-01	2.29E-01	100.1%
[Ba] [mg/L]	**2**	1.72E-01	1.72E-01	1.72E-01	82%	4.92E-02	100%	0.00E+00	94%	1.13E-02	6.90E-01	2.02E-01	6.04E-01	4.44E-02	3.84E+00	2.51E-03	2.51E-03	100.0%
[Be] [mg/L]	**0.004**	1.61E-04	1.61E-04	1.61E-04	94%	2.51E-03	99%	1.50E-06	15%	2.04E-04	6.42E-04	1.18E-02	2.61E-03	2.60E-03	2.65E-03	4.64E-05	4.64E-05	100.2%
[C] [mg/L]		3.42E+02	3.42E+02	3.42E+02	49%	2.28E+03	99%	5.93E+00	40%	1.46E+03	1.36E+03	5.59E+03	3.86E+03	2.35E+03	9.07E+03	3.28E+02	1.38E+02	100.0%
[Ca] [mg/L]		3.76E+01	3.76E+01	3.76E+01	81%	1.79E+01	99%	4.01E-01	89%	4.30E+00	1.50E+02	7.25E+01	1.36E+02	1.71E+01	8.26E+02	1.27E+00	5.32E+00	100.1%
[Cd] [mg/L]	**0.0025**	1.04E-04	1.04E-04	1.04E-04	93%	1.43E-05	99%	1.25E-06	97%	1.19E-06	4.14E-04	6.69E-05	3.53E-04	1.07E-05	2.33E-03	1.24E-06	1.24E-06	100.0%
[Cl] [mg/L]	**230**	1.88E+01	1.88E+01	1.88E+01	9%	6.64E+01	99%	2.51E-01	13%	7.51E+01	7.47E+01	3.14E+01	6.71E+01	6.83E+01	6.07E+01	1.69E+01	1.69E+01	100.0%
[Co] [mg/L]	**0.005**	2.09E-03	3.24E-05	3.24E-05	97%	7.46E-06	99%	3.45E-07	95%	2.98E-07	1.29E-04	3.63E-05	1.13E-04	6.48E-06	7.27E-04	3.35E-07	3.35E-07	100.0%
[Cr] [mg/L]	**0.011**	4.52E-04	4.52E-04	4.52E-04	93%	2.17E-04	99%	4.81E-06	89%	1.79E-05	1.80E-03	1.02E-03	1.66E-03	2.08E-04	1.01E-02	7.72E-06	7.73E-06	100.0%
[Cu] [mg/L]	**0.0093**	8.10E-03	4.95E-04	4.95E-04	94%	8.36E-05	99%	6.60E-06	97%	6.47E-06	1.97E-03	3.94E-04	1.69E-03	6.75E-05	1.11E-02	6.57E-06	6.56E-06	100.0%
[F] [mg/L]	**2**	3.89E+00	3.89E+00	3.89E+00	87%	1.84E+01	99%	5.70E-02	40%	3.00E+00	1.55E+01	8.02E+01	2.69E+01	1.89E+01	7.29E+01	7.11E-01	7.11E-01	100.1%
[Fe] [mg/L]	**0.3**	1.23E+00	1.30E-02	1.30E-02	81%	2.51E-03	100%	0.00E+00	96%	5.98E-04	5.20E-02	1.02E-02	4.46E-02	2.10E-03	2.91E-01	1.33E-04	1.33E-04	100.0%
[K] [mg/L]		7.65E+00	7.65E+00	7.65E+00	59%	1.39E+01	99%	1.02E-01	63%	7.13E+00	3.04E+01	4.13E+01	3.23E+01	1.42E+01	1.37E+02	1.66E+00	1.66E+00	100.1%
[Mg] [mg/L]		6.40E+01	6.40E+01	6.40E+01	94%	7.68E+01	99%	5.11E-01	76%	5.66E+00	2.55E+02	3.64E+02	2.74E+02	7.74E+01	1.41E+03	1.65E+00	1.66E+00	100.1%
[Mn] [mg/L]	**0.05**	3.00E-01	4.74E-02	4.74E-02	89%	6.07E-02	100%	0.00E+00	75%	8.56E-03	1.90E-01	2.71E-01	2.05E-01	6.12E-02	1.03E+00	1.90E-03	1.90E-03	100.0%
[Na] [mg/L]		5.91E+01	5.91E+01	5.91E+01	58%	9.30E+01	99%	7.87E-01	67%	4.92E+01	2.35E+02	2.69E+02	2.41E+02	9.43E+01	1.09E+03	1.15E+01	1.15E+01	100.1%
[Ni] [mg/L]	**0.052**	1.16E+01	1.60E+00	1.60E+00	97%	3.30E-01	99%	1.71E-02	96%	1.40E-02	6.38E+00	1.60E+00	5.54E+00	2.80E-01	3.60E+01	1.64E-02	1.64E-02	100.0%
[Pb] [mg/L]	**0.0032**	1.10E-03	1.20E-04	1.20E-04	96%	1.68E-05	99%	1.44E-06	97%	7.77E-07	4.78E-04	8.14E-05	4.08E-04	1.28E-05	2.70E-03	1.29E-06	1.29E-06	100.0%
[Sb] [mg/L]	**0.031**	4.38E-04	4.38E-04	4.38E-04	94%	1.09E-04	99%	4.67E-06	95%	8.68E-06	1.75E-03	5.11E-04	1.53E-03	9.57E-05	9.82E-03	5.56E-06	5.57E-06	100.0%
[Se] [mg/L]	**0.005**	4.53E-04	4.53E-04	4.53E-04	97%	5.71E-05	100%	3.01E-06	98%	2.21E-06	1.81E-03	2.78E-04	1.54E-03	4.16E-05	1.02E-02	2.83E-06	2.84E-06	100.0%
[SiO2] [mg/L]		6.51E+01	6.51E+01	6.51E+01	22%	2.56E+01	99%	5.20E-01	91%	2.48E+01	2.60E+02	2.84E+01	2.19E+02	2.40E+01	1.35E+03	5.92E+00	5.93E+00	100.0%
[SO4] [mg/L]	**10**	1.68E+02	1.68E+02	1.68E+02	97%	1.14E+02	100%	1.12E+00	85%	4.57E+00	6.72E+02	5.57E+02	6.52E+02	1.12E+02	3.77E+03	1.89E+00	1.89E+00	100.1%
[Tl] [mg/L]	**0.00056**	1.48E-04	1.48E-04	1.48E-04	94%	3.64E-05	99%	1.58E-06	95%	2.95E-06	5.90E-04	1.71E-04	5.16E-04	3.20E-05	3.32E-03	1.88E-06	1.88E-06	100.0%
[V] [mg/L]		3.87E-03	3.87E-03	3.87E-03	93%	2.35E-03	99%	4.12E-05	87%	1.94E-04	1.54E-02	1.10E-02	1.46E-02	2.29E-03	8.61E-02	7.51E-05	7.51E-05	100.1%
[Zn] [mg/L]	**0.12**	1.05E-02	2.42E-04	2.42E-04	96%	6.00E-05	99%	2.90E-06	95%	3.07E-06	9.63E-04	2.89E-04	8.45E-04	5.29E-05	5.42E-03	2.94E-06	2.94E-06	100.0%
[Alkalinity] [mg/L] as CaCO3	**250**	2.85E+02	2.85E+02	2.85E+02	49%	7.11E+02	99%	4.94E+00	50%	4.54E+02	1.13E+03	1.74E+03	1.24E+03	7.27E+02	4.20E+03	1.05E+02	1.15E+02	101.6%
Hardness [mg/L]**	**100**	357.5	357.5	357.5	0%	361.1	0.0	3.1	0.0	34.1	1425.2	1678.4	1470.5	361.2	7889.2	10.0	20.1	N/A
[Ionic_Strength] [M]		0.014	0.014	0.014	0.000	0.019	0.000	0.000	0.000	0.008	0.049	0.058	0.051	0.019	0.20298	0.00181	0.00211	N/A
[Charge_pct_err]		2.193	0.142	0.142	0.000	-26.567	0.000	-14.127	0.000	-58.774	0.304	-6.193	-1.065	-27.208	15.36081	-56.18841	-50.47973	N/A
[pH] [std units]	**6.5-8.5**	7.9	8.0	8.0	0.0	6.1	0.0	8.0	0.0	6.1	7.9	6.0	6.0	6.1	6.2	6.1	8.1	N/A
mEQ-Na$^+$/mEQ-∑Cations	**0.6**	25%	26%	26%	0%	35%	0%	34%	0%	71%	26%	25%	26%	35%	23%	67%	53%	N/A
CO2 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1284.8	0.0	0.0	0.0	0.0	N/A
CO2 [kg/d]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4000.0	0.0	0.0	0.0	0.0	N/A
CaCO3 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.1	N/A
CaCO3 [kg/day]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0	N/A

****Calculated as the sum of Ca and Mg as CaCO3**

Tailings Basin Seepage Treatment Train - Year 7 - P90 Annual Average Flows

Qualities and Quantities	Preliminary Water Quality Targets	(1) Influent Seepage	(2) Green Sand Effluent	(3) RO Feed	NF Rejection	(4) NF Feed	RO Rejection	(5) RO Permeate	VSEP Rejection	(6) NF Permeate	(7) RO Concentrate	(8) NF Concentrate	(9) NF/RO Concentrate w/CO2	(10) VSEP Permeate	(11) VSEP Concentrate	(12) Stabilization Influent	(13) Stabilized Effluent	System Mass Balance
Flow Rate, gpm		**2000**	**1900**	**1881**		**504**		**1411**		**404**	**470**	**101**	**571**	**485**	**86**	**1814**	**1814**	**N/A**
[Ag] [mg/L]	**0.001**	3.04E-04	3.04E-04	3.04E-04	54%	5.85E-05	100%	1.62E-06	96%	3.39E-05	1.22E-03	1.57E-04	1.03E-03	4.88E-05	6.74E-03	8.81E-06	8.81E-06	100.0%
[Al] [mg/L]	**0.125**	1.27E-02	1.27E-02	1.27E-02	95%	7.85E-04	99%	1.52E-04	99%	4.80E-05	5.06E-02	3.75E-03	4.23E-02	3.18E-04	2.87E-01	1.29E-04	1.29E-04	100.0%
[As] [mg/L]	**0.01**	1.42E-02	1.04E-04	1.04E-04	99%	3.81E-04	99%	1.11E-06	51%	5.23E-06	4.15E-04	1.89E-03	6.76E-04	3.92E-04	2.33E-03	2.03E-06	2.03E-06	100.0%
[B] [mg/L]	**0.5**	2.77E-01	2.77E-01	2.77E-01	21%	6.68E-01	61%	1.42E-01	15%	6.60E-01	6.82E-01	6.98E-01	6.85E-01	6.83E-01	7.01E-01	2.57E-01	2.58E-01	100.1%
[Ba] [mg/L]	**2**	4.86E-02	4.86E-02	4.86E-02	94%	1.40E-02	100%	0.00E+00	94%	1.13E-03	1.95E-01	6.57E-02	1.72E-01	1.26E-02	1.10E+00	2.52E-04	2.52E-04	100.0%
[Be] [mg/L]	**0.004**	4.31E-04	4.31E-04	4.31E-04	95%	7.19E-03	100%	2.29E-06	15%	4.40E-04	1.72E-03	3.43E-02	7.47E-03	7.45E-03	7.64E-03	9.95E-05	9.95E-05	100.1%
[C] [mg/L]		2.33E+02	2.33E+02	2.33E+02	49%	8.90E+02	98%	7.03E+00	40%	5.69E+02	8.97E+02	2.18E+03	1.70E+03	9.25E+02	3.58E+03	1.26E+02	1.21E+02	100.0%
[Ca] [mg/L]		8.72E+01	8.72E+01	8.72E+01	93%	4.20E+01	100%	4.64E-01	89%	3.88E+00	3.49E+02	1.96E+02	3.22E+02	4.03E+01	1.96E+03	1.22E+00	1.74E+01	100.1%
[Cd] [mg/L]	**0.0025**	7.91E-04	7.91E-04	7.91E-04	95%	1.09E-04	100%	1.05E-06	97%	6.80E-06	3.17E-03	5.20E-04	2.70E-03	8.22E-05	1.80E-02	2.33E-06	2.33E-06	100.0%
[Cl] [mg/L]	**230**	2.42E+01	2.42E+01	2.42E+01	9%	8.47E+01	98%	5.47E-01	13%	9.58E+01	9.54E+01	4.00E+01	8.56E+01	8.70E+01	7.78E+01	2.17E+01	2.17E+01	100.0%
[Co] [mg/L]	**0.005**	2.10E-02	3.26E-04	3.26E-04	98%	7.54E-05	100%	4.34E-07	95%	2.35E-06	1.31E-03	3.69E-04	1.14E-03	6.56E-05	7.40E-03	8.60E-07	8.61E-07	100.0%
[Cr] [mg/L]	**0.011**	3.60E-03	3.60E-03	3.60E-03	95%	1.75E-03	100%	4.79E-06	89%	1.07E-04	1.44E-02	8.34E-03	1.34E-02	1.67E-03	8.14E-02	2.75E-05	2.75E-05	100.0%
[Cu] [mg/L]	**0.0093**	2.32E-01	1.42E-02	1.42E-02	94%	2.40E-03	99%	1.70E-04	97%	1.86E-04	5.65E-02	1.13E-02	4.85E-02	1.93E-03	3.19E-01	1.74E-04	1.74E-04	100.0%
[F] [mg/L]	**2**	2.08E+00	2.08E+00	2.08E+00	39%	6.07E+00	98%	5.26E-02	40%	4.61E+00	8.18E+00	1.19E+01	8.84E+00	6.22E+00	2.41E+01	1.07E+00	1.07E+00	100.1%
[Fe] [mg/L]	**0.3**	8.39E+00	8.83E-02	8.83E-02	95%	1.72E-02	100%	0.00E+00	96%	1.03E-03	3.54E-01	8.21E-02	3.06E-01	1.44E-02	2.01E+00	2.29E-04	2.29E-04	100.0%
[K] [mg/L]		1.53E+01	1.53E+01	1.53E+01	59%	2.79E+01	99%	1.22E-01	63%	1.43E+01	6.10E+01	8.27E+01	6.48E+01	2.84E+01	2.77E+02	3.27E+00	3.27E+00	100.1%
[Mg] [mg/L]		1.02E+02	1.02E+02	1.02E+02	95%	1.23E+02	100%	5.44E-01	76%	7.98E+00	4.08E+02	5.86E+02	4.40E+02	1.24E+02	2.28E+03	2.20E+00	2.20E+00	100.1%
[Mn] [mg/L]	**0.05**	9.01E-01	1.42E-01	1.42E-01	96%	1.86E-01	100%	0.00E+00	75%	9.53E-03	5.71E-01	8.97E-01	6.29E-01	1.88E-01	3.20E+00	2.12E-03	2.12E-03	100.0%
[Na] [mg/L]		7.31E+01	7.31E+01	7.31E+01	58%	1.15E+02	99%	8.76E-01	67%	6.09E+01	2.91E+02	3.33E+02	2.98E+02	1.17E+02	1.36E+03	1.42E+01	1.42E+01	100.1%
[Ni] [mg/L]	**0.052**	2.56E-01	3.54E-02	3.54E-02	97%	7.31E-03	100%	4.71E-05	96%	2.37E-04	1.42E-01	3.58E-02	1.23E-01	6.21E-03	8.04E-01	8.94E-05	8.94E-05	100.0%
[Pb] [mg/L]	**0.0032**	1.21E-02	1.32E-03	1.32E-03	97%	1.86E-04	100%	1.76E-06	97%	6.52E-06	5.30E-03	9.10E-04	4.53E-03	1.42E-04	3.01E-02	2.82E-06	2.82E-06	100.0%
[Sb] [mg/L]	**0.031**	6.01E-03	6.01E-03	6.01E-03	95%	1.50E-03	100%	8.00E-06	95%	9.16E-05	2.41E-02	7.15E-03	2.11E-02	1.32E-03	1.36E-01	2.66E-05	2.66E-05	100.0%
[Se] [mg/L]	**0.005**	1.69E-03	1.69E-03	1.69E-03	97%	2.13E-04	100%	4.50E-06	98%	7.46E-06	6.77E-03	1.04E-03	5.77E-03	1.56E-04	3.84E-02	5.16E-06	5.17E-06	100.0%
[SiO2] [mg/L]		3.48E+01	3.48E+01	3.48E+01	22%	1.36E+01	99%	2.78E-01	91%	1.33E+01	1.39E+02	1.51E+01	1.17E+02	1.28E+01	7.24E+02	3.17E+00	3.17E+00	100.0%
[SO4] [mg/L]	**10**	6.51E+02	6.51E+02	6.51E+02	97%	4.42E+02	99%	6.07E+00	85%	1.60E+01	2.60E+03	2.15E+03	2.52E+03	4.34E+02	1.47E+04	8.28E+00	8.28E+00	100.1%
[Tl] [mg/L]	**0.00056**	2.23E-04	2.23E-04	2.23E-04	95%	5.54E-05	100%	1.49E-06	95%	3.39E-06	8.92E-04	2.64E-04	7.81E-04	4.88E-05	5.04E-03	1.91E-06	1.91E-06	100.0%
[V] [mg/L]		6.13E-03	6.13E-03	6.13E-03	95%	3.74E-03	100%	4.08E-05	87%	2.29E-04	2.45E-02	1.79E-02	2.33E-02	3.65E-03	1.38E-01	8.26E-05	8.26E-05	100.1%
[Zn] [mg/L]	**0.12**	5.00E-02	1.15E-03	1.15E-03	97%	2.87E-04	100%	3.07E-06	95%	1.18E-05	4.61E-03	1.39E-03	4.05E-03	2.53E-04	2.61E-02	5.01E-06	5.02E-06	100.0%
[Alkalinity] [mg/L] as CaCO3	**250**	1.64E+02	1.64E+02	1.64E+02	51%	4.11E+02	98%	4.81E+00	50%	2.51E+02	6.44E+02	1.05E+03	7.16E+02	4.20E+02	2.44E+03	5.96E+01	1.00E+02	110.1%
Hardness [mg/L]**	**100**	638.2	638.2	638.2	0%	611.4	0.0	3.4	0.0	42.6	2551.5	2900.1	2614.0	610.4	14275.8	12.1	52.6	N/A
[Ionic_Strength] [M]		0.024	0.024	0.024	0.000	0.025	0.000	0.000	0.000	0.007	0.082	0.086	0.083	0.025	0.32643	0.00169	0.00285	N/A
[Charge_pct_err]		-3.728	-4.712	-4.712	0.000	-6.519	0.000	-37.755	0.000	-36.746	-4.955	6.537	-2.787	-6.577	-1.52666	-36.70776	-24.09774	N/A
[pH] [std units]	**6.5-8.5**	7.0	7.0	7.0	0.0	6.4	0.0	7.0	0.0	6.4	7.0	6.4	6.2	6.4	6.8	6.4	8.1	N/A
mEQ-Na^+/mEQ-∑Cations	**0.6**	19%	19%	19%	0%	28%	0%	35%	0%	69%	19%	19%	19%	28%	17%	65%	35%	N/A
CO2 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	963.6	0.0	0.0	0.0	0.0	N/A
CO2 [kg/d]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3000.0	0.0	0.0	0.0	0.0	N/A
CaCO3 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.4	N/A
CaCO3 [kg/day]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	400.0	N/A

Temp 7.55 degrees C

128.21

****Calculated as the sum of Ca and Mg as CaCO3**

Tailings Basin Seepage Treatment Train - Year 7 - P90 Peak Flow

Qualities and Quantities	Preliminary Water Quality Targets	(1) Influent Seepage	(2) Green Sand Effluent	(3) RO Feed	NF Rejection	(4) NF Feed	RO Rejection	(5) RO Permeate	VSEP Rejection	(6) NF Permeate	(7) RO Concentrate	(8) NF Concentrate	(9) NF/RO Concentrate w/CO2	(10) VSEP Permeate	(11) VSEP Concentrate	(12) Stabilization Influent	(13) Stabilized Effluent	System Mass Balance
Flow Rate, gpm		**2000**	**1900**	**1881**		**504**		**1411**		**404**	**470**	**101**	**571**	**485**	**86**	**1814**	**1814**	**N/A**
[Ag] [mg/L]	**0.001**	3.04E-04	3.04E-04	3.04E-04	54%	5.85E-05	100%	1.62E-06	96%	3.39E-05	1.22E-03	1.57E-04	1.03E-03	4.88E-05	6.74E-03	8.81E-06	8.81E-06	100.0%
[Al] [mg/L]	**0.125**	1.27E-02	1.27E-02	1.27E-02	95%	7.85E-04	99%	1.52E-04	99%	4.80E-05	5.06E-02	3.75E-03	4.23E-02	3.18E-04	2.87E-01	1.29E-04	1.29E-04	100.0%
[As] [mg/L]	**0.01**	1.42E-02	1.04E-04	1.04E-04	99%	3.81E-04	99%	1.11E-06	51%	5.23E-06	4.15E-04	1.89E-03	6.76E-04	3.92E-04	2.33E-03	2.03E-06	2.03E-06	100.0%
[B] [mg/L]	**0.5**	2.77E-01	2.77E-01	2.77E-01	21%	6.68E-01	61%	1.42E-01	15%	6.60E-01	6.82E-01	6.98E-01	6.85E-01	6.83E-01	7.01E-01	2.57E-01	2.58E-01	100.1%
[Ba] [mg/L]	**2**	4.86E-02	4.86E-02	4.86E-02	94%	1.40E-02	100%	0.00E+00	94%	1.13E-03	1.95E-01	6.57E-02	1.72E-01	1.26E-02	1.10E+00	2.52E-04	2.52E-04	100.0%
[Be] [mg/L]	**0.004**	4.31E-04	4.31E-04	4.31E-04	95%	7.19E-03	100%	2.29E-06	15%	4.40E-04	1.72E-03	3.43E-02	7.47E-03	7.45E-03	7.64E-03	9.95E-05	9.95E-05	100.1%
[C] [mg/L]		2.33E+02	2.33E+02	2.33E+02	49%	8.90E+02	98%	7.03E+00	40%	5.69E+02	8.97E+02	2.18E+03	1.70E+03	9.25E+02	3.58E+03	1.26E+02	1.21E+02	100.0%
[Ca] [mg/L]		8.72E+01	8.72E+01	8.72E+01	93%	4.20E+01	100%	4.64E-01	89%	3.88E+00	3.49E+02	1.96E+02	3.22E+02	4.03E+01	1.96E+03	1.22E+00	1.74E+01	100.1%
[Cd] [mg/L]	**0.0025**	7.91E-04	7.91E-04	7.91E-04	95%	1.09E-04	100%	1.05E-06	97%	6.80E-06	3.17E-03	5.20E-04	2.70E-03	8.22E-05	1.80E-02	2.33E-06	2.33E-06	100.0%
[Cl] [mg/L]	**230**	2.42E+01	2.42E+01	2.42E+01	9%	8.47E+01	98%	5.47E-01	13%	9.58E+01	9.54E+01	4.00E+01	8.56E+01	8.70E+01	7.78E+01	2.17E+01	2.17E+01	100.0%
[Co] [mg/L]	**0.005**	2.10E-02	3.26E-04	3.26E-04	98%	7.54E-05	100%	4.34E-07	95%	2.35E-06	1.31E-03	3.69E-04	1.14E-03	6.56E-05	7.40E-03	8.60E-07	8.61E-07	100.0%
[Cr] [mg/L]	**0.011**	3.60E-03	3.60E-03	3.60E-03	95%	1.75E-03	100%	4.79E-06	89%	1.07E-04	1.44E-02	8.34E-03	1.34E-02	1.67E-03	8.14E-02	2.75E-05	2.75E-05	100.0%
[Cu] [mg/L]	**0.0093**	2.32E-01	1.42E-02	1.42E-02	94%	2.40E-03	99%	1.70E-04	97%	1.86E-04	5.65E-02	1.13E-02	4.85E-02	1.93E-03	3.19E-01	1.74E-04	1.74E-04	100.0%
[F] [mg/L]	**2**	2.08E+00	2.08E+00	2.08E+00	39%	6.07E+00	98%	5.26E-02	40%	4.61E+00	8.18E+00	1.19E+01	8.84E+00	6.22E+00	2.41E+01	1.07E+00	1.07E+00	100.1%
[Fe] [mg/L]	**0.3**	8.39E+00	8.83E-02	8.83E-02	95%	1.72E-02	100%	0.00E+00	96%	1.03E-03	3.54E-01	8.21E-02	3.06E-01	1.44E-02	2.01E+00	2.29E-04	2.29E-04	100.0%
[K] [mg/L]		1.53E+01	1.53E+01	1.53E+01	59%	2.79E+01	99%	1.22E-01	63%	1.43E+01	6.10E+01	8.27E+01	6.48E+01	2.84E+01	2.77E+02	3.27E+00	3.27E+00	100.1%
[Mg] [mg/L]		1.02E+02	1.02E+02	1.02E+02	95%	1.23E+02	100%	5.44E-01	76%	7.98E+00	4.08E+02	5.86E+02	4.40E+02	1.24E+02	2.28E+03	2.20E+00	2.20E+00	100.1%
[Mn] [mg/L]	**0.05**	9.01E-01	1.42E-01	1.42E-01	96%	1.86E-01	100%	0.00E+00	75%	9.53E-03	5.71E-01	8.97E-01	6.29E-01	1.88E-01	3.20E+00	2.12E-03	2.12E-03	100.0%
[Na] [mg/L]		7.31E+01	7.31E+01	7.31E+01	58%	1.15E+02	99%	8.76E-01	67%	6.09E+01	2.91E+02	3.33E+02	2.98E+02	1.17E+02	1.36E+03	1.42E+01	1.42E+01	100.1%
[Ni] [mg/L]	**0.052**	2.56E-01	3.54E-02	3.54E-02	97%	7.31E-03	100%	4.71E-05	96%	2.37E-04	1.42E-01	3.58E-02	1.23E-01	6.21E-03	8.04E-01	8.94E-05	8.94E-05	100.0%
[Pb] [mg/L]	**0.0032**	1.21E-02	1.32E-03	1.32E-03	97%	1.86E-04	100%	1.76E-06	97%	6.52E-06	5.30E-03	9.10E-04	4.53E-03	1.42E-04	3.01E-02	2.82E-06	2.82E-06	100.0%
[Sb] [mg/L]	**0.031**	6.01E-03	6.01E-03	6.01E-03	95%	1.50E-03	100%	8.00E-06	95%	9.16E-05	2.41E-02	7.15E-03	2.11E-02	1.32E-03	1.36E-01	2.66E-05	2.66E-05	100.0%
[Se] [mg/L]	**0.005**	1.69E-03	1.69E-03	1.69E-03	97%	2.13E-04	100%	4.50E-06	98%	7.46E-06	6.77E-03	1.04E-03	5.77E-03	1.56E-04	3.84E-02	5.16E-06	5.17E-06	100.0%
[SiO2] [mg/L]		3.48E+01	3.48E+01	3.48E+01	22%	1.36E+01	99%	2.78E-01	91%	1.33E+01	1.39E+02	1.51E+01	1.17E+02	1.28E+01	7.24E+02	3.17E+00	3.17E+00	100.0%
[SO4] [mg/L]	**10**	6.51E+02	6.51E+02	6.51E+02	97%	4.42E+02	99%	6.07E+00	85%	1.60E+01	2.60E+03	2.15E+03	2.52E+03	4.34E+02	1.47E+04	8.28E+00	8.28E+00	100.1%
[Tl] [mg/L]	**0.00056**	2.23E-04	2.23E-04	2.23E-04	95%	5.54E-05	100%	1.49E-06	95%	3.39E-06	8.92E-04	2.64E-04	7.81E-04	4.88E-05	5.04E-03	1.91E-06	1.91E-06	100.0%
[V] [mg/L]		6.13E-03	6.13E-03	6.13E-03	95%	3.74E-03	100%	4.08E-05	87%	2.29E-04	2.45E-02	1.79E-02	2.33E-02	3.65E-03	1.38E-01	8.26E-05	8.26E-05	100.1%
[Zn] [mg/L]	**0.12**	5.00E-02	1.15E-03	1.15E-03	97%	2.87E-04	100%	3.07E-06	95%	1.18E-05	4.61E-03	1.39E-03	4.05E-03	2.53E-04	2.61E-02	5.01E-06	5.02E-06	100.0%
[Alkalinity] [mg/L] as CaCO3	**250**	1.64E+02	1.64E+02	1.64E+02	51%	4.11E+02	98%	4.81E+00	50%	2.51E+02	6.44E+02	1.05E+03	7.16E+02	4.20E+02	2.44E+03	5.96E+01	1.00E+02	110.1%
Hardness [mg/L]**	**100**	638.2	638.2	638.2	0%	611.4	0.0	3.4	0.0	42.6	2551.5	2900.1	2614.0	610.4	14275.8	12.1	52.6	N/A
[Ionic_Strength] [M]		0.024	0.024	0.024	0.000	0.025	0.000	0.000	0.000	0.007	0.082	0.086	0.083	0.025	0.32643	0.00169	0.00285	N/A
[Charge_pct_err]		-3.728	-4.712	-4.712	0.000	-6.519	0.000	-37.755	0.000	-36.746	-4.955	6.537	-2.787	-6.577	-1.52666	-36.70776	-24.09774	N/A
[pH] [std units]	**6.5-8.5**	7.0	7.0	7.0	0.0	6.4	0.0	7.0	0.0	6.4	7.0	6.4	6.2	6.4	6.8	6.4	8.1	N/A
mEQ-Na$^+$/mEQ-∑Cations	**0.6**	19%	19%	19%	0%	28%	0%	35%	0%	69%	19%	19%	19%	28%	17%	65%	35%	N/A
CO2 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	963.6	0.0	0.0	0.0	0.0	N/A
CO2 [kg/d]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3000.0	0.0	0.0	0.0	0.0	N/A
CaCO3 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.4	N/A
CaCO3 [kg/day]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	400.0	N/A

****Calculated as the sum of Ca and Mg as CaCO3**

Tailings Basin Seepage Treatment Train - Year 8 - P90 Annual Average Flow

Qualities and Quantities	**Preliminary Water Quality Targets**	**(1) Influent Seepage**	**(2) Green Sand Effluent**	**(3) RO Feed**	**NF Rejection**	**(4) NF Feed**	**RO Rejection**	**(5) RO Permeate**	**VSEP Rejection**	**(6) NF Permeate**	**(7) RO Concentrate**	**(8) NF Concentrate**	**(9) NF/RO Concentrate w/CO2**	**(10) VSEP Permeate**	**(11) VSEP Concentrate**	**(12) Stabilization Influent**	**(13) Stabilized Effluent**	**System Mass Balance**
Flow Rate, gpm		**2868**	**2725**	**2697**		**723**		**2023**		**579**	**674**	**145**	**819**	**696**	**123**	**2602**	**2602**	**N/A**
[Ag] [mg/L]	**0.001**	3.06E-04	3.06E-04	3.06E-04	60%	5.83E-05	98%	7.34E-06	96%	2.90E-05	1.21E-03	1.76E-04	1.03E-03	4.86E-05	6.70E-03	1.22E-05	1.22E-05	100.0%
[Al] [mg/L]	**0.125**	1.14E-02	1.14E-02	1.14E-02	95%	7.05E-04	99%	1.37E-04	99%	4.31E-05	4.54E-02	3.37E-03	3.80E-02	2.85E-04	2.57E-01	1.16E-04	1.16E-04	100.0%
[As] [mg/L]	**0.01**	1.84E-02	1.35E-04	1.35E-04	99%	4.89E-04	98%	3.24E-06	51%	7.32E-06	5.33E-04	2.42E-03	8.67E-04	5.02E-04	2.99E-03	4.15E-06	4.15E-06	100.0%
[B] [mg/L]	**0.5**	2.45E-01	2.45E-01	2.45E-01	21%	4.86E-01	50%	1.63E-01	15%	4.80E-01	4.94E-01	5.13E-01	4.97E-01	4.96E-01	5.07E-01	2.33E-01	2.34E-01	100.1%
[Ba] [mg/L]	**2**	3.37E-02	3.37E-02	3.37E-02	94%	9.70E-03	100%	0.00E+00	94%	7.87E-04	1.35E-01	4.55E-02	1.19E-01	8.76E-03	7.62E-01	1.75E-04	1.75E-04	100.0%
[Be] [mg/L]	**0.004**	4.52E-04	4.52E-04	4.52E-04	95%	7.49E-03	99%	6.01E-06	15%	4.58E-04	1.79E-03	3.58E-02	7.79E-03	7.77E-03	7.95E-03	1.07E-04	1.07E-04	100.1%
[C] [mg/L]		1.59E+02	1.59E+02	1.59E+02	49%	8.11E+02	98%	5.09E+00	40%	5.19E+02	6.24E+02	1.99E+03	1.32E+03	8.37E+02	3.24E+03	1.19E+02	8.99E+01	100.0%
[Ca] [mg/L]		8.87E+01	8.87E+01	8.87E+01	93%	4.26E+01	99%	1.06E+00	89%	3.93E+00	3.53E+02	1.98E+02	3.26E+02	4.08E+01	1.98E+03	1.70E+00	1.30E+01	100.1%
[Cd] [mg/L]	**0.0025**	1.00E-03	1.00E-03	1.00E-03	95%	1.37E-04	99%	1.20E-05	97%	8.39E-06	3.98E-03	6.54E-04	3.40E-03	1.03E-04	2.25E-02	1.12E-05	1.12E-05	100.0%
[Cl] [mg/L]	**230**	2.51E+01	2.51E+01	2.51E+01	9%	8.76E+01	98%	6.34E-01	13%	9.90E+01	9.87E+01	4.13E+01	8.86E+01	9.00E+01	8.03E+01	2.25E+01	2.25E+01	100.0%
[Co] [mg/L]	**0.005**	2.23E-02	3.45E-04	3.45E-04	98%	7.95E-05	99%	4.14E-06	95%	2.48E-06	1.37E-03	3.89E-04	1.20E-03	6.90E-05	7.77E-03	3.77E-06	3.77E-06	100.0%
[Cr] [mg/L]	**0.011**	4.93E-03	4.93E-03	4.93E-03	95%	2.37E-03	99%	5.90E-05	89%	1.45E-04	1.96E-02	1.13E-02	1.81E-02	2.27E-03	1.10E-01	7.82E-05	7.82E-05	100.0%
[Cu] [mg/L]	**0.0093**	3.27E-01	2.00E-02	2.00E-02	74%	3.34E-03	99%	3.73E-04	97%	1.09E-03	7.92E-02	1.24E-02	6.74E-02	2.69E-03	4.43E-01	5.33E-04	5.32E-04	100.0%
[F] [mg/L]	**2**	1.79E+00	1.79E+00	1.79E+00	38%	5.14E+00	98%	4.76E-02	40%	4.02E+00	7.03E+00	9.69E+00	7.50E+00	5.28E+00	2.04E+01	9.29E-01	9.30E-01	100.1%
[Fe] [mg/L]	**0.3**	7.36E+00	7.75E-02	7.75E-02	95%	1.51E-02	100%	0.00E+00	96%	1.02E-03	3.11E-01	7.16E-02	2.69E-01	1.26E-02	1.76E+00	2.26E-04	2.26E-04	100.0%
[K] [mg/L]		1.77E+01	1.77E+01	1.77E+01	59%	3.19E+01	98%	4.24E-01	63%	1.63E+01	6.97E+01	9.44E+01	7.40E+01	3.24E+01	3.16E+02	3.96E+00	3.96E+00	100.1%
[Mg] [mg/L]		9.56E+01	9.56E+01	9.56E+01	95%	1.15E+02	99%	1.15E+00	76%	7.44E+00	3.81E+02	5.46E+02	4.10E+02	1.15E+02	2.12E+03	2.55E+00	2.55E+00	100.1%
[Mn] [mg/L]	**0.05**	9.11E-01	1.44E-01	1.44E-01	96%	1.88E-01	100%	0.00E+00	75%	9.40E-03	5.78E-01	9.07E-01	6.36E-01	1.90E-01	3.23E+00	2.09E-03	2.09E-03	100.0%
[Na] [mg/L]		7.20E+01	7.20E+01	7.20E+01	58%	1.13E+02	99%	1.34E+00	67%	5.96E+01	2.85E+02	3.26E+02	2.92E+02	1.14E+02	1.33E+03	1.43E+01	1.43E+01	100.1%
[Ni] [mg/L]	**0.052**	2.84E-01	3.91E-02	3.91E-02	97%	8.04E-03	99%	4.69E-04	96%	2.61E-04	1.56E-01	3.93E-02	1.35E-01	6.82E-03	8.80E-01	4.23E-04	4.23E-04	100.0%
[Pb] [mg/L]	**0.0032**	2.01E-02	2.20E-03	2.20E-03	97%	3.08E-04	99%	2.63E-05	97%	1.08E-05	8.74E-03	1.50E-03	7.46E-03	2.34E-04	4.94E-02	2.29E-05	2.29E-05	100.0%
[Sb] [mg/L]	**0.031**	6.63E-03	6.63E-03	6.63E-03	95%	1.64E-03	99%	7.94E-05	95%	1.00E-04	2.64E-02	7.83E-03	2.31E-02	1.44E-03	1.49E-01	8.41E-05	8.41E-05	100.0%
[Se] [mg/L]	**0.005**	1.89E-03	1.89E-03	1.89E-03	97%	2.37E-04	99%	2.26E-05	98%	8.29E-06	7.51E-03	1.16E-03	6.39E-03	1.72E-04	4.25E-02	1.94E-05	1.94E-05	100.0%
[SiO2] [mg/L]		3.48E+01	3.48E+01	3.48E+01	22%	1.36E+01	99%	5.10E-01	91%	1.32E+01	1.38E+02	1.51E+01	1.16E+02	1.27E+01	7.19E+02	3.33E+00	3.33E+00	100.0%
[SO4] [mg/L]	**10**	6.11E+02	6.11E+02	6.11E+02	97%	4.14E+02	99%	5.70E+00	85%	1.50E+01	2.44E+03	2.02E+03	2.36E+03	4.07E+02	1.37E+04	7.77E+00	7.77E+00	100.1%
[Tl] [mg/L]	**0.00056**	2.22E-04	2.22E-04	2.22E-04	95%	5.48E-05	99%	3.26E-06	95%	3.35E-06	8.83E-04	2.62E-04	7.73E-04	4.83E-05	4.98E-03	3.28E-06	3.28E-06	100.0%
[V] [mg/L]		7.20E-03	7.20E-03	7.20E-03	95%	4.38E-03	99%	8.63E-05	87%	2.68E-04	2.86E-02	2.09E-02	2.73E-02	4.27E-03	1.61E-01	1.27E-04	1.27E-04	100.1%
[Zn] [mg/L]	**0.12**	6.55E-02	1.51E-03	1.51E-03	97%	3.74E-04	99%	1.81E-05	95%	1.54E-05	6.01E-03	1.82E-03	5.27E-03	3.29E-04	3.39E-02	1.75E-05	1.75E-05	100.0%
[Alkalinity] [mg/L] as CaCO3	**250**	1.26E+02	1.26E+02	1.26E+02	51%	3.15E+02	98%	4.02E+00	50%	1.91E+02	4.93E+02	8.10E+02	5.49E+02	3.22E+02	1.87E+03	4.57E+01	7.39E+01	109.3%
Hardness [mg/L]**	**100**	615.4	615.4	615.4	0%	578.3	0.0	7.4	0.0	40.5	2448.6	2741.1	2500.6	576.9	13670.8	14.7	43.0	N/A
[Ionic_Strength] [M]		0.023	0.023	0.023	0.000	0.023	0.000	0.000	0.000	0.006	0.078	0.081	0.078	0.023	0.31052	0.00161	0.00243	N/A
[Charge_pct_err]		0.175	-0.571	-0.571	0.000	-1.242	0.000	-0.637	0.000	-30.519	-0.643	11.706	1.670	-1.264	3.51856	-26.79277	-19.20929	N/A
[pH] [std units]	**6.5-8.5**	7.4	7.5	7.5	0.0	6.2	0.0	7.5	0.0	6.2	7.4	6.2	6.2	6.2	6.5	6.3	8.0	N/A
mEQ-Na$^+$/mEQ-∑Cations	**0.6**	19%	20%	20%	0%	28%	0%	27%	0%	68%	20%	20%	20%	29%	17%	61%	39%	N/A
CO2 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	336.0	0.0	0.0	0.0	0.0	N/A
CO2 [kg/d]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1500.0	0.0	0.0	0.0	0.0	N/A
CaCO3 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.2	N/A
CaCO3 [kg/day]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	400.0	N/A

****Calculated as the sum of Ca and Mg as CaCO3**

Tailings Basin Seepage Treatment Train - Year 8 - P90 Peak Flow

Qualities and Quantities	Preliminary Water Quality Targets	(1) Influent Seepage	(2) Green Sand Effluent	(3) RO Feed	NF Rejection	(4) NF Feed	RO Rejection	(5) RO Permeate	VSEP Rejection	(6) NF Permeate	(7) RO Concentrate	(8) NF Concentrate	(9) NF/RO Concentrate w/CO2	(10) VSEP Permeate	(11) VSEP Concentrate	(12) Stabilization Influent	(13) Stabilized Effluent	System Mass Balance
Flow Rate, gpm		**3496**	**3321**	**3288**		**882**		**2466**		**705**	**822**	**176**	**998**	**849**	**150**	**3171**	**3171**	**N/A**
[Ag] [mg/L]	**0.001**	3.06E-04	3.06E-04	3.06E-04	60%	5.83E-05	98%	7.34E-06	96%	2.90E-05	1.21E-03	1.76E-04	1.03E-03	4.86E-05	6.70E-03	1.22E-05	1.22E-05	100.0%
[Al] [mg/L]	**0.125**	1.14E-02	1.14E-02	1.14E-02	95%	7.05E-04	99%	1.37E-04	99%	4.31E-05	4.54E-02	3.36E-03	3.80E-02	2.85E-04	2.57E-01	1.16E-04	1.16E-04	100.0%
[As] [mg/L]	**0.01**	1.84E-02	1.35E-04	1.35E-04	99%	4.89E-04	98%	3.24E-06	51%	7.32E-06	5.33E-04	2.42E-03	8.67E-04	5.02E-04	2.98E-03	4.15E-06	4.15E-06	100.0%
[B] [mg/L]	**0.5**	2.45E-01	2.45E-01	2.45E-01	21%	4.86E-01	50%	1.63E-01	15%	4.80E-01	4.94E-01	5.13E-01	4.97E-01	4.96E-01	5.07E-01	2.33E-01	2.34E-01	100.1%
[Ba] [mg/L]	**2**	3.37E-02	3.37E-02	3.37E-02	94%	9.70E-03	100%	0.00E+00	94%	7.87E-04	1.35E-01	4.55E-02	1.19E-01	8.76E-03	7.62E-01	1.75E-04	1.75E-04	100.0%
[Be] [mg/L]	**0.004**	4.52E-04	4.52E-04	4.52E-04	95%	7.49E-03	99%	6.01E-06	15%	4.58E-04	1.79E-03	3.58E-02	7.79E-03	7.77E-03	7.95E-03	1.07E-04	1.07E-04	100.1%
[C] [mg/L]		1.59E+02	1.59E+02	1.59E+02	49%	7.55E+02	98%	5.09E+00	40%	4.83E+02	6.24E+02	1.85E+03	1.22E+03	7.79E+02	3.01E+03	1.11E+02	8.40E+01	100.0%
[Ca] [mg/L]		8.87E+01	8.87E+01	8.87E+01	93%	4.26E+01	99%	1.06E+00	89%	3.93E+00	3.53E+02	1.98E+02	3.26E+02	4.08E+01	1.98E+03	1.70E+00	1.10E+01	100.1%
[Cd] [mg/L]	**0.0025**	1.00E-03	1.00E-03	1.00E-03	95%	1.37E-04	99%	1.20E-05	97%	8.39E-06	3.98E-03	6.54E-04	3.40E-03	1.03E-04	2.25E-02	1.12E-05	1.12E-05	100.0%
[Cl] [mg/L]	**230**	2.51E+01	2.51E+01	2.51E+01	9%	8.75E+01	98%	6.34E-01	13%	9.90E+01	9.87E+01	4.13E+01	8.86E+01	9.00E+01	8.03E+01	2.25E+01	2.25E+01	100.0%
[Co] [mg/L]	**0.005**	2.23E-02	3.45E-04	3.45E-04	98%	7.94E-05	99%	4.14E-06	95%	2.48E-06	1.37E-03	3.89E-04	1.20E-03	6.90E-05	7.77E-03	3.77E-06	3.77E-06	100.0%
[Cr] [mg/L]	**0.011**	4.93E-03	4.93E-03	4.93E-03	95%	2.37E-03	99%	5.90E-05	89%	1.45E-04	1.96E-02	1.13E-02	1.81E-02	2.27E-03	1.10E-01	7.82E-05	7.82E-05	100.0%
[Cu] [mg/L]	**0.0093**	3.27E-01	2.00E-02	2.00E-02	74%	3.34E-03	99%	3.73E-04	97%	1.09E-03	7.92E-02	1.24E-02	6.74E-02	2.68E-03	4.42E-01	5.33E-04	5.32E-04	100.0%
[F] [mg/L]	**2**	1.79E+00	1.79E+00	1.79E+00	38%	5.14E+00	98%	4.76E-02	40%	4.01E+00	7.03E+00	9.69E+00	7.50E+00	5.28E+00	2.04E+01	9.29E-01	9.30E-01	100.1%
[Fe] [mg/L]	**0.3**	7.36E+00	7.75E-02	7.75E-02	95%	1.51E-02	100%	0.00E+00	96%	1.02E-03	3.11E-01	7.15E-02	2.69E-01	1.26E-02	1.76E+00	2.26E-04	2.26E-04	100.0%
[K] [mg/L]		1.77E+01	1.77E+01	1.77E+01	59%	3.19E+01	98%	4.24E-01	63%	1.63E+01	6.97E+01	9.44E+01	7.40E+01	3.24E+01	3.16E+02	3.96E+00	3.96E+00	100.1%
[Mg] [mg/L]		9.56E+01	9.56E+01	9.56E+01	95%	1.15E+02	99%	1.15E+00	76%	7.44E+00	3.81E+02	5.45E+02	4.10E+02	1.15E+02	2.12E+03	2.55E+00	2.55E+00	100.1%
[Mn] [mg/L]	**0.05**	9.11E-01	1.44E-01	1.44E-01	96%	1.88E-01	100%	0.00E+00	75%	9.40E-03	5.78E-01	9.07E-01	6.36E-01	1.90E-01	3.22E+00	2.09E-03	2.09E-03	100.0%
[Na] [mg/L]		7.20E+01	7.20E+01	7.20E+01	58%	1.13E+02	99%	1.34E+00	67%	5.96E+01	2.85E+02	3.26E+02	2.92E+02	1.14E+02	1.33E+03	1.43E+01	1.43E+01	100.1%
[Ni] [mg/L]	**0.052**	2.84E-01	3.91E-02	3.91E-02	97%	8.04E-03	99%	4.69E-04	96%	2.61E-04	1.56E-01	3.93E-02	1.35E-01	6.82E-03	8.80E-01	4.23E-04	4.23E-04	100.0%
[Pb] [mg/L]	**0.0032**	2.01E-02	2.20E-03	2.20E-03	97%	3.08E-04	99%	2.63E-05	97%	1.08E-05	8.74E-03	1.50E-03	7.46E-03	2.34E-04	4.94E-02	2.29E-05	2.29E-05	100.0%
[Sb] [mg/L]	**0.031**	6.63E-03	6.63E-03	6.63E-03	95%	1.64E-03	99%	7.94E-05	95%	1.00E-04	2.64E-02	7.83E-03	2.31E-02	1.44E-03	1.49E-01	8.41E-05	8.41E-05	100.0%
[Se] [mg/L]	**0.005**	1.89E-03	1.89E-03	1.89E-03	97%	2.37E-04	99%	2.26E-05	98%	8.29E-06	7.51E-03	1.16E-03	6.39E-03	1.72E-04	4.25E-02	1.94E-05	1.94E-05	100.0%
[SiO2] [mg/L]		3.48E+01	3.48E+01	3.48E+01	22%	1.36E+01	99%	5.10E-01	91%	1.32E+01	1.38E+02	1.51E+01	1.16E+02	1.27E+01	7.18E+02	3.33E+00	3.33E+00	100.0%
[SO4] [mg/L]	**10**	6.11E+02	6.11E+02	6.11E+02	97%	4.14E+02	99%	5.70E+00	85%	1.50E+01	2.44E+03	2.02E+03	2.36E+03	4.07E+02	1.37E+04	7.77E+00	7.77E+00	100.1%
[Tl] [mg/L]	**0.00056**	2.22E-04	2.22E-04	2.22E-04	95%	5.48E-05	99%	3.26E-06	95%	3.35E-06	8.83E-04	2.62E-04	7.73E-04	4.83E-05	4.98E-03	3.28E-06	3.28E-06	100.0%
[V] [mg/L]		7.20E-03	7.20E-03	7.20E-03	95%	4.38E-03	99%	8.63E-05	87%	2.68E-04	2.86E-02	2.09E-02	2.73E-02	4.27E-03	1.61E-01	1.27E-04	1.27E-04	100.1%
[Zn] [mg/L]	**0.12**	6.55E-02	1.51E-03	1.51E-03	97%	3.74E-04	99%	1.81E-05	95%	1.54E-05	6.01E-03	1.81E-03	5.27E-03	3.29E-04	3.39E-02	1.75E-05	1.75E-05	100.0%
[Alkalinity] [mg/L] as CaCO3	**250**	1.26E+02	1.26E+02	1.26E+02	51%	3.15E+02	98%	4.02E+00	50%	1.91E+02	4.93E+02	8.10E+02	5.49E+02	3.22E+02	1.87E+03	4.57E+01	6.88E+01	107.8%
Hardness [mg/L]**	**100**	615.4	615.4	615.4	0%	578.3	0.0	7.4	0.0	40.5	2448.6	2740.7	2500.4	576.9	13667.8	14.7	37.9	N/A
[Ionic_Strength] [M]		0.023	0.023	0.023	0.000	0.023	0.000	0.000	0.000	0.006	0.078	0.081	0.078	0.023	0.31045	0.00161	0.00228	N/A
[Charge_pct_err]		0.175	-0.571	-0.571	0.000	-1.242	0.000	-0.637	0.000	-30.520	-0.643	11.706	1.670	-1.264	3.51864	-26.79420	-20.23279	N/A
[pH] [std units]	**6.5-8.5**	7.4	7.5	7.5	0.0	6.3	0.0	7.5	0.0	6.3	7.4	6.3	6.3	6.3	6.6	6.3	7.9	N/A
mEQ-Na^+/mEQ-∑Cations	**0.6**	19%	20%	20%	0%	28%	0%	27%	0%	68%	20%	20%	20%	29%	17%	61%	42%	N/A
CO2 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	275.6	0.0	0.0	0.0	0.0	N/A
CO2 [kg/d]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1500.0	0.0	0.0	0.0	0.0	N/A
CaCO3 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	23.1	N/A
CaCO3 [kg/day]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	400.0	N/A

****Calculated as the sum of Ca and Mg as CaCO3**

Tailings Basin Seepage Treatment Train - Year 10 - P90 Annual Average Flows

Qualities and Quantities	Preliminary Water Quality Targets	(1) Influent Seepage	(2) Green Sand Effluent	(3) RO Feed	NF Rejection	(4) NF Feed	RO Rejection	(5) RO Permeate	VSEP Rejection	(6) NF Permeate	(7) RO Concentrate	(8) NF Concentrate	(9) NF/RO Concentrate w/CO2	(10) VSEP Permeate	(11) VSEP Concentrate	(12) Stabilization Influent	(13) Stabilized Effluent	System Mass Balance
Flow Rate, gpm		**3900**	**3705**	**2223**		**2355**		**1667**		**1884**	**556**	**471**	**1027**	**873**	**154**	**3551**	**3551**	**N/A**
[Ag] [mg/L]	**0.001**	2.21E-04	2.21E-04	2.21E-04	43%	1.50E-04	98%	4.71E-06	96%	1.06E-04	8.75E-04	3.27E-04	6.24E-04	2.96E-05	4.09E-03	5.87E-05	5.87E-05	100.1%
[Al] [mg/L]	**0.125**	9.99E-03	9.99E-03	9.99E-03	92%	6.39E-03	98%	2.13E-04	99%	6.22E-04	3.95E-02	2.96E-02	3.50E-02	2.63E-04	2.37E-01	4.30E-04	4.30E-04	100.1%
[As] [mg/L]	**0.01**	2.43E-02	1.79E-04	1.79E-04	99%	3.82E-04	99%	3.09E-06	51%	4.77E-06	7.09E-04	1.90E-03	1.26E-03	7.28E-04	4.33E-03	3.98E-06	3.98E-06	100.0%
[B] [mg/L]	**0.5**	2.17E-01	2.17E-01	2.17E-01	18%	2.75E-01	55%	1.32E-01	15%	2.80E-01	4.76E-01	2.54E-01	3.74E-01	3.73E-01	3.83E-01	2.10E-01	2.10E-01	100.1%
[Ba] [mg/L]	**2**	2.65E-02	2.65E-02	2.65E-02	81%	1.92E-02	100%	0.00E+00	94%	4.61E-03	1.07E-01	7.81E-02	9.36E-02	6.86E-03	5.98E-01	2.45E-03	2.45E-03	100.1%
[Be] [mg/L]	**0.004**	4.34E-04	4.34E-04	4.34E-04	92%	2.86E-03	99%	8.66E-06	15%	2.78E-04	1.72E-03	1.32E-02	7.00E-03	6.98E-03	7.16E-03	1.52E-04	1.52E-04	100.3%
[C] [mg/L]		4.77E+02	4.77E+02	4.77E+02	47%	1.23E+03	98%	1.33E+01	40%	8.17E+02	1.88E+03	2.87E+03	3.55E+03	2.50E+03	9.69E+03	4.40E+02	4.71E+02	100.0%
[Ca] [mg/L]		9.07E+01	9.07E+01	9.07E+01	85%	7.27E+01	98%	1.93E+00	89%	1.34E+01	3.59E+02	3.11E+02	3.37E+02	4.22E+01	2.05E+03	8.03E+00	2.87E+01	100.1%
[Cd] [mg/L]	**0.0025**	1.26E-03	1.26E-03	1.26E-03	92%	8.42E-04	98%	2.68E-05	97%	8.20E-05	4.97E-03	3.90E-03	4.48E-03	1.36E-04	2.98E-02	5.60E-05	5.60E-05	100.1%
[Cl] [mg/L]	**230**	2.45E+01	2.45E+01	2.45E+01	9%	3.83E+01	98%	5.22E-01	13%	4.33E+01	9.68E+01	1.81E+01	6.07E+01	6.17E+01	5.52E+01	2.32E+01	2.32E+01	100.0%
[Co] [mg/L]	**0.005**	2.45E-02	3.78E-04	3.78E-04	96%	2.68E-04	99%	7.56E-06	95%	1.31E-05	1.50E-03	1.30E-03	1.41E-03	8.08E-05	9.12E-03	1.05E-05	1.05E-05	100.0%
[Cr] [mg/L]	**0.011**	6.04E-03	6.04E-03	6.04E-03	92%	4.88E-03	98%	1.29E-04	89%	4.76E-04	2.39E-02	2.26E-02	2.33E-02	2.92E-03	1.42E-01	3.13E-04	3.13E-04	100.1%
[Cu] [mg/L]	**0.0093**	3.95E-01	2.42E-02	2.42E-02	94%	1.65E-02	99%	4.18E-04	97%	1.28E-03	9.59E-02	7.78E-02	8.76E-02	3.49E-03	5.76E-01	8.74E-04	8.74E-04	100.0%
[F] [mg/L]	**2**	1.40E+00	1.40E+00	1.40E+00	33%	2.08E+00	98%	3.18E-02	40%	1.74E+00	5.55E+00	3.42E+00	4.58E+00	3.22E+00	1.25E+01	9.39E-01	9.39E-01	100.1%
[Fe] [mg/L]	**0.3**	2.85E+00	3.00E-02	3.00E-02	72%	2.06E-02	100%	0.00E+00	96%	7.24E-03	1.21E-01	7.45E-02	9.95E-02	4.67E-03	6.52E-01	3.84E-03	3.84E-03	100.0%
[K] [mg/L]		2.11E+01	2.11E+01	2.11E+01	57%	2.61E+01	98%	4.49E-01	63%	1.41E+01	8.33E+01	7.42E+01	7.92E+01	3.47E+01	3.38E+02	7.71E+00	7.71E+00	100.1%
[Mg] [mg/L]		8.71E+01	8.71E+01	8.71E+01	94%	9.61E+01	99%	9.28E-01	76%	7.80E+00	3.47E+02	4.51E+02	3.95E+02	1.11E+02	2.05E+03	4.57E+00	4.57E+00	100.1%
[Mn] [mg/L]	**0.05**	8.31E-01	1.31E-01	1.31E-01	86%	1.46E-01	100%	0.00E+00	75%	2.56E-02	5.28E-01	6.32E-01	5.76E-01	1.72E-01	2.93E+00	1.36E-02	1.36E-02	100.0%
[Na] [mg/L]		6.92E+01	6.92E+01	6.92E+01	51%	7.83E+01	99%	1.20E+00	67%	4.84E+01	2.74E+02	1.98E+02	2.40E+02	9.38E+01	1.09E+03	2.62E+01	2.62E+01	100.1%
[Ni] [mg/L]	**0.052**	3.44E-01	4.75E-02	4.75E-02	96%	3.32E-02	98%	1.01E-03	96%	1.66E-03	1.88E-01	1.60E-01	1.75E-01	8.84E-03	1.14E+00	1.35E-03	1.35E-03	100.0%
[Pb] [mg/L]	**0.0032**	3.17E-02	3.46E-03	3.46E-03	96%	2.33E-03	98%	7.38E-05	97%	1.22E-04	1.37E-02	1.12E-02	1.26E-02	3.93E-04	8.33E-02	9.93E-05	9.93E-05	100.0%
[Sb] [mg/L]	**0.031**	8.01E-03	8.01E-03	8.01E-03	92%	5.73E-03	98%	1.71E-04	95%	5.58E-04	3.17E-02	2.65E-02	2.93E-02	1.83E-03	1.89E-01	3.76E-04	3.76E-04	100.1%
[Se] [mg/L]	**0.005**	1.96E-03	1.96E-03	1.96E-03	96%	1.31E-03	99%	2.09E-05	98%	6.85E-05	7.82E-03	6.29E-03	7.12E-03	1.92E-04	4.74E-02	4.61E-05	4.61E-05	100.1%
[SiO2] [mg/L]		3.48E+01	3.48E+01	3.48E+01	22%	2.55E+01	99%	4.63E-01	91%	2.48E+01	1.38E+02	2.83E+01	8.80E+01	9.64E+00	5.44E+02	1.34E+01	1.34E+01	100.1%
[SO4] [mg/L]	**10**	3.37E+02	3.37E+02	3.37E+02	96%	3.01E+02	99%	2.69E+00	85%	1.62E+01	1.35E+03	1.45E+03	1.39E+03	2.40E+02	8.10E+03	9.83E+00	9.83E+00	100.1%
[Tl] [mg/L]	**0.00056**	1.74E-04	1.74E-04	1.74E-04	92%	1.25E-04	98%	3.72E-06	95%	1.20E-05	6.90E-04	5.78E-04	6.39E-04	3.99E-05	4.13E-03	8.10E-06	8.10E-06	100.1%
[V] [mg/L]		7.98E-03	7.98E-03	7.98E-03	92%	6.86E-03	98%	1.70E-04	87%	6.68E-04	3.16E-02	3.18E-02	3.17E-02	4.96E-03	1.87E-01	4.34E-04	4.34E-04	100.1%
[Zn] [mg/L]	**0.12**	8.67E-02	2.00E-03	2.00E-03	95%	1.43E-03	98%	4.26E-05	95%	8.40E-05	7.91E-03	6.85E-03	7.42E-03	4.65E-04	4.79E-02	6.45E-05	6.45E-05	100.0%
[Alkalinity] [mg/L] as CaCO3	**250**	3.73E+02	3.73E+02	3.73E+02	47%	5.32E+02	98%	1.04E+01	50%	3.55E+02	1.47E+03	1.24E+03	1.37E+03	8.02E+02	4.66E+03	1.93E+02	2.45E+02	106.0%
Hardness [mg/L]**	**100**	585.2	585.2	585.2	0%	577.3	0.0	8.6	0.0	65.7	2325.8	2634.9	2468.5	563.8	13561.8	38.9	90.5	N/A
[Ionic_Strength] [M]		0.021	0.021	0.021	0.000	0.022	0.000	0.000	0.000	0.007	0.073	0.074	0.073	0.025	0.29087	0.00388	0.00534	N/A
[Charge_pct_err]		0.437	0.038	0.038	0.000	-8.220	0.000	-8.676	0.000	-40.092	0.183	8.233	3.777	-18.605	17.28691	-38.83944	-30.13137	N/A
[pH] [std units]	**6.5-8.5**	7.4	7.4	7.4	0.0	6.3	0.0	7.5	0.0	6.3	7.4	6.3	6.2	6.1	6.2	6.4	6.5	N/A
mEQ-Na^+/mEQ-∑Cations	**0.6**	19%	20%	20%	0%	22%	0%	22%	0%	56%	20%	14%	17%	25%	14%	54%	36%	N/A
CO2 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	893.4	0.0	0.0	0.0	0.0	N/A
CO2 [kg/d]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5000.0	0.0	0.0	0.0	0.0	N/A
CaCO3 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.7	N/A
CaCO3 [kg/day]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1000.0	N/A

Temp 7.55 degrees C

247.88

**Calculated as the sum of Ca and Mg as CaCO3

Tailings Basin Seepage Treatment Train - Year 10 - P90 Peak Flow

Qualities and Quantities	Preliminary Water Quality Targets	(1) Influent Seepage	(2) Green Sand Effluent	(3) RO Feed	NF Rejection	(4) NF Feed	RO Rejection	(5) RO Permeate	VSEP Rejection	(6) NF Permeate	(7) RO Concentrate	(8) NF Concentrate	(9) NF/RO Concentrate w/CO2	(10) VSEP Permeate	(11) VSEP Concentrate	(12) Stabilization Influent	(13) Stabilized Effluent	System Mass Balance
Flow Rate, gpm		4000	3800	2280		2415		1710		1932	570	483	1053	895	158	3642	3642	N/A
[Ag] [mg/L]	0.001	2.21E-04	2.21E-04	2.21E-04	43%	1.50E-04	98%	4.71E-06	96%	1.06E-04	8.75E-04	3.27E-04	6.24E-04	2.96E-05	4.10E-03	5.87E-05	5.87E-05	100.1%
[Al] [mg/L]	0.125	9.99E-03	9.99E-03	9.99E-03	92%	6.39E-03	98%	2.13E-04	99%	6.22E-04	3.95E-02	2.96E-02	3.50E-02	2.63E-04	2.38E-01	4.30E-04	4.30E-04	100.1%
[As] [mg/L]	0.01	2.43E-02	1.79E-04	1.79E-04	99%	3.82E-04	99%	3.09E-06	51%	4.77E-06	7.09E-04	1.90E-03	1.26E-03	7.28E-04	4.34E-03	3.98E-06	3.98E-06	100.0%
[B] [mg/L]	0.5	2.17E-01	2.17E-01	2.17E-01	18%	2.75E-01	55%	1.32E-01	15%	2.80E-01	4.76E-01	2.54E-01	3.74E-01	3.74E-01	3.84E-01	2.10E-01	2.10E-01	100.1%
[Ba] [mg/L]	2	2.65E-02	2.65E-02	2.65E-02	81%	1.93E-02	100%	0.00E+00	94%	4.62E-03	1.07E-01	7.81E-02	9.36E-02	6.87E-03	6.00E-01	2.45E-03	2.45E-03	100.1%
[Be] [mg/L]	0.004	4.34E-04	4.34E-04	4.34E-04	92%	2.86E-03	99%	8.66E-06	15%	2.78E-04	1.72E-03	1.32E-02	7.00E-03	6.98E-03	7.17E-03	1.51E-04	1.52E-04	100.2%
[C] [mg/L]		4.77E+02	4.77E+02	4.77E+02	47%	1.47E+03	98%	1.33E+01	40%	9.82E+02	1.88E+03	3.45E+03	4.50E+03	3.17E+03	1.23E+04	5.27E+02	2.52E+02	100.0%
[Ca] [mg/L]		9.07E+01	9.07E+01	9.07E+01	85%	7.28E+01	98%	1.93E+00	89%	1.34E+01	3.59E+02	3.11E+02	3.37E+02	4.22E+01	2.06E+03	8.03E+00	1.61E+01	100.1%
[Cd] [mg/L]	0.0025	1.26E-03	1.26E-03	1.26E-03	92%	8.42E-04	98%	2.68E-05	97%	8.20E-05	4.97E-03	3.90E-03	4.48E-03	1.36E-04	2.98E-02	5.60E-05	5.61E-05	100.1%
[Cl] [mg/L]	230	2.45E+01	2.45E+01	2.45E+01	9%	3.83E+01	98%	5.22E-01	13%	4.33E+01	9.68E+01	1.81E+01	6.08E+01	6.18E+01	5.53E+01	2.32E+01	2.32E+01	100.0%
[Co] [mg/L]	0.005	2.45E-02	3.78E-04	3.78E-04	96%	2.68E-04	99%	7.56E-06	95%	1.31E-05	1.50E-03	1.30E-03	1.41E-03	8.09E-05	9.14E-03	1.05E-05	1.05E-05	100.0%
[Cr] [mg/L]	0.011	6.04E-03	6.04E-03	6.04E-03	92%	4.88E-03	98%	1.29E-04	89%	4.76E-04	2.39E-02	2.26E-02	2.33E-02	2.92E-03	1.42E-01	3.13E-04	3.13E-04	100.1%
[Cu] [mg/L]	0.0093	3.95E-01	2.42E-02	2.42E-02	94%	1.65E-02	99%	4.18E-04	97%	1.28E-03	9.59E-02	7.78E-02	8.77E-02	3.49E-03	5.78E-01	8.74E-04	8.74E-04	100.0%
[F] [mg/L]	2	1.40E+00	1.40E+00	1.40E+00	33%	2.08E+00	98%	3.18E-02	40%	1.74E+00	5.55E+00	3.42E+00	4.58E+00	3.22E+00	1.25E+01	9.39E-01	9.39E-01	100.1%
[Fe] [mg/L]	0.3	2.85E+00	3.00E-02	3.00E-02	72%	2.06E-02	100%	0.00E+00	96%	7.24E-03	1.21E-01	7.46E-02	9.96E-02	4.68E-03	6.53E-01	3.84E-03	3.84E-03	100.0%
[K] [mg/L]		2.11E+01	2.11E+01	2.11E+01	57%	2.61E+01	98%	4.49E-01	63%	1.42E+01	8.33E+01	7.43E+01	7.92E+01	3.47E+01	3.39E+02	7.71E+00	7.72E+00	100.1%
[Mg] [mg/L]		8.71E+01	8.71E+01	8.71E+01	94%	9.61E+01	99%	9.28E-01	76%	7.80E+00	3.47E+02	4.51E+02	3.95E+02	1.11E+02	2.05E+03	4.57E+00	4.57E+00	100.1%
[Mn] [mg/L]	0.05	8.31E-01	1.31E-01	1.31E-01	86%	1.46E-01	100%	0.00E+00	75%	2.56E-02	5.28E-01	6.33E-01	5.76E-01	1.72E-01	2.93E+00	1.36E-02	1.36E-02	100.0%
[Na] [mg/L]		6.92E+01	6.92E+01	6.92E+01	51%	7.83E+01	99%	1.20E+00	67%	4.84E+01	2.74E+02	1.99E+02	2.40E+02	9.38E+01	1.09E+03	2.62E+01	2.62E+01	100.1%
[Ni] [mg/L]	0.052	3.44E-01	4.75E-02	4.75E-02	96%	3.32E-02	98%	1.01E-03	96%	1.66E-03	1.88E-01	1.60E-01	1.75E-01	8.84E-03	1.15E+00	1.35E-03	1.35E-03	100.0%
[Pb] [mg/L]	0.0032	3.17E-02	3.46E-03	3.46E-03	96%	2.33E-03	98%	7.38E-05	97%	1.22E-04	1.37E-02	1.12E-02	1.26E-02	3.94E-04	8.35E-02	9.94E-05	9.94E-05	100.0%
[Sb] [mg/L]	0.031	8.01E-03	8.01E-03	8.01E-03	92%	5.73E-03	98%	1.71E-04	95%	5.58E-04	3.17E-02	2.65E-02	2.93E-02	1.84E-03	1.90E-01	3.76E-04	3.76E-04	100.1%
[Se] [mg/L]	0.005	1.96E-03	1.96E-03	1.96E-03	96%	1.31E-03	99%	2.09E-05	98%	6.85E-05	7.82E-03	6.29E-03	7.12E-03	1.92E-04	4.76E-02	4.61E-05	4.62E-05	100.1%
[SiO2] [mg/L]		3.48E+01	3.48E+01	3.48E+01	22%	2.55E+01	99%	4.63E-01	91%	2.48E+01	1.38E+02	2.83E+01	8.80E+01	9.64E+00	5.46E+02	1.34E+01	1.34E+01	100.1%
[SO4] [mg/L]	10	3.37E+02	3.37E+02	3.37E+02	96%	3.01E+02	99%	2.69E+00	85%	1.62E+01	1.35E+03	1.45E+03	1.39E+03	2.40E+02	8.12E+03	9.83E+00	9.84E+00	100.1%
[Tl] [mg/L]	0.00056	1.74E-04	1.74E-04	1.74E-04	92%	1.25E-04	98%	3.72E-06	95%	1.20E-05	6.90E-04	5.78E-04	6.39E-04	3.99E-05	4.14E-03	8.10E-06	8.11E-06	100.1%
[V] [mg/L]		7.98E-03	7.98E-03	7.98E-03	92%	6.86E-03	98%	1.70E-04	87%	6.69E-04	3.16E-02	3.18E-02	3.17E-02	4.96E-03	1.88E-01	4.34E-04	4.35E-04	100.1%
[Zn] [mg/L]	0.12	8.67E-02	2.00E-03	2.00E-03	95%	1.43E-03	98%	4.26E-05	95%	8.40E-05	7.91E-03	6.85E-03	7.43E-03	4.65E-04	4.81E-02	6.45E-05	6.46E-05	100.0%
[Alkalinity] [mg/L] as CaCO3	250	3.73E+02	3.73E+02	3.73E+02	47%	5.32E+02	98%	1.04E+01	50%	3.55E+02	1.47E+03	1.25E+03	1.37E+03	8.02E+02	4.67E+03	1.93E+02	2.13E+02	102.5%
Hardness** [mg/L]	100	585.2	585.2	585.2	0%	577.4	0.0	8.6	0.0	65.7	2325.8	2636.4	2469.6	564.1	13596.9	38.9	59.1	N/A
[Ionic_Strength] [M]		0.021	0.021	0.021	0.000	0.022	0.000	0.000	0.000	0.007	0.073	0.074	0.073	0.025	0.29151	0.00388	0.00444	N/A
[Charge_pct_err]		0.437	0.038	0.038	0.000	-8.219	0.000	-8.676	0.000	-40.090	0.183	8.233	3.776	-18.604	17.29044	-38.83628	-35.31243	N/A
[pH] [std units]	6.5-8.5	7.4	7.4	7.4	0.0	6.2	0.0	7.5	0.0	6.2	7.4	6.1	6.0	5.9	6.0	6.2	8.4	N/A
mEQ-Na$^+$/mEQ-∑Cations	0.6	19%	20%	20%	0%	22%	0%	22%	0%	56%	20%	14%	17%	25%	14%	54%	45%	N/A
CO2 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1393.7	0.0	0.0	0.0	0.0	N/A
CO2 [kg/d]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8000.0	0.0	0.0	0.0	0.0	N/A
CaCO3 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.1	N/A
CaCO3 [kg/day]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	400.0	N/A

****Calculated as the sum of Ca and Mg as CaCO3**

Tailings Basin Seepage Treatment Train - Year 15 - P90 Annual Average Flows

Qualities and Quantities	Preliminary Water Quality Targets	(1) Influent Seepage	(2) Green Sand Effluent	(3) RO Feed	NF Rejection	(4) NF Feed	RO Rejection	(5) RO Permeate	VSEP Rejection	(6) NF Permeate	(7) RO Concentrate	(8) NF Concentrate	(9) NF/RO Concentrate w/CO2	(10) VSEP Permeate	(11) VSEP Concentrate	(12) Stabilization Influent	(13) Stabilized Effluent	System Mass Balance
Flow Rate, gpm		**3525**	**3349**	**2009**		**2128**		**1507**		**1703**	**502**	**426**	**928**	**789**	**139**	**3210**	**3210**	**N/A**
[Ag] [mg/L]	**0.001**	2.09E-04	2.09E-04	2.09E-04	35%	1.81E-04	99%	3.62E-06	96%	1.15E-04	8.33E-04	2.51E-04	5.66E-04	2.68E-05	3.74E-03	6.25E-05	6.25E-05	100.1%
[Al] [mg/L]	**0.125**	1.14E-02	1.14E-02	1.14E-02	93%	2.41E-03	99%	1.36E-04	99%	6.27E-04	4.54E-02	3.41E-02	4.02E-02	3.02E-04	2.75E-01	3.96E-04	3.96E-04	100.1%
[As] [mg/L]	**0.01**	4.58E-02	3.38E-04	3.38E-04	99%	4.60E-04	99%	6.74E-06	51%	9.89E-06	1.34E-03	3.59E-03	2.37E-03	1.37E-03	8.25E-03	8.41E-06	8.41E-06	100.0%
[B] [mg/L]	**0.5**	2.30E-01	2.30E-01	2.30E-01	19%	1.06E-01	57%	1.32E-01	15%	3.00E-01	5.26E-01	2.86E-01	4.16E-01	4.15E-01	4.29E-01	2.21E-01	2.21E-01	100.0%
[Ba] [mg/L]	**2**	2.64E-02	2.64E-02	2.64E-02	81%	1.97E-02	100%	0.00E+00	94%	4.61E-03	1.06E-01	7.77E-02	9.32E-02	6.83E-03	6.00E-01	2.44E-03	2.44E-03	100.1%
[Be] [mg/L]	**0.004**	4.76E-04	4.76E-04	4.76E-04	93%	3.78E-04	99%	5.07E-06	15%	2.35E-04	1.90E-03	1.28E-02	6.89E-03	6.87E-03	7.10E-03	1.27E-04	1.27E-04	86.1%
[C] [mg/L]		8.00E+02	8.00E+02	8.00E+02	49%	9.08E+02	93%	7.67E+01	40%	1.16E+03	2.99E+03	4.45E+03	5.01E+03	3.52E+03	1.38E+04	6.49E+02	6.84E+02	100.0%
[Ca] [mg/L]		1.69E+02	1.69E+02	1.69E+02	91%	2.14E+02	99%	2.03E+00	89%	1.54E+01	6.75E+02	6.27E+02	6.53E+02	8.17E+01	4.01E+03	9.10E+00	3.20E+01	100.1%
[Cd] [mg/L]	**0.0025**	2.36E-03	2.36E-03	2.36E-03	93%	1.67E-03	99%	2.82E-05	97%	1.36E-04	9.40E-03	7.40E-03	8.49E-03	2.58E-04	5.68E-02	8.54E-05	8.54E-05	100.1%
[Cl] [mg/L]	**230**	2.44E+01	2.44E+01	2.44E+01	9%	2.63E+01	99%	4.23E-01	13%	4.33E+01	9.71E+01	1.81E+01	6.09E+01	6.19E+01	5.58E+01	2.31E+01	2.31E+01	100.0%
[Co] [mg/L]	**0.005**	4.08E-02	6.31E-04	6.31E-04	97%	5.26E-04	99%	7.56E-06	95%	1.96E-05	2.52E-03	2.18E-03	2.36E-03	1.36E-04	1.54E-02	1.39E-05	1.39E-05	100.0%
[Cr] [mg/L]	**0.011**	7.16E-03	7.16E-03	7.16E-03	93%	7.21E-03	99%	8.57E-05	89%	5.07E-04	2.86E-02	2.72E-02	2.79E-02	3.49E-03	1.72E-01	3.09E-04	3.09E-04	100.1%
[Cu] [mg/L]	**0.0093**	5.35E-01	3.27E-02	3.27E-02	94%	2.72E-02	99%	5.22E-04	97%	1.73E-03	1.30E-01	1.06E-01	1.19E-01	4.73E-03	7.88E-01	1.16E-03	1.16E-03	100.0%
[F] [mg/L]	**2**	1.19E+00	1.19E+00	1.19E+00	33%	1.26E+00	100%	0.00E+00	40%	1.49E+00	4.79E+00	2.91E+00	3.93E+00	2.76E+00	1.08E+01	7.90E-01	7.90E-01	100.1%
[Fe] [mg/L]	**0.3**	2.36E+00	2.49E-02	2.49E-02	75%	2.29E-03	99%	4.30E-04	96%	5.34E-03	9.89E-02	6.46E-02	8.32E-02	3.90E-03	5.49E-01	3.03E-03	3.03E-03	100.0%
[K] [mg/L]		3.12E+01	3.12E+01	3.12E+01	48%	3.72E+01	99%	5.39E-01	63%	2.43E+01	1.24E+02	8.86E+01	1.08E+02	4.72E+01	4.64E+02	1.31E+01	1.31E+01	100.1%
[Mg] [mg/L]		9.96E+01	9.96E+01	9.96E+01	94%	8.54E+01	99%	9.28E-01	76%	8.37E+00	3.98E+02	5.19E+02	4.54E+02	1.28E+02	2.37E+03	4.87E+00	4.87E+00	100.0%
[Mn] [mg/L]	**0.05**	9.00E-01	1.42E-01	1.42E-01	87%	9.23E-02	99%	2.46E-03	75%	2.66E-02	5.65E-01	6.88E-01	6.21E-01	1.86E-01	3.18E+00	1.53E-02	1.53E-02	100.0%
[Na] [mg/L]		7.79E+01	7.79E+01	7.79E+01	47%	1.04E+02	99%	1.24E+00	67%	5.80E+01	3.10E+02	2.03E+02	2.61E+02	1.02E+02	1.20E+03	3.13E+01	3.13E+01	100.1%
[Ni] [mg/L]	**0.052**	5.65E-01	7.79E-02	7.79E-02	96%	6.72E-02	99%	9.33E-04	96%	2.45E-03	3.11E-01	2.64E-01	2.90E-01	1.46E-02	1.91E+00	1.74E-03	1.74E-03	100.0%
[Pb] [mg/L]	**0.0032**	5.41E-02	5.90E-03	5.90E-03	96%	6.90E-03	99%	7.07E-05	97%	1.88E-04	2.35E-02	1.92E-02	2.16E-02	6.75E-04	1.44E-01	1.33E-04	1.33E-04	100.0%
[Sb] [mg/L]	**0.031**	1.29E-02	1.29E-02	1.29E-02	93%	1.73E-02	99%	1.54E-04	95%	7.94E-04	5.14E-02	4.32E-02	4.77E-02	2.98E-03	3.10E-01	4.94E-04	4.94E-04	100.1%
[Se] [mg/L]	**0.005**	3.51E-03	3.51E-03	3.51E-03	96%	4.87E-03	99%	3.26E-05	98%	1.11E-04	1.40E-02	1.13E-02	1.28E-02	3.45E-04	8.58E-02	7.41E-05	7.41E-05	100.1%
[SiO2] [mg/L]		3.48E+01	3.48E+01	3.48E+01	22%	3.50E-02	99%	3.71E-01	91%	2.48E+01	1.39E+02	2.84E+01	8.84E+01	9.67E+00	5.51E+02	1.33E+01	1.33E+01	100.1%
[SO4] [mg/L]	**10**	3.59E+02	3.59E+02	3.59E+02	96%	3.81E+02	99%	2.87E+00	85%	1.56E+01	1.44E+03	1.55E+03	1.49E+03	2.56E+02	8.74E+03	9.63E+00	9.63E+00	100.1%
[Tl] [mg/L]	**0.00056**	1.94E-04	1.94E-04	1.94E-04	93%	1.79E-04	99%	2.07E-06	95%	1.21E-05	7.76E-04	6.50E-04	7.18E-04	4.48E-05	4.68E-03	7.40E-06	7.40E-06	100.1%
[V] [mg/L]		9.20E-03	9.20E-03	9.20E-03	93%	9.16E-03	99%	8.56E-05	87%	6.93E-04	3.68E-02	3.71E-02	3.69E-02	5.77E-03	2.20E-01	4.07E-04	4.07E-04	100.1%
[Zn] [mg/L]	**0.12**	1.64E-01	3.77E-03	3.77E-03	96%	3.13E-03	99%	4.52E-05	95%	1.45E-04	1.51E-02	1.30E-02	1.41E-02	8.83E-04	9.19E-02	9.81E-05	9.81E-05	100.0%
[Alkalinity] [mg/L] as CaCO3	**250**	6.26E+02	6.26E+02	6.26E+02	49%	7.10E+02	93%	6.00E+01	50%	5.65E+02	2.34E+03	2.17E+03	2.26E+03	1.33E+03	7.78E+03	3.28E+02	3.85E+02	104.0%
Hardness [mg/L]**	**100**	832.7	832.7	832.7	0%	885.2	0.0	8.9	0.0	72.8	3326.2	3703.4	3500.6	730.1	19782.0	42.8	99.9	N/A
[Ionic_Strength] [M]		0.027	0.027	0.027	0.000	0.030	0.000	0.001	0.000	0.009	0.095	0.097	0.096	0.033	0.37295	0.00545	0.00704	N/A
[Charge_pct_err]		0.569	0.256	0.256	0.000	0.538	0.000	-67.846	0.000	-48.111	2.724	7.018	4.646	-27.304	24.84109	-49.36955	-40.57144	N/A
[pH] [std units]	**6.5-8.5**	7.4	7.4	7.4	0.0	7.4	0.0	7.5	0.0	6.5	7.3	6.3	6.3	6.2	6.4	6.5	6.6	N/A
mEQ-Na$^+$/mEQ-∑Cations	**0.6**	16%	16%	16%	0%	19%	0%	22%	0%	55%	16%	10%	14%	22%	11%	53%	37%	N/A
CO2 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	988.5	0.0	0.0	0.0	0.0	N/A
CO2 [kg/d]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5000.0	0.0	0.0	0.0	0.0	N/A
CaCO3 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	57.2	N/A
CaCO3 [kg/day]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1000.0	N/A

Temp 7.55 degrees C

345.88

****Calculated as the sum of Ca and Mg as CaCO3**

Tailings Basin Seepage Treatment Train - Year 15 -P90 Peak Flow

Qualities and Quantities	Preliminary Water Quality Targets	(1) Influent Seepage	(2) Green Sand Effluent	(3) RO Feed	NF Rejection	(4) NF Feed	RO Rejection	(5) RO Permeate	VSEP Rejection	(6) NF Permeate	(7) RO Concentrate	(8) NF Concentrate	(9) NF/RO Concentrate w/CO2	(10) VSEP Permeate	(11) VSEP Concentrate	(12) Stabilization Influent	(13) Stabilized Effluent	System Mass Balance
Flow Rate, gpm		4000	3800	2280		2415		1710		1932	570	483	1053	895	158	3642	3642	N/A
[Ag] [mg/L]	0.001	2.09E-04	2.09E-04	2.09E-04	35%	1.42E-04	99%	3.62E-06	96%	1.15E-04	8.33E-04	2.51E-04	5.66E-04	2.68E-05	3.74E-03	6.25E-05	6.26E-05	100.1%
[Al] [mg/L]	0.125	1.14E-02	1.14E-02	1.14E-02	93%	7.28E-03	99%	1.36E-04	99%	6.27E-04	4.54E-02	3.41E-02	4.02E-02	3.02E-04	2.75E-01	3.96E-04	3.97E-04	100.1%
[As] [mg/L]	0.01	4.58E-02	3.38E-04	3.38E-04	99%	7.21E-04	99%	6.74E-06	51%	9.89E-06	1.34E-03	3.59E-03	2.37E-03	1.37E-03	8.25E-03	8.41E-06	8.42E-06	100.0%
[B] [mg/L]	0.5	2.30E-01	2.30E-01	2.30E-01	19%	2.98E-01	57%	1.32E-01	15%	3.01E-01	5.26E-01	2.87E-01	4.16E-01	4.15E-01	4.29E-01	2.21E-01	2.21E-01	100.1%
[Ba] [mg/L]	2	2.64E-02	2.64E-02	2.64E-02	81%	1.91E-02	100%	0.00E+00	94%	4.61E-03	1.06E-01	7.77E-02	9.32E-02	6.83E-03	6.00E-01	2.44E-03	2.44E-03	100.1%
[Be] [mg/L]	0.004	4.76E-04	4.76E-04	4.76E-04	93%	3.26E-03	99%	5.07E-06	15%	2.81E-04	1.90E-03	1.53E-02	8.05E-03	8.02E-03	8.30E-03	1.51E-04	1.51E-04	100.3%
[C] [mg/L]		8.00E+02	8.00E+02	8.00E+02	49%	1.83E+03	93%	7.67E+01	40%	1.17E+03	2.99E+03	4.51E+03	5.11E+03	3.60E+03	1.41E+04	6.57E+02	3.95E+02	100.0%
[Ca] [mg/L]		1.69E+02	1.69E+02	1.69E+02	91%	1.37E+02	99%	2.03E+00	89%	1.54E+01	6.75E+02	6.27E+02	6.53E+02	8.17E+01	4.01E+03	9.10E+00	1.31E+01	100.1%
[Cd] [mg/L]	0.0025	2.36E-03	2.36E-03	2.36E-03	93%	1.58E-03	99%	2.82E-05	97%	1.36E-04	9.40E-03	7.40E-03	8.49E-03	2.58E-04	5.68E-02	8.54E-05	8.54E-05	100.1%
[Cl] [mg/L]	230	2.44E+01	2.44E+01	2.44E+01	9%	3.83E+01	99%	4.23E-01	13%	4.33E+01	9.71E+01	1.81E+01	6.09E+01	6.19E+01	5.58E+01	2.31E+01	2.31E+01	100.0%
[Co] [mg/L]	0.005	4.08E-02	6.31E-04	6.31E-04	97%	4.48E-04	99%	7.56E-06	95%	1.96E-05	2.52E-03	2.18E-03	2.36E-03	1.36E-04	1.54E-02	1.39E-05	1.39E-05	100.0%
[Cr] [mg/L]	0.011	7.16E-03	7.16E-03	7.16E-03	93%	5.80E-03	99%	8.57E-05	89%	5.07E-04	2.86E-02	2.72E-02	2.79E-02	3.50E-03	1.72E-01	3.09E-04	3.09E-04	100.1%
[Cu] [mg/L]	0.0093	5.35E-01	3.27E-02	3.27E-02	94%	2.24E-02	99%	5.22E-04	97%	1.73E-03	1.30E-01	1.06E-01	1.19E-01	4.73E-03	7.88E-01	1.16E-03	1.16E-03	100.0%
[F] [mg/L]	2	1.19E+00	1.19E+00	1.19E+00	33%	1.77E+00	100%	0.00E+00	40%	1.49E+00	4.79E+00	2.91E+00	3.93E+00	2.76E+00	1.08E+01	7.90E-01	7.91E-01	100.1%
[Fe] [mg/L]	0.3	2.36E+00	2.49E-02	2.49E-02	75%	1.71E-02	99%	4.30E-04	96%	5.34E-03	9.89E-02	6.46E-02	8.32E-02	3.90E-03	5.49E-01	3.03E-03	3.04E-03	100.0%
[K] [mg/L]		3.12E+01	3.12E+01	3.12E+01	48%	3.71E+01	99%	5.39E-01	63%	2.43E+01	1.24E+02	8.86E+01	1.08E+02	4.72E+01	4.64E+02	1.31E+01	1.31E+01	100.1%
[Mg] [mg/L]		9.96E+01	9.96E+01	9.96E+01	94%	1.10E+02	99%	9.28E-01	76%	8.38E+00	3.98E+02	5.20E+02	4.54E+02	1.28E+02	2.37E+03	4.88E+00	4.88E+00	100.1%
[Mn] [mg/L]	0.05	9.00E-01	1.42E-01	1.42E-01	87%	1.58E-01	99%	2.46E-03	75%	2.67E-02	5.65E-01	6.89E-01	6.22E-01	1.86E-01	3.19E+00	1.53E-02	1.53E-02	100.0%
[Na] [mg/L]		7.79E+01	7.79E+01	7.79E+01	47%	8.68E+01	99%	1.24E+00	67%	5.80E+01	3.10E+02	2.03E+02	2.61E+02	1.02E+02	1.20E+03	3.13E+01	3.13E+01	100.1%
[Ni] [mg/L]	0.052	5.65E-01	7.79E-02	7.79E-02	96%	5.45E-02	99%	9.33E-04	96%	2.45E-03	3.11E-01	2.64E-01	2.90E-01	1.46E-02	1.91E+00	1.74E-03	1.74E-03	100.0%
[Pb] [mg/L]	0.0032	5.41E-02	5.90E-03	5.90E-03	96%	3.97E-03	99%	7.07E-05	97%	1.88E-04	2.35E-02	1.92E-02	2.16E-02	6.75E-04	1.44E-01	1.33E-04	1.33E-04	100.0%
[Sb] [mg/L]	0.031	1.29E-02	1.29E-02	1.29E-02	93%	9.23E-03	99%	1.54E-04	95%	7.94E-04	5.14E-02	4.32E-02	4.77E-02	2.98E-03	3.10E-01	4.94E-04	4.94E-04	100.1%
[Se] [mg/L]	0.005	3.51E-03	3.51E-03	3.51E-03	96%	2.34E-03	99%	3.26E-05	98%	1.11E-04	1.40E-02	1.13E-02	1.28E-02	3.45E-04	8.59E-02	7.41E-05	7.41E-05	100.1%
[SiO2] [mg/L]		3.48E+01	3.48E+01	3.48E+01	22%	2.55E+01	99%	3.71E-01	91%	2.48E+01	1.39E+02	2.84E+01	8.84E+01	9.67E+00	5.51E+02	1.33E+01	1.33E+01	100.1%
[SO4] [mg/L]	10	3.59E+02	3.59E+02	3.59E+02	96%	3.21E+02	99%	2.87E+00	85%	1.56E+01	1.44E+03	1.55E+03	1.49E+03	2.56E+02	8.75E+03	9.63E+00	9.64E+00	100.1%
[Tl] [mg/L]	0.00056	1.94E-04	1.94E-04	1.94E-04	93%	1.39E-04	99%	2.07E-06	95%	1.21E-05	7.76E-04	6.50E-04	7.18E-04	4.48E-05	4.68E-03	7.40E-06	7.41E-06	100.1%
[V] [mg/L]		9.20E-03	9.20E-03	9.20E-03	93%	7.93E-03	99%	8.56E-05	87%	6.93E-04	3.68E-02	3.71E-02	3.69E-02	5.77E-03	2.20E-01	4.07E-04	4.08E-04	100.1%
[Zn] [mg/L]	0.12	1.64E-01	3.77E-03	3.77E-03	96%	2.70E-03	99%	4.52E-05	95%	1.45E-04	1.51E-02	1.30E-02	1.41E-02	8.83E-04	9.20E-02	9.81E-05	9.82E-05	100.0%
[Alkalinity] [mg/L] as CaCO3	250	6.26E+02	6.26E+02	6.26E+02	49%	8.85E+02	93%	6.00E+01	50%	5.66E+02	2.34E+03	2.17E+03	2.26E+03	1.33E+03	7.78E+03	3.28E+02	3.38E+02	100.8%
Hardness** [mg/L]	100	832.7	832.7	832.7	0%	795.0	0.0	8.9	0.0	72.9	3326.2	3706.8	3502.2	730.6	19795.2	42.8	52.9	N/A
[Ionic_Strength] [M]		0.027	0.027	0.027	0.000	0.029	0.000	0.001	0.000	0.009	0.095	0.097	0.096	0.033	0.37314	0.00545	0.00576	N/A
[Charge_pct_err]		0.569	0.256	0.256	0.000	-12.042	0.000	-67.846	0.000	-48.118	2.724	7.048	4.659	-27.292	24.85796	-49.37516	-48.33641	N/A
[pH] [std units]	6.5-8.5	7.4	7.4	7.4	0.0	6.4	0.0	7.5	0.0	6.4	7.3	6.3	6.3	6.2	6.3	6.5	8.6	N/A
mEQ-Na^+/mEQ-∑Cations	0.6	16%	16%	16%	0%	18%	0%	22%	0%	55%	16%	10%	13%	22%	11%	53%	49%	N/A
CO2 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1045.3	0.0	0.0	0.0	0.0	N/A
CO2 [kg/d]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6000.0	0.0	0.0	0.0	0.0	N/A
CaCO3 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.1	N/A
CaCO3 [kg/day]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	200.0	N/A

****Calculated as the sum of Ca and Mg as CaCO3**

Tailings Basin Seepage Treatment Train - Year 20 - P90 Annual Average Flows

Qualities and Quantities	Preliminary Water Quality Targets	(1) Influent Seepage	(2) Green Sand Effluent	(3) RO Feed	NF Rejection	(4) NF Feed	RO Rejection	(5) RO Permeate	VSEP Rejection	(6) NF Permeate	(7) RO Concentrate	(8) NF Concentrate	(9) NF/RO Concentrate w/CO2	(10) VSEP Permeate	(11) VSEP Concentrate	(12) Stabilization Influent	(13) Stabilized Effluent	System Mass Balance
Flow Rate, gpm		**2282**	**2168**	**1626**		**1069**		**1219**		**855**	**406**	**214**	**620**	**527**	**93**	**2075**	**2075**	**N/A**
[Ag] [mg/L]	**0.001**	1.87E-04	1.87E-04	1.87E-04	32%	1.08E-04	99%	3.72E-06	96%	9.12E-05	1.80E-04	1.74E-04	5.47E-04	2.59E-05	3.66E-03	3.97E-05	3.97E-05	100.1%
[Al] [mg/L]	**0.125**	5.13E-03	5.13E-03	5.13E-03	93%	2.67E-03	99%	7.50E-05	99%	2.50E-04	6.38E-03	1.25E-02	1.77E-02	1.33E-04	1.23E-01	1.47E-04	1.47E-04	100.1%
[As] [mg/L]	**0.01**	6.77E-02	4.99E-04	4.99E-04	99%	1.22E-03	99%	9.95E-06	51%	1.67E-05	5.33E-03	6.10E-03	3.40E-03	1.97E-03	1.20E-02	1.27E-05	1.27E-05	100.0%
[B] [mg/L]	**0.5**	1.23E-01	1.23E-01	1.23E-01	18%	1.76E-01	55%	7.37E-02	15%	1.81E-01	1.28E-01	1.56E-01	2.32E-01	2.31E-01	2.43E-01	1.18E-01	1.18E-01	100.1%
[Ba] [mg/L]	**2**	2.07E-02	2.07E-02	2.07E-02	87%	1.32E-02	100%	0.00E+00	94%	2.21E-03	5.80E-02	5.78E-02	7.48E-02	5.48E-03	4.89E-01	9.10E-04	9.10E-04	100.1%
[Be] [mg/L]	**0.004**	3.95E-04	3.95E-04	3.95E-04	93%	3.32E-03	99%	5.77E-06	15%	3.10E-04	1.36E-02	1.55E-02	6.37E-03	6.33E-03	6.65E-03	1.31E-04	1.31E-04	100.3%
[C] [mg/L]		1.17E+03	1.17E+03	1.17E+03	47%	3.36E+03	91%	1.42E+02	40%	2.21E+03	6.33E+03	7.98E+03	7.99E+03	5.61E+03	2.23E+04	9.95E+02	1.03E+03	100.0%
[Ca] [mg/L]		2.89E+02	2.89E+02	2.89E+02	90%	2.14E+02	99%	4.23E+00	89%	2.80E+01	7.38E+02	9.68E+02	1.09E+03	1.36E+02	6.80E+03	1.40E+01	3.53E+01	100.1%
[Cd] [mg/L]	**0.0025**	00 gpm to 3900 g	4.02E-03	4.02E-03	93%	2.26E-03	99%	5.88E-05	97%	2.11E-04	4.70E-03	1.05E-02	1.42E-02	4.30E-04	9.62E-02	1.21E-04	1.21E-04	100.1%
[Cl] [mg/L]	**230**	3.07E+01	3.07E+01	3.07E+01	9%	6.04E+01	98%	6.52E-01	13%	6.82E+01	2.26E+01	2.87E+01	8.99E+01	9.11E+01	8.34E+01	2.85E+01	2.85E+01	100.0%
[Co] [mg/L]	**0.005**	7.62E-02	1.18E-03	1.18E-03	96%	7.20E-04	99%	1.72E-05	95%	3.41E-05	1.66E-03	3.50E-03	4.29E-03	2.46E-04	2.85E-02	2.42E-05	2.42E-05	100.0%
[Cr] [mg/L]	**0.011**	7.60E-03	7.60E-03	7.60E-03	93%	5.64E-03	99%	1.21E-04	89%	5.27E-04	2.59E-02	2.63E-02	2.90E-02	3.62E-03	1.80E-01	2.88E-04	2.88E-04	100.1%
[Cu] [mg/L]	**0.0093**	6.03E-01	3.69E-02	3.69E-02	94%	2.13E-02	99%	6.38E-04	97%	1.65E-03	7.97E-02	1.01E-01	1.31E-01	5.22E-03	8.82E-01	1.05E-03	1.05E-03	100.0%
[F] [mg/L]	**2**	1.37E+00	1.37E+00	1.37E+00	41%	2.60E+00	100%	0.00E+00	40%	1.90E+00	4.66E+00	5.43E+00	5.50E+00	3.86E+00	1.53E+01	7.80E-01	7.80E-01	100.1%
[Fe] [mg/L]	**0.3**	5.49E-01	5.78E-03	5.78E-03	75%	3.38E-03	98%	1.69E-04	96%	1.04E-03	5.44E-03	1.29E-02	1.94E-02	9.09E-04	1.30E-01	5.26E-04	5.26E-04	100.0%
[K] [mg/L]		3.88E+01	3.88E+01	3.88E+01	46%	5.00E+01	98%	8.25E-01	63%	3.39E+01	1.07E+02	1.15E+02	1.41E+02	6.16E+01	6.15E+02	1.44E+01	1.44E+01	100.1%
[Mg] [mg/L]		9.89E+01	9.89E+01	9.89E+01	94%	1.11E+02	99%	1.05E+00	76%	8.73E+00	4.50E+02	5.26E+02	4.41E+02	1.24E+02	2.33E+03	4.21E+00	4.21E+00	100.1%
[Mn] [mg/L]	**0.05**	8.17E-01	1.29E-01	1.29E-01	87%	1.47E-01	99%	2.57E-03	75%	2.45E-02	4.57E-01	6.46E-01	5.59E-01	1.67E-01	2.90E+00	1.16E-02	1.16E-02	100.0%
[Na] [mg/L]		1.14E+02	1.14E+02	1.14E+02	45%	1.35E+02	99%	1.97E+00	67%	9.29E+01	2.71E+02	3.06E+02	4.03E+02	1.57E+02	1.87E+03	3.94E+01	3.94E+01	100.1%
[Ni] [mg/L]	**0.052**	9.69E-01	1.34E-01	1.34E-01	96%	7.99E-02	99%	1.95E-03	96%	3.79E-03	2.08E-01	3.88E-01	4.84E-01	2.44E-02	3.23E+00	2.71E-03	2.71E-03	100.0%
[Pb] [mg/L]	**0.0032**	6.80E-02	7.42E-03	7.42E-03	96%	4.18E-03	99%	1.09E-04	97%	2.08E-04	2.02E-02	2.03E-02	2.64E-02	8.26E-04	1.79E-01	1.50E-04	1.50E-04	100.0%
[Sb] [mg/L]	**0.031**	2.07E-02	2.07E-02	2.07E-02	93%	1.28E-02	99%	3.03E-04	95%	1.20E-03	5.30E-02	6.00E-02	7.50E-02	4.68E-03	4.95E-01	6.73E-04	6.73E-04	100.1%
[Se] [mg/L]	**0.005**	6.05E-03	6.05E-03	6.05E-03	96%	3.36E-03	99%	6.43E-05	98%	1.72E-04	1.41E-02	1.63E-02	2.15E-02	5.79E-04	1.46E-01	1.09E-04	1.09E-04	100.1%
[SiO2] [mg/L]		3.49E+01	3.49E+01	3.49E+01	22%	2.31E+01	99%	4.17E-01	91%	2.25E+01	2.69E-02	2.58E+01	1.00E+02	1.10E+01	6.35E+02	9.48E+00	9.48E+00	100.1%
[SO4] [mg/L]	**10**	4.33E+02	4.33E+02	4.33E+02	96%	3.68E+02	99%	3.46E+00	85%	1.93E+01	1.60E+03	1.78E+03	1.75E+03	3.01E+02	1.04E+04	9.97E+00	9.97E+00	100.1%
[Tl] [mg/L]	**0.00056**	1.86E-04	1.86E-04	1.86E-04	93%	1.15E-04	99%	3.21E-06	95%	1.07E-05	5.49E-04	5.36E-04	6.70E-04	4.17E-05	4.42E-03	6.31E-06	6.31E-06	100.1%
[V] [mg/L]		9.39E-03	9.39E-03	9.39E-03	93%	7.60E-03	99%	1.37E-04	87%	7.01E-04	3.55E-02	3.55E-02	3.68E-02	5.75E-03	2.23E-01	3.69E-04	3.69E-04	100.1%
[Zn] [mg/L]	**0.12**	2.54E-01	5.87E-03	5.87E-03	100%	3.65E-03	99%	8.58E-05	95%	2.27E-05	1.04E-02	1.83E-02	2.17E-02	1.35E-03	1.43E-01	5.98E-05	5.98E-05	100.0%
[Alkalinity] [mg/L] as CaCO3	**250**	9.19E+02	9.19E+02	9.19E+02	47%	1.45E+03	91%	1.11E+02	50%	9.53E+02	2.53E+03	3.44E+03	3.40E+03	1.99E+03	1.18E+04	4.58E+02	5.11E+02	102.6%
Hardness [mg/L]**	**100**	1130.0	1129.9	1129.9	0%	992.7	0.0	14.9	0.0	106.0	3697.3	4583.0	4542.5	850.9	26584.6	52.4	105.4	N/A
[Ionic_Strength] [M]		0.036	0.036	0.036	0.000	0.039	0.000	0.002	0.000	0.015	0.101	0.122	0.124	0.043	0.46710	0.00717	0.00862	N/A
[Charge_pct_err]		0.591	0.401	0.401	0.000	-19.597	0.000	-70.601	0.000	-51.546	2.849	0.607	2.757	-34.356	27.17800	-53.60098	-46.62834	N/A
[pH] [std units]	**6.5-8.5**	7.4	7.4	7.4	0.0	6.3	0.0	7.5	0.0	6.3	6.2	6.2	6.2	6.1	6.3	6.4	6.5	N/A
mEQ-Na^+/mEQ-∑Cations	**0.6**	17%	17%	17%	0%	22%	0%	21%	0%	57%	13%	12%	16%	27%	13%	55%	41%	N/A
CO2 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1774.4	0.0	0.0	0.0	0.0	N/A
CO2 [kg/d]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6000.0	0.0	0.0	0.0	0.0	N/A
CaCO3 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53.1	N/A
CaCO3 [kg/day]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	600.0	N/A

****Calculated as the sum of Ca and Mg as CaCO3**

Temp 10 degrees C

TDS **438.89**

Tailings Basin Seepage Treatment Train - Year 20 - P90 Peak Flow

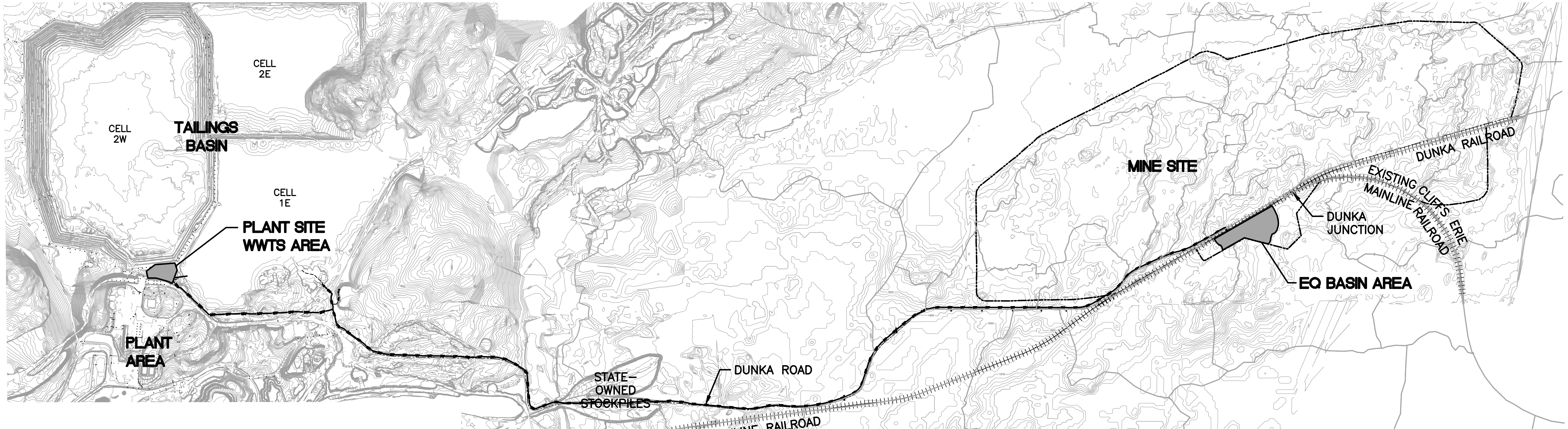
Qualities and Quantities	Preliminary Water Quality Targets	(1) Influent Seepage	(2) Green Sand Effluent	(3) RO Feed	NF Rejection	(4) NF Feed	RO Rejection	(5) RO Permeate	VSEP Rejection	(6) NF Permeate	(7) RO Concentrate	(8) NF Concentrate	(9) NF/RO Concentrate w/CO2	(10) VSEP Permeate	(11) VSEP Concentrate	(12) Stabilization Influent	(13) Stabilized Effluent	System Mass Balance
Flow Rate, gpm		**2900**	**2755**	**2204**		**1228**		**1653**		**983**	**551**	**246**	**797**	**677**	**119**	**2636**	**2636**	**N/A**
[Ag] [mg/L]	**0.001**	1.87E-04	1.87E-04	1.87E-04	32%	9.88E-05	99%	3.72E-06	96%	3.72E-06	7.42E-04	7.42E-04	5.65E-04	2.67E-05	3.82E-03	3.35E-05	3.35E-05	100.1%
[Al] [mg/L]	**0.125**	5.13E-03	5.13E-03	5.13E-03	93%	2.38E-03	99%	7.50E-05	99%	7.50E-05	2.05E-02	2.05E-02	1.77E-02	1.32E-04	1.24E-01	1.30E-04	1.30E-04	100.1%
[As] [mg/L]	**0.01**	6.77E-02	4.99E-04	4.99E-04	99%	1.30E-03	99%	9.95E-06	51%	9.95E-06	1.98E-03	1.98E-03	3.37E-03	1.95E-03	1.20E-02	1.29E-05	1.29E-05	100.0%
[B] [mg/L]	**0.5**	1.23E-01	1.23E-01	1.23E-01	18%	1.87E-01	55%	7.37E-02	15%	7.37E-02	2.72E-01	2.72E-01	2.40E-01	2.39E-01	2.54E-01	1.18E-01	1.18E-01	100.1%
[Ba] [mg/L]	**2**	2.07E-02	2.07E-02	2.07E-02	87%	1.24E-02	100%	0.00E+00	94%	0.00E+00	8.37E-02	8.37E-02	7.48E-02	5.48E-03	4.95E-01	7.67E-04	7.67E-04	100.1%
[Be] [mg/L]	**0.004**	3.95E-04	3.95E-04	3.95E-04	93%	3.64E-03	99%	5.77E-06	15%	5.77E-06	1.58E-03	1.58E-03	6.33E-03	6.31E-03	6.70E-03	1.30E-04	1.30E-04	100.2%
[C] [mg/L]		1.17E+03	1.17E+03	1.17E+03	47%	5.73E+03	91%	1.42E+02	40%	1.42E+02	4.30E+03	4.30E+03	1.35E+04	9.48E+03	3.80E+04	1.49E+03	5.19E+02	100.0%
[Ca] [mg/L]		2.89E+02	2.89E+02	2.89E+02	90%	2.05E+02	99%	4.23E+00	89%	4.23E+00	1.16E+03	1.16E+03	1.09E+03	1.36E+02	6.86E+03	1.26E+01	1.40E+01	100.1%
[Cd] [mg/L]	**0.0025**	4.02E-03	4.02E-03	4.02E-03	93%	2.05E-03	99%	5.88E-05	97%	5.88E-05	1.61E-02	1.61E-02	1.41E-02	4.28E-04	9.70E-02	1.08E-04	1.08E-04	100.1%
[Cl] [mg/L]	**230**	3.07E+01	3.07E+01	3.07E+01	9%	6.64E+01	98%	6.52E-01	13%	6.52E-01	1.22E+02	1.22E+02	9.44E+01	9.58E+01	8.87E+01	2.83E+01	2.83E+01	100.0%
[Co] [mg/L]	**0.005**	7.62E-02	1.18E-03	1.18E-03	96%	6.66E-04	99%	1.72E-05	95%	1.72E-05	4.71E-03	4.71E-03	4.27E-03	2.45E-04	2.86E-02	2.26E-05	2.26E-05	100.0%
[Cr] [mg/L]	**0.011**	7.60E-03	7.60E-03	7.60E-03	93%	5.40E-03	99%	1.21E-04	89%	1.21E-04	3.03E-02	3.03E-02	2.88E-02	3.60E-03	1.82E-01	2.64E-04	2.64E-04	100.1%
[Cu] [mg/L]	**0.0093**	6.03E-01	3.69E-02	3.69E-02	94%	1.95E-02	99%	6.38E-04	97%	6.38E-04	1.47E-01	1.47E-01	1.31E-01	5.20E-03	8.89E-01	9.60E-04	9.59E-04	100.0%
[F] [mg/L]	**2**	1.37E+00	1.37E+00	1.37E+00	41%	2.80E+00	100%	0.00E+00	40%	0.00E+00	5.53E+00	5.53E+00	5.64E+00	3.97E+00	1.59E+01	7.59E-01	7.59E-01	100.1%
[Fe] [mg/L]	**0.3**	5.49E-01	5.78E-03	5.78E-03	75%	3.11E-03	98%	1.69E-04	96%	1.69E-04	2.28E-02	2.28E-02	1.95E-02	9.14E-04	1.32E-01	4.60E-04	4.60E-04	100.0%
[K] [mg/L]		3.88E+01	3.88E+01	3.88E+01	46%	5.21E+01	98%	8.25E-01	63%	8.25E-01	1.54E+02	1.54E+02	1.44E+02	6.31E+01	6.37E+02	1.36E+01	1.36E+01	100.1%
[Mg] [mg/L]		9.89E+01	9.89E+01	9.89E+01	94%	1.12E+02	99%	1.05E+00	76%	1.05E+00	3.96E+02	3.96E+02	4.39E+02	1.23E+02	2.35E+03	3.94E+00	3.94E+00	100.1%
[Mn] [mg/L]	**0.05**	8.17E-01	1.29E-01	1.29E-01	87%	1.50E-01	99%	2.57E-03	75%	2.57E-03	5.13E-01	5.13E-01	5.58E-01	1.67E-01	2.93E+00	1.08E-02	1.08E-02	100.0%
[Na] [mg/L]		1.14E+02	1.14E+02	1.14E+02	45%	1.40E+02	99%	1.97E+00	67%	1.97E+00	4.53E+02	4.53E+02	4.13E+02	1.61E+02	1.94E+03	3.69E+01	3.69E+01	100.1%
[Ni] [mg/L]	**0.052**	9.69E-01	1.34E-01	1.34E-01	96%	7.36E-02	99%	1.95E-03	96%	1.95E-03	5.34E-01	5.34E-01	4.81E-01	2.42E-02	3.25E+00	2.52E-03	2.52E-03	100.0%
[Pb] [mg/L]	**0.0032**	6.80E-02	7.42E-03	7.42E-03	96%	3.80E-03	99%	1.09E-04	97%	1.09E-04	2.96E-02	2.96E-02	2.63E-02	8.22E-04	1.80E-01	1.39E-04	1.39E-04	100.0%
[Sb] [mg/L]	**0.031**	2.07E-02	2.07E-02	2.07E-02	93%	1.19E-02	99%	3.03E-04	95%	3.03E-04	8.28E-02	8.28E-02	7.47E-02	4.67E-03	4.99E-01	6.04E-04	6.05E-04	100.1%
[Se] [mg/L]	**0.005**	6.05E-03	6.05E-03	6.05E-03	96%	3.04E-03	99%	6.43E-05	98%	6.43E-05	2.42E-02	2.42E-02	2.14E-02	5.76E-04	1.47E-01	9.82E-05	9.83E-05	100.1%
[SiO2] [mg/L]		3.49E+01	3.49E+01	3.49E+01	22%	2.20E+01	99%	4.17E-01	91%	4.17E-01	1.39E+02	1.39E+02	1.04E+02	1.14E+01	6.68E+02	8.20E+00	8.20E+00	100.1%
[SO4] [mg/L]	**10**	4.33E+02	4.33E+02	4.33E+02	96%	3.60E+02	99%	3.46E+00	85%	3.46E+00	1.74E+03	1.74E+03	1.74E+03	3.00E+02	1.05E+04	9.17E+00	9.18E+00	100.1%
[Tl] [mg/L]	**0.00056**	1.86E-04	1.86E-04	1.86E-04	93%	1.07E-04	99%	3.21E-06	95%	3.21E-06	7.40E-04	7.40E-04	6.67E-04	4.16E-05	4.46E-03	5.72E-06	5.72E-06	100.1%
[V] [mg/L]		9.39E-03	9.39E-03	9.39E-03	93%	7.38E-03	99%	1.37E-04	87%	1.37E-04	3.75E-02	3.75E-02	3.67E-02	5.73E-03	2.24E-01	3.39E-04	3.39E-04	100.1%
[Zn] [mg/L]	**0.12**	2.54E-01	5.87E-03	5.87E-03	100%	3.38E-03	99%	8.58E-05	95%	8.58E-05	2.34E-02	2.34E-02	2.15E-02	1.34E-03	1.44E-01	6.17E-05	6.17E-05	100.0%
[Alkalinity] [mg/L] as CaCO3	**250**	9.19E+02	9.19E+02	9.19E+02	47%	1.53E+03	91%	1.11E+02	50%	1.11E+02	3.37E+03	3.37E+03	3.46E+03	2.03E+03	1.22E+04	4.44E+02	4.48E+02	100.3%
Hardness [mg/L]**	**100**	1130.0	1129.9	1129.9	0%	975.4	0.0	14.9	0.0	14.9	4516.2	4516.2	4526.1	848.4	26828.3	47.8	51.3	N/A
[Ionic_Strength] [M]		0.036	0.036	0.036	0.000	0.040	0.000	0.002	0.000	0.002	0.124	0.124	0.124	0.043	0.47257	0.00688	0.00704	N/A
[Charge_pct_err]		0.591	0.401	0.401	0.000	-21.998	0.000	-70.601	0.000	-70.601	3.873	3.873	2.099	-34.931	26.55637	-55.12891	-55.68265	N/A
[pH] [std units]	**6.5-8.5**	7.4	7.4	7.4	0.0	5.9	0.0	7.5	0.0	7.5	7.3	7.3	5.8	5.8	5.8	6.1	8.7	N/A
mEQ-Na^+/mEQ-∑Cations	**0.6**	17%	17%	17%	0%	23%	0%	21%	0%	21%	17%	17%	16%	27%	13%	55%	54%	N/A
CO2 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4605.7	0.0	0.0	0.0	0.0	N/A
CO2 [kg/d]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20000.0	0.0	0.0	0.0	0.0	N/A
CaCO3 [mg/L]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.5	N/A
CaCO3 [kg/day]		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	N/A

****Calculated as the sum of Ca and Mg as CaCO3**

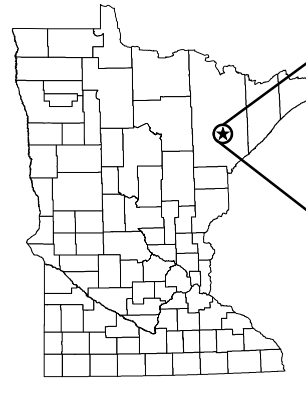
Attachment I

WWTS Permit Application Support Drawings

POLY MET MINING, INC. NORTHMET PROJECT
PERMIT APPLICATION SUPPORT DRAWINGS
WASTE WATER TREATMENT SYSTEM
HOYT LAKES, MINNESOTA

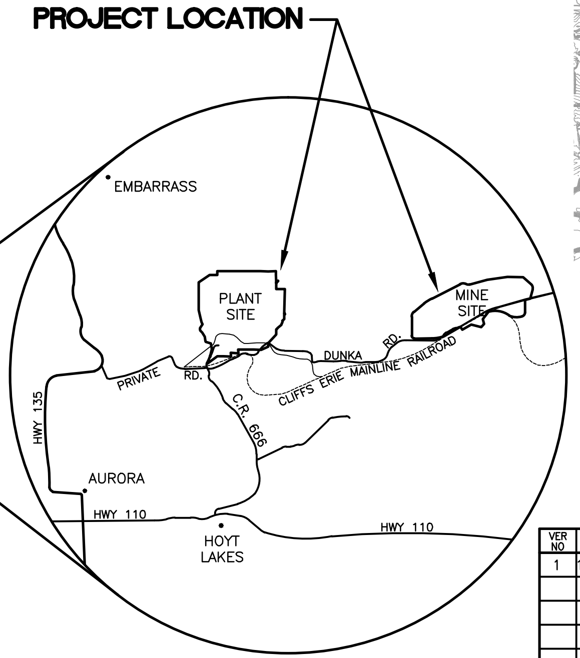


SITE MAP



LOCATION MAP

NOT TO SCALE



VICINITY MAP

NOT TO SCALE

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-001.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 9:34 AM

VER NO	DATE	DESCRIPTION
1	10/3/2017	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/2017
FOR CONSTRUCTION		

NOT APPROVED FOR CONSTRUCTION.

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

PRINTED NAME JEFF S. UBL

SIGNATURE Jeff Ubl

DATE 10/3/17 REG. NO. 19646

DRAWN: BJH

CHECKED: ALL

BARR PROJECT NO.: 23690862.12

SCALE: AS SHOWN

PLANT DRAWING NUMBER:

LOCATION MAP AND SITE MAP

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-001

REV

INCHES 1 2

DRAWING INDEX

DRAWING NO.	TITLE
GENERAL DRAWINGS	
WWTS–001	LOCATION MAP AND SITE MAP
WWTS–002	LEGEND, ABBREVIATIONS, AND DRAWING INDEX
CIVIL SITEWORK – EQ BASIN AREA	
WWTS–003	EQ BASIN AREA – EXISTING CONDITIONS
WWTS–004	EQ BASIN AREA – SITE GRADING PLAN AND CONSTRUCTION LIMITS
WWTS–005	EQ BASIN AREA – BURIED PIPING PLAN
WWTS–006	EQ BASIN AREA – BASINS LINER PLAN
WWTS–007	EQ BASIN AREA – BASIN INLET AND OUTLET SECTIONS
CIVIL UTILITIES – EQ BASIN AREA	
WWTS–008	EQ BASIN AREA – CENTRAL PUMPING STATION – AT GRADE PLAN
WWTS–009	EQ BASIN AREA – CENTRAL PUMPING STATION – BELOW GRADE PLAN
WWTS–010	EQ BASIN AREA – CENTRAL PUMPING STATION – BUILDING SECTION
WWTS–011	EQ BASIN AREA – CENTRAL PUMPING STATION – BUILDING SECTIONS
WWTS–012	EQ BASIN AREA – CONSTRUCTION MINE WATER PUMPING STATION – PLANS
WWTS–013	EQ BASIN AREA – CONSTRUCTION MINE WATER PUMPING STATION – BUILDING SECTIONS
CIVIL SITEWORK – WWTS	
WWTS–014	PLANT SITE WWTS – EXISTING CONDITIONS
WWTS–015	PLANT SITE WWTS – SITE GRADING PLAN AND CONSTRUCTION LIMITS
WWTS–016	PLANT SITE WWTS – BURIED PIPING PLAN
CIVIL UTILITIES – WWTS	
WWTS–017	PLANT SITE WWTS – PRE–TREATMENT BASIN PUMPING STATION – PLAN
WWTS–018	PLANT SITE WWTS – PRE–TREATMENT BASIN PUMPING STATION – SECTION
CIVIL DETAILS	
WWTS–019	SECTIONS AND DETAILS
WWTS–020	SECTIONS AND DETAILS
MECHANICAL – PROCESS FLOW DIAGRAMS	
WWTS–021	MECHANICAL SYMBOLS AND LEGEND
WWTS–022	HYDRAULIC PROFILE – MINE WATER TREATMENT TRAINS – PRIMARY FLOW
WWTS–023	HYDRAULIC PROFILE – MINE WATER TREATMENT TRAINS – RESIDUALS
WWTS–024	HYDRAULIC PROFILE – TAILINGS BASIN SEEPAGE TREATMENT TRAIN
WWTS–025	PROCESS FLOW DIAGRAMS – MINE WATER TREATMENT TRAINS OVERVIEW
WWTS–026	PROCESS FLOW DIAGRAMS – MINE WATER TREATMENT TRAINS – EQUALIZATION BASINS
WWTS–027	PROCESS FLOW DIAGRAMS – MINE WATER TREATMENT TRAINS – CHEMICAL PRECIPITATION OVERVIEW
WWTS–028	PROCESS FLOW DIAGRAMS – MINE WATER TREATMENT TRAINS – HDS METALS REMOVAL
WWTS–029	PROCESS FLOW DIAGRAMS – MINE WATER TREATMENT TRAINS – SULFATE REMOVAL
WWTS–030	PROCESS FLOW DIAGRAMS – MINE WATER TREATMENT TRAINS – RECARBONATION
WWTS–031	PROCESS FLOW DIAGRAMS – MINE WATER TREATMENT TRAINS – GREENSAND FILTERS AND PRIMARY MEMBRANES
WWTS–032	PROCESS FLOW DIAGRAMS – MINE WATER TREATMENT TRAINS – SECONDARY MEMBRANES
WWTS–033	PROCESS FLOW DIAGRAMS – TAILINGS BASIN SEEPAGE TREATMENT TRAIN – OVERVIEW
WWTS–034	PROCESS FLOW DIAGRAMS – TAILINGS BASIN SEEPAGE TREATMENT TRAIN – PRETREATMENT AND GREENSAND FILTERS
WWTS–035	PROCESS FLOW DIAGRAMS – TAILINGS BASIN SEEPAGE TREATMENT TRAIN – PRIMARY MEMBRANES
WWTS–036	PROCESS FLOW DIAGRAMS – TAILINGS BASIN SEEPAGE TREATMENT TRAIN – SECONDARY MEMBRANES
WWTS–037	PROCESS FLOW DIAGRAMS – TAILINGS BASIN SEEPAGE TREATMENT TRAIN – PERMEATE STABILIZATION AND STREAM AUGMENTATION
WWTS–038	PROCESS FLOW DIAGRAMS – MINE WATER TREATMENT TRAINS – SOLIDS HANDLING
WWTS–039	PROCESS FLOW DIAGRAMS – HYDRATED LIME STORAGE AND FEED, SEEPAGE PLANT WATER
WWTS–040	PROCESS FLOW DIAGRAMS – CARBON DIOXIDE STORAGE AND FEED
WWTS–041	PROCESS FLOW DIAGRAMS – CHEMICAL STORAGE AND FEED
MECHANICAL LAYOUT – WWTS	
WWTS–042	PLANT SITE WWTS – GENERAL ARRANGEMENT WEST
WWTS–043	PLANT SITE WWTS – GENERAL ARRANGEMENT EAST

NOTES

1. COORDINATE SYSTEM IS MINNESOTA STATE PLANE NORTH ZONE, NAD83.
2. ELEVATIONS ARE MEAN SEA LEVEL (MSL), NAVD88.
3. EXISTING TOPOGRAPHIC INFORMATION SHOWN ON THE DRAWINGS WAS PREPARED BY AEROMETRIC, INC. FROM LIDAR DATA COLLECTED ON MARCH 17, 2010.
4. ALL EXISTING SUBSURFACE UTILITY INFORMATION SHOWN ON DRAWINGS SHALL BE CONSIDERED QUALITY LEVEL D (QL–D) AS DEFINED BY THE STANDARD GUIDELINES FOR THE COLLECTION DEPICTION OF EXISTING SUBSURFACE UTILITY DATA (ASCE, 2003) UNLESS OTHERWISE SPECIFIED.

GENERAL LEGEND

——1000——	EXISTING CONTOUR – MAJOR
————	EXISTING CONTOUR – MINOR
——1000——	PROPOSED CONTOUR – MAJOR
————	PROPOSED CONTOUR – MINOR
⊗	EXISTING POWER POLE
Ⓤ	UNIDENTIFIED
+++++++++++	EXISTING RAILROAD
═══════	EXISTING ROAD
– – – – – – – –	EXISTING TRAIL
═ ═ ═ ═ ═ ═	EXISTING UNIMPROVED TRAIL
▨	EXISTING STRUCTURES
⌒⌒⌒	TREE LINE
⌒	WETLAND BOUNDARY
>—<	EXISTING CULVERT
▨	MnDOT CATEGORY 4 EROSION CONTROL BLANKET
▨	INLET PROTECTION AND DITCH CHECKS
▩	MnDOT TYPE 4 MULCH
>—<	PROPOSED CULVERT (NON–MINE DRAINAGE)
○	PROPOSED MANHOLE
▩	PROPOSED RIPRAP
—·—·—·—	MINE SITE BOUNDARY
– – – – – – –	CONSTRUCTION LIMITS
— SF — SF —	PROPOSED SILT FENCE
—<—<—	PROPOSED PIPELINE
——P——	EXISTING PIPELINE
—◁	SLOPE INDICATOR
▭	PROPOSED STRUCTURES
▭	PROPOSED STRUCTURE EXPANSION
═══════	PROPOSED ROAD
———→	SURFACE DRAINAGE
—— MPP ——	MMP ALIGNMENT
┼┼┼┼┼┼┼┼	PROPOSED RAIL ROAD

GENERAL ABBREVIATIONS (DWGS. 010–020)

APPROX. – APPROXIMATE

CATEGORY 1 STOCKPILE – CATEGORY 1 WASTE ROCK STOCKPILE

CIP – CAST IN PLACE ~OR~ CLEAN IN PLACE

CMU– CONCRETE MASONRY UNIT

CMWPS – CONSTRUCTION MINE WATER PUMPING STATION

CPS – CENTRAL PUMPING STATION

ø – DIAMETER

DIP – DUCTILE IRON PIPE

DWG – DRAWING

EBA – EQUALIZATION BASIN AREA

EL – ELEVATION

EQ – EQUALIZATION

FFE – FINISHED FLOOR ELEVATION

FTB – FLOTATION TAILINGS BASIN

GAL. – GALLON

GCL – GEOSYNTHETIC CLAY LINER

HP – HORSEPOWER

HDPE – HIGH DENSITY POLYETHYLENE

MIL – MILLIMETER

MIN – MINIMUM

MnDOT – MINNESOTA DEPARTMENT OF TRANSPORTATION

MPP – MINE TO PLANT PIPELINES

NTS – NOT TO SCALE

OSLA – OVERBURDEN STORAGE AND LAYDOWN AREA

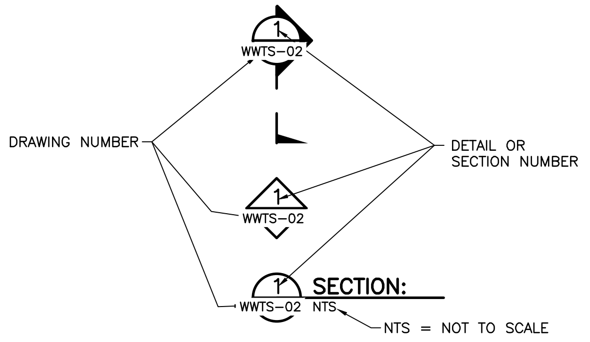
RCP – REINFORCED CONCRETE PIPE

RTH – RAIL TRANSFER HOPPER

TYP – TYPICAL

WWTS – WASTE WATER TREATMENT SYSTEM

DRAWING NUMBERING



PLANT DRAWING NUMBER:

LEGEND, ABBREVIATIONS, AND DRAWING INDEX

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		
NOT APPROVED FOR CONSTRUCTION.		

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

PRINTED NAME JEFF S. UBL
SIGNATURE Jeff Ubl
DATE 10/3/17 REG. NO. 19646

DRAWN: BJH
CHECKED: BTO
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

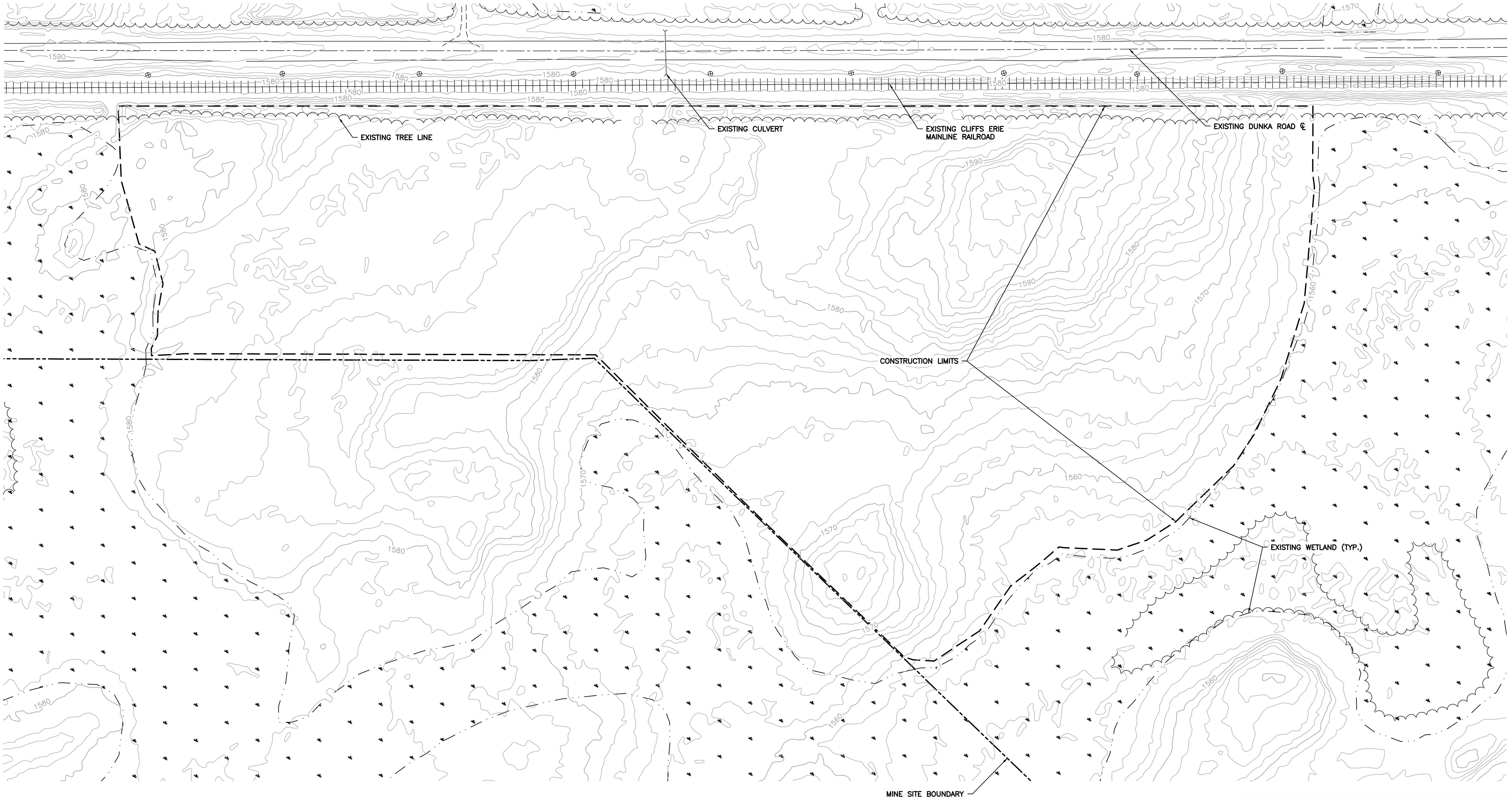
BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1–800–632–2277

DWG. NO. WWTS–002
REV

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM–46–WWTS–002.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 9:35 AM

INCHES 1 2



① PLAN: PLAN: EXISTING CONDITIONS

0 100 200
SCALE IN FEET

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-003.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 9:35 AM

INCHES 1 2

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

NOT APPROVED FOR CONSTRUCTION.

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE
DATE 10/3/17 REG. NO. 24480

DRAWN: BJH
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

EQ BASIN AREA
EXISTING CONDITIONS

POLYMET MINING

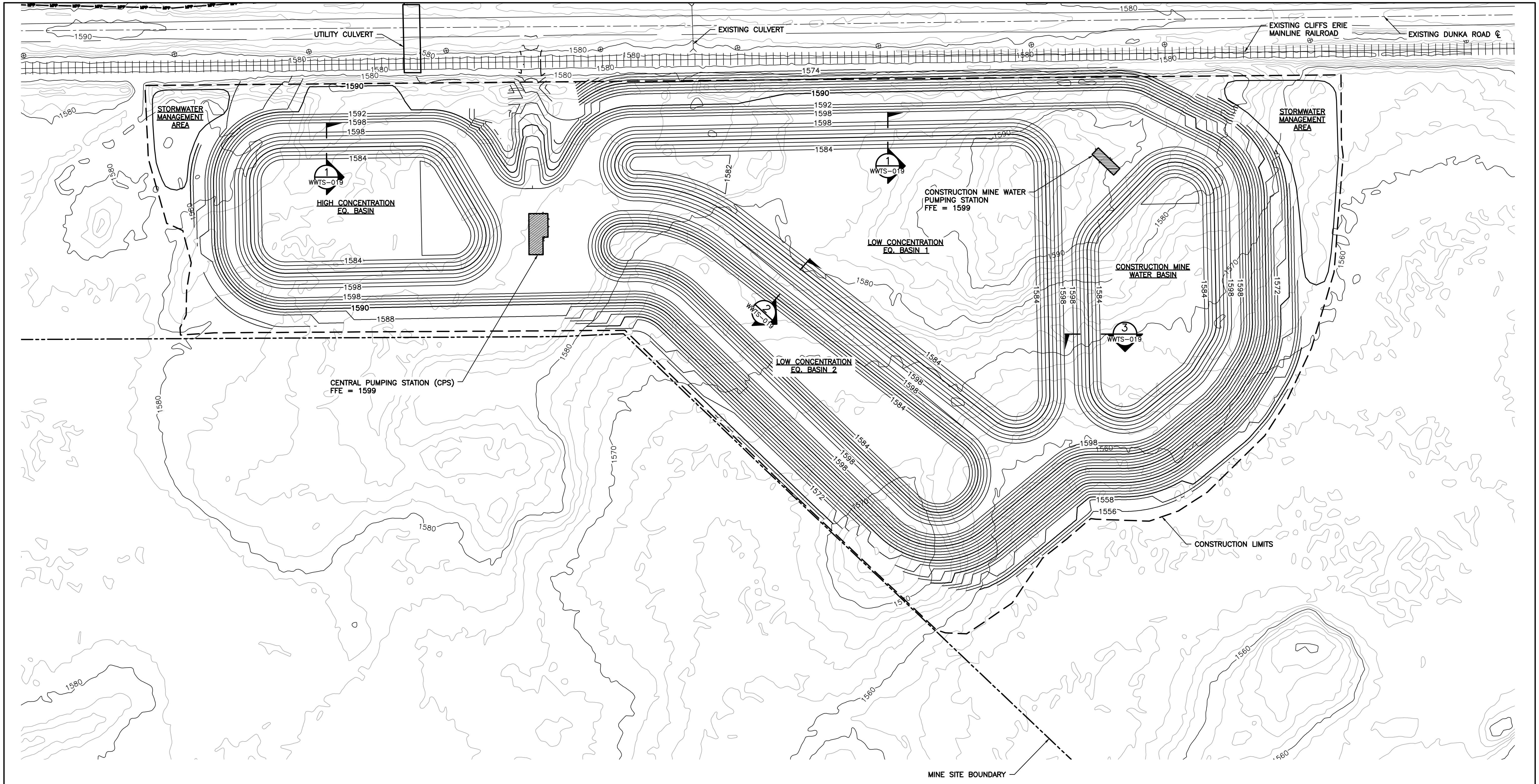
POLY MET MINING INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-003

REV



1 PLAN: EQUALIZATION BASINS AND ACCESS ROADS

0 100 200
SCALE IN FEET

PLANT DRAWING NUMBER:

EQ BASIN AREA
SITE GRADING PLAN AND CONSTRUCTION LIMITS

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

NOT APPROVED FOR CONSTRUCTION.

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE B. T. Oakley
DATE 10/3/17 LICENSE# 24480

DRAWN: BJH
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

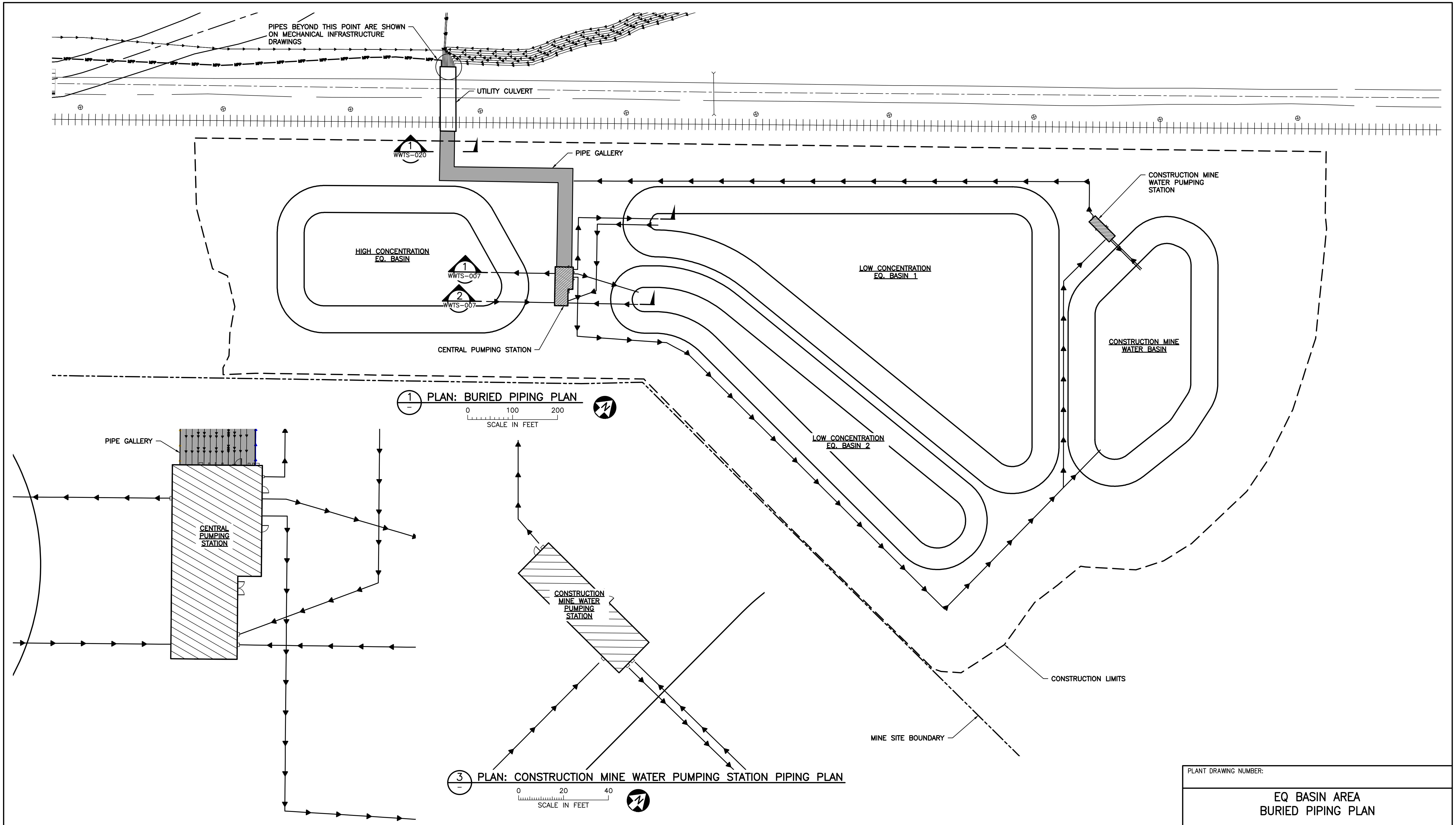
POLYMET MINING
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-004
REV

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-004.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 2:37 PM

INCHES 1 2



1 PLAN: BURIED PIPING PLAN

2 PLAN: CENTRAL PUMPING STATION PIPING PLAN

3 PLAN: CONSTRUCTION MINE WATER PUMPING STATION PIPING PLAN

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-005.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 2:38 PM

INCHES 1 2

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE
DATE 10/3/17 LICENSE# 24480

DRAWN: BJH
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

EQ BASIN AREA
BURIED PIPING PLAN

POLYMET MINING

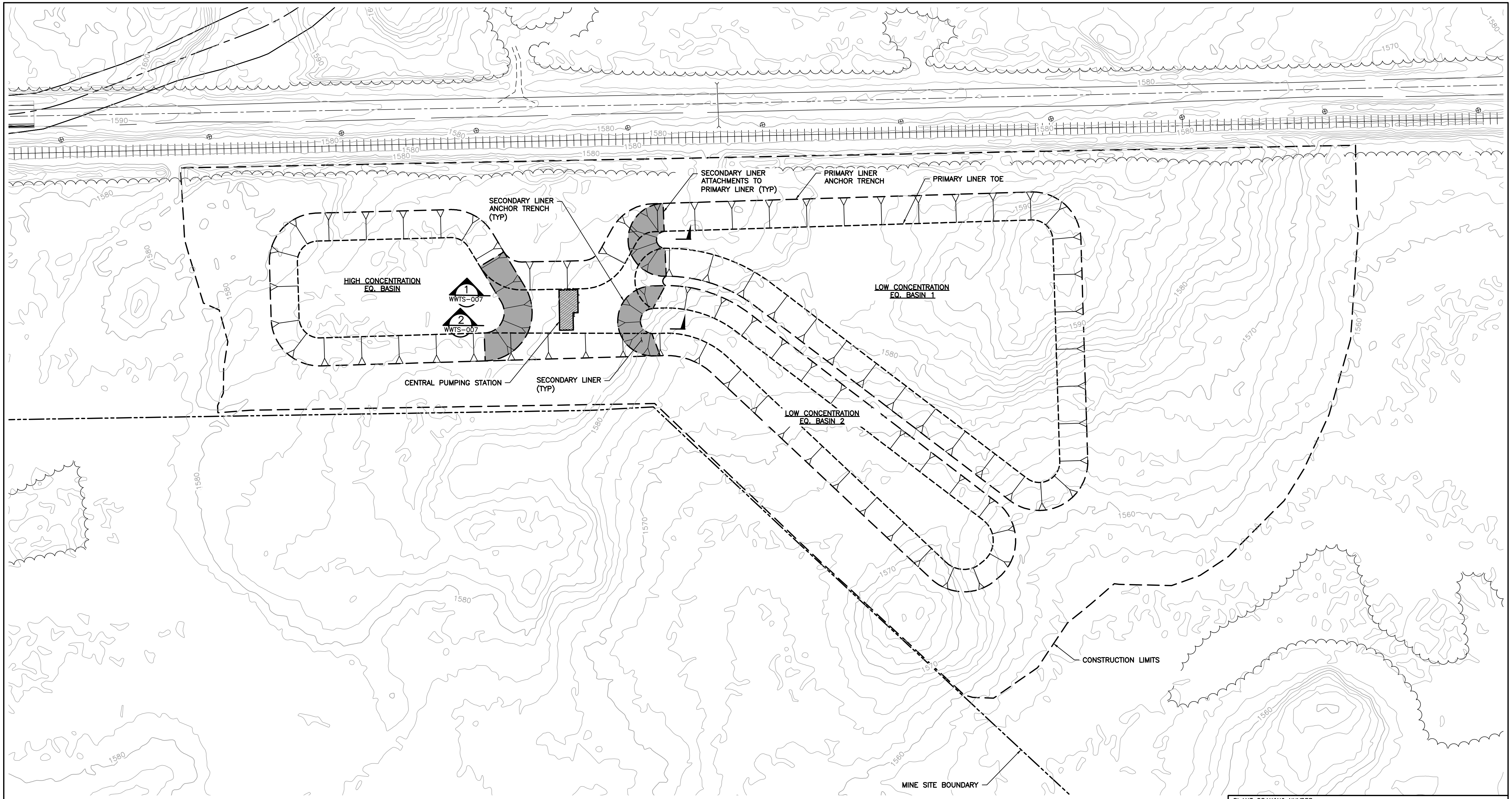
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-005

REV



1 PLAN: OVERALL LINER PLAN
–

0 100 200
SCALE IN FEET

INCHES 1 2

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		
NOT APPROVED FOR CONSTRUCTION		

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE B. T. Oakley
DATE 10/3/17 LICENSE# 24480

DRAWN: BJH
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

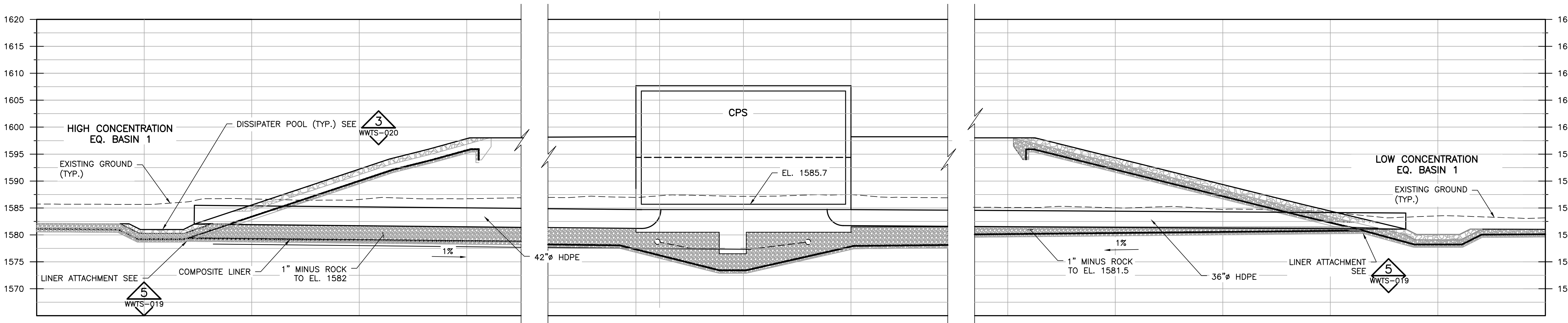
EQ BASIN AREA
BASINS LINER PLAN

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

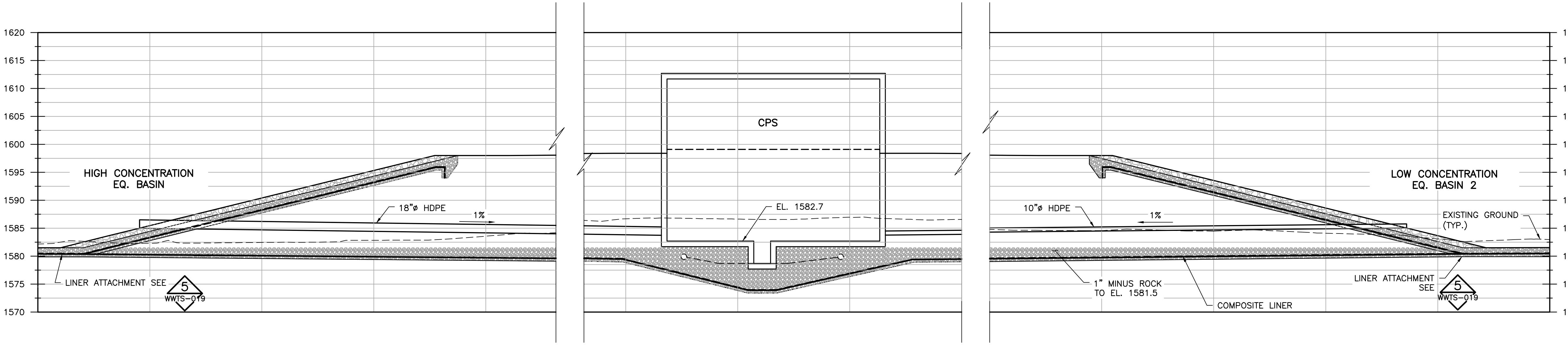
DWG. NO. WWTS-006
REV



1 SECTION: BASINS INLET STRUCTURES

WWTS-005, WWTS-006

0 10 20
SCALE IN FEET



2 SECTION: BASINS OUTLET STRUCTURES

WWTS-005, WWTS-006

0 10 20
SCALE IN FEET

NOTE:

PIPE DIAMETERS ARE PRELIMINARY

PLANT DRAWING NUMBER:

EQ BASIN AREA
BASIN INLET AND OUTLET SECTIONS

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		
NOT APPROVED FOR CONSTRUCTION		

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE B. T. Oakley
DATE 10/3/17 LICENSE# 24480

DRAWN: BJH
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

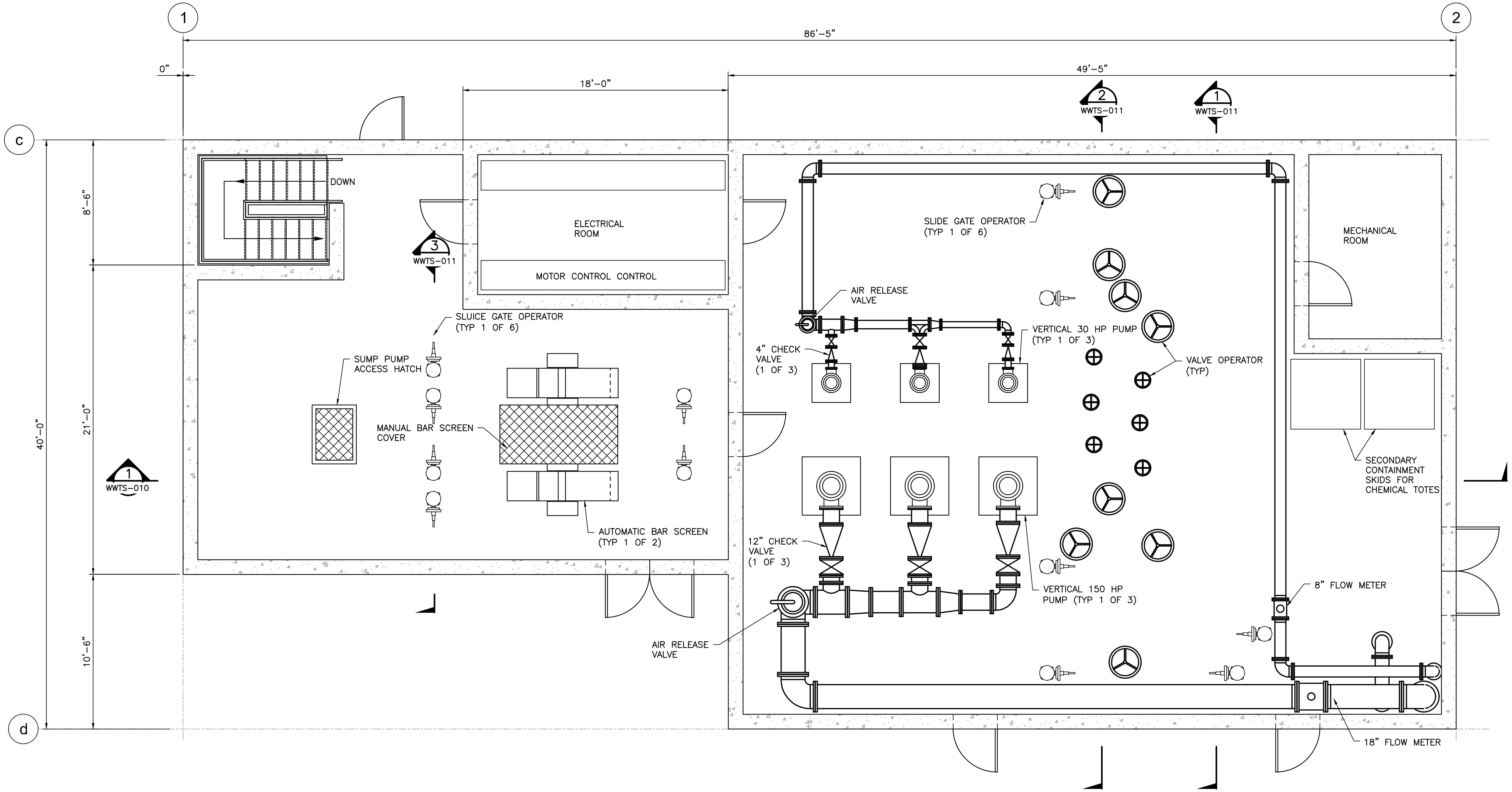
BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-007
REV

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-007.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 2:23 PM

INCHES 1 2



① PLAN: GRADE LEVEL
—

0 1' 2' 4' 6' 8' 10' 12'
SCALE

PLANT DRAWING NUMBER:

EQ BASIN AREA
CENTRAL PUMPING STATION
AT GRADE PLAN

POLY MET MINING INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

VER NO	DATE	DESCRIPTION
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ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

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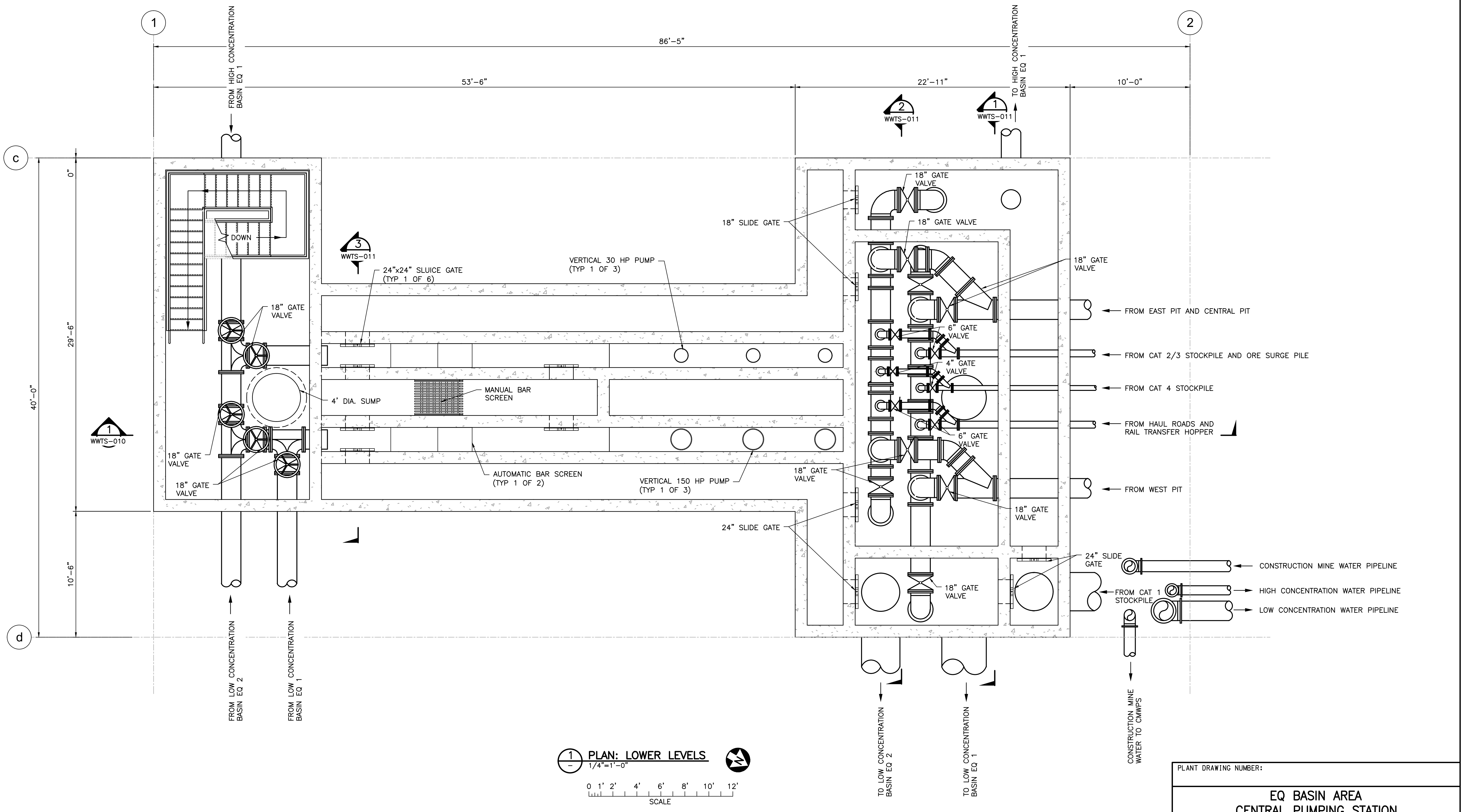
PRINTED NAME BRYAN T. OAKLEY
SIGNATURE B. Oakley
DATE 10/3/17 REG. NO. 24480

DRAWN: JAM4
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

DWG. NO. WWTS-008
REV

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-008.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 9:40 AM

INCHES 1 2



① PLAN: LOWER LEVELS
1/4"=1'-0"

PLANT DRAWING NUMBER:

EQ BASIN AREA
CENTRAL PUMPING STATION
BELOW GRADE PLAN

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

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ISSUED	VERSION	DATE
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FOR CONSTRUCTION		
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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE
DATE 10/3/17 REG. NO. 24480

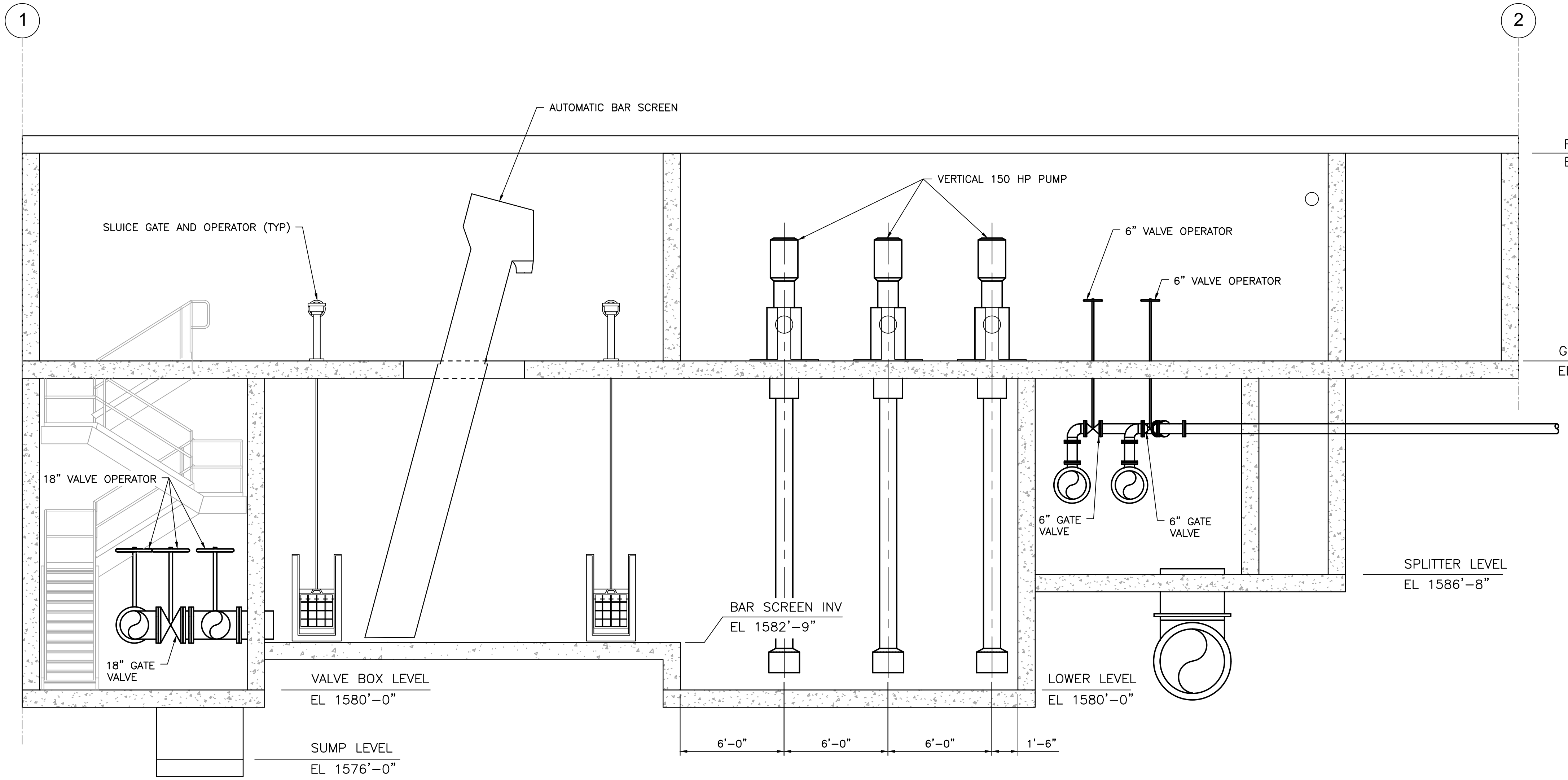
DRAWN: JAM4
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET MINING
POLY MET MINING INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-009
REV

INCHES 1 2



1 SECTION: CENTRAL PUMPING STATION

WWTS-008
WWTS-009

0 1' 2' 4' 6' 8' 10' 12'
SCALE

PLANT DRAWING NUMBER:

EQ BASIN AREA
CENTRAL PUMPING STATION
BUILDING SECTION

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

NOT APPROVED FOR CONSTRUCTION.

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE
DATE 10/3/17 REG. NO. 24480

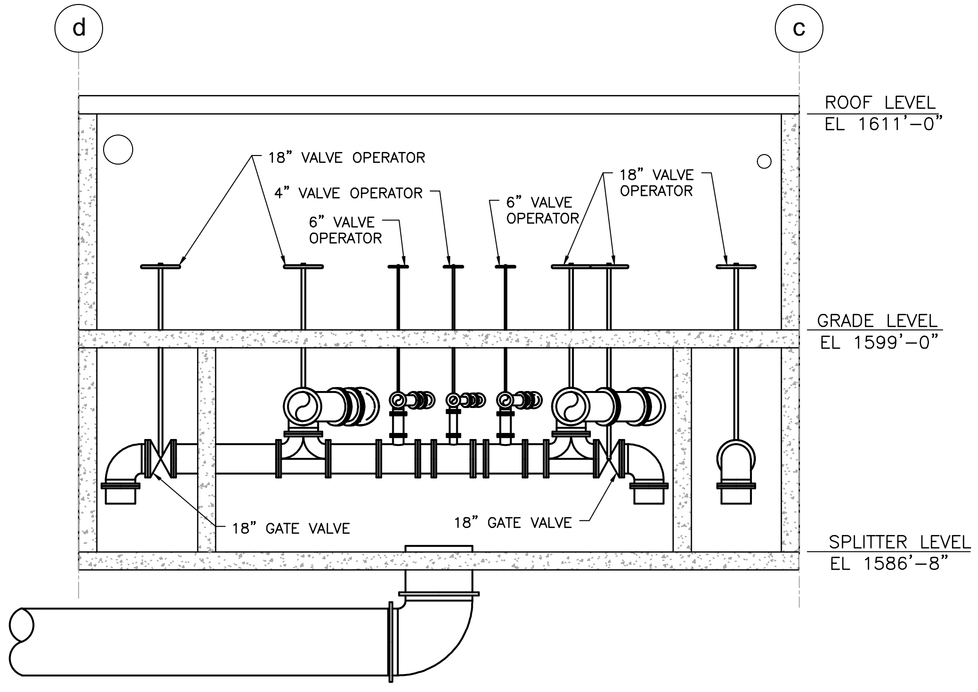
DRAWN: JAM4
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET
MINING

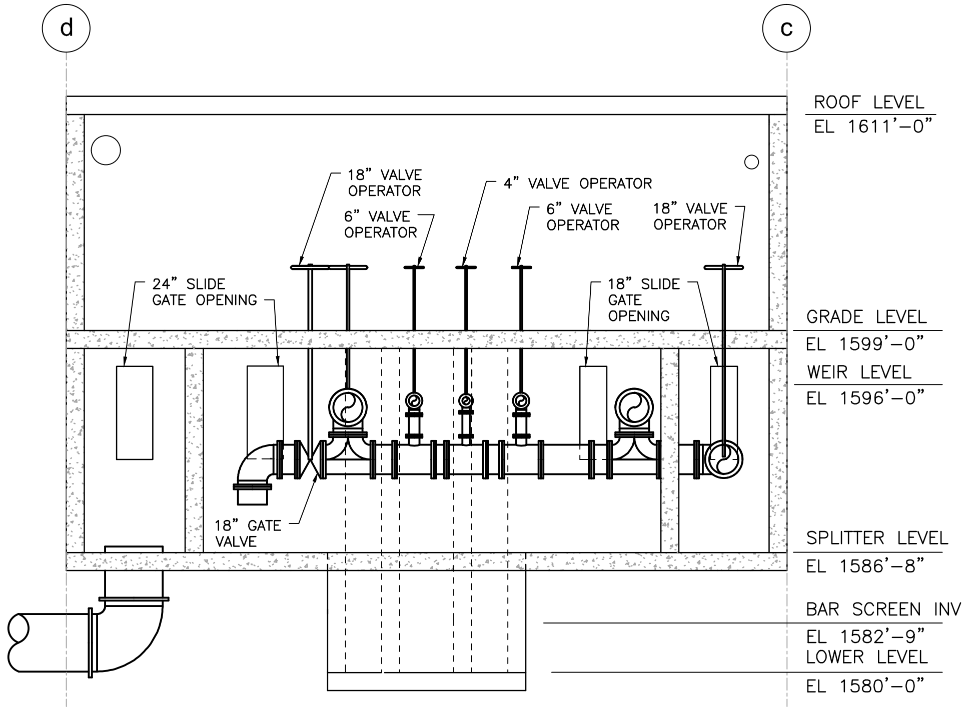
POLY MET MINING INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

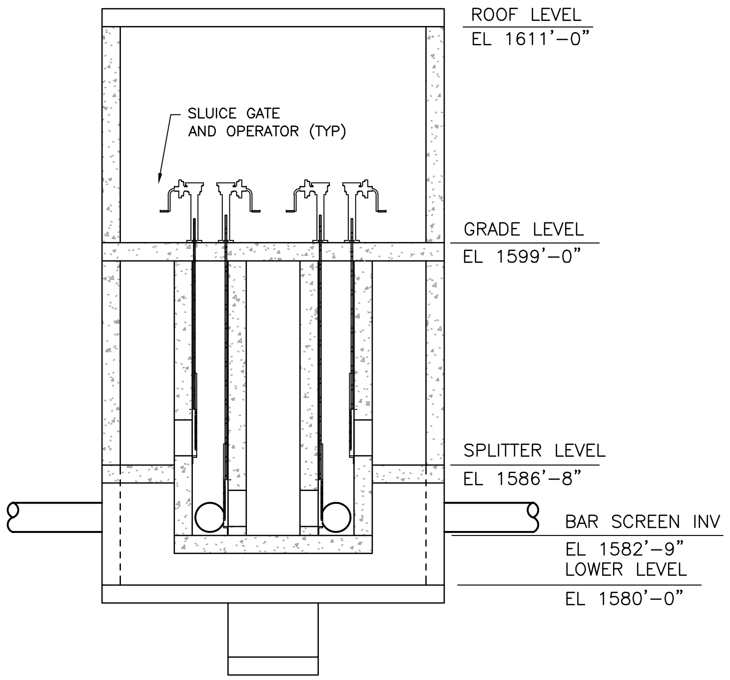
DWG. NO. WWTS-010
REV



1 SECTION: SPLITTER BOX
WWTS-008
WWTS-009
0 1' 4' 8' 12' 16'
SCALE



2 SECTION: SPLITTER BOX
WWTS-008
WWTS-009
0 1' 4' 8' 12' 16'
SCALE



3 SECTION: CHANNELS
WWTS-008
WWTS-009
0 1' 4' 8' 12' 16'
SCALE

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

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ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE
DATE 10/3/17 REG. NO. 24480

DRAWN: JAM4
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

EQ BASIN AREA
CENTRAL PUMPING STATION
BUILDING SECTIONS

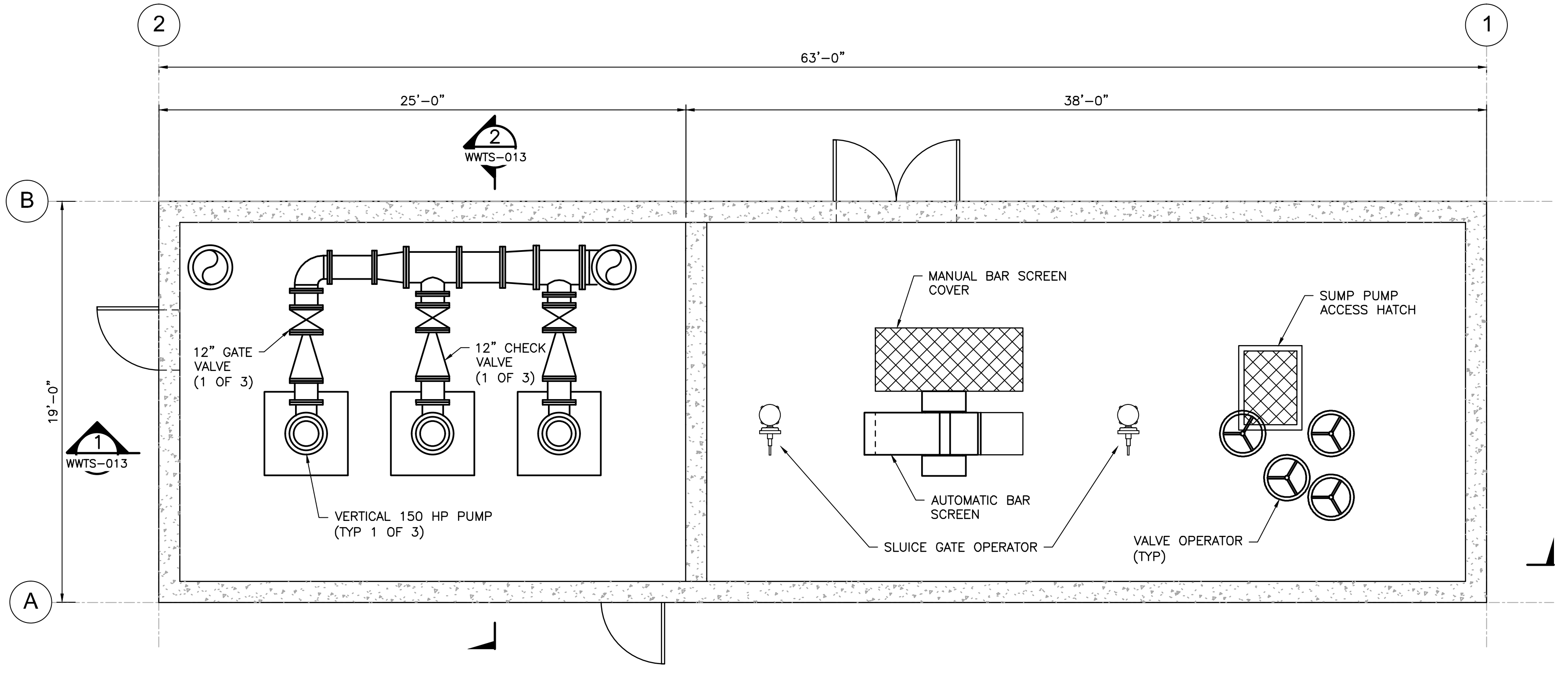
POLYMET MINING
POLY MET MINING INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-011
REV

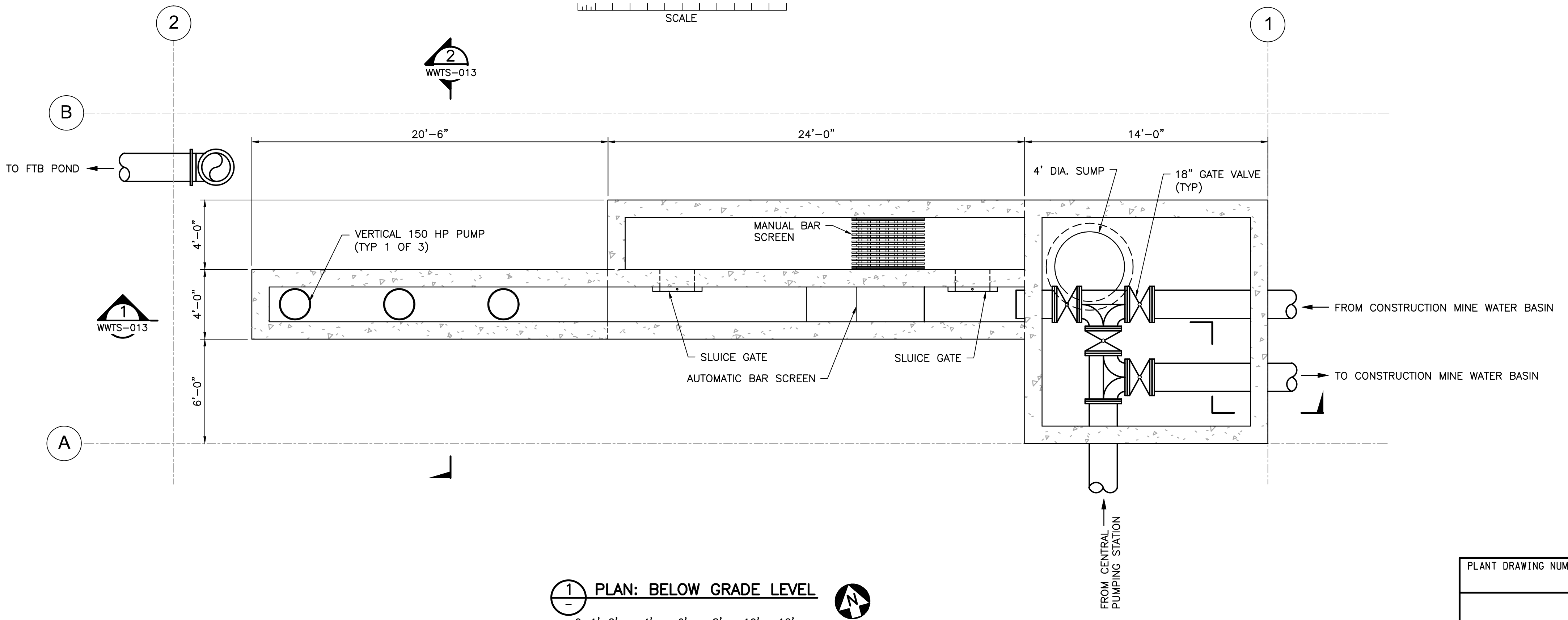
CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-011.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 9:47 AM

INCHES 1 2



1 – PLAN: GRADE LEVEL

SCALE 0 1' 2' 4' 6' 8' 10' 12'



1 – PLAN: BELOW GRADE LEVEL

SCALE 0 1' 2' 4' 6' 8' 10' 12'

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

DRAWING STATUS		
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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE
DATE 10/3/17 REG. NO. 24480

DRAWN: JAM4
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

EQ BASIN AREA
CONSTRUCTION MINE WATER PUMPING STATION PLANS

POLYMET MINING

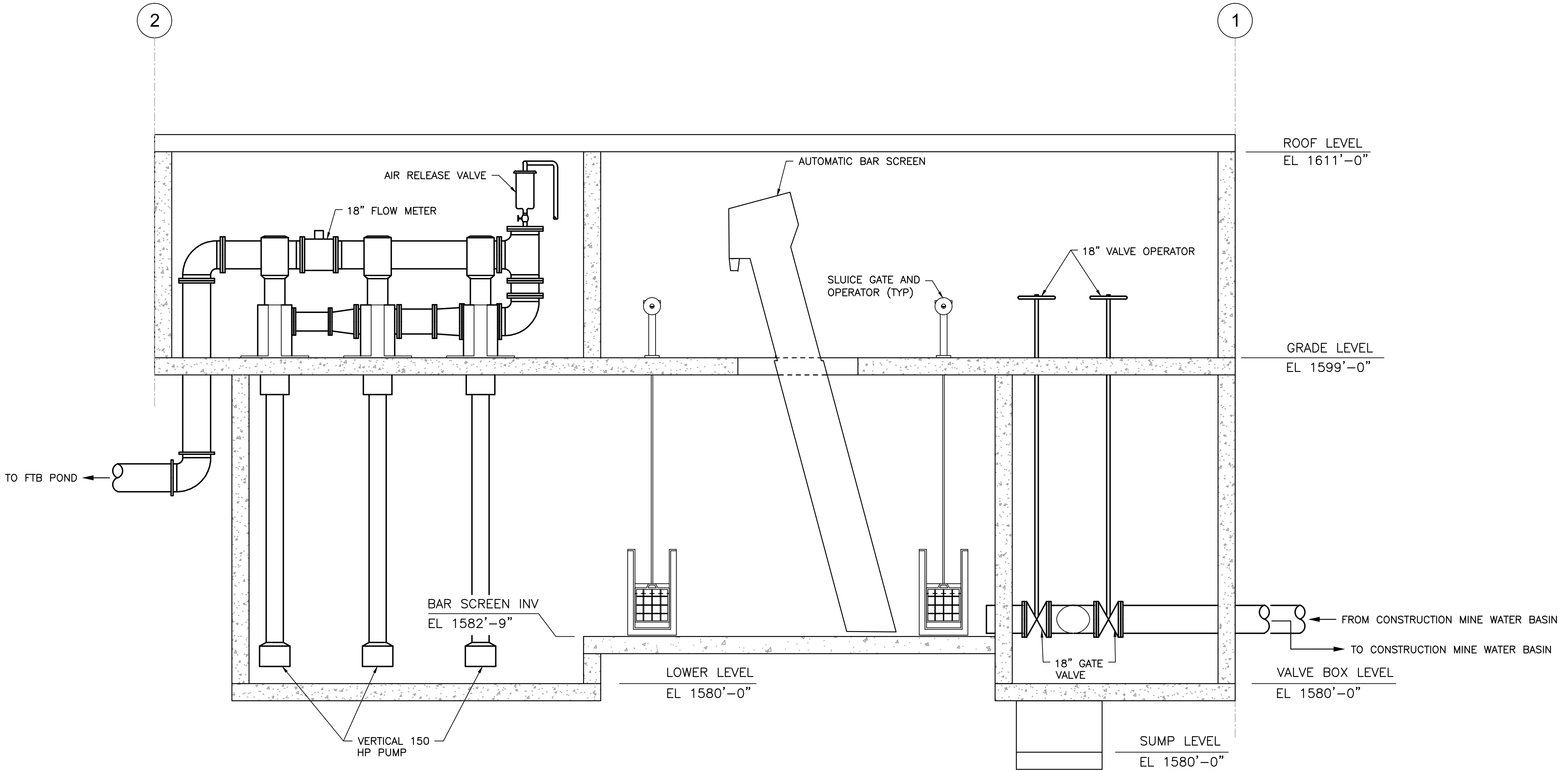
POLY MET MINING INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1–800–632–2277

DWG. NO. WWTS–012
REV

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-012.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 9:50 AM

INCHES 1 2



1 SECTION: PUMPING STATION
WWTS-012

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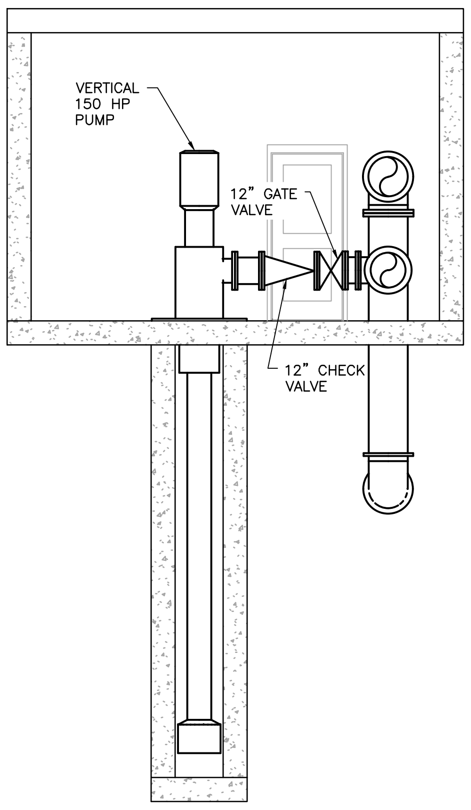
SCALE



2 SECTION: PUMPING STATION
WWTS-012

0 1' 2' 4' 6' 8' 10' 12'
SCALE

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-013.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 9:51 AM

INCHES 1 2

PLANT DRAWING NUMBER:

EQ BASIN AREA
CONSTRUCTION MINE WATER PUMPING STATION
BUILDING SECTIONS

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE
DATE 10/3/17 REG. NO. 24480

DRAWN: JAM4
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET MINING

POLY MET MINING INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-013
REV

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-014.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 9:53 AM

① PLAN: EXISTING CONDITIONS

PLANT DRAWING NUMBER:

PLANT SITE WWTS
EXISTING CONDITIONS

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		
NOT APPROVED FOR CONSTRUCTION.		

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE B. Oakley
DATE 10/3/17 REG. NO. 24480

DRAWN: BJH
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET MINING

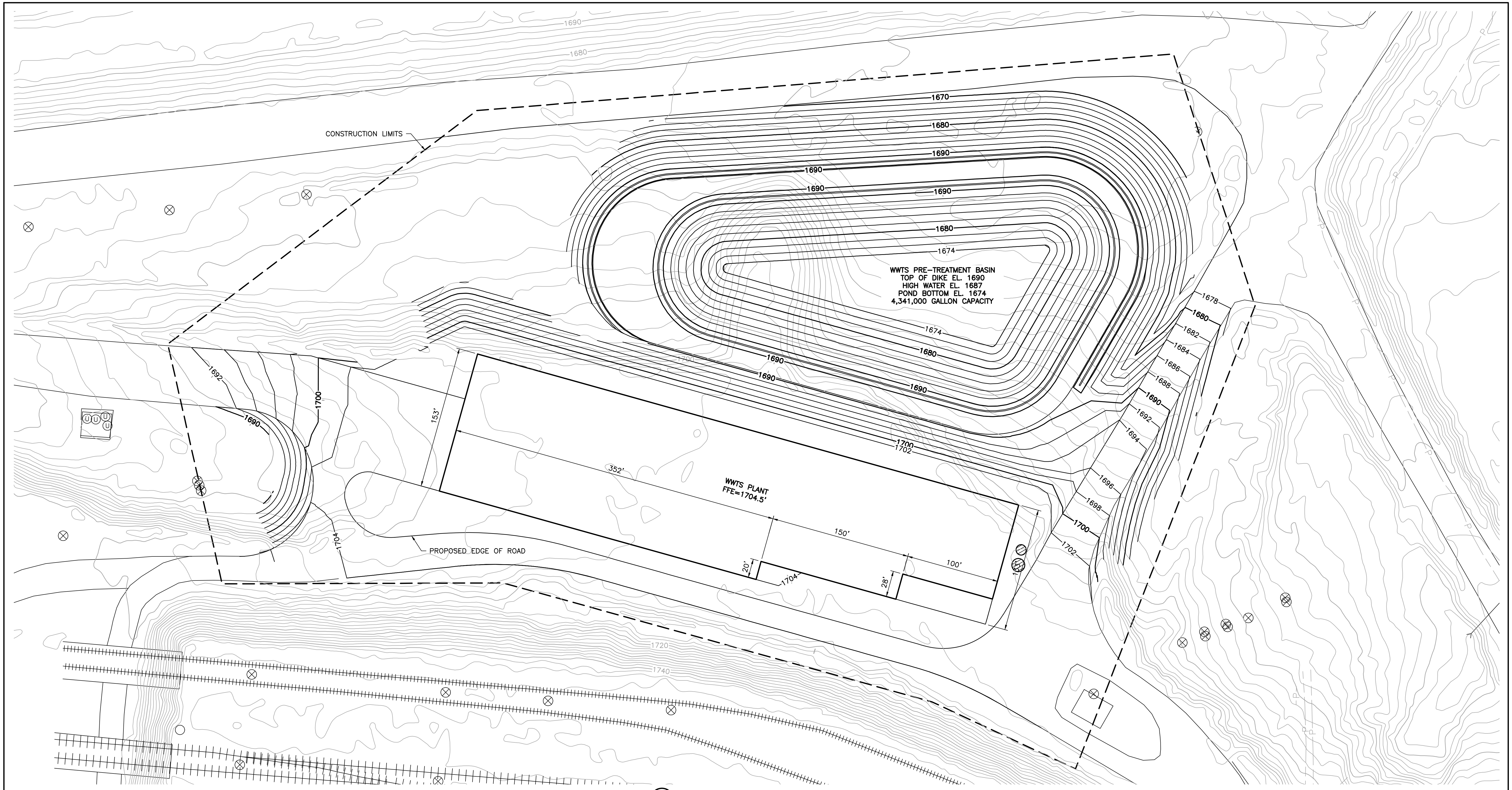
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-014
REV

INCHES
2
1



1 PLAN: SITE GRADING

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE B. Oakley
DATE 10/3/17 REG. NO. 24480

DRAWN: BJH
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

PLANT SITE WWTS
SITE GRADING PLAN AND CONSTRUCTION LIMITS

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-015

REV

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-015.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 10:00 AM

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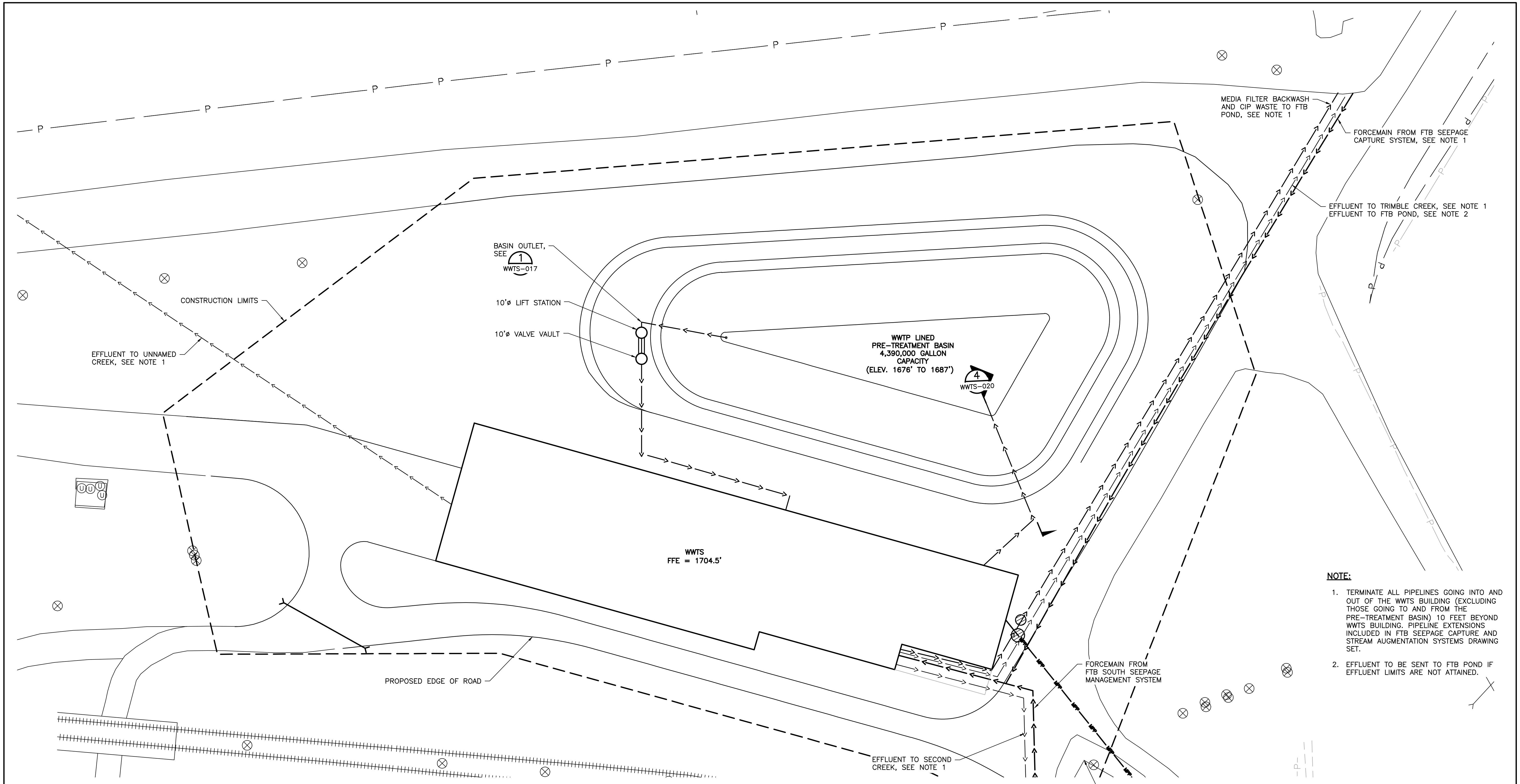

NOTE:

1. TERMINATE ALL PIPELINES GOING INTO AND OUT OF THE WWTS BUILDING (EXCLUDING THOSE GOING TO AND FROM THE PRE-TREATMENT BASIN) 10 FEET BEYOND WWTS BUILDING. PIPELINE EXTENSIONS INCLUDED IN FTB SEEPAGE CAPTURE AND STREAM AUGMENTATION SYSTEMS DRAWING SET.
2. EFFLUENT TO BE SENT TO FTB POND IF EFFLUENT LIMITS ARE NOT ATTAINED.

1 – PLAN: YARD PIPING

0 50 100
SCALE IN FEET

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-016.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 10:09 AM

INCHES 1 2

VER NO	DATE	DESCRIPTION
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FOR CONSTRUCTION		
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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE
DATE 10/3/17 REG. NO. 24480

DRAWN: BJH
CHECKED: JSU
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

PLANT SITE WWTS
BURIED PIPING PLAN

POLYMET MINING

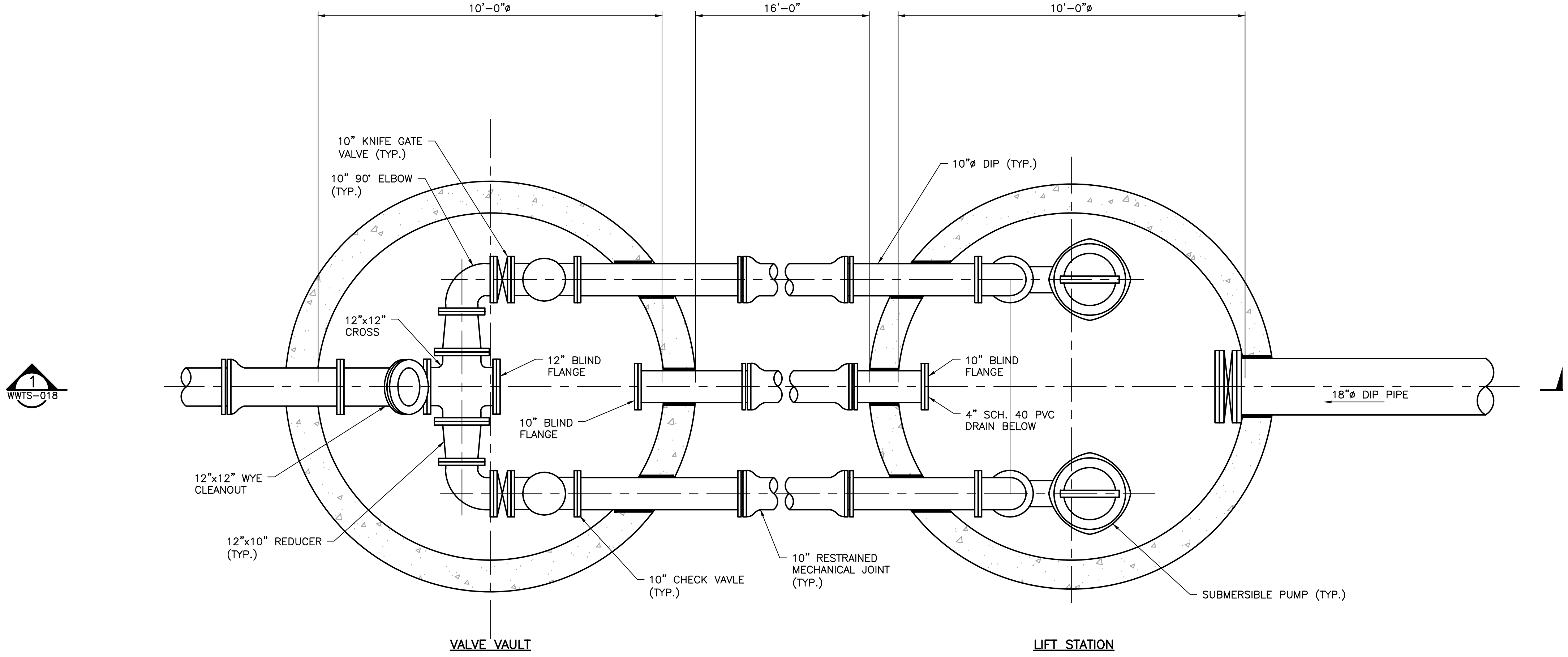
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-016

REV



1 PLAN: PRE-TREATMENT BASIN OUTLET LIFT STATION
WWTP-005

0 2 4
SCALE IN FEET

NOTE:

1. PIPE SIZES ARE PRELIMINARY

VER NO	DATE	DESCRIPTION
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FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		
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PRINTED NAME JEFF S. UBL
SIGNATURE Jeff Ubl
DATE 10/3/17 REG. NO. 19646

DRAWN: MDS
CHECKED: BTO
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

PLANT SITE WWTS
PRETREATMENT BASIN PUMPING STATION
PLAN

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

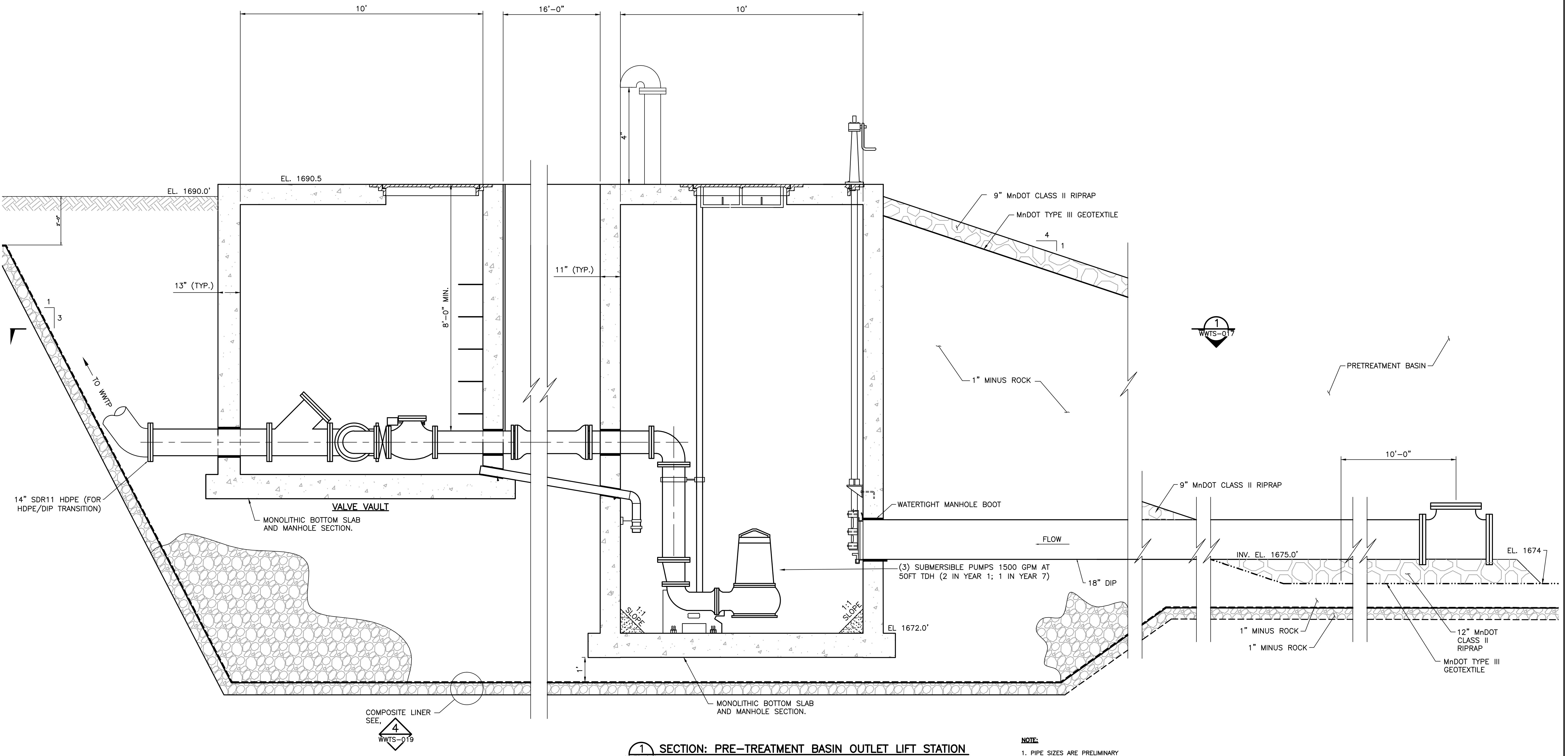
BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-017
REV

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-017.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 10:12 AM

INCHES 1 2



1 WWTP-016 SECTION: PRE-TREATMENT BASIN OUTLET LIFT STATION

0 1 2 3 4
SCALE IN FEET

NOTE:

1. PIPE SIZES ARE PRELIMINARY

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-018.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 10:13 AM

INCHES 1 2

PLANT DRAWING NUMBER:

PLANT SITE WWTS
PRETREATMENT BASIN PUMPING STATION
SECTION

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

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ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		
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PRINTED NAME JEFF S. UBL
SIGNATURE Jeff Ubl
DATE 10/3/17 REG. NO. 19646

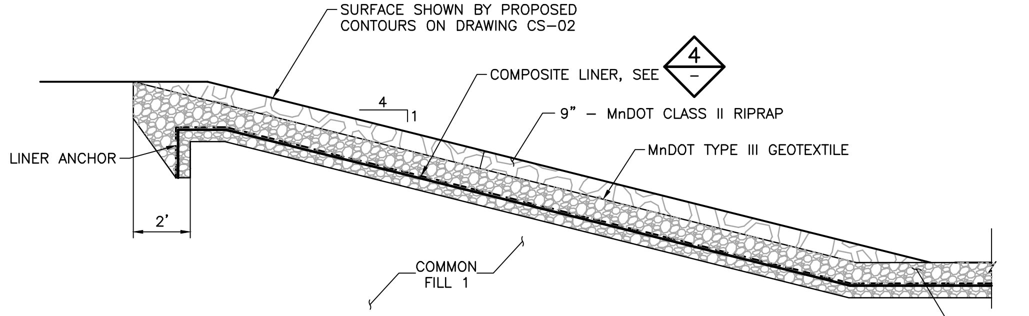
DRAWN: MDS
CHECKED: BTO
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET MINING
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-018
REV

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-019.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 2:28 PM



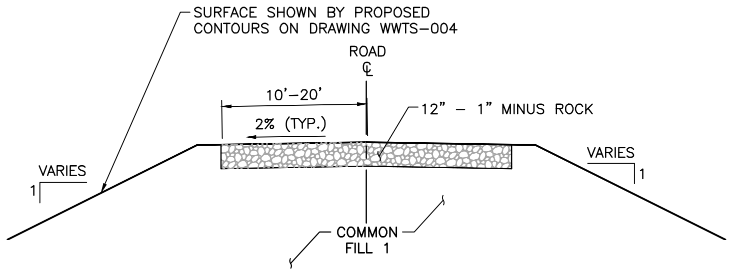
1 SECTION: LINED BASIN SIDESLOPE AND BOTTOM (TYP.)

WWTS-004

0 4 8
SCALE IN FEET

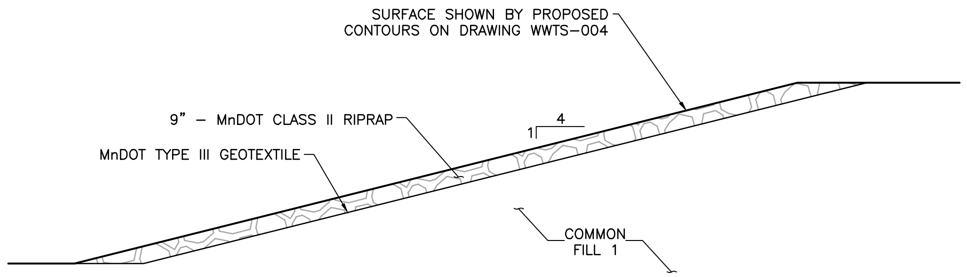
NOTE:

SEE DETAIL 5 – FOR SIDESLOPE LINER NEAR CENTRAL



2 SECTION: ACCESS/SERVICE ROAD (TYP.)

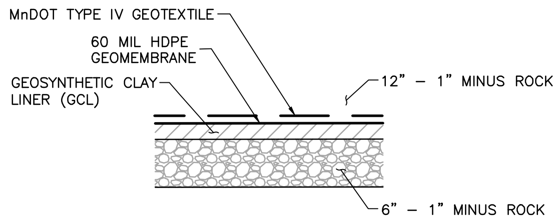
WWTS-004



3 SECTION: CONSTRUCTION MINE WATER BASIN SIDESLOPE AND BOTTOM (TYP.)

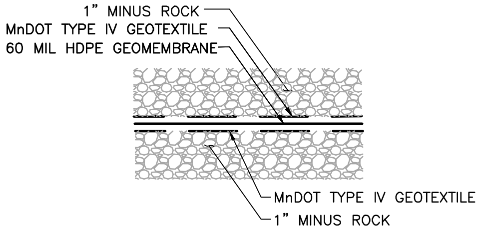
WWTS-004

0 4 8
SCALE IN FEET



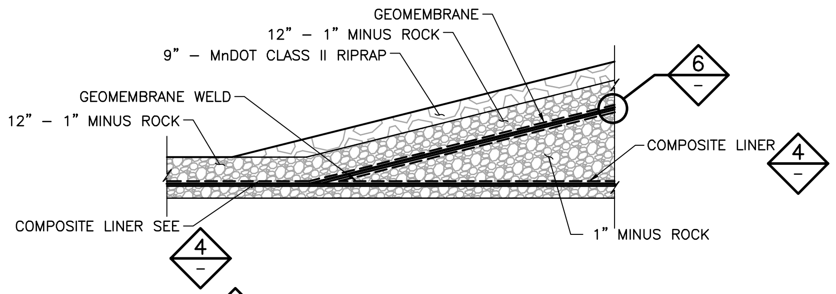
4 DETAIL: EQ BASIN COMPOSITE LINER

WWTS-018 & 020 NOT TO SCALE



6 DETAIL: PRE-TREATMENT LINER

– NOT TO SCALE



5 DETAIL: SECONDARY CONTAINMENT LINER ATTACHMENT

WWTS-007

0 4 8
SCALE IN FEET

PLANT DRAWING NUMBER:

SECTIONS AND DETAILS

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

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PRINTED NAME JEFF S. UBL
SIGNATURE Jeff Ubl
DATE 10/3/17 LICENSE# 19646

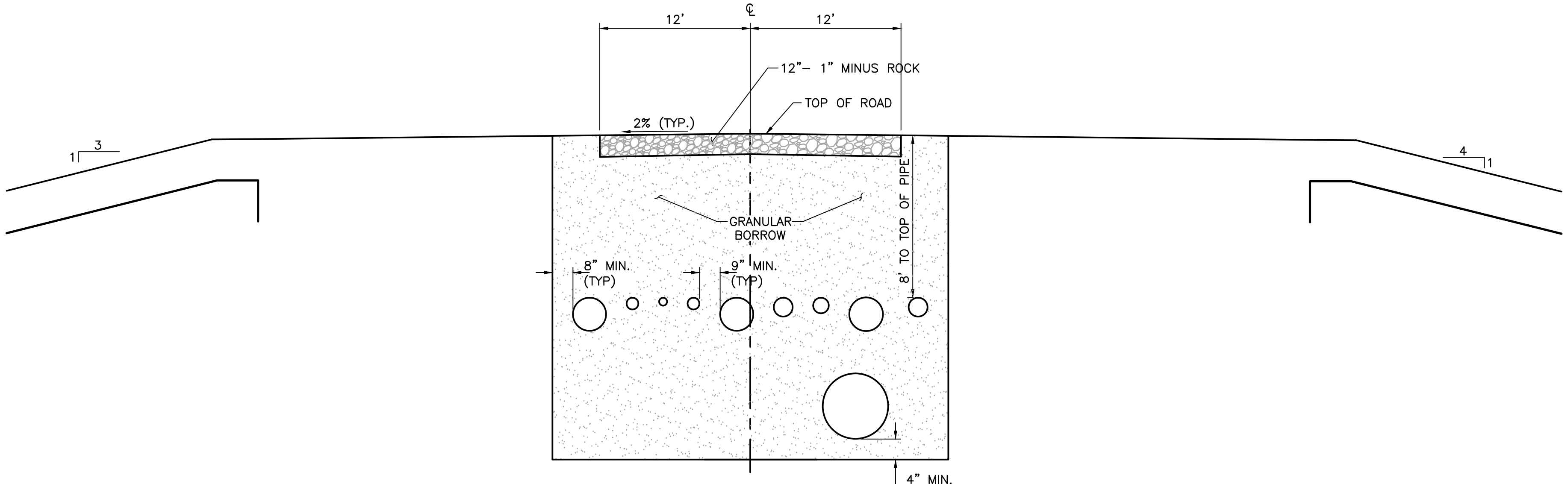
DRAWN: BJH
CHECKED: BTO
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET MINING
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

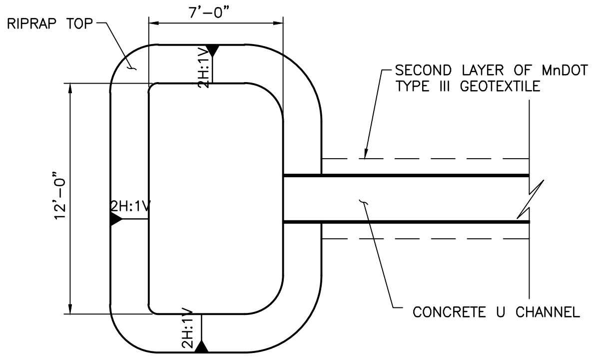
BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-019
REV

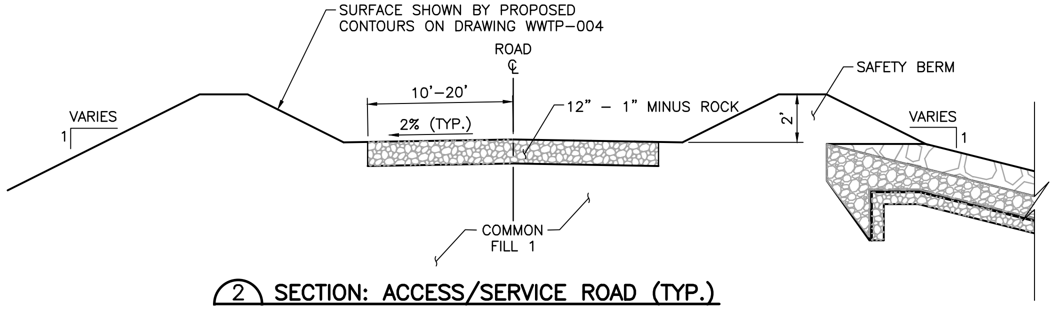
INCHES 1 2



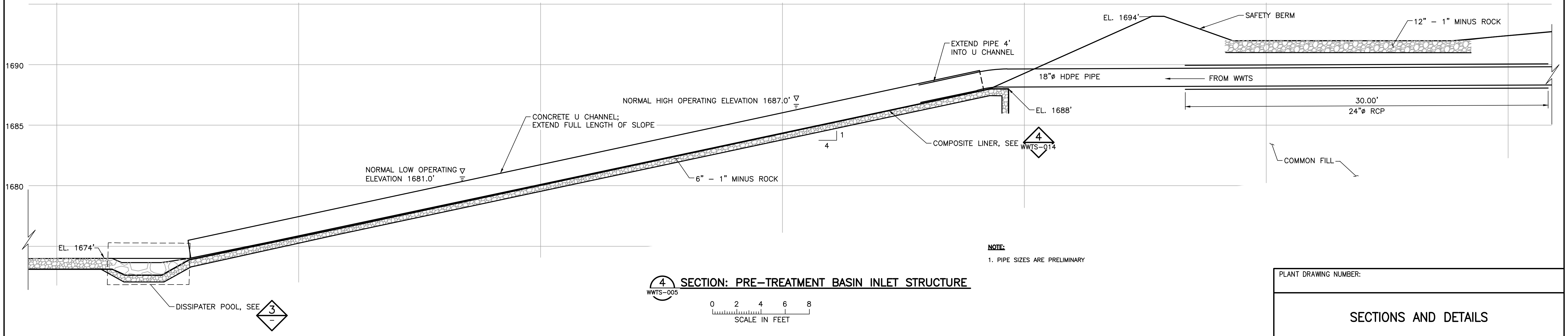
1 SECTION: PIPE TRENCH (TYP.)
WWTS-005 NOT TO SCALE



3 DETAIL: DISSIPATER POOL
WWTS-007
0 5 10
SCALE IN FEET



2 SECTION: ACCESS/SERVICE ROAD (TYP.)
WWTS-015 NOT TO SCALE



NOTE:

1. PIPE SIZES ARE PRELIMINARY

4 SECTION: PRE-TREATMENT BASIN INLET STRUCTURE
WWTS-005
0 2 4 6 8
SCALE IN FEET

PLANT DRAWING NUMBER:

SECTIONS AND DETAILS

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PRINTED NAME JEFF S. UBL
SIGNATURE Jeff Ubl
DATE 10/3/17 REG. NO. 19646

DRAWN: BJH
CHECKED: BTO
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

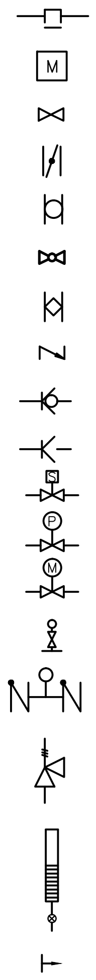
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-020
REV

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-020.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 10:19 AM

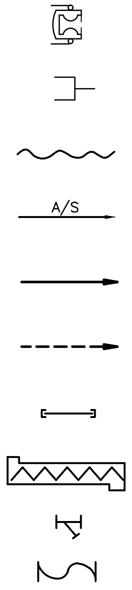
CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-021.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 10:19 AM

VALVE SYMBOLS



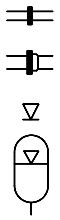
- IPS EXPANSION JOINT COUPLING
- FLOW METER
- GATE OR GENERIC VALVE
- BUTTERFLY VALVE
- GLOBE VALVE
- BALL VALVE
- PLUG VALVE
- CHECK VALVE
- BALL CHECK VALVE
- BUTTERFLY CHECK VALVE
- SOLENOID OPERATED VALVE
- PNEUMATIC OPERATED VALVE
- MOTOR OPERATED VALVE
- AIR RELEASE VALVE
- PNEUMATIC OPERATED BACKFLOW PREVENTER
- PRESSURE RELIEF VALVE
- CALIBRATION CYLINDER
- SLUICE GATE

PIPING SYMBOLS



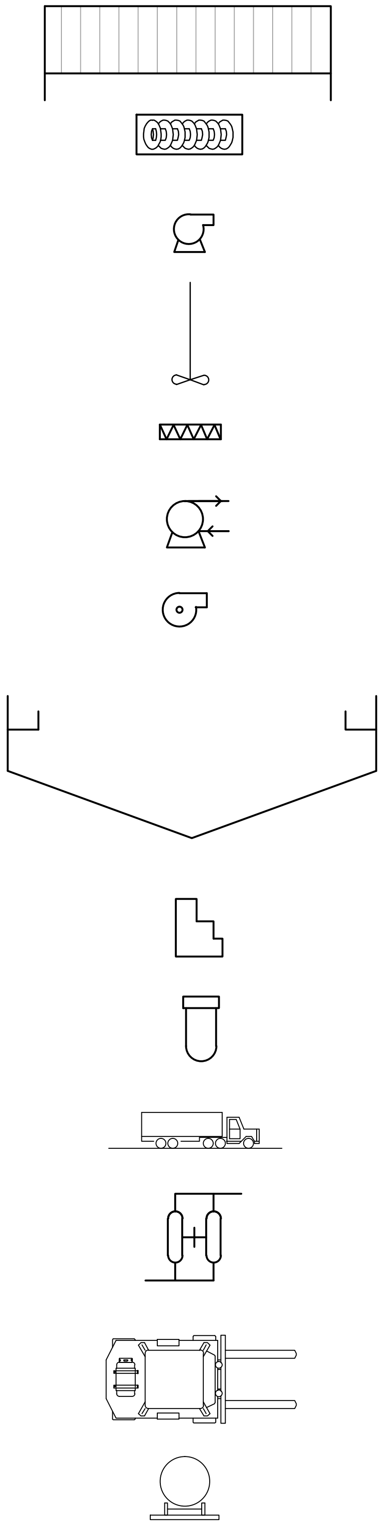
- QUICK CONNECT COUPLING
- HOSE COUPLING
- FLEXIBLE HOSE
- AIR SUPPLY
- CONNECTION TO PROCESS
- INTERMITTENT OR SEASONAL FLOW
- SLIDE GATE/SLUICE GATE
- SCREW CONVEYOR
- Y-STRAINER
- FLEXIBLE CONNECTION

MECHANICAL PIPING



- FLANGED JOINT
- MECANICAL JOINT
- LIQUID LEVEL
- PULSATION DAMPENER

TYPICAL EQUIPMENT



- FILTER PRESS
- SCREW FEED
- CENTRIFUGAL PUMP
- MIXER
- STATIC MIXER
- HOSE PUMP
- BLOWER
- CLARIFIER
- CHEMICAL METERING PUMP
- CARTRIDGE FILTER OR BASKET STRAINER
- TRUCK
- DIAPHRAGM PUMP
- FORK LIFT
- RAIL CAR

MECHANICAL ABBREVIATIONS

PIPING MATERIALS

BSP	BLACK STEEL PIPE	GALV	GALVANIZED STEEL PIPE
CI	CAST IRON PIPE	HDPE	HIGH DENSITY POLYETHYLENE
		PIP	POLYETHYLENE PIPE
CMP	CORRUGATED METAL PIPE	PVC	POLYVINYL CHLORIDE PIPE
CS	CARBON STEEL	RCP	REINFORCED CONCRETE PIPE
CU	COPPER PIPE	RED	REDUCER
DIP	DUCTILE IRON PIPE	SST,SS	STAINLESS STEEL PIPE
FRP	FIBERGLASS REINFORCED PLASTIC		

PROCESS FLOW STREAM

AIR	COMPRESSED AIR	NPW	NON-POTABLE-WATER
BYP	BYPASS	OVF	OVERFLOW
CW	COLD WATER	PA	PLANT AIR
DR	DRAIN	PW	PLANT WATER
EFF	EFFLUENT	REC	RECYCLE
FE	FINAL EFFLUENT	SC	SCUM
FM	FORCEMAIN	SE	SECONDARY EFFLUENT
FW	FLUSHING WATER	SN	SUPERNATANT, SUBNATANT
GS	GRIT SLURRY	SW	STORM WATER
HC	HOSE CONNECTION	TD	TANK DRAIN
INF	PROCESS BASIN INFLUENT	VT	VENT

VALVE AND FITTING NOMENCLATURE

BCV	BALL CHECK VALVE		
BFV	BUTTERFLY VALVE		
BPRV	BACK PRESSURE REGULATING VALVE	PE	PLAIN END
BV	BALL VALVE	POJ	PUSH ON JOINT
COMP JT	COMPRESSION JOINT	PRV	PRESSURE RELIEF VALVE
CPLG	COUPLING	PV	PLUG VALVE
CV	CHECK VALVE (AIR CUSHION)	PVRV	PRESSURE VACUUM RELIEF VALVE
DO	DISSOLVED OXYGEN PROBE	RJ	RESTRAINED JOINT
EXP JT	EXPANSION JOINT	SJ	SOLDERED JOINT
FAC	FLANGED ADAPTER COUPLING	SOLV	SOLENOID VALVE
FH	FIRE HYDRANT	THD	THREADED
FS	FLOOR STAND	TUBV	TRUE IRON BALL VALVE
GOV	GLOBE VALVE	UN	UNION
GV	GATE VALVE	VB	VALVE BOX
MJ	MECHANICAL JOINT	VC	VICTAULIC COUPLING (SHOULDERED ENDS)
MV	MUD VALVE	WAP	WALL PIPE
P	PUMP	WJ	WELDED JOINT
PBAV	PLASTIC BALL VALVE	WP	WELDED PIPE
		WSV	WALL SLEEVE

PROCESS ABBREVIATIONS

CIP	CLEAN IN PLACE
CPS	CENTRAL PUMPING STATION
FTB	FLOTATION TAILINGS BASIN
HCL	HYDROCHLORIC ACID
HDS	HIGH DENSITY SLUDGE
NF	NANO FILTRATION
RO	REVERSE OSMOSIS
WWTS	WASTE WATER TREATMENT SYSTEM

VER NO	DATE	DESCRIPTION
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PRINTED NAME DON E. RICHARD
SIGNATURE DER
DATE 10/3/17 REG. NO. 21193

DRAWN: KKB
CHECKED: ALL
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

MECHANICAL SYMBOLS AND LEGEND

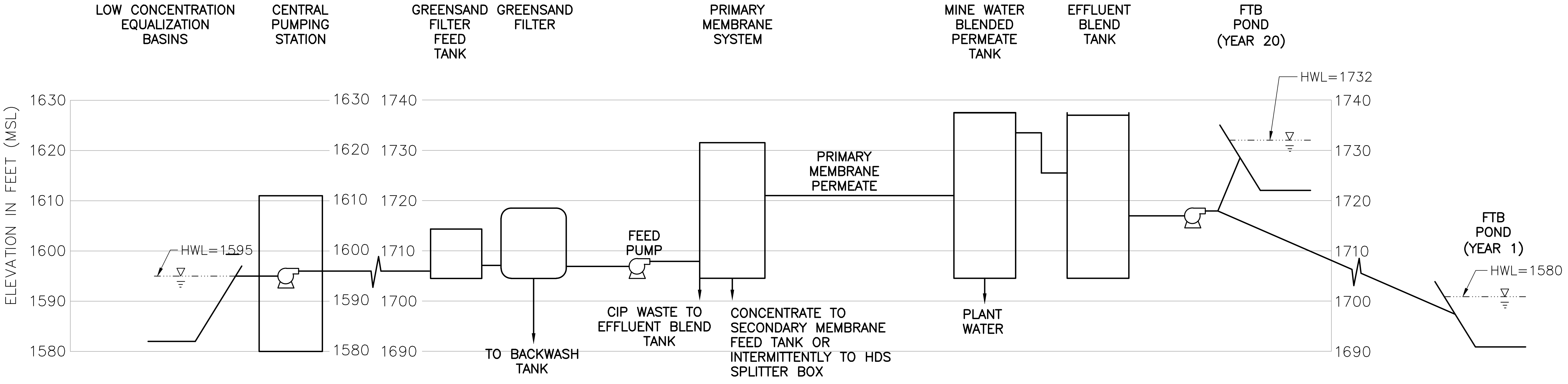
POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

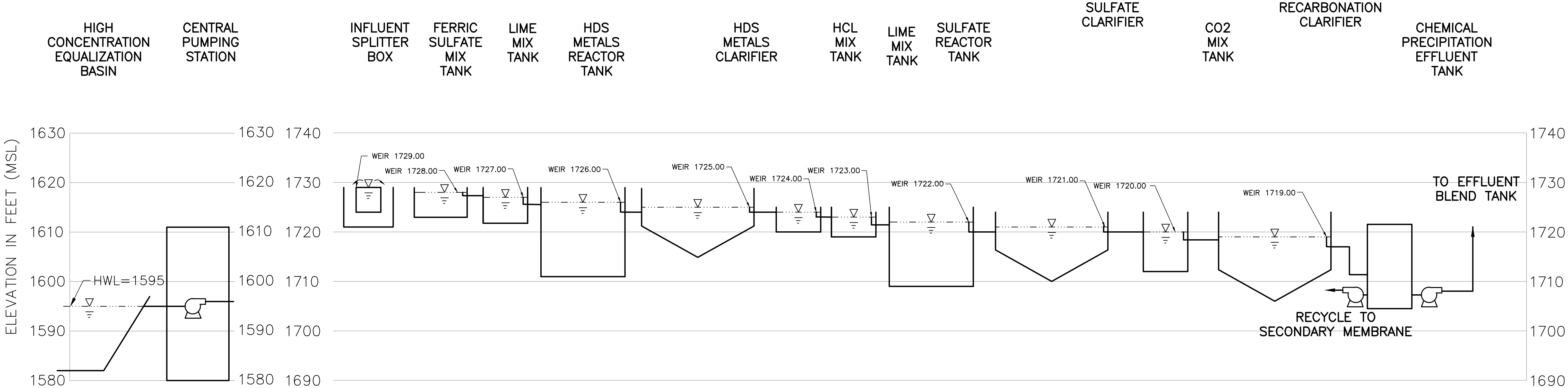
BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-021
REV



MINE WATER MEMBRANE FILTRATION TRAIN – HYDRAULIC PROFILE
(NO HORIZONTAL SCALE)



MINE WATER CHEMICAL PRECIPITATION TRAIN – HYDRAULIC PROFILE
(NO HORIZONTAL SCALE)

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE
DATE 10/3/17 REG. NO. 24480

DRAWN: KKB
CHECKED: ALL
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDRAULIC PROFILE
MINE WATER TREATMENT TRAINS
PRIMARY FLOW

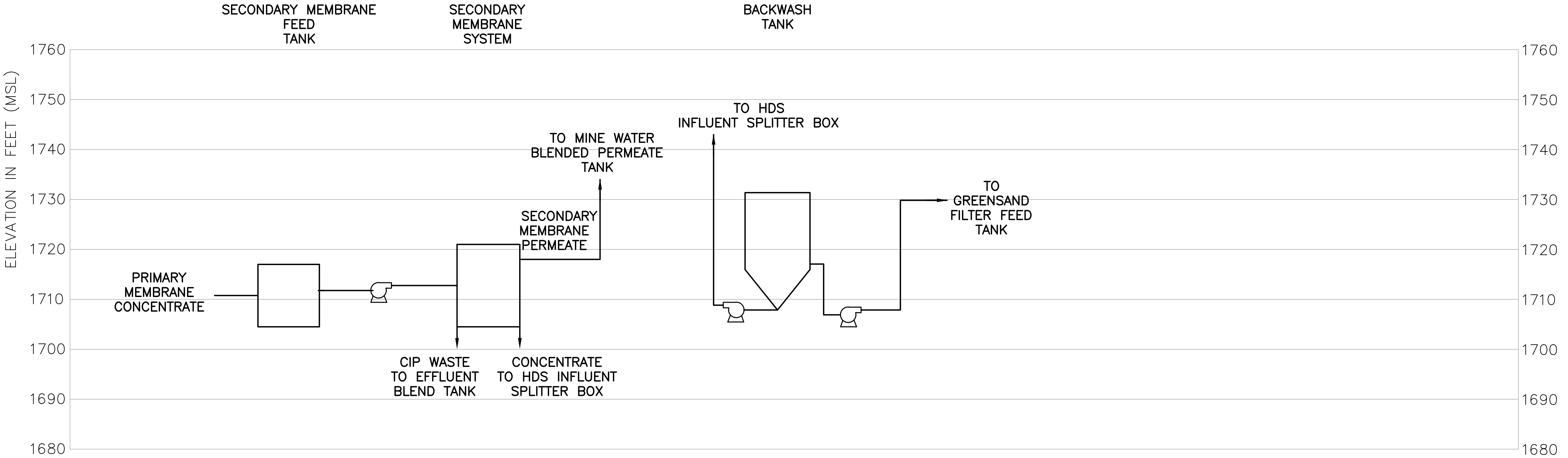
POLYMET MINING
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-022
REV

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-022.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 10:20 AM

INCHES 1 2



MINE WATER TRAINS RESIDUALS – HYDRAULIC PROFILE
(NO HORIZONTAL SCALE)

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-023.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 10:21 AM

INCHES 1 2

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE B.S.O.
DATE 10/3/17 REG. NO. 24480

DRAWN: KKB
CHECKED: ALL
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

HYDRAULIC PROFILE
MINE WATER TREATMENT TRAINS
RESIDUALS

POLYMET MINING

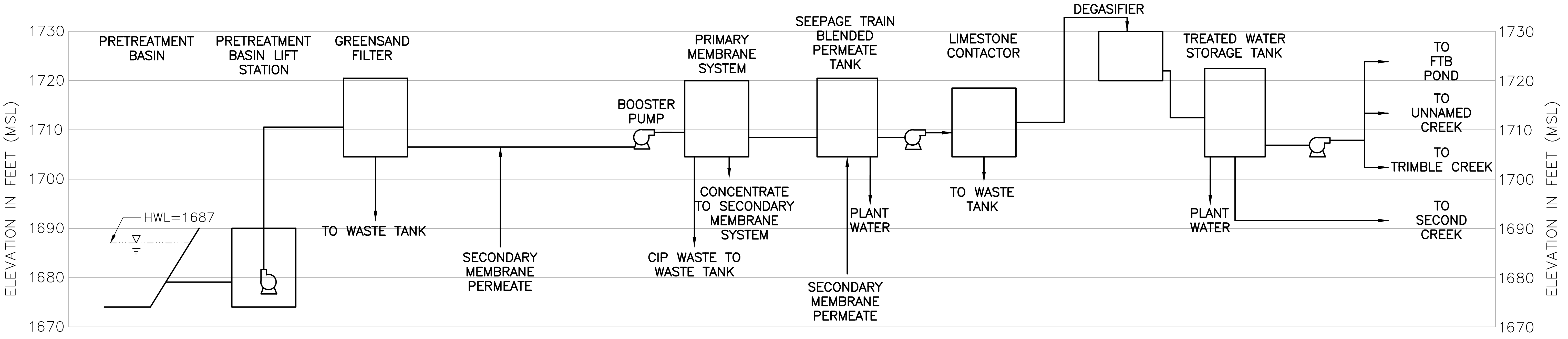
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

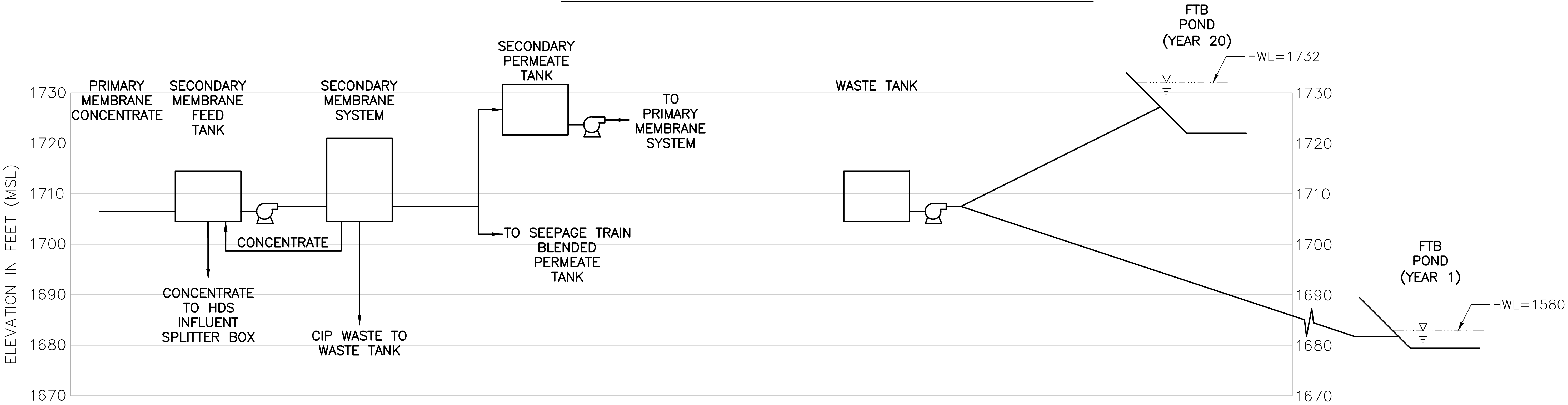
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-023
REV

CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-024.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 10:22 AM



SEEPAGE TRAIN PRIMARY MEMBRANE SYSTEM – HYDRAULIC PROFILE



SEEPAGE TRAIN RESIDUALS – HYDRAULIC PROFILE

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE B. SOQQ
DATE 10/3/17 REG. NO. 24480

DRAWN: KKB
CHECKED: ALL
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

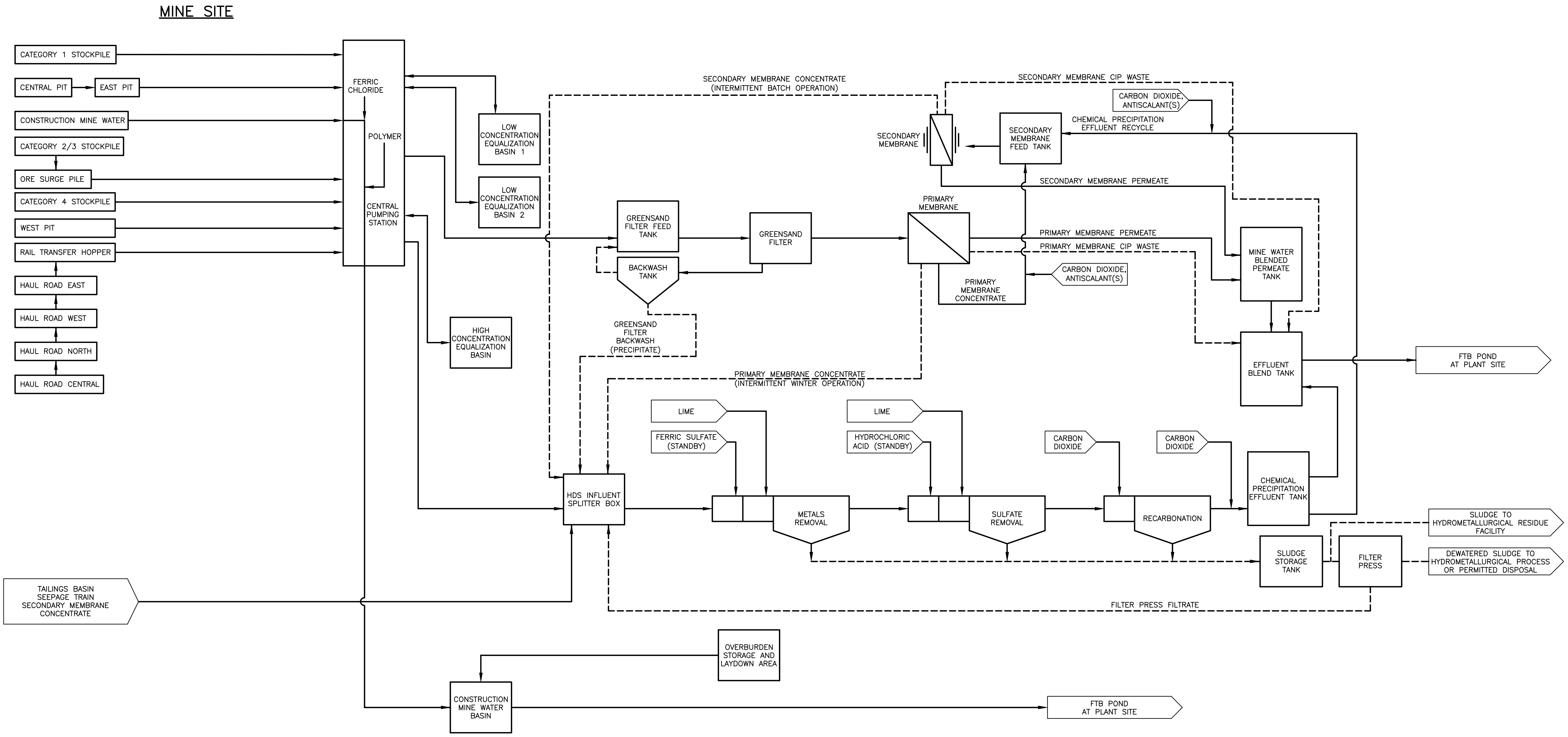
HYDRAULIC PROFILE
TAILINGS BASIN SEEPAGE TREATMENT TRAIN

POLYMET MINING
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-024
REV

INCHES 1 2



VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUE STATUS

ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

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PRINTED NAME DON E. RICHARD
SIGNATURE Don Richard
DATE 10/3/17 LICENSE# 21193

DRAWN: MDS
CHECKED: ALL
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
MINE WATER TREATMENT TRAINS OVERVIEW

POLYMET MINING

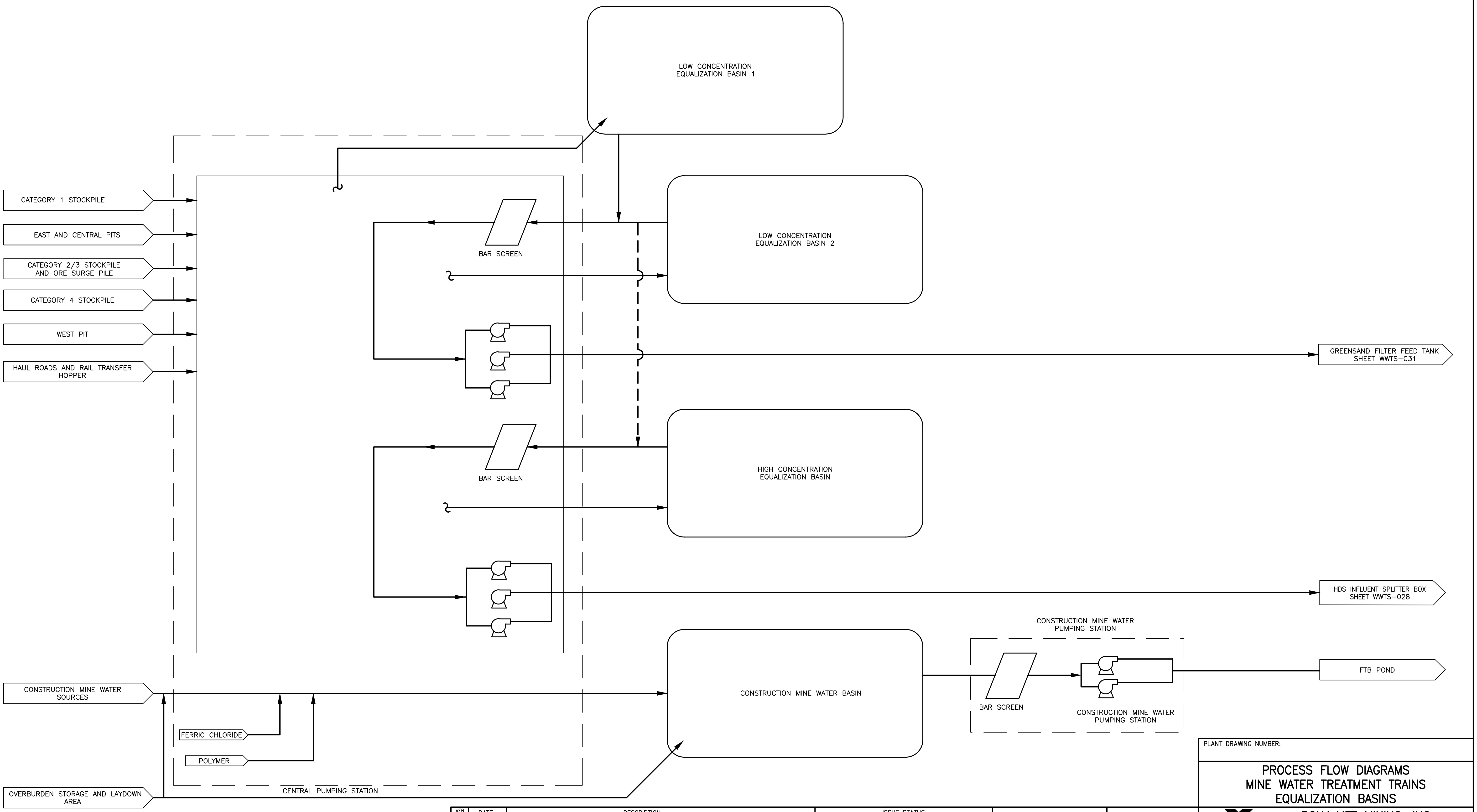
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-025
REV

INCHES 1 2



CADD USER: Joseph A. Milashius FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-026.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 12:32 PM

INCHES 1 2

PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
MINE WATER TREATMENT TRAINS
EQUALIZATION BASINS

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

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PRINTED NAME DON E. RICHARD
SIGNATURE
DATE 10/3/17 LICENSE# 21193

DRAWN: KKB
CHECKED: BTO
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

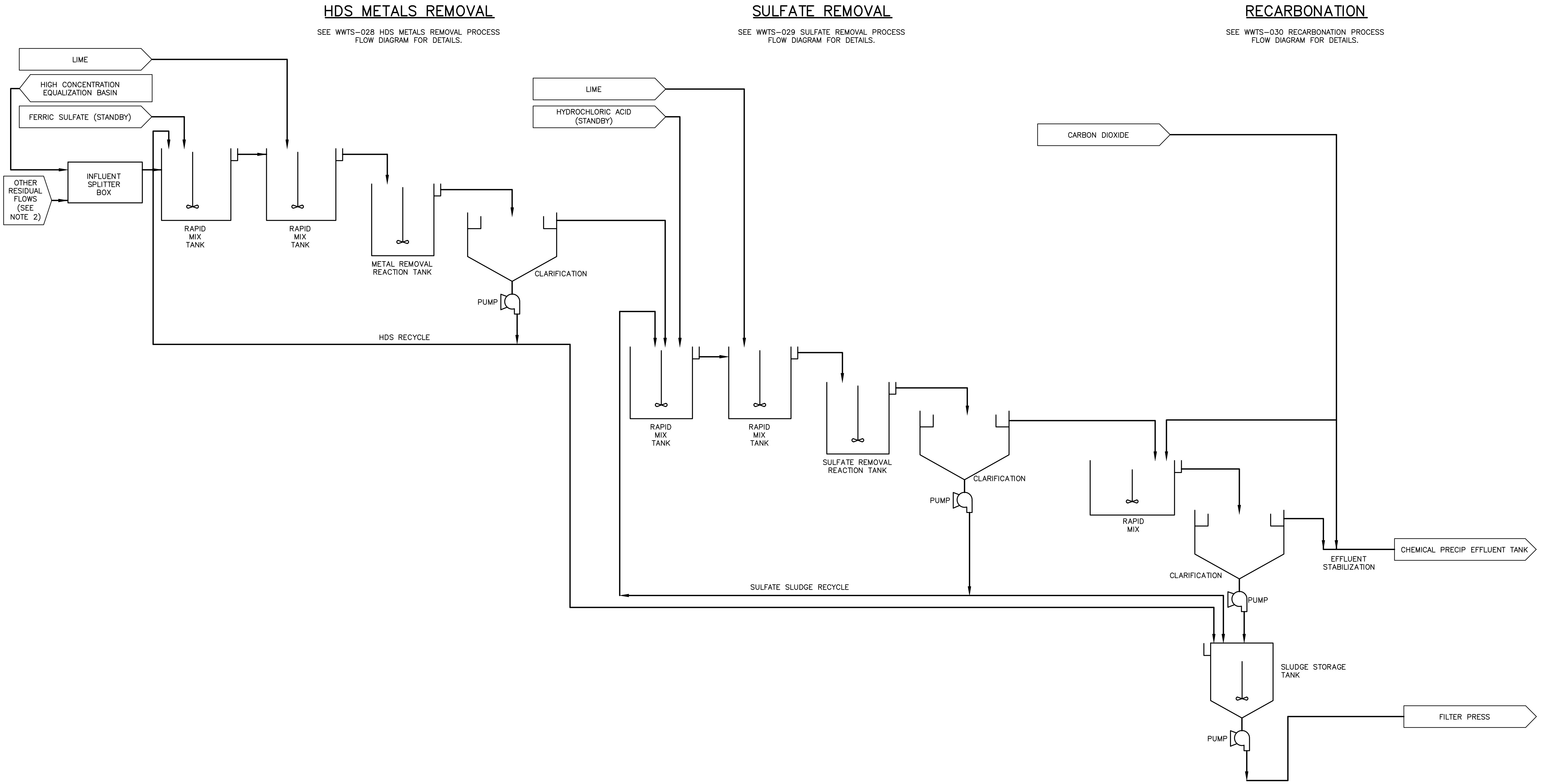
POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-026
REV



NOTES:
1. TREATMENT LAYOUT IS TYPICAL FOR TWO TRAINS.
2. SEE SHEET WWTS-028 FOR OTHER RESIDUAL FLOWS.

VER NO	DATE	DESCRIPTION	ISSUE STATUS	VERSION	DATE
			ISSUED	VERSION	DATE
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS	FOR PERMITTING	1	10/3/17
			FOR CONSTRUCTION		
			NOT APPROVED FOR CONSTRUCTION.		

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PRINTED NAME DON E. RICHARD
SIGNATURE
DATE 10/3/17 LICENSE# 21193

DRAWN: KKB
CHECKED: ALL
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
MINE WATER TREATMENT TRAINS
CHEMICAL PRECIPITATION OVERVIEW

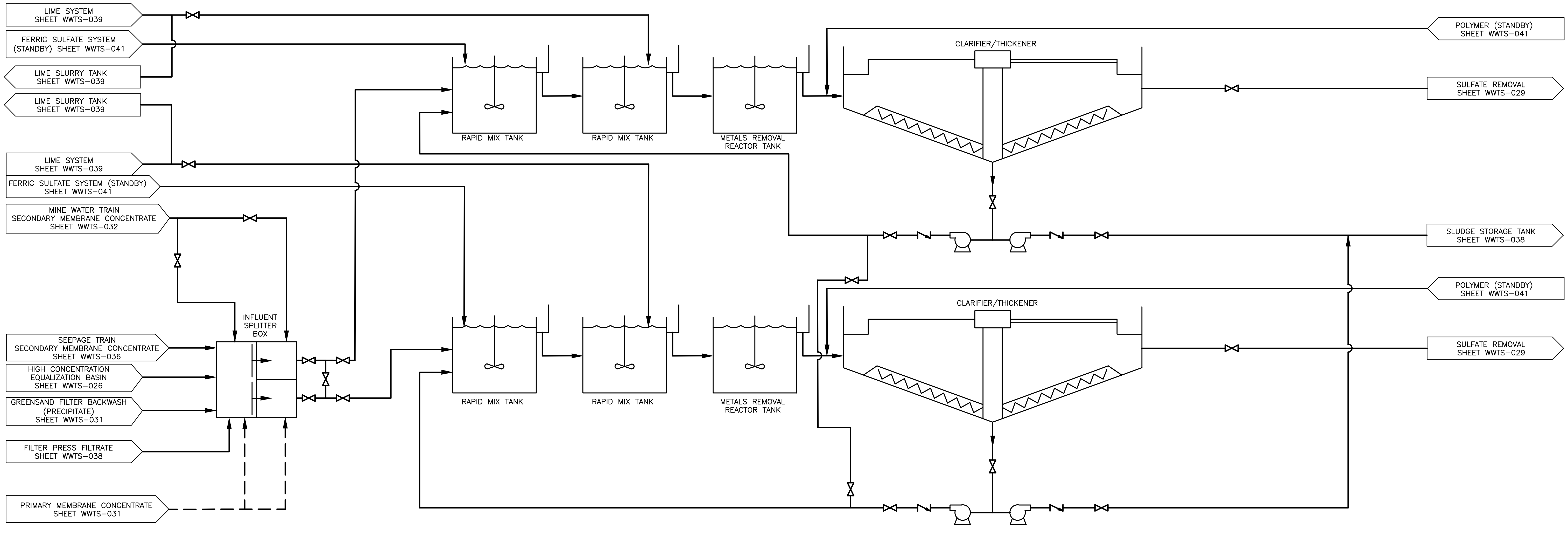
POLYMET MINING
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-027
REV

CADD USER: Joseph A. Milashius FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-027.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 12:36 PM

INCHES 1 2



PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
MINEWATER TREATMENT TRAINS
HDS METALS REMOVAL

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

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PRINTED NAME DON E. RICHARD
SIGNATURE Don Richard
DATE 10/3/17 LICENSE# 21193

DRAWN: KKB
CHECKED: EJA
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

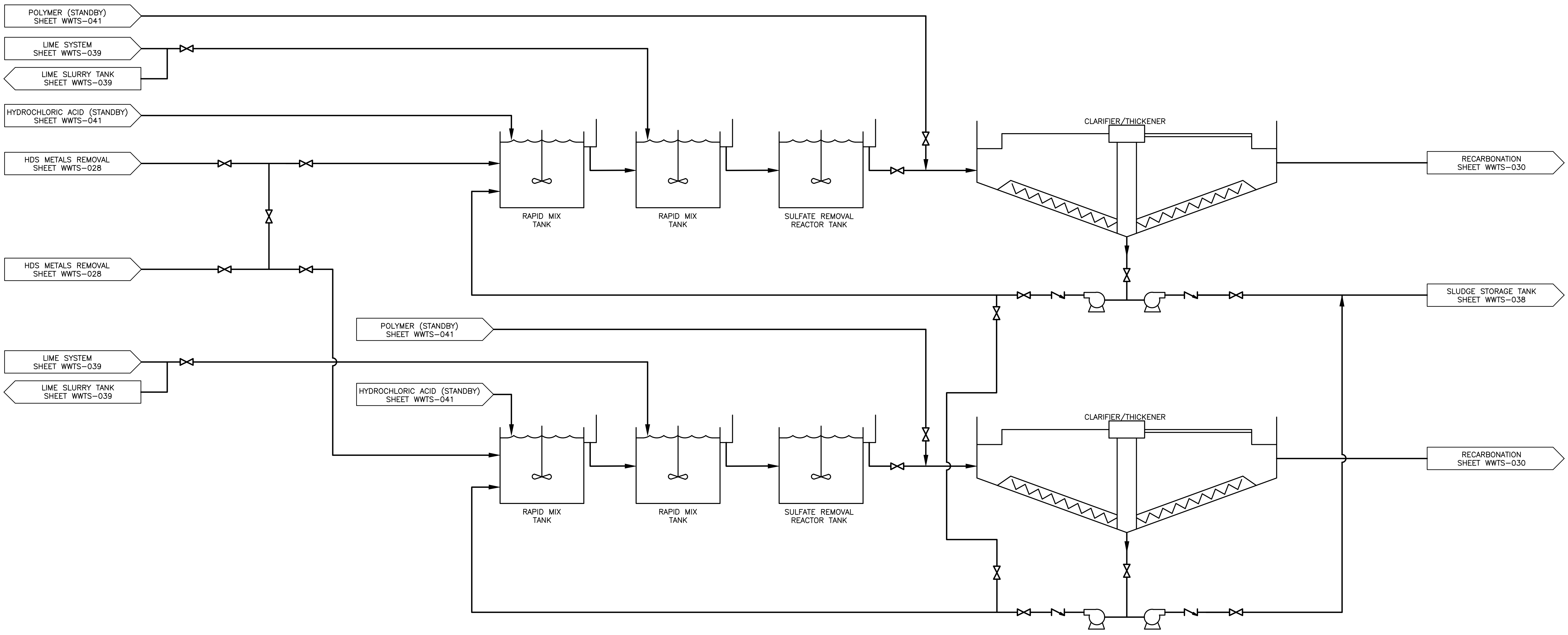
BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-028
REV

CADD USER: Joseph A. Milashius FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-028.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 12:37 PM

INCHES 1 2



CADD USER: Joseph A. Milashius FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-029.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 12:39 PM

INCHES 1 2

PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
MINE WATER TREATMENT TRAINS
SULFATE REMOVAL

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

POLYMET MINING

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

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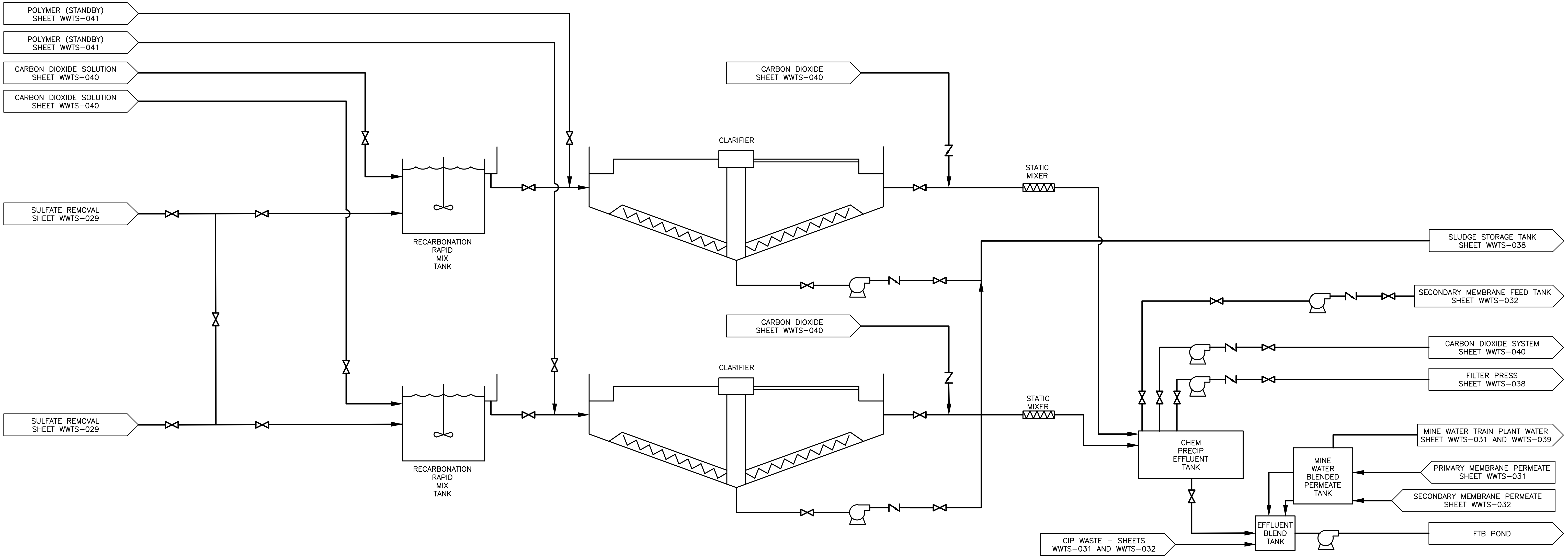
PRINTED NAME DON E. RICHARD
SIGNATURE DERd
DATE 10/3/17 LICENSE# 21193

DRAWN: KKB
CHECKED: EJA
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

DWG. NO. WWTS-029
REV



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INCHES 1 2

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		
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PRINTED NAME DON E. RICHARD
SIGNATURE
DATE 10/3/17 LICENSE# 21193

DRAWN: KKB
CHECKED: EJA
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
MINE WATER TREATMENT TRAINS
RECARBONATION

POLYMET MINING

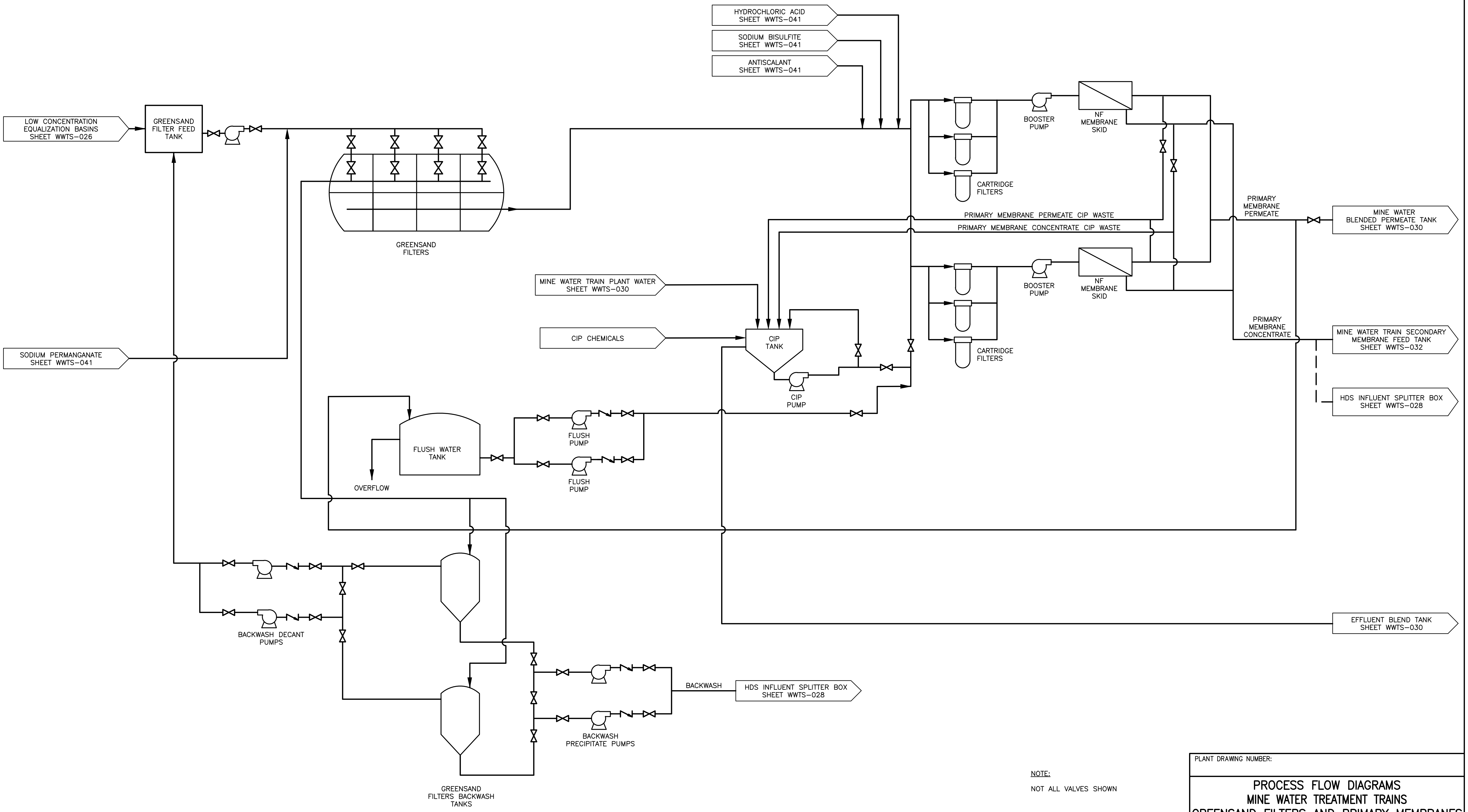
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-030
REV

CADD USER: Joseph A. Milashius FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-031.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 11:22 AM



NOTE:

NOT ALL VALVES SHOWN

PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
MINE WATER TREATMENT TRAINS
GREENSAND FILTERS AND PRIMARY MEMBRANES

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		
NOT APPROVED FOR CONSTRUCTION.		

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PRINTED NAME DON E. RICHARD
SIGNATURE Don Richard
DATE 10/3/17 LICENSE# 21193

DRAWN: KKB
CHECKED: EJA
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

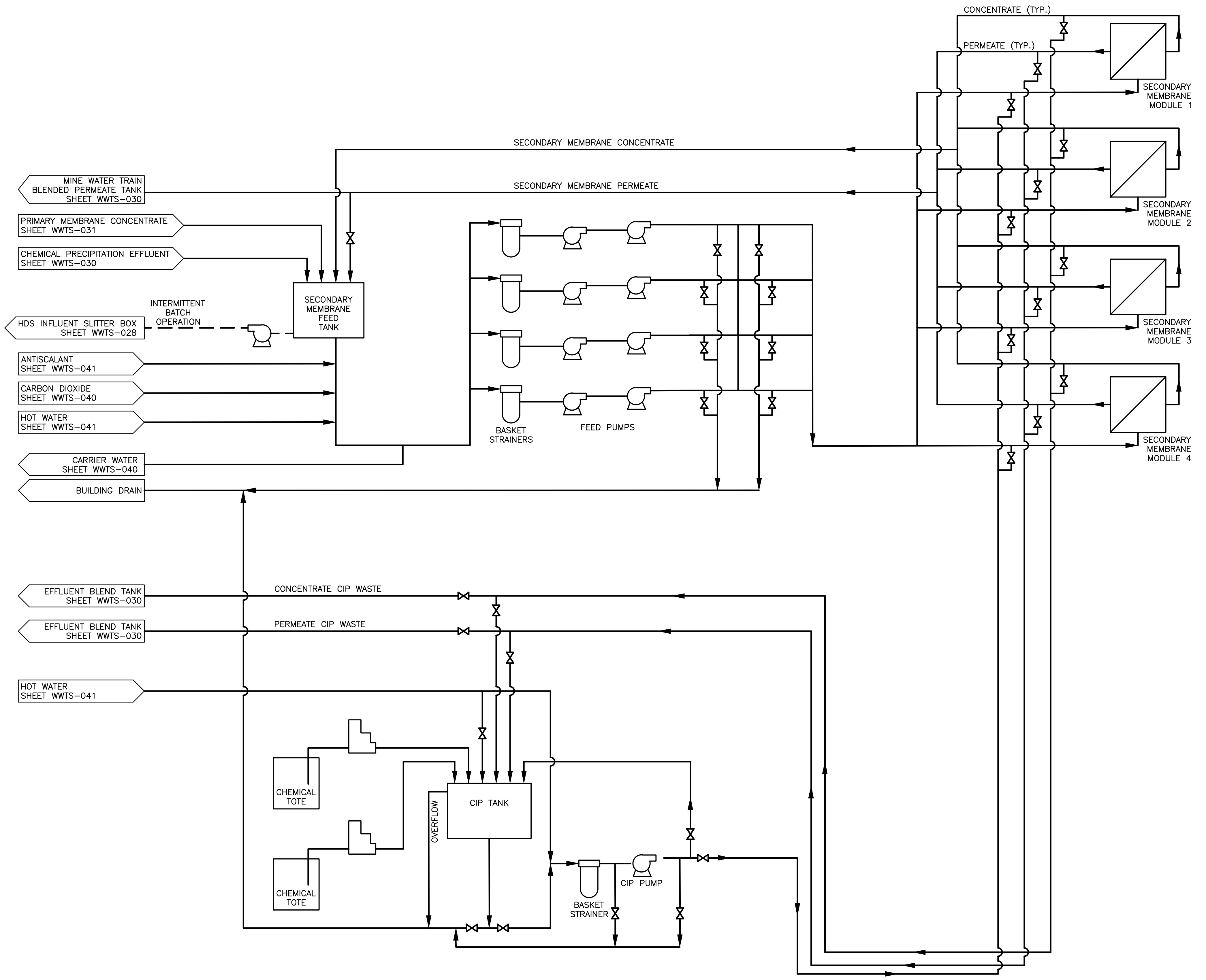
BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-031

REV

INCHES 1 2



NOTE:

1. LAYOUT IS TYPICAL FOR TWO TREATMENT TRAINS, HOWEVER, FOR CLARITY, NOT ALL SECONDARY MEMBRANE MODULES ARE SHOWN
2. NOT ALL VALVES SHOWN

PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
MINE WATER TREATMENT TRAINS
SECONDARY MEMBRANES

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUE STATUS		
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FOR CONSTRUCTION		
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PRINTED NAME DON E. RICHARD
SIGNATURE Don Richard
DATE 10/3/17 LICENSE# 21193

DRAWN: KKB
CHECKED: EJA
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

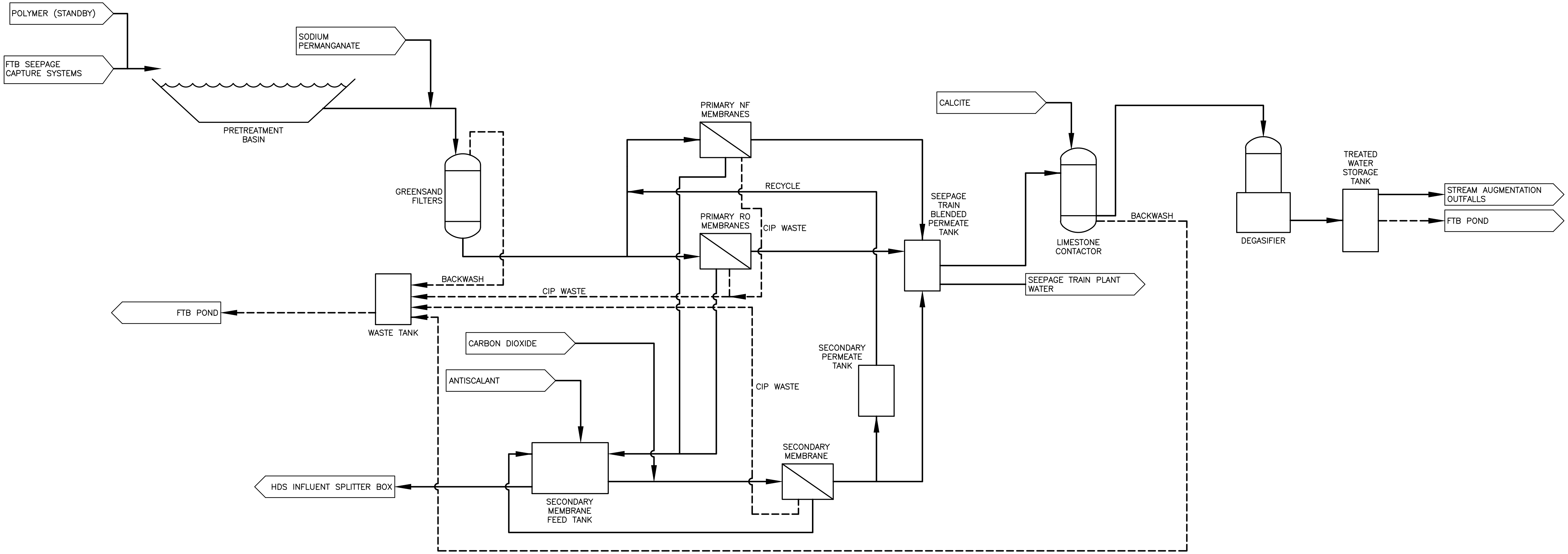
POLYMET MINING
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-032
REV

CADD USER: Joseph A. Milashius FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-032.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 11:24 AM

INCHES 1 2



INCHES 1 2

PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
TAILINGS BASIN SEEPAGE TREATMENT TRAIN OVERVIEW

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

VER NO	DATE	DESCRIPTION
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ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

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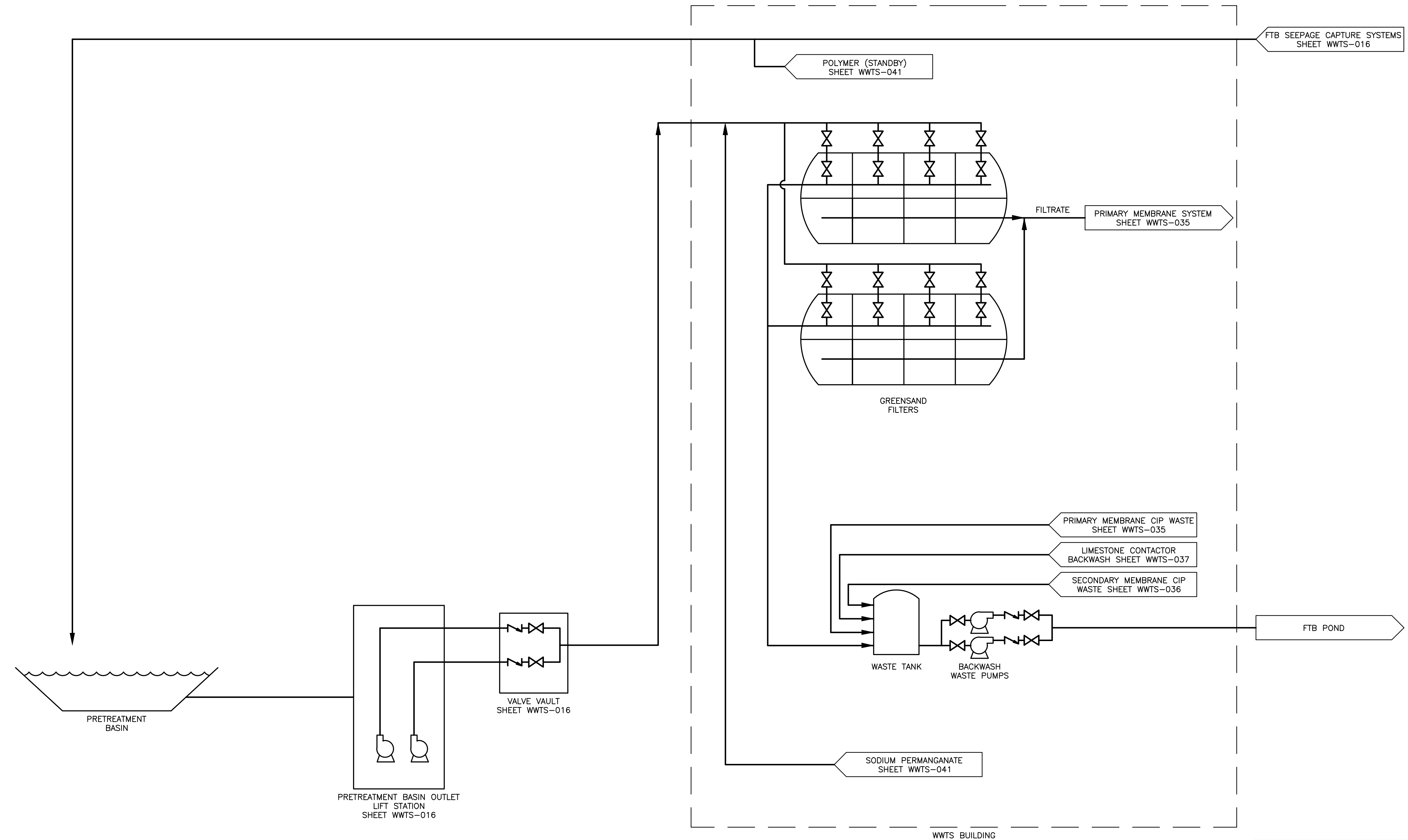
PRINTED NAME DON E. RICHARD
SIGNATURE Don Richard
DATE 10/3/17 LICENSE# 21193

DRAWN: KKB
CHECKED: ALL
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

DWG. NO. WWTS-033
REV



CADD USER: Brian Hughes FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-034.DWG PLOT SCALE: 1:2 PLOT DATE: 10/5/2017 10:26 AM

INCHES 1 2

PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAM
TAILINGS BASIN SEEPAGE TREATMENT TRAIN
PRETREATMENT AND GREENSAND FILTERS

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

DRAWING STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

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PRINTED NAME DON E. RICHARD
SIGNATURE Don Richard
DATE 10/3/17 REG. NO. 21193

DRAWN: KKB
CHECKED: EJA
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

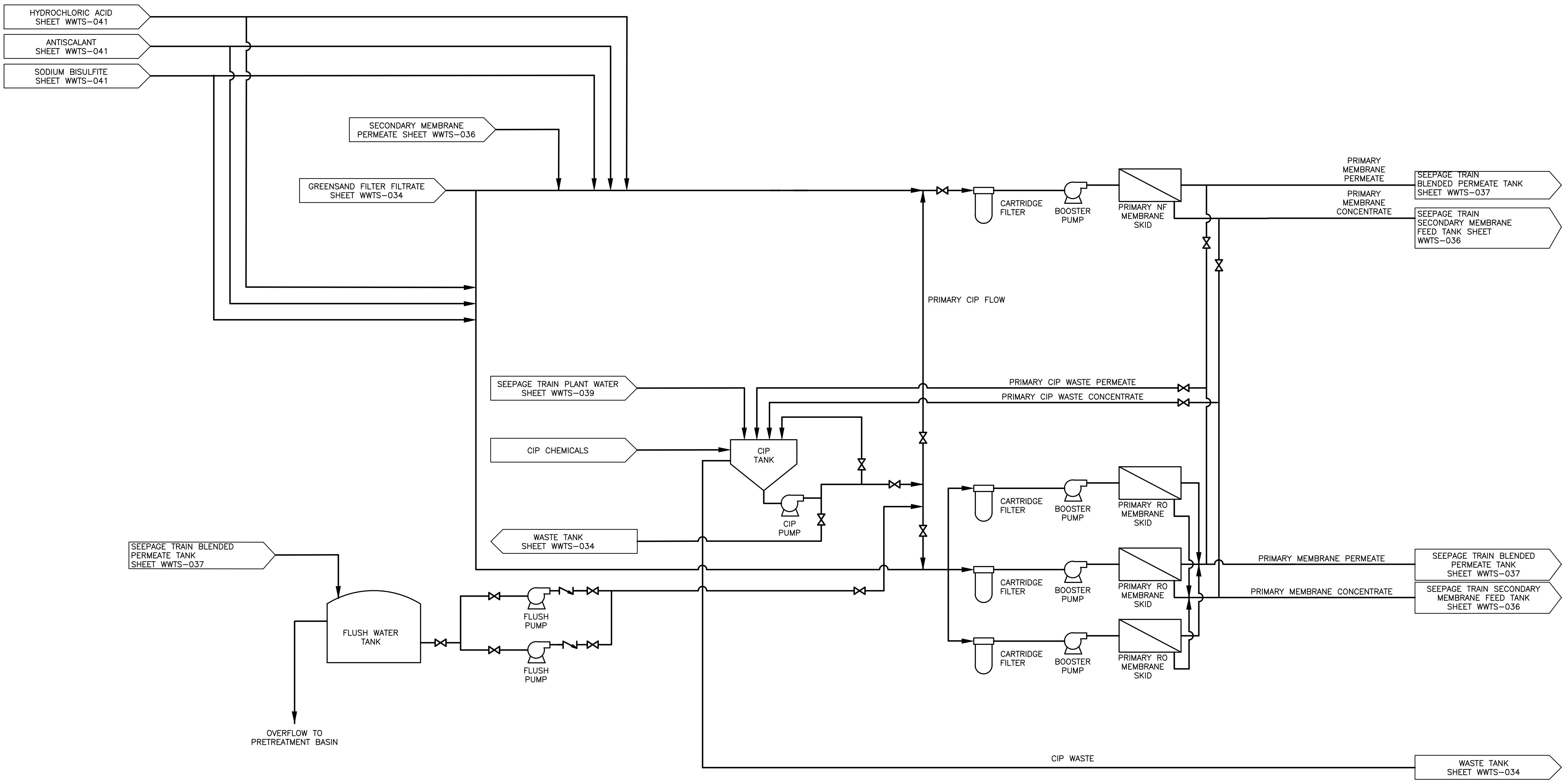
POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1–800–632–2277

DWG. NO. WWTS–034
REV



NOTE:

NOT ALL VALVES ARE SHOWN

PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
TAILINGS BASIN SEEPAGE TREATMENT TRAIN
PRIMARY MEMBRANES

VER NO	DATE	DESCRIPTION	ISSUE STATUS		
			ISSUED	VERSION	DATE
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS	FOR PERMITTING	1	10/3/17
			FOR CONSTRUCTION		
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PRINTED NAME DON E. RICHARD
SIGNATURE Don Richard
DATE 10/3/17 LICENSE# 21193

DRAWN: KKB
CHECKED: EJA
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

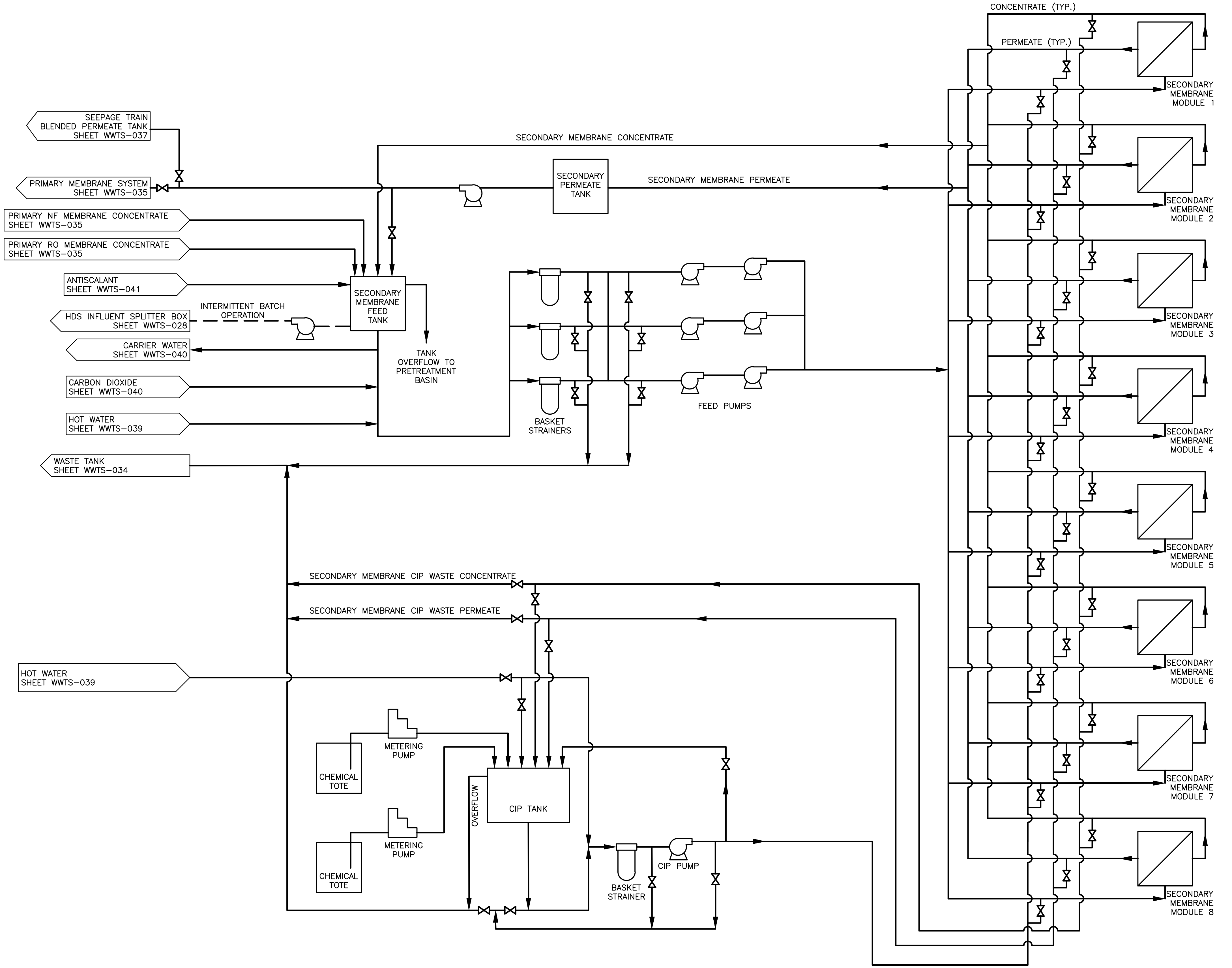
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-035

REV

CADD USER: Joseph A. Milashius FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-035.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 11:31 AM

INCHES 1 2



NOTE:

1. LAYOUT IS TYPICAL FOR 2 TRAINS, HOWEVER, FOR CLARITY NOT ALL SECONDARY MEMBRANE MODULES ARE SHOWN
2. NOT ALL VALVES ARE SHOWN

CADD USER: Joseph A. Milashius FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-036.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 11:34 AM

INCHES 1 2

PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
TAILINGS BASIN SEEPAGE TREATMENT TRAIN
SECONDARY MEMBRANES

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		
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PRINTED NAME DON E. RICHARD
SIGNATURE Don Richard
DATE 10/3/17 LICENSE# 21193

DRAWN: KKB
CHECKED: EJA
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

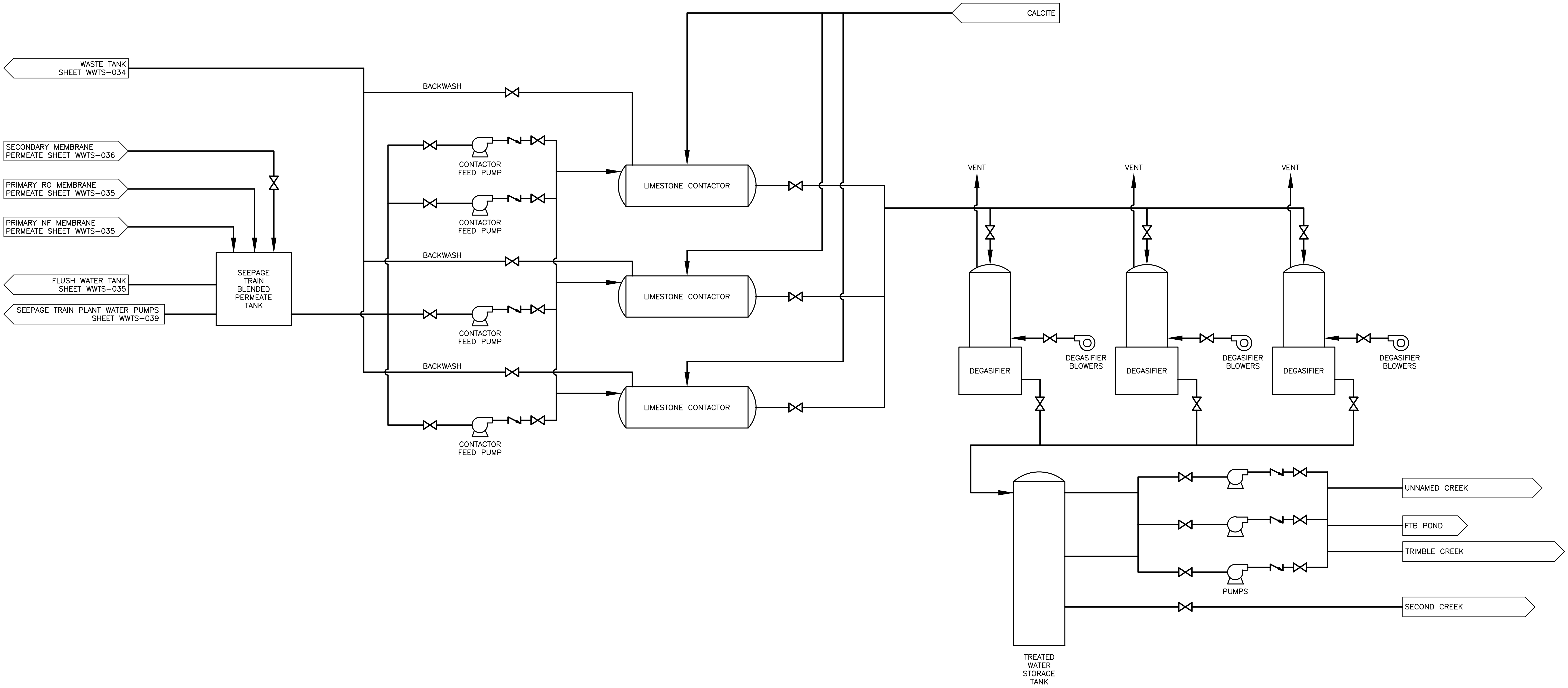
POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-036
REV



CADD USER: Joseph A. Milashius FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-037.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 11:40 AM

INCHES 1 2

PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
TAILINGS BASIN SEEPAGE TREATMENT TRAIN
PERMEATE STABILIZATION AND STREAM AUGMENTATION

POLYMET
MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

VER NO	DATE	DESCRIPTION
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ISSUED	VERSION	DATE
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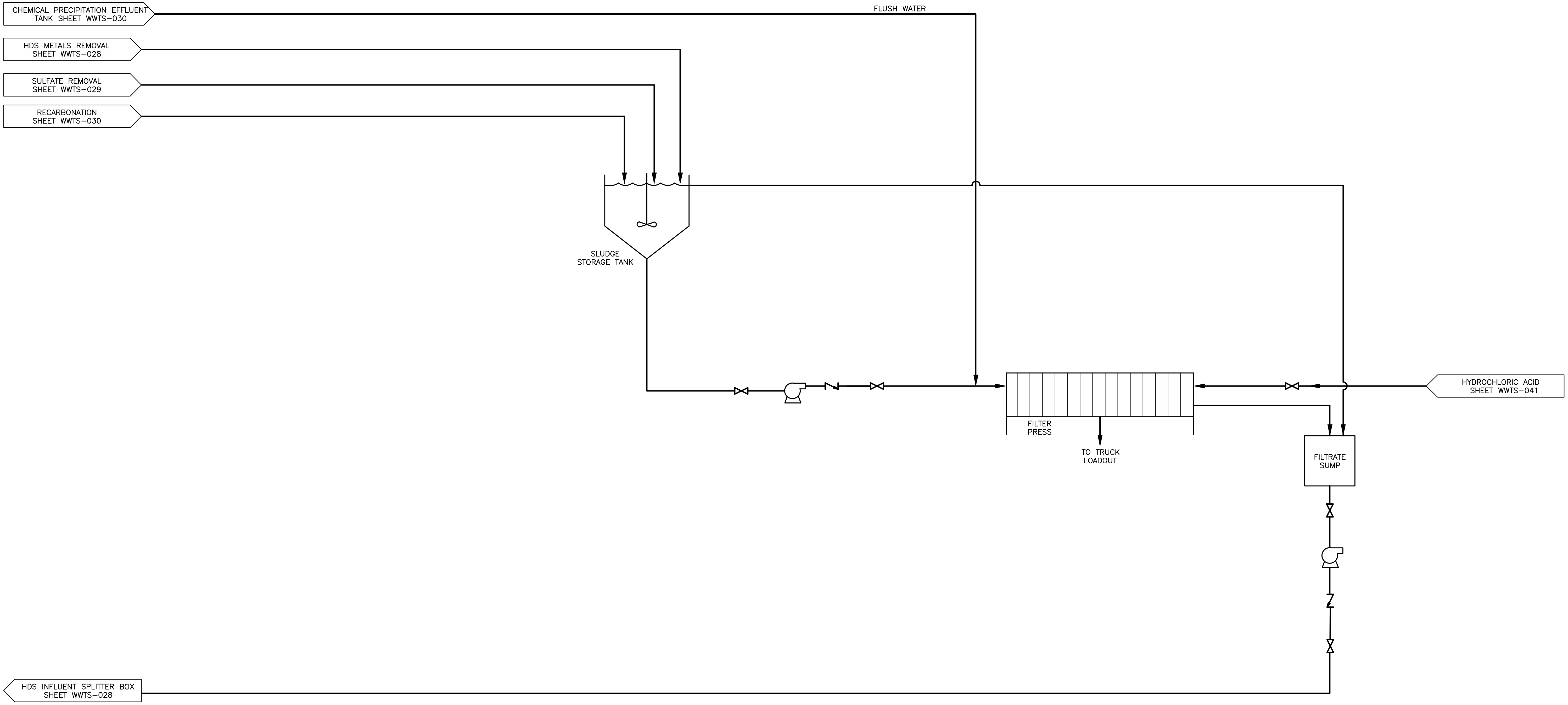
PRINTED NAME DON E. RICHARD
SIGNATURE
DATE 10/3/17 LICENSE# 21193

DRAWN: KKB
CHECKED: ALL
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

DWG. NO. WWTS-037
REV

CADD USER: Joseph A. Milashius FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-038.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 11:44 AM



PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
MINE WATER TREATMENT TRAINS
SOLIDS HANDLING

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
FOR CONSTRUCTION		

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PRINTED NAME DON E. RICHARD
SIGNATURE Don Richard
DATE 10/3/17 LICENSE# 21193

DRAWN: KKB
CHECKED: ALL
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET MINING

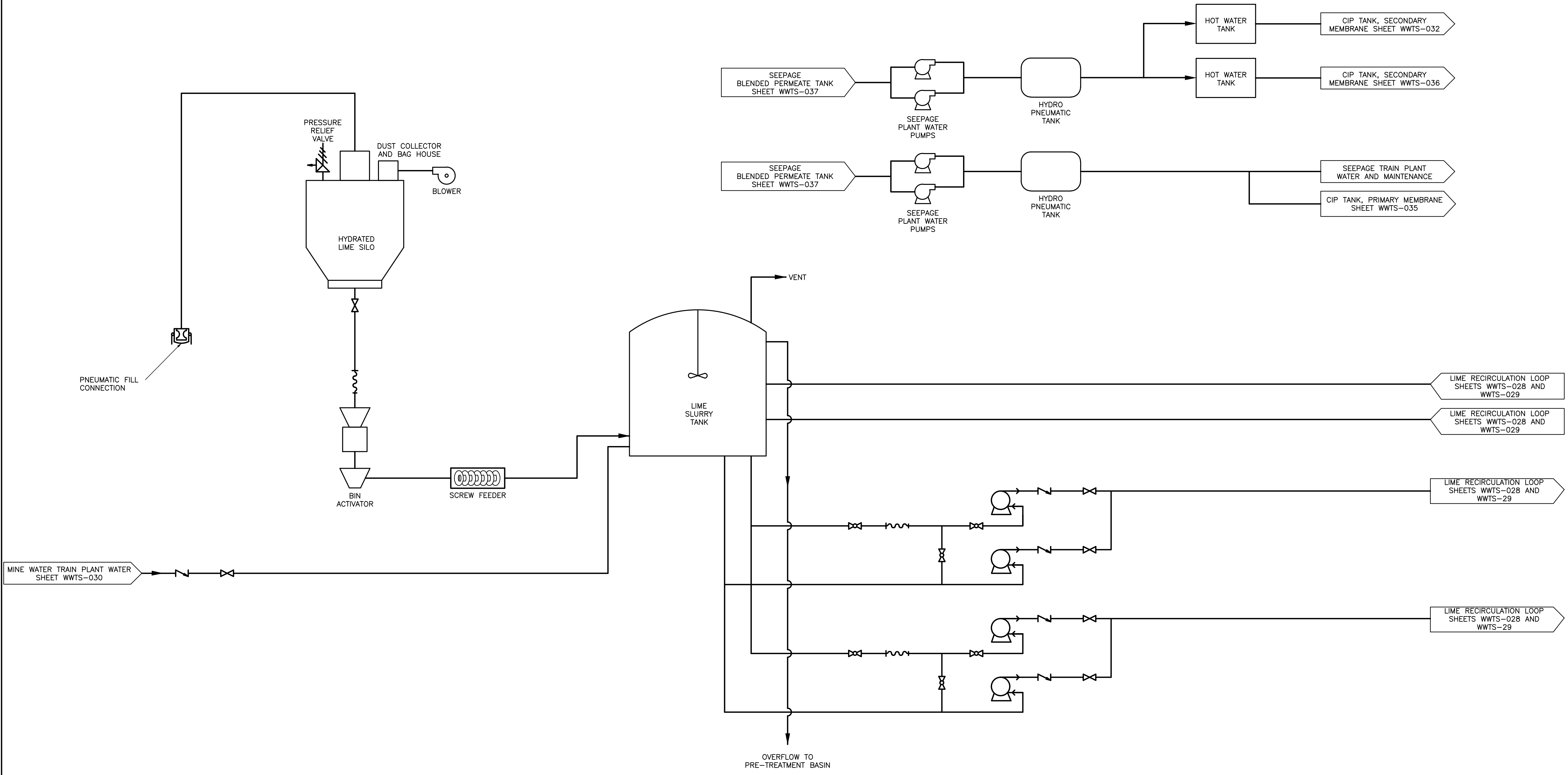
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-038
REV

INCHES 1 2

CADD USER: Joseph A. Milashius FILE: K:\DESIGN\23690C29.10\PERMIT_NMM-46-WWTS-039.DWG PLOT SCALE: 1:2 PLOT DATE: 10/3/2017 11:51 AM



PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
HYDRATED LIME STORAGE AND FEED, SEEPAGE PLANT WATER

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

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FOR CONSTRUCTION		

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PRINTED NAME DON E. RICHARD
SIGNATURE Don Richard
DATE 10/3/17 LICENSE# 21193

DRAWN: KKB
CHECKED: ALL
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-039

REV

INCHES 1 2

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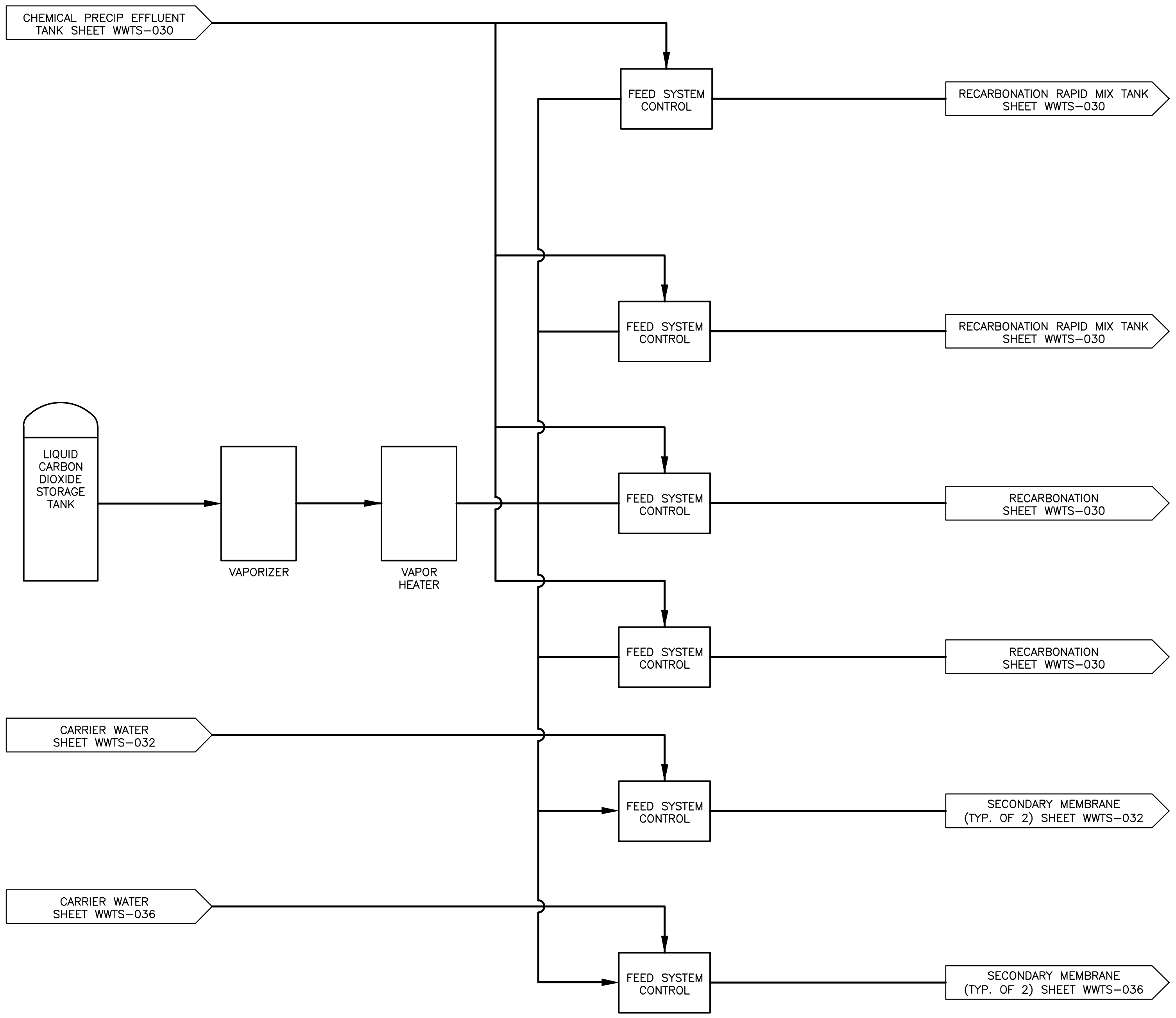

PLANT DRAWING NUMBER:

PROCESS FLOW DIAGRAMS
CARBON DIOXIDE STORAGE AND FEED

VER NO	DATE	DESCRIPTION
1	10/3/17	ISSUED FOR INCLUSION IN PERMIT APPLICATIONS

ISSUE STATUS		
ISSUED	VERSION	DATE
FOR PERMITTING	1	10/3/17
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SIGNATURE Don Richard
DATE 10/3/17 LICENSE# 21193

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POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
SUITE 200
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-040
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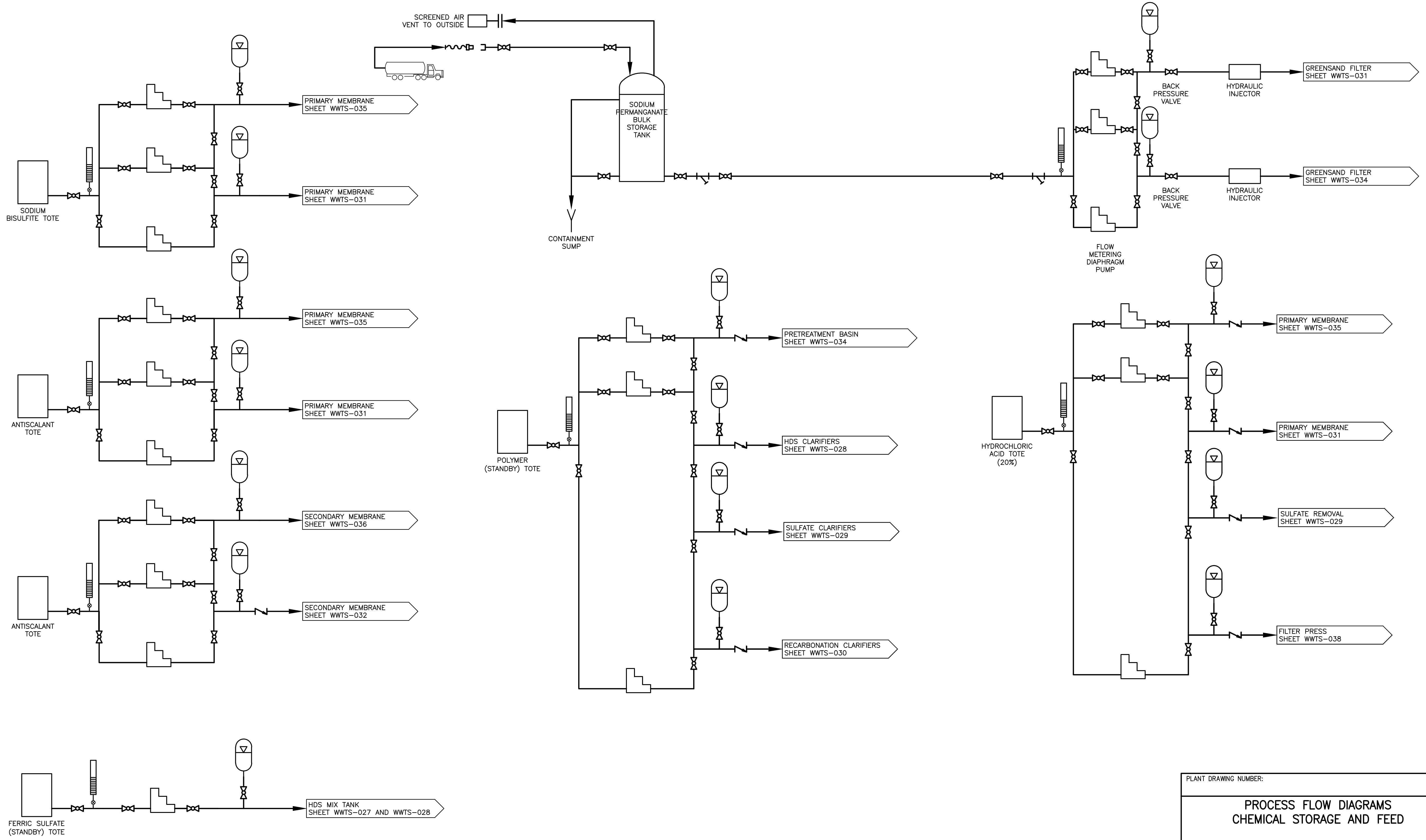

INCHES 1 2

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ISSUE STATUS		
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FOR PERMITTING	1	10/3/17
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PROCESS FLOW DIAGRAMS
CHEMICAL STORAGE AND FEED

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING CO.
4300 MARKETPOINTE DRIVE
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DWG. NO. WWTS-041

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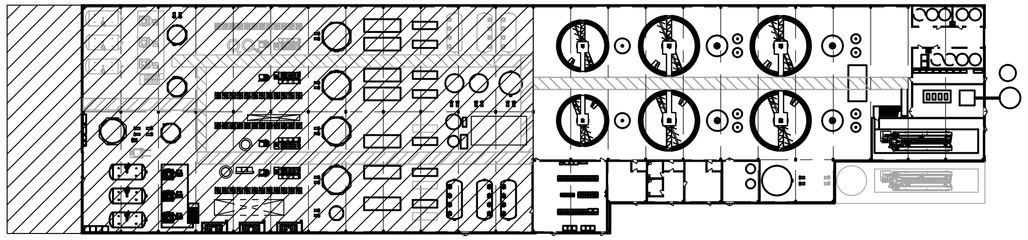
NOTES:

1. FUTURE BUILD OUT SHOWN GRAYED OUT.



KEY PLAN: WWTS

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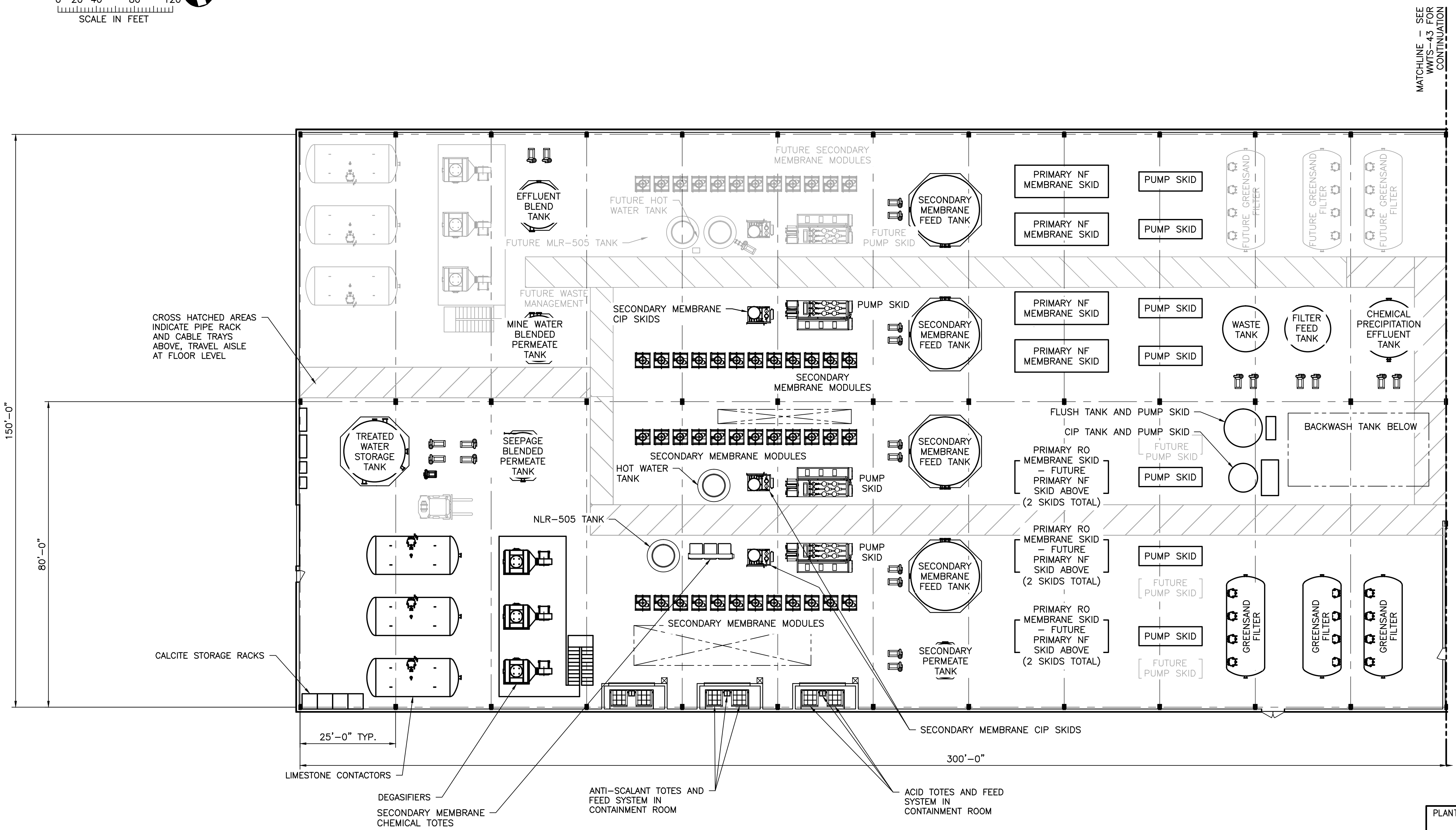
SCALE IN FEET



1 PLAN: WWTS GENERAL ARRANGEMENT

0 5 10 20 30

SCALE IN FEET

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FOR PERMITTING	1	10/3/17
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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE
DATE 10/3/17 LICENSE #24480

DRAWN: DAK
CHECKED: ALL
BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

PLANT SITE WWTS
GENERAL ARRANGEMENT WEST

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING COMPANY
4300 MARKETPOINTE DRIVE
Suite 200
MINNEAPOLIS, MN 55435
Ph: 1-800-632-2277

DWG. NO. WWTS-042
REV

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INCHES 1 2

NOTES:

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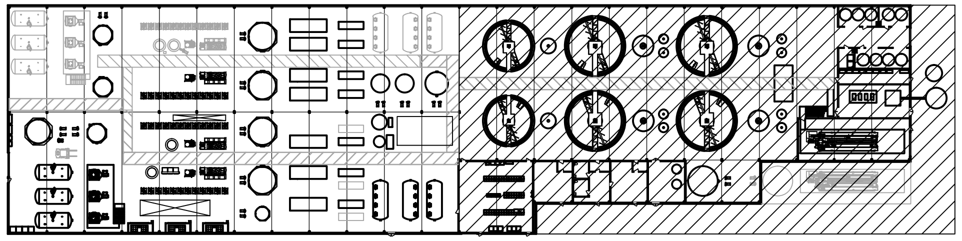

KEY PLAN: WWTS

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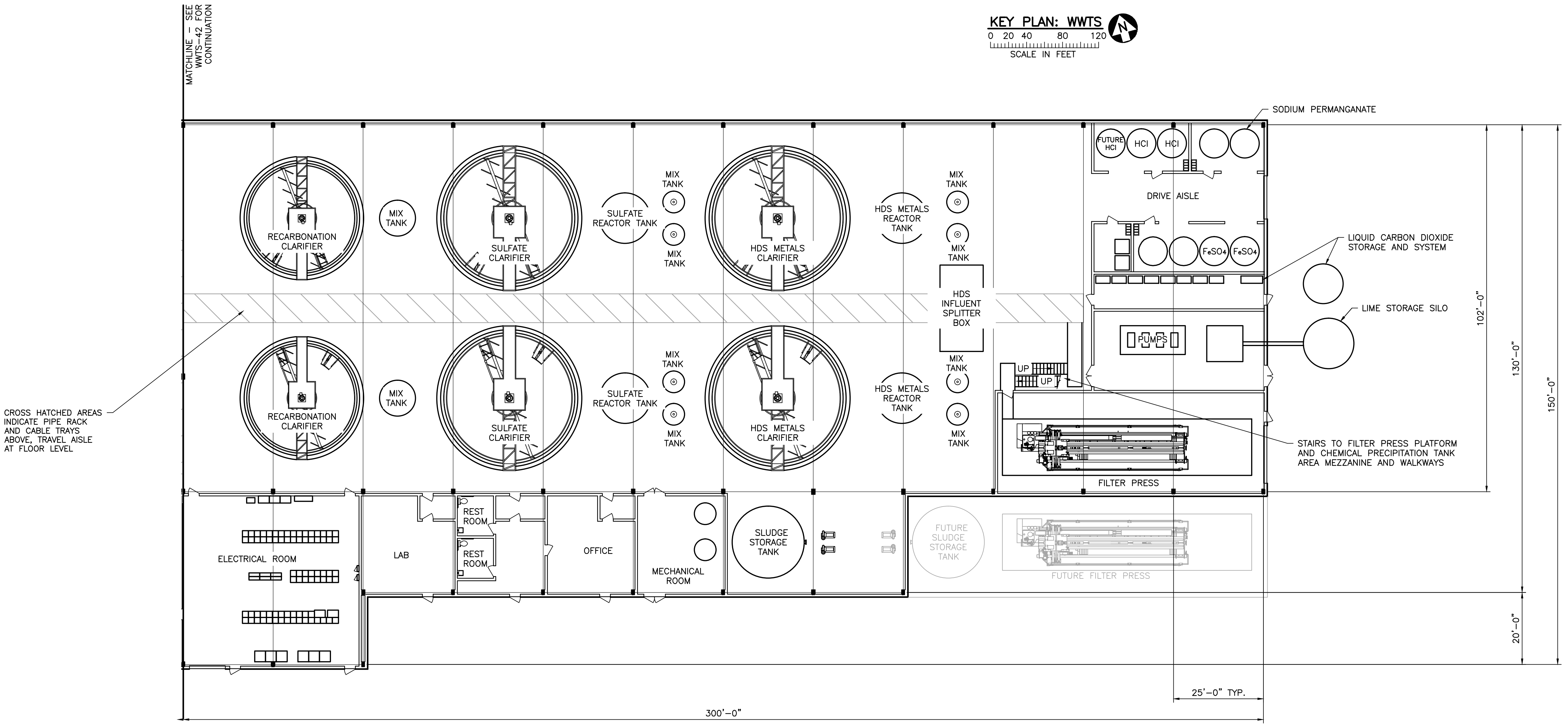
SCALE IN FEET



①/-- PLAN: WWTS GENERAL ARRANGEMENT

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SCALE IN FEET

PLANT DRAWING NUMBER:

PLANT SITE WWTS
GENERAL ARRANGEMENT EAST

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PRINTED NAME BRYAN T. OAKLEY
SIGNATURE
DATE 10/3/17 LICENSE #24480

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BARR PROJECT NO.: 23690862.12
SCALE: AS SHOWN

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

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DWG. NO. WWTS–043
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INCHES 1 2

Attachment J

Tailings Basin Seepage Treatment Train Design Criteria

Design Standard Checklist

Tailings Basin Seepage Treatment Train of Waste Water Treatment System
NorthMet Project
Poly Met Mining, Inc.

			Standard			**PolyMet WWTS Information**			
Process	**Equipment**	**Design Requirement**	**10 State Standards**[1]	**Minnesota Pollution Control Agency**[2]	**Pilot/Bench Testing**	**NPDES Permit Design Basis**	**Standards Met?**	**Rationale for Design Basis if Inconsistent with Ten State and MPCA Standards**	**WWTS Design and Operation Report Section**
Intake	Pretreatment Basin	Size				HRT of 36 hours at initial buildout design capacity, 18 hours at final buildout design capacity			3.3.4
	Feed Pump	Redundancy	Yes, each with capacity to pump peak hourly flow.			Designed to accommodate initial design capacity of 2,000 gpm with one pump	Yes		
	Flocculant					Added in-line at WWTS building			
	Lift Station					Two pumps, 2,000 gpm each, sized for third pump to be added in Mine Year 8			
Tailings Basin Seepage Filtration	Greensand Filter	Pretreatment	Required			Pretreatment basin to remove some soluble iron upstream of GSF	Yes		3.3.5
		Rate	Typically 2-4 gpm/sq. ft., must be justified by design engineer to satisfaction of reviewing authority	Maximum allowable flow is 5 gpm/sq. ft. of filter area	3.5-4.9 gpm/sq. ft. succussfully pilot tested	3.7 gpm/sq. ft. at design flow with all cells in service, 4.9 gpm/sq. ft. with one cell in backwash	Yes		
		Backwash Cycle Time	At least 15 minutes			15-25 minutes	Yes		
		Backwash Rate	minimum rate of 15 gpm/sqft, 10 gpm/sqft acceptable for full depth filters			12-15 gpm/sqft	Yes	Greensand filtration media requires lower backwash rate to avoid washout	
	Sodium Permanganate	Use to oxidize arsenite and selenite	Iron and manganese can be oxidized with sodium permanganate		Tested 1.65 mg/L to 4.3 mg/L	Use 1.65 mg/L to 4.3 mg/L for optimum removal and dose efficiency	Yes	Pilot testing used for basis	

Design Standard Checklist

Tailings Basin Seepage Treatment Train of Waste Water Treatment System
NorthMet Project
Poly Met Mining, Inc.

			Standard			PolyMet WWTS Information			
Process	Equipment	Design Requirement	10 State Standards(1)	Minnesota Pollution Control Agency(2)	Pilot/Bench Testing	NPDES Permit Design Basis	Standards Met?	Rationale for Design Basis if Inconsistent with Ten State and MPCA Standards	WWTS Design and Operation Report Section
Tailings Basin Seepage Primary Membranes	Pretreatment	Necessary	Yes			Pretreatment will consist of filtration, pH adjustment, and antiscalant addition	Yes		3.3.6
	RO Membranes	Redundancy	Yes, of critical components	Yes, of critical components		Yes	Yes		
		Flux				16 gpd/sq. ft.			
		Type			Tested GE model AK90-LE (4" element)	Use GE AG8010F400 (8" element), equivalent membrane with higher rejection membrane			
		Recovery				75%			
		Cleaning	Required, with acid/detergents			Use MC1 and MC4 products from GE	Yes		
	NF Membranes	Redundancy	Yes, of critical components	Yes, of critical components		Yes	Yes		
		Flux				16 gpd/sq. ft.			
		Type			Tested GE HL4040FM (4" element)	Use GE Muni-NF-400 (8" element), equivalent membrane with same flat sheet	Yes		
		Recovery				80%	Yes		
		Cleaning	Required, with acid/detergents			Use MC1 and MC4 products from GE	Yes		
	Anti-Scalant	Chemical and Dose			GE Hypersperse MDC700	GE Hypersperse MDC150 or MDC700 at 2.2 ppm		Recommended by manufacturer	
	Sodium Bisulfite	Dose				1 ppm			
Tailings Basin Seepage Secondary VSEP Membranes		Redundancy		Yes, of critical components		Yes, one extra VSEP module per 12-unit skid	Yes		3.3.7
		Flux			60 gpd/sq. ft. successfully pilot tested	60 gpd/sq. ft.		Pilot testing used for basis	
		Type			Use Dow NF-270	Use Dow NF-270	Yes		
		Recovery			Recovery at 80%-90%	85%	Yes		
		Cleaning	Required, with acid/detergents		Clean membranes at 50 C	Designed for NLR 505 and 404	Yes		
	Anti-Scalant	Chemical and Dose			Use phosphonic acid salt antiscalant at 10 ppm	NLR 759 at 10 ppm	Yes		
	Carbon Dioxide	pH Setpoint			Adjust pH to 6.0	Adjust pH to <6.2	Yes		

Design Standard Checklist

Tailings Basin Seepage Treatment Train of Waste Water Treatment System
NorthMet Project
Poly Met Mining, Inc.

			Standard			PolyMet WWTS Information			
Process	**Equipment**	**Design Requirement**	**10 State Standards(1)**	**Minnesota Pollution Control Agency(2)**	**Pilot/Bench Testing**	**NPDES Permit Design Basis**	**Standards Met?**	**Rationale for Design Basis if Inconsistent with Ten State and MPCA Standards**	**WWTS Design and Operation Report Section**
WWTS Effluent Stabilization	Carbon Dioxide Injection	Tank Location	Locate tanks outside or sealed and vented			Tanks will be located outside	Yes		3.3.8
	Limesone Bed Contactors	Hydraulic Loading			2.4 gpm/sq. ft.	1-5 gpm/sq. ft.	Yes		
		EBCT				2.5-5.0 minutes			
WWTS Discharge Works	Floodwater protection		Yes			Will be addressed in final design			3.4.1
	Concentrate Loading					Will be addressed in final design			
	Permeate Holding Tank					Will be addressed in final design			

(1) Ten State 2012 Recommended Standards for Water Works or Ten State 2014 Recommended Standards from Wastewater Facilities

(2) MPCA Waste and Wastewater Treatment Checklists

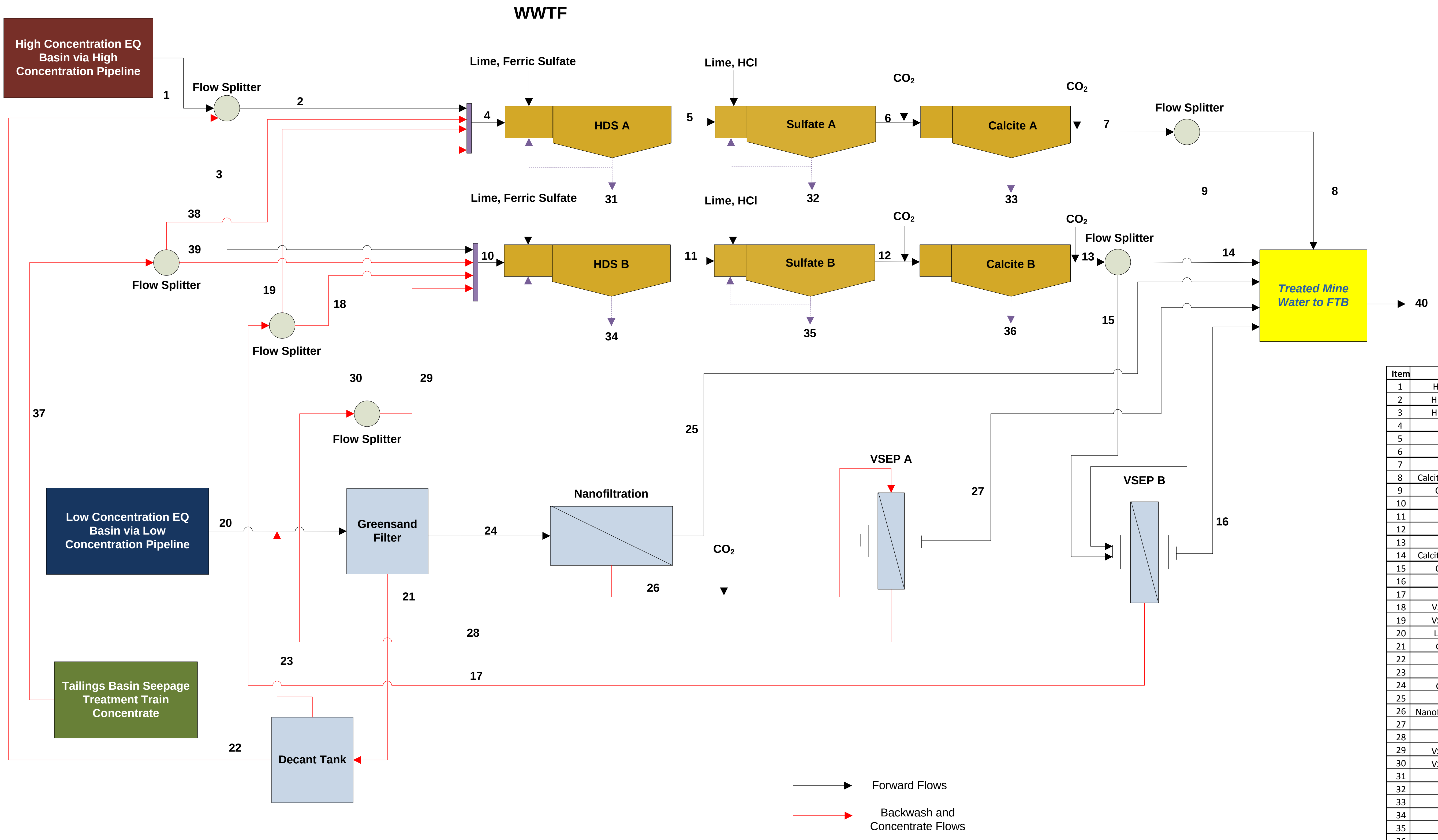
From MPCA's "Reliability for Mechanical Wastewater Treatment Plants," General Information: 1) where duplicate units are not provided, unit bypass structures must be provided so that each unit operation of the plant can be independently removed from service, 2) where duplicate units are provided, each unit operation must be designed such that, with the largest unit out of serive, the hydraulic capacity of the interconnecting piping will be sufficient to transport the peak instantaneous wet weather flow throug the remaining units. 3) duplication of all primary clarifiers, aeration basins, and final clarifiers must be provided in accordane with the must be sufficient number of units of a size such that, with the largest unit out of service, the remaining units will have a design load capacity of at least 50 percent of the total design loading to that unit

Attachment K

Mine Water Treatment Trains Model Outputs

GoldPHREEQC Mine Water Treatment Process Flow Diagram

5/10/2017



Item	Flow Name
1	High Conc. EQ Basin Effluent
2	High Conc. EQ Basin to HDS A
3	High Conc. EQ Basin to HDS B
4	HDS A Influent
5	HDS A Effluent
6	Sulfate A Effluent
7	Calcite A Effluent
8	Calcite A Eff. to Treated Mine Water
9	Calcite A Effluent to VSEP B
10	HDS B Influent
11	HDS B Effluent
12	Sulfate B Effluent
13	Calcite B Effluent
14	Calcite B Eff. to Treated Mine Water
15	Calcite B Effluent to VSEP B
16	VSEP B Permeate
17	VSEP B Concentrate
18	VSEP B Concentrate to HDS B
19	VSEP B Concentrate to HDS A
20	Low Conc. EQ Basin Effluent
21	Greensand Filter Backwash
22	Backwash Solids
23	Backwash Decant
24	Greensand Filter Permeate
25	Nanofiltration Permeate
26	Nanofiltration Concentrate to VSEP A
27	VSEP A Permeate
28	VSEP A Concentrate
29	VSEP A Concentrate to HDS B
30	VSEP A Concentrate to HDS A
31	HDS A Sludge
32	Sulfate A Sludge
33	Calcite A Sludge
34	HDS B Sludge
35	Sulfate B Sludge
36	Calcite B Sludge
37	TBSTT VSEP Concentrate
38	TBSTT VSEP Concentrate to HDS A
39	TBSTT VSEP Concentrate to HDS B
40	Treated Mine Water to CPS

TBSTT = Tailings Basin Seepage Treatment Train

P:\Mpls\23 MN\69\2369862\WorkFiles\APA\Permitting\NPDES\Permit Applications\Volume III - WWTF-WWTP\Design and Operation Report\2017 version\Attachments\Attachments D and K figures

Mine Water Treatment Trains Model Outputs

Annual Average Effluent Concentrations for Limiting Parameters and Sulfate

				Silver				Selenium				Sulfate				Limiting Parameter
	Flow Durations			PWQ Target = 1.00E-3 µg/L				PWQ Target = 5.00E-3 µg/L				PWQ Target = 250 mg/L				
	Peak	Summer	Winter	Peak	Summer	Winter	Average	Peak	Summer	Winter	Average	Peak	Summer	Winter	Average	
Mine Year	days	days	days	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	mg/L	
1	242	0	123	**1.09E-03**		3.52E-04	9.49E-04	2.87E-03		3.84E-04	2.39E-03	240		41	202	Silver
2	229	0	136	8.66E-04		2.43E-04	7.43E-04	**5.92E-03**		5.42E-04	4.86E-03	**264**		59	223	Selenium
3	218	0	147	7.65E-04		2.26E-04	6.49E-04	**5.54E-03**		8.71E-04	4.53E-03	221		54	185	Selenium
4	223	0	142	4.20E-04		1.26E-04	3.65E-04	**5.90E-03**		8.20E-04	4.95E-03	250		59	214	Selenium
5	235	0	130	3.70E-04		1.29E-04	3.34E-04	**5.68E-03**		8.85E-04	4.96E-03	206		54	183	Selenium
6	232	0	133	8.10E-04		4.68E-04	7.39E-04	**5.77E-03**		7.32E-04	4.73E-03	**258**		139	233	Selenium
7	30	185	150	3.23E-04	3.15E-04	1.52E-04	2.77E-04	**6.26E-03**	**6.08E-03**	7.56E-04	4.84E-03	**277**	**272**	73.7	226	Selenium
8	30	185	150	1.00E-03	4.50E-04	1.50E-04	4.50E-04	5.00E-03	**6.03E-03**	8.18E-04	4.73E-03	250	**290**	86	239	Selenium
9	30	185	150	5.10E-04	4.80E-04	1.50E-04	4.13E-04	**6.38E-03**	**5.95E-03**	8.53E-04	4.91E-03	239	229	71	196	Selenium
10	30	185	150	5.40E-04	5.20E-04	1.60E-04	4.33E-04	**6.50E-03**	**6.20E-03**	7.27E-04	4.87E-03	236	232	65	191	Selenium

Cells highlighted in grey indicate exceedance of Mine Water Treatment Trains Preliminary Water Quality Target (PWQT) Cells with bold text indicate limiting parameter

Mine Water Treatment Trains Flow and Load Detail
Year 1 P90 Annual Average

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	101.0	1.5E-02	1.3E+02	3.1E-01	2.3E-02	3.8E+02	5.6E-02	2.1E+02	3.3E+00	9.5E-03	8.6E+00	2.2E+00	1.9E+02	1.8E+02	5.1E+00	7.3E+01	1.2E+01	1.1E-01	2.3E-01	3.7E-02	2.6E+03	5.4E-04	4.5E-02	6.5E+00	5.1
2	High Conc EQ Effluent to HDS A	50.5	1.5E-02	1.3E+02	3.1E-01	2.3E-02	3.8E+02	5.6E-02	2.1E+02	3.3E+00	9.5E-03	8.6E+00	2.2E+00	1.9E+02	1.8E+02	5.1E+00	7.3E+01	1.2E+01	1.1E-01	2.3E-01	3.7E-02	2.6E+03	5.4E-04	4.5E-02	6.5E+00	5.1
3	High Conc EQ Effluent to HDS B	50.5	1.5E-02	1.3E+02	3.1E-01	2.3E-02	3.8E+02	5.6E-02	2.1E+02	3.3E+00	9.5E-03	8.6E+00	2.2E+00	1.9E+02	1.8E+02	5.1E+00	7.3E+01	1.2E+01	1.1E-01	2.3E-01	3.7E-02	2.6E+03	5.4E-04	4.5E-02	6.5E+00	5.1
4	Combined HDS A Influent	126.9	1.2E-02	5.4E+01	2.2E-01	1.2E-02	1.0E+03	3.8E-02	1.3E+02	2.0E+00	3.5E-02	8.1E+00	2.6E+01	7.7E+01	6.8E+02	3.3E+00	8.2E+02	1.2E+01	4.8E-02	1.7E-01	3.9E-02	4.1E+03	5.7E-03	6.2E-02	4.5E+00	6.4
5	Sulfate A Influent	126.9	6.8E-03	5.3E+01	1.3E-05	6.2E-03	6.8E+02	2.3E-04	1.3E+02	2.1E-04	2.6E-02	5.0E-03	2.5E+01	1.6E-03	2.0E+02	3.3E-02	8.1E+02	6.9E-04	2.3E-05	1.7E-01	2.7E-02	2.3E+03	5.6E-03	1.1E-06	8.7E-01	10.7
6	Sulfate A Effluent	126.9	6.8E-03	5.3E-02	1.3E-05	6.2E-03	1.5E+03	2.3E-04	1.3E+02	1.0E-07	2.6E-02	5.0E-03	1.6E+00	1.6E-03	3.6E-01	3.3E-02	8.1E+02	2.2E-06	2.3E-05	8.4E-03	1.4E-02	1.3E+03	5.6E-03	1.1E-06	8.7E-01	12.4
7	Calcite A Effluent	126.9	6.9E-03	5.4E-02	1.3E-05	6.3E-03	3.3E+02	2.3E-04	1.3E+02	1.0E-07	2.6E-02	5.1E-03	1.6E+00	1.6E-03	3.6E-01	3.3E-02	8.2E+02	2.2E-06	2.3E-05	8.5E-03	1.4E-02	1.3E+03	5.6E-03	1.2E-06	8.7E-01	10.1
8	Calcite A Effluent to Final Effluent	50.8	6.8E-03	5.4E-02	1.3E-05	6.3E-03	3.3E+02	2.3E-04	1.3E+02	1.0E-07	2.6E-02	5.0E-03	1.6E+00	1.6E-03	3.6E-01	3.3E-02	8.1E+02	2.2E-06	2.3E-05	8.5E-03	1.4E-02	1.3E+03	5.6E-03	1.2E-06	8.7E-01	9.5
9	Calcite A Effluent to VSEP B	76.1	6.8E-03	5.4E-02	1.3E-05	6.3E-03	3.3E+02	2.3E-04	1.3E+02	1.0E-07	2.6E-02	5.0E-03	1.6E+00	1.6E-03	3.6E-01	3.3E-02	8.1E+02	2.2E-06	2.3E-05	8.5E-03	1.4E-02	1.3E+03	5.6E-03	1.2E-06	8.7E-01	9.5
10	Combined HDS B Influent	126.9	1.2E-02	5.4E+01	2.2E-01	1.2E-02	1.0E+03	3.8E-02	1.3E+02	2.0E+00	3.5E-02	8.1E+00	2.6E+01	7.7E+01	6.8E+02	3.3E+00	8.2E+02	1.2E+01	4.8E-02	1.7E-01	3.9E-02	4.1E+03	5.7E-03	6.2E-02	4.5E+00	6.4
11	Sulfate B Influent	126.9	6.8E-03	5.3E+01	1.3E-05	6.2E-03	6.8E+02	2.3E-04	1.3E+02	2.1E-04	2.6E-02	5.0E-03	2.5E+01	1.6E-03	2.0E+02	3.3E-02	8.1E+02	6.9E-04	2.3E-05	1.7E-01	2.7E-02	2.3E+03	5.6E-03	1.1E-06	8.7E-01	10.7
12	Sulfate B Effluent	126.9	6.8E-03	5.3E-02	1.3E-05	6.2E-03	1.5E+03	2.3E-04	1.3E+02	1.0E-07	2.6E-02	5.0E-03	1.6E+00	1.6E-03	3.6E-01	3.3E-02	8.1E+02	2.2E-06	2.3E-05	8.4E-03	1.4E-02	1.3E+03	5.6E-03	1.1E-06	8.7E-01	12.4
13	Calcite B Effluent	126.9	6.9E-03	5.4E-02	1.3E-05	6.3E-03	3.3E+02	2.3E-04	1.3E+02	1.0E-07	2.6E-02	5.1E-03	1.6E+00	1.6E-03	3.6E-01	3.3E-02	8.2E+02	2.2E-06	2.3E-05	8.5E-03	1.4E-02	1.3E+03	5.6E-03	1.2E-06	8.7E-01	10.1
14	Calcite B Effluent to Final Effluent	50.8	6.8E-03	5.4E-02	1.3E-05	6.3E-03	3.3E+02	2.3E-04	1.3E+02	1.0E-07	2.6E-02	5.0E-03	1.6E+00	1.6E-03	3.6E-01	3.3E-02	8.1E+02	2.2E-06	2.3E-05	8.5E-03	1.4E-02	1.3E+03	5.6E-03	1.2E-06	8.7E-01	9.5
15	Calcite B Effluent to VSEP B	76.1	6.8E-03	5.4E-02	1.3E-05	6.3E-03	3.3E+02	2.3E-04	1.3E+02	1.0E-07	2.6E-02	5.0E-03	1.6E+00	1.6E-03	3.6E-01	3.3E-02	8.1E+02	2.2E-06	2.3E-05	8.5E-03	1.4E-02	1.3E+03	5.6E-03	1.2E-06	8.7E-01	9.5
16	VSEP B Permeate to Final Effluent	154.3	2.7E-04	3.3E-04	8.0E-06	5.0E-03	2.3E+01	6.0E-06	1.4E+02	6.2E-09	2.8E-03	2.1E-04	9.7E-01	6.3E-05	8.6E-02	8.3E-03	4.5E+02	1.2E-07	5.2E-07	4.5E-04	8.4E-04	3.3E+01	3.0E-04	1.5E-07	5.5E-02	6.3
17	VSEP B Concentrate	38.6	3.4E-02	2.7E-01	3.3E-05	1.1E-02	1.6E+03	1.1E-03	8.4E+01	4.9E-07	1.2E-01	2.5E-02	4.3E+00	7.7E-03	1.5E+00	1.3E-01	2.3E+03	1.1E-05	1.2E-04	4.1E-02	6.6E-02	6.7E+03	2.7E-02	5.2E-06	4.2E+00	9.8
18	VSEP B Concentrate to HDS B	19.3	3.4E-02	2.7E-01	3.3E-05	1.1E-02	1.6E+03	1.1E-03	8.4E+01	4.9E-07	1.2E-01	2.5E-02	4.3E+00	7.7E-03	1.5E+00	1.3E-01	2.3E+03	1.1E-05	1.2E-04	4.1E-02	6.6E-02	6.7E+03	2.7E-02	5.2E-06	4.2E+00	9.8
19	VSEP B Concentrate to HDS A	19.3	3.4E-02	2.7E-01	3.3E-05	1.1E-02	1.6E+03	1.1E-03	8.4E+01	4.9E-07	1.2E-01	2.5E-02	4.3E+00	7.7E-03	1.5E+00	1.3E-01	2.3E+03	1.1E-05	1.2E-04	4.1E-02	6.6E-02	6.7E+03	2.7E-02	5.2E-06	4.2E+00	9.8
20	Low Conc EQ Effluent	495.4	1.2E-04	1.4E-03	5.7E-02	3.4E-04	2.0E+02	7.3E-03	1.4E+02	3.4E-01	5.4E-03	2.4E+00	1.4E+00	1.6E-01	7.2E+01	4.9E-01	8.5E+01	3.8E+00	2.2E-03	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	6.3E-01	7.4
21	GSF Backwash	24.8	1.2E-04	1.4E-03	9.3E-01	3.4E-04	2.0E+02	1.4E-01	1.4E+02	6.8E+00	5.4E-03	4.7E+01	1.4E+00	3.1E+00	7.2E+01	9.4E+00	8.5E+01	6.9E+01	4.1E-02	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	1.3E+01	7.0
22	GSF Backwash Solids	12.4	1.2E-04	1.4E-03	1.6E+00	3.4E-04	2.0E+02	2.5E-01	1.4E+02	1.3E+01	5.4E-03	8.9E+01	1.4E+00	6.1E+00	7.2E+01	1.8E+01	8.5E+01	1.3E+02	7.5E-02	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	2.4E+01	7.0
23	GSF Backwash Decant	12.4	1.2E-04	1.4E-03	2.9E-01	3.4E-04	2.0E+02	2.0E-02	1.4E+02	4.4E-01	5.4E-03	5.1E+00	1.4E+00	1.9E-01	7.2E+01	9.4E-01	8.5E+01	1.2E+01	6.1E-03	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	9.0E-01	7.0
24	GSF Permeate/NF Feed	470.6	1.2E-04	1.4E-03	1.7E-02	3.4E-04	2.0E+02	8.0E-04	1.4E+02	5.5E-03	5.4E-03	1.5E-01	1.4E+00	1.7E-03	7.2E+01	2.6E-02	8.5E+01	5.5E-01	2.4E-04	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	1.5E-02	7.4
25	NF Permeate	376.5	8.9E-05	1.0E-04	2.4E-04	2.3E-05	2.9E+01	5.6E-05	1.6E+02	1.9E-04	3.7E-04	1.2E-02	1.1E+00	0.0E+00	4.9E+00	2.9E-03	5.5E+01	2.0E-02	9.2E-06	2.6E-03	2.4E-04	5.2E+01	8.9E-06	5.8E-04	3.0E-04	5.3
26	NF Concentrate to VSEP A	94.1	2.3E-04	6.8E-03	8.5E-02	1.6E-03	9.0E+02	3.8E-03	6.8E+01	2.7E-02	2.6E-02	7.2E-01	2.8E+00	8.4E-03	3.4E+02	1.2E-01	2.1E+02	2.7E+00	1.2E-03	1.8E-01	2.9E-02	1.4E+03	6.4E-04	4.0E-02	7.3E-02	10.1
27	VSEP A Permeate to Final Effluent	75.3	9.2E-06	4.3E-05	5.3E-02	1.3E-03	6.4E+01	1.0E-04	7.4E+01	1.6E-03	2.7E-03	3.0E-02	1.7E+00	3.3E-04	8.3E+01	3.1E-02	1.2E+02	1.4E-01	2.6E-05	9.8E-03	1.8E-03	3.4E+01	3.4E-05	5.4E-03	4.7E-03	5.4
28	VSEP A Concentrate	18.8	1.2E-03	3.5E-02	2.2E-01	3.0E-03	4.4E+03	1.9E-02	4.6E+01	1.3E-01	1.2E-01	3.6E+00	7.5E+00	4.2E-02	1.4E+03	4.9E-01	5.9E+02	1.3E+01	5.9E-03	9.0E-01	1.4E-01	6.8E+03	3.2E-03	1.8E-01	3.6E-01	8.5
29	VSEP A Concentrate to HDS B	9.4	1.2E-03	3.5E-02	2.2E-01	3.0E-03	4.4E+03	1.9E-02	4.6E+01	1.3E-01	1.2E-01	3.6E+00	7.5E+00	4.2E-02	1.4E+03	4.9E-01	5.9E+02	1.3E+01	5.9E-03	9.0E-01	1.4E-01	6.8E+03	3.2E-03	1.8E-01	3.6E-01	8.5
30	VSEP A Concentrate to HDS A	9.4	1.2E-03	3.5E-02	2.2E-01	3.0E-03	4.4E+03	1.9E-02	4.6E+01	1.3E-01	1.2E-01	3.6E+00	7.5E+00	4.2E-02	1.4E+03	4.9E-01	5.9E+02	1.3E+01	5.9E-03	9.0E-01	1.4E-01	6.8E+03	3.2E-03	1.8E-01	3.6E-01	8.5
31	HDS A Underflow Sludge	5.0	1.3E-01	0.0E+00	5.4E+00	1.5E-01	8.6E+04	9.3E-01	2.1E+00	4.9E+01	2.2E-01	2.0E+02	1.5E-01	1.9E+03	1.2E+04	8.1E+01	0.0E+00	3.0E+02	1.2E+00	0.0E+00	2.9E-01	4.5E+04	0.0E+00	1.5E+00	8.9E+01	10.7
32	Sulfate A Underflow Sludge	7.8	7.5E-08	8.7E+02	0.0E+00	0.0E+00	5.0E+04	0.0E+00	1.3E+00	3.3E-03	0.0E+00	1.2E-04	3.8E+02	0.0E+00	3.2E+03	0.0E+00	0.0E+00	1.1E-02	0.0E+00	2.6E+00	2.2E-01	1.5E+04	0.0E+00	0.0E+00	0.0E+00	12.4
33	Calcite A Underflow Sludge	6.2	2.0E-08	1.7E-10	0.0E+00	0.0E+00	2.4E+04	0.0E+00	2.4E-09	0.0E+00	0.0E+00	7.8E-05	0.0E+00	0.0E+00	0.0E+00	5.5E-07	0.0E+00	0.0E+00	0.0E+00	2.6E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.1
34	HDS B Underflow Sludge	5.0	1.3E-01	0.0E+00	5.4E+00	1.5E-01	8.6E+04	9.3E-01	2.1E+00	4.9E+01	2.2E-01	2.0E+02	1.5E-01	1.9E+03	1.2E+04	8.1E+01	0.0E+00	3.0E+02	1.2E+00	0.0E+00	2.9E-01	4.5E+04	0.0E+00	1.5E+00	8.9E+01	10.7
35	Sulfate B Underflow Sludge	7.8	7.5E-08	8.7E+02	0.0E+00	0.0E+00	5.0E+04	0.0E+00	1.3E+00	3.3E-03	0.0E+00	1.2E-04	3.8E+02	0.0E+00	3.2E+03	0.0E+00	0.0E+00	1.1E-02	0.0E+00	2.6E+00	2.2E-01	1.5E+04	0.0E+00	0.0E+00	0.0E+00	12.4
36	Calcite B Underflow Sludge	6.2	2.0E-08	1.7E-10	0.0E+00	0.0E+00	2.4E+04	0.0E+00	2.4E-09	0.0E+00	0.0E+00	7.8E-05	0.0E+00	0.0E+00	0.0E+00	5.5E-07	0.0E+00	0.0E+00	0.0E+00	2.6E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.1
37	Plant Site VSEP Concentrate	83.0	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
38	Plant Site Concentrate to HDS A	41.5	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
39	Plant Site Concentrate to HDS B	41.5	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
40	Final Effluent to CPS	667.0	7.4E-04	5.0E-03	6.1E-03	1.9E-03	5.9E+01	6.5E-05	1.4E+02	2.9E-04	3.6E-03	1.1E-02	1.2E+00	2.0E-04	1.2E+01	1.0E-02	2.2E+02	2.7E-02	1.0E-05	3.5E-03	1.8E-03	1.6E+02	5.9E-04	9.3E-04	9.3E-02	5.7

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	126.9	NA	NA	NA	167.1	3.3	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	45.3	40.23	5.0	NA	NA	NA	NA	NA	NA	25	1.18	3.35	0.37	2.98
5	Sulfate A Influent	126.9	NA	NA	NA	141.0	3.3	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	21.9	14.10	7.8	NA	NA	NA	NA	NA	NA	10	1.05	0.56	0.19	0.37
6	Sulfate A Effluent	126.9	NA	NA	82.5	209.4	NA	NA	1.0	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	6.2	0.00	6.2	NA	NA	NA	NA	NA	NA	10	1.06	0.15	0.15	0.00
7	Calcite A Effluent	126.9	NA	NA	9.2	136.1	NA	NA	0.1	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	126.9	NA	NA	NA	167.1	3.3	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	45.3	40.23	5.0	NA	NA	NA	NA	NA	NA	25	1.18	3.35	0.37	2.98
11	Sulfate B Influent	126.9	NA	NA		141.0	3.3	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	21.9	14.10	7.8	NA	NA	NA	NA	NA	NA	10	1.05	0.56	0.19	0.37
12	Sulfate B Effluent	126.9	NA	NA	82.5	209.4	NA	NA	1.0	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	6.2	0.00	6.2	NA	NA	NA	NA	NA	NA	10	1.06	0.15	0.15	0.00
13	Calcite B Effluent	126.9	NA	NA	9.2	126.9	NA	NA	0.1	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	495.4	NA	NA	NA	NA	NA	NA	NA	9.8	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	94.1	NA	NA	183.3*	NA	NA	NA	2.2	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 1 P90 Peak Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	157.0	1.5E-02	1.3E+02	3.1E-01	2.3E-02	3.8E+02	5.6E-02	2.1E+02	3.3E+00	9.5E-03	8.6E+00	2.2E+00	1.9E+02	1.8E+02	5.1E+00	7.3E+01	1.2E+01	1.1E-01	2.3E-01	3.7E-02	2.6E+03	5.4E-04	4.5E-02	6.5E+00	5.1
2	High Conc EQ Effluent to HDS A	78.5	1.5E-02	1.3E+02	3.1E-01	2.3E-02	3.8E+02	5.6E-02	2.1E+02	3.3E+00	9.5E-03	8.6E+00	2.2E+00	1.9E+02	1.8E+02	5.1E+00	7.3E+01	1.2E+01	1.1E-01	2.3E-01	3.7E-02	2.6E+03	5.4E-04	4.5E-02	6.5E+00	5.1
3	High Conc EQ Effluent to HDS B	78.5	1.5E-02	1.3E+02	3.1E-01	2.3E-02	3.8E+02	5.6E-02	2.1E+02	3.3E+00	9.5E-03	8.6E+00	2.2E+00	1.9E+02	1.8E+02	5.1E+00	7.3E+01	1.2E+01	1.1E-01	2.3E-01	3.7E-02	2.6E+03	5.4E-04	4.5E-02	6.5E+00	5.1
4	Combined HDS A Influent	161.0	1.2E-02	6.6E+01	2.5E-01	1.4E-02	1.2E+03	4.4E-02	1.4E+02	2.3E+00	2.9E-02	9.4E+00	2.1E+01	9.4E+01	6.2E+02	3.8E+00	5.9E+02	1.4E+01	5.8E-02	2.0E-01	4.1E-02	3.7E+03	3.0E-03	6.2E-02	5.0E+00	6.1
5	Sulfate A Influent	161.0	6.4E-03	6.5E+01	1.0E-05	8.2E-03	9.4E+02	3.4E-04	1.4E+02	2.6E-04	2.2E-02	5.0E-03	2.1E+01	1.6E-03	1.7E+02	3.8E-02	5.8E+02	8.6E-04	3.7E-05	1.9E-01	2.8E-02	1.6E+03	3.0E-03	8.0E-07	8.6E-01	10.7
6	Sulfate A Effluent	161.0	6.4E-03	6.5E-02	1.0E-05	8.2E-03	1.8E+03	3.4E-04	1.4E+02	1.4E-07	2.2E-02	5.0E-03	1.5E+00	1.6E-03	4.1E-01	3.8E-02	5.8E+02	2.8E-06	3.7E-05	9.7E-03	1.4E-02	1.1E+03	3.0E-03	8.0E-07	8.6E-01	12.4
7	Calcite A Effluent	161.0	6.5E-03	6.6E-02	1.0E-05	8.2E-03	7.9E+02	3.4E-04	1.4E+02	1.4E-07	2.2E-02	5.1E-03	1.5E+00	1.6E-03	4.2E-01	3.8E-02	5.9E+02	2.8E-06	3.7E-05	9.7E-03	1.4E-02	1.2E+03	3.0E-03	8.1E-07	8.7E-01	10.3
8	Calcite A Effluent to Final Effluent	64.4	6.4E-03	6.6E-02	1.0E-05	8.2E-03	7.9E+02	3.4E-04	1.4E+02	1.4E-07	2.2E-02	5.0E-03	1.5E+00	1.6E-03	4.2E-01	3.8E-02	5.9E+02	2.8E-06	3.7E-05	9.7E-03	1.4E-02	1.2E+03	3.0E-03	8.0E-07	8.7E-01	6.5
9	Calcite A Effluent to VSEP B	96.6	6.4E-03	6.6E-02	1.0E-05	8.2E-03	7.9E+02	3.4E-04	1.4E+02	1.4E-07	2.2E-02	5.0E-03	1.5E+00	1.6E-03	4.2E-01	3.8E-02	5.9E+02	2.8E-06	3.7E-05	9.7E-03	1.4E-02	1.2E+03	3.0E-03	8.0E-07	8.7E-01	6.5
10	Combined HDS B Influent	161.0	1.2E-02	6.6E+01	2.5E-01	1.4E-02	1.2E+03	4.4E-02	1.4E+02	2.3E+00	2.9E-02	9.4E+00	2.1E+01	9.4E+01	6.2E+02	3.8E+00	5.9E+02	1.4E+01	5.8E-02	2.0E-01	4.1E-02	3.7E+03	3.0E-03	6.2E-02	5.0E+00	6.1
11	Sulfate B Influent	161.0	6.4E-03	6.5E+01	1.0E-05	8.2E-03	9.4E+02	3.4E-04	1.4E+02	2.6E-04	2.2E-02	5.0E-03	2.1E+01	1.6E-03	1.7E+02	3.8E-02	5.8E+02	8.6E-04	3.7E-05	1.9E-01	2.8E-02	1.6E+03	3.0E-03	8.0E-07	8.6E-01	10.7
12	Sulfate B Effluent	161.0	6.4E-03	6.5E-02	1.0E-05	8.2E-03	1.8E+03	3.4E-04	1.4E+02	1.4E-07	2.2E-02	5.0E-03	1.5E+00	1.6E-03	4.1E-01	3.8E-02	5.8E+02	2.8E-06	3.7E-05	9.7E-03	1.4E-02	1.1E+03	3.0E-03	8.0E-07	8.6E-01	12.4
13	Calcite B Effluent	161.0	6.5E-03	6.6E-02	1.0E-05	8.2E-03	7.9E+02	3.4E-04	1.4E+02	1.4E-07	2.2E-02	5.1E-03	1.5E+00	1.6E-03	4.2E-01	3.8E-02	5.9E+02	2.8E-06	3.7E-05	9.7E-03	1.4E-02	1.2E+03	3.0E-03	8.1E-07	8.7E-01	10.3
14	Calcite B Effluent to Final Effluent	64.4	6.4E-03	6.6E-02	1.0E-05	8.2E-03	7.9E+02	3.4E-04	1.4E+02	1.4E-07	2.2E-02	5.0E-03	1.5E+00	1.6E-03	4.2E-01	3.8E-02	5.9E+02	2.8E-06	3.7E-05	9.7E-03	1.4E-02	1.2E+03	3.0E-03	8.0E-07	8.7E-01	6.5
15	Calcite B Effluent to VSEP B	96.6	6.4E-03	6.6E-02	1.0E-05	8.2E-03	7.9E+02	3.4E-04	1.4E+02	1.4E-07	2.2E-02	5.0E-03	1.5E+00	1.6E-03	4.2E-01	3.8E-02	5.9E+02	2.8E-06	3.7E-05	9.7E-03	1.4E-02	1.2E+03	3.0E-03	8.0E-07	8.7E-01	6.5
16	VSEP B Permeate to Final Effluent	141.6	2.6E-04	4.1E-04	6.3E-06	6.5E-03	5.6E+01	8.9E-06	1.5E+02	8.7E-09	2.4E-03	2.1E-04	8.7E-01	6.3E-05	1.0E-01	9.6E-03	3.3E+02	1.5E-07	8.3E-07	5.2E-04	8.6E-04	2.9E+01	1.6E-04	1.1E-07	5.5E-02	7.4
17	VSEP B Concentrate	35.4	3.2E-02	3.3E-01	2.6E-05	1.5E-02	3.8E+03	1.7E-03	9.3E+01	6.9E-07	1.0E-01	2.5E-02	3.8E+00	7.7E-03	1.7E+00	1.5E-01	1.6E+03	1.4E-05	1.8E-04	4.7E-02	6.8E-02	5.7E+03	1.4E-02	3.6E-06	4.2E+00	5.2
18	VSEP B Concentrate to HDS B	17.7	3.2E-02	3.3E-01	2.6E-05	1.5E-02	3.8E+03	1.7E-03	9.3E+01	6.9E-07	1.0E-01	2.5E-02	3.8E+00	7.7E-03	1.7E+00	1.5E-01	1.6E+03	1.4E-05	1.8E-04	4.7E-02	6.8E-02	5.7E+03	1.4E-02	3.6E-06	4.2E+00	5.2
19	VSEP B Concentrate to HDS A	17.7	3.2E-02	3.3E-01	2.6E-05	1.5E-02	3.8E+03	1.7E-03	9.3E+01	6.9E-07	1.0E-01	2.5E-02	3.8E+00	7.7E-03	1.7E+00	1.5E-01	1.6E+03	1.4E-05	1.8E-04	4.7E-02	6.8E-02	5.7E+03	1.4E-02	3.6E-06	4.2E+00	5.2
20	Low Conc EQ Effluent	695.4	1.2E-04	1.4E-03	5.7E-02	3.4E-04	2.0E+02	7.3E-03	1.4E+02	3.4E-01	5.4E-03	2.4E+00	1.4E+00	1.6E-01	7.2E+01	4.9E-01	8.5E+01	3.8E+00	2.2E-03	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	6.3E-01	7.4
21	GSF Backwash	34.8	1.2E-04	1.4E-03	9.3E-01	3.3E-04	2.0E+02	1.4E-01	1.4E+02	6.8E+00	5.4E-03	4.7E+01	1.4E+00	3.1E+00	7.2E+01	9.4E+00	8.5E+01	6.9E+01	4.1E-02	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	1.3E+01	7.0
22	GSF Backwash Solids	17.4	1.2E-04	1.4E-03	1.6E+00	3.3E-04	2.0E+02	2.5E-01	1.4E+02	1.3E+01	5.4E-03	8.9E+01	1.4E+00	6.1E+00	7.2E+01	1.8E+01	8.5E+01	1.3E+02	7.5E-02	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	2.4E+01	7.0
23	GSF Backwash Decant	17.4	1.2E-04	1.4E-03	2.9E-01	3.3E-04	2.0E+02	2.0E-02	1.4E+02	4.4E-01	5.4E-03	5.1E+00	1.4E+00	1.9E-01	7.2E+01	9.4E-01	8.5E+01	1.2E+01	6.1E-03	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	9.0E-01	7.0
24	GSF Permeate/NF Feed	660.6	1.2E-04	1.4E-03	1.7E-02	3.4E-04	2.0E+02	8.0E-04	1.4E+02	5.5E-03	5.4E-03	1.5E-01	1.4E+00	1.7E-03	7.2E+01	2.6E-02	8.5E+01	5.5E-01	2.4E-04	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	1.5E-02	7.4
25	NF Permeate	528.5	8.9E-05	1.0E-04	2.4E-04	2.3E-05	2.9E+01	5.6E-05	1.6E+02	1.9E-04	3.7E-04	1.2E-02	1.1E+00	0.0E+00	4.9E+00	2.9E-03	5.5E+01	2.0E-02	9.2E-06	2.6E-03	2.4E-04	5.2E+01	8.9E-06	5.8E-04	3.0E-04	7.5
26	NF Concentrate to VSEP A	132.1	2.3E-04	6.8E-03	8.5E-02	1.6E-03	9.0E+02	3.8E-03	6.8E+01	2.7E-02	2.6E-02	7.2E-01	2.8E+00	8.4E-03	3.4E+02	1.2E-01	2.1E+02	2.7E+00	1.2E-03	1.8E-01	2.9E-02	1.4E+03	6.4E-04	4.0E-02	7.3E-02	7.3
27	VSEP A Permeate to Final Effluent	105.7	9.2E-06	4.2E-05	5.3E-02	1.3E-03	6.4E+01	9.9E-05	7.4E+01	1.6E-03	2.7E-03	3.0E-02	1.7E+00	3.3E-04	8.3E+01	3.0E-02	1.2E+02	1.4E-01	2.6E-05	9.8E-03	1.8E-03	3.4E+01	3.4E-05	5.4E-03	4.7E-03	5.2
28	VSEP A Concentrate	26.4	1.1E-03	3.5E-02	2.2E-01	2.9E-03	4.3E+03	1.9E-02	4.5E+01	1.3E-01	1.2E-01	3.5E+00	7.4E+00	4.1E-02	1.4E+03	4.9E-01	5.9E+02	1.3E+01	5.8E-03	8.9E-01	1.4E-01	6.8E+03	3.1E-03	1.8E-01	3.6E-01	6.6
29	VSEP A Concentrate to HDS B	13.2	1.1E-03	3.5E-02	2.2E-01	2.9E-03	4.3E+03	1.9E-02	4.5E+01	1.3E-01	1.2E-01	3.5E+00	7.4E+00	4.1E-02	1.4E+03	4.9E-01	5.9E+02	1.3E+01	5.8E-03	8.9E-01	1.4E-01	6.8E+03	3.1E-03	1.8E-01	3.6E-01	6.6
30	VSEP A Concentrate to HDS A	13.2	1.1E-03	3.5E-02	2.2E-01	2.9E-03	4.3E+03	1.9E-02	4.5E+01	1.3E-01	1.2E-01	3.5E+00	7.4E+00	4.1E-02	1.4E+03	4.9E-01	5.9E+02	1.3E+01	5.8E-03	8.9E-01	1.4E-01	6.8E+03	3.1E-03	1.8E-01	3.6E-01	6.6
31	HDS A Underflow Sludge	6.0	1.4E-01	0.0E+00	6.7E+00	1.6E-01	8.4E+04	1.2E+00	2.4E+00	6.2E+01	1.8E-01	2.5E+02	1.3E-01	2.5E+03	1.2E+04	1.0E+02	0.0E+00	3.7E+02	1.5E+00	7.5E-06	3.2E-01	5.6E+04	0.0E+00	1.6E+00	1.1E+02	10.7
32	Sulfate A Underflow Sludge	8.1	0.0E+00	1.3E+03	3.1E-10	2.2E-08	5.7E+04	0.0E+00	1.8E+00	5.2E-03	1.6E-06	1.4E-04	3.8E+02	0.0E+00	3.4E+03	1.3E-08	0.0E+00	1.7E-02	0.0E+00	3.6E+00	2.8E-01	8.5E+03	0.0E+00	0.0E+00	1.9E-06	12.4
33	Calcite A Underflow Sludge	4.3	0.0E+00	0.0E+00	1.6E-09	0.0E+00	3.8E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.3
34	HDS B Underflow Sludge	6.0	1.4E-01	0.0E+00	6.7E+00	1.6E-01	8.4E+04	1.2E+00	2.4E+00	6.2E+01	1.8E-01	2.5E+02	1.3E-01	2.5E+03	1.2E+04	1.0E+02	0.0E+00	3.7E+02	1.5E+00	7.5E-06	3.2E-01	5.6E+04	0.0E+00	1.6E+00	1.1E+02	10.7
35	Sulfate B Underflow Sludge	8.1	0.0E+00	1.3E+03	3.1E-10	2.2E-08	5.7E+04	0.0E+00	1.8E+00	5.2E-03	1.6E-06	1.4E-04	3.8E+02	0.0E+00	3.4E+03	1.3E-08	0.0E+00	1.7E-02	0.0E+00	3.6E+00	2.8E-01	8.5E+03	0.0E+00	0.0E+00	1.9E-06	12.4
36	Calcite B Underflow Sludge	4.3	0.0E+00	0.0E+00	1.6E-09	0.0E+00	3.8E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.3
37	Plant Site VSEP Concentrate	85.7	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
38	Plant Site Concentrate to HDS A	42.9	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
39	Plant Site Concentrate to HDS B	42.9	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
40	Final Effluent to CPS	920.7	1.1E-03	1.0E-02	6.2E-03	2.5E-03	1.6E+02	9.8E-05	1.5E+02	3.0E-04	4.4E-03	1.1E-02	1.2E+00	3.0E-04	1.2E+01	1.3E-02	1.9E+02	2.8E-02	1.4E-05	4.2E-03	2.7E-03	2.2E+02	5.0E-04	9.5E-04	1.5E-01	6.2

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	161.0	NA	NA	NA	195.7	3.9	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	40.7	34.74	6.0	NA	NA	NA	NA	NA	NA	25	1.18	3.01	0.44	2.57
5	Sulfate A Influent	161.0	NA	NA	NA	178.8	3.3	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	26.0	17.88	8.1	NA	NA	NA	NA	NA	NA	10	1.05	0.67	0.20	0.47
6	Sulfate A Effluent	161.0	NA	NA	91.7	252.6	NA	NA	1.1	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	4.3	0.00	4.3	NA	NA	NA	NA	NA	NA	10	1.06	0.10	0.10	0.00
7	Calcite A Effluent	161.0	NA	NA	36.7	197.6	NA	NA	0.4	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	161.0	NA	NA	NA	195.7	3.9	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	40.7	34.74	6.0	NA	NA	NA	NA	NA	NA	25	1.18	3.01	0.44	2.57
11	Sulfate B Influent	161.0	NA	NA		178.8	3.3	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	26.0	17.88	8.1	NA	NA	NA	NA	NA	NA	10	1.05	0.67	0.20	0.47
12	Sulfate B Effluent	161.0	NA	NA	91.7	252.6	NA	NA	1.1	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	4.3	0.00	4.3	NA	NA	NA	NA	NA	NA	10	1.06	0.10	0.10	0.00
13	Calcite B Effluent	161.0	NA	NA	36.7	161.0	NA	NA	0.4	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	695.4	NA	NA	NA	NA	NA	NA	NA	13.8	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	132.1	NA	NA	183.3*	NA	NA	NA	2.2	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 1 P90 Winter Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	37.0	1.5E-02	1.3E+02	3.1E-01	2.3E-02	3.8E+02	5.6E-02	2.1E+02	3.3E+00	9.5E-03	8.6E+00	2.2E+00	1.9E+02	1.8E+02	5.1E+00	7.3E+01	1.2E+01	1.1E-01	2.3E-01	3.7E-02	2.6E+03	5.4E-04	4.5E-02	6.5E+00	5.1
2	High Conc EQ Effluent to HDS A	18.5	1.5E-02	1.3E+02	3.1E-01	2.3E-02	3.8E+02	5.6E-02	2.1E+02	3.3E+00	9.5E-03	8.6E+00	2.2E+00	1.9E+02	1.8E+02	5.1E+00	7.3E+01	1.2E+01	1.1E-01	2.3E-01	3.7E-02	2.6E+03	5.4E-04	4.5E-02	6.5E+00	5.1
3	High Conc EQ Effluent to HDS B	18.5	1.5E-02	1.3E+02	3.1E-01	2.3E-02	3.8E+02	5.6E-02	2.1E+02	3.3E+00	9.5E-03	8.6E+00	2.2E+00	1.9E+02	1.8E+02	5.1E+00	7.3E+01	1.2E+01	1.1E-01	2.3E-01	3.7E-02	2.6E+03	5.4E-04	4.5E-02	6.5E+00	5.1
4	Combined HDS A Influent	116.4	2.0E-02	2.2E+01	1.3E-01	7.8E-03	1.6E+03	3.0E-02	9.2E+01	9.9E-01	1.4E-01	4.7E+00	2.7E+01	3.1E+01	6.6E+02	1.8E+00	1.1E+03	7.1E+00	2.2E-02	9.7E-02	2.7E-02	3.6E+03	2.1E-02	5.0E-02	2.4E+00	7.1
5	Sulfate A Influent	116.4	1.7E-02	2.1E+01	1.6E-05	6.3E-03	8.2E+02	1.0E-02	9.0E+01	4.4E-03	1.3E-01	3.6E-03	2.6E+01	8.0E-04	6.3E+02	1.8E-02	1.1E+03	1.2E-02	3.0E-04	9.5E-02	1.9E-02	2.6E+03	2.1E-02	2.2E-06	5.4E-01	10.4
6	Sulfate A Effluent	116.4	1.7E-02	2.1E-02	1.6E-05	6.3E-03	2.3E+03	1.0E-02	9.0E+01	6.3E-07	1.3E-01	3.6E-03	1.4E+00	8.0E-04	4.9E-01	1.8E-02	1.1E+03	1.1E-05	3.0E-04	4.8E-03	9.3E-03	1.1E+03	2.1E-02	2.2E-06	5.4E-01	12.3
7	Calcite A Effluent	116.4	1.8E-02	2.2E-02	1.6E-05	6.4E-03	1.1E+03	1.0E-02	9.1E+01	6.4E-07	1.3E-01	3.6E-03	1.4E+00	8.1E-04	4.9E-01	1.8E-02	1.1E+03	1.1E-05	3.1E-04	4.8E-03	9.4E-03	1.1E+03	2.1E-02	2.2E-06	5.4E-01	10.4
8	Calcite A Effluent to Final Effluent	46.6	1.8E-02	2.2E-02	1.6E-05	6.4E-03	1.1E+03	1.0E-02	9.1E+01	6.4E-07	1.3E-01	3.6E-03	1.4E+00	8.1E-04	4.9E-01	1.8E-02	1.1E+03	1.1E-05	3.1E-04	4.8E-03	9.4E-03	1.1E+03	2.1E-02	2.2E-06	5.4E-01	6.9
9	Calcite A Effluent to VSEP B	69.8	1.8E-02	2.2E-02	1.6E-05	6.4E-03	1.1E+03	1.0E-02	9.1E+01	6.4E-07	1.3E-01	3.6E-03	1.4E+00	8.1E-04	4.9E-01	1.8E-02	1.1E+03	1.1E-05	3.1E-04	4.8E-03	9.4E-03	1.1E+03	2.1E-02	2.2E-06	5.4E-01	6.9
10	Combined HDS B Influent	116.4	2.0E-02	2.2E+01	1.3E-01	7.8E-03	1.6E+03	3.0E-02	9.2E+01	9.9E-01	1.4E-01	4.7E+00	2.7E+01	3.1E+01	6.6E+02	1.8E+00	1.1E+03	7.1E+00	2.2E-02	9.7E-02	2.7E-02	3.6E+03	2.1E-02	5.0E-02	2.4E+00	7.1
11	Sulfate B Influent	116.4	1.7E-02	2.1E+01	1.6E-05	6.3E-03	8.2E+02	1.0E-02	9.0E+01	4.4E-03	1.3E-01	3.6E-03	2.6E+01	8.0E-04	6.3E+02	1.8E-02	1.1E+03	1.2E-02	3.0E-04	9.5E-02	1.9E-02	2.6E+03	2.1E-02	2.2E-06	5.4E-01	10.4
12	Sulfate B Effluent	116.4	1.7E-02	2.1E-02	1.6E-05	6.3E-03	2.3E+03	1.0E-02	9.0E+01	6.3E-07	1.3E-01	3.6E-03	1.4E+00	8.0E-04	4.9E-01	1.8E-02	1.1E+03	1.1E-05	3.0E-04	4.8E-03	9.3E-03	1.1E+03	2.1E-02	2.2E-06	5.4E-01	12.3
13	Calcite B Effluent	116.4	1.8E-02	2.2E-02	1.6E-05	6.4E-03	1.1E+03	1.0E-02	9.1E+01	6.4E-07	1.3E-01	3.6E-03	1.4E+00	8.1E-04	4.9E-01	1.8E-02	1.1E+03	1.1E-05	3.1E-04	4.8E-03	9.4E-03	1.1E+03	2.1E-02	2.2E-06	5.4E-01	10.4
14	Calcite B Effluent to Final Effluent	46.6	1.8E-02	2.2E-02	1.6E-05	6.4E-03	1.1E+03	1.0E-02	9.1E+01	6.4E-07	1.3E-01	3.6E-03	1.4E+00	8.1E-04	4.9E-01	1.8E-02	1.1E+03	1.1E-05	3.1E-04	4.8E-03	9.4E-03	1.1E+03	2.1E-02	2.2E-06	5.4E-01	6.9
15	Calcite B Effluent to VSEP B	69.8	1.8E-02	2.2E-02	1.6E-05	6.4E-03	1.1E+03	1.0E-02	9.1E+01	6.4E-07	1.3E-01	3.6E-03	1.4E+00	8.1E-04	4.9E-01	1.8E-02	1.1E+03	1.1E-05	3.1E-04	4.8E-03	9.4E-03	1.1E+03	2.1E-02	2.2E-06	5.4E-01	6.9
16	VSEP B Permeate to Final Effluent	186.3	7.0E-04	1.3E-04	9.8E-06	5.1E-03	8.0E+01	2.6E-04	9.9E+01	3.9E-08	1.4E-02	1.5E-04	8.4E-01	3.2E-05	1.2E-01	4.5E-03	6.1E+02	5.8E-07	6.9E-06	2.6E-04	5.7E-04	2.8E+01	1.1E-03	3.0E-07	3.4E-02	5.8
17	VSEP B Concentrate	46.6	8.8E-02	1.1E-01	4.2E-05	1.2E-02	5.5E+03	5.1E-02	6.1E+01	3.1E-06	6.2E-01	1.8E-02	3.8E+00	4.1E-03	2.1E+00	7.4E-02	3.2E+03	5.4E-05	1.6E-03	2.4E-02	4.6E-02	5.7E+03	1.0E-01	1.0E-05	2.7E+00	9.1
18	VSEP B Concentrate to HDS B	23.3	8.8E-02	1.1E-01	4.2E-05	1.2E-02	5.5E+03	5.1E-02	6.1E+01	3.1E-06	6.2E-01	1.8E-02	3.8E+00	4.1E-03	2.1E+00	7.4E-02	3.2E+03	5.4E-05	1.6E-03	2.4E-02	4.6E-02	5.7E+03	1.0E-01	1.0E-05	2.7E+00	9.1
19	VSEP B Concentrate to HDS A	23.3	8.8E-02	1.1E-01	4.2E-05	1.2E-02	5.5E+03	5.1E-02	6.1E+01	3.1E-06	6.2E-01	1.8E-02	3.8E+00	4.1E-03	2.1E+00	7.4E-02	3.2E+03	5.4E-05	1.6E-03	2.4E-02	4.6E-02	5.7E+03	1.0E-01	1.0E-05	2.7E+00	9.1
20	Low Conc EQ Effluent	317.9	1.2E-04	1.4E-03	5.7E-02	3.4E-04	2.0E+02	7.3E-03	1.4E+02	3.4E-01	5.4E-03	2.4E+00	1.8E+00	1.6E-01	7.2E+01	4.9E-01	8.5E+01	3.8E+00	2.2E-03	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	6.3E-01	7.4
21	GSF Backwash	15.9	1.2E-04	1.4E-03	9.3E-01	3.4E-04	2.0E+02	1.4E-01	1.4E+02	6.8E+00	5.4E-03	4.7E+01	1.8E+00	3.1E+00	7.2E+01	9.4E+00	8.5E+01	6.9E+01	4.1E-02	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	1.3E+01	7.0
22	GSF Backwash Solids	7.9	1.2E-04	1.4E-03	1.6E+00	3.4E-04	2.0E+02	2.5E-01	1.4E+02	1.3E+01	5.4E-03	8.9E+01	1.8E+00	6.1E+00	7.2E+01	1.8E+01	8.5E+01	1.3E+02	7.5E-02	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	2.4E+01	7.0
23	GSF Backwash Decant	7.9	1.2E-04	1.4E-03	2.9E-01	3.4E-04	2.0E+02	2.0E-02	1.4E+02	4.4E-01	5.4E-03	5.1E+00	1.8E+00	1.9E-01	7.2E+01	9.4E-01	8.5E+01	1.2E+01	6.1E-03	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	9.0E-01	7.0
24	GSF Permeate/NF Feed	302.1	1.2E-04	1.4E-03	1.7E-02	3.4E-04	2.0E+02	8.0E-04	1.4E+02	5.5E-03	5.4E-03	1.5E-01	1.8E+00	1.7E-03	7.2E+01	2.6E-02	8.5E+01	5.5E-01	2.4E-04	3.8E-02	6.0E-03	3.1E+02	1.3E-04	8.4E-03	1.5E-02	7.4
25	NF Permeate	241.6	8.9E-05	1.0E-04	2.4E-04	2.3E-05	2.9E+01	5.6E-05	1.6E+02	1.9E-04	3.7E-04	1.2E-02	1.4E+00	0.0E+00	4.9E+00	2.9E-03	5.5E+01	2.0E-02	9.2E-06	2.6E-03	2.4E-04	5.2E+01	8.9E-06	5.8E-04	3.0E-04	5.3
26	NF Concentrate to VSEP A	60.4	2.3E-04	6.8E-03	8.5E-02	1.6E-03	9.0E+02	3.8E-03	6.8E+01	2.7E-02	2.6E-02	7.2E-01	3.4E+00	8.4E-03	3.4E+02	1.2E-01	2.1E+02	2.7E+00	1.2E-03	1.8E-01	2.9E-02	1.4E+03	6.4E-04	4.0E-02	7.3E-02	10.1
27	VSEP A Permeate to Final Effluent	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	VSEP A Concentrate	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29	VSEP A Concentrate to HDS B	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30	VSEP A Concentrate to HDS A	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	4.1	7.6E-02	2.2E-03	3.5E+00	3.9E-02	1.0E+05	5.5E-01	1.7E+00	2.8E+01	1.3E-01	1.3E+02	2.2E-01	8.7E+02	3.5E+02	5.0E+01	0.0E+00	2.0E+02	6.0E-01	9.5E-06	2.3E-01	2.5E+04	0.0E+00	1.4E+00	5.3E+01	10.4
32	Sulfate A Underflow Sludge	8.2	0.0E+00	3.0E+02	0.0E+00	0.0E+00	3.9E+04	0.0E+00	8.3E-01	6.2E-02	6.5E-07	7.2E-05	3.6E+02	0.0E+00	9.0E+03	0.0E+00	0.0E+00	1.7E-01	0.0E+00	1.3E+00	1.3E-01	2.1E+04	0.0E+00	0.0E+00	0.0E+00	12.3
33	Calcite A Underflow Sludge	3.7	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+04	0.0E+00	6.6E-09	2.5E-11	3.0E-05	8.8E-05	1.8E-04	1.1E-09	0.0E+00	0.0E+00	1.2E-01	2.5E-09	0.0E+00	0.0E+00	0.0E+00	1.2E-01	0.0E+00	0.0E+00	9.1E-06	10.4
34	HDS B Underflow Sludge	4.1	7.6E-02	2.2E-03	3.5E+00	3.9E-02	1.0E+05	5.5E-01	1.7E+00	2.8E+01	1.3E-01	1.3E+02	2.2E-01	8.7E+02	3.5E+02	5.0E+01	0.0E+00	2.0E+02	6.0E-01	9.5E-06	2.3E-01	2.5E+04	0.0E+00	1.4E+00	5.3E+01	10.4
35	Sulfate B Underflow Sludge	8.2	0.0E+00	3.0E+02	0.0E+00	0.0E+00	3.9E+04	0.0E+00	8.3E-01	6.2E-02	6.5E-07	7.2E-05	3.6E+02	0.0E+00	9.0E+03	0.0E+00	0.0E+00	1.7E-01	0.0E+00	1.3E+00	1.3E-01	2.1E+04	0.0E+00	0.0E+00	0.0E+00	12.3
36	Calcite B Underflow Sludge	3.7	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+04	0.0E+00	6.6E-09	2.5E-11	3.0E-05	8.8E-05	1.8E-04	1.1E-09	0.0E+00	0.0E+00	1.2E-01	2.5E-09	0.0E+00	0.0E+00	0.0E+00	1.2E-01	0.0E+00	0.0E+00	9.1E-06	10.4
37	Plant Site VSEP Concentrate	80.9	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
38	Plant Site Concentrate to HDS A	40.5	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
39	Plant Site Concentrate to HDS B	40.5	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
40	Final Effluent to CPS	427.9	3.5E-04	1.2E-04	1.4E-04	2.2E-03	5.1E+01	1.5E-04	1.4E+02	1.1E-04	6.3E-03	7.0E-03	1.1E+00	1.4E-05	2.8E+00	3.6E-03	3.0E+02	1.1E-02	8.2E-06	1.6E-03	3.8E-04	4.1E+01	4.9E-04	3.3E-04	1.5E-02	5.7

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	.	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	116.4	NA	NA	NA	277.3	2.7	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	164.9	160.84	4.1	NA	NA	NA	NA	NA	NA	25	1.19	12.23	0.30	11.93
5	Sulfate A Influent	116.4	NA	NA	NA	129.3	2.2	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	21.1	12.93	8.2	NA	NA	NA	NA	NA	NA	10	1.05	0.54	0.20	0.34
6	Sulfate A Effluent	116.4	NA	NA	77.9	194.3	NA	NA	0.9	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	3.7	0.00	3.7	NA	NA	NA	NA	NA	NA	10	1.06	0.09	0.09	0.00
7	Calcite A Effluent	116.4	NA	NA	137.5	253.9	NA	NA	1.7	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	116.4	NA	NA	NA	277.3	2.7	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	164.9	160.84	4.1	NA	NA	NA	NA	NA	NA	25	1.19	12.23	0.30	11.93
11	Sulfate B Influent	116.4	NA	NA		129.3	2.2	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	21.1	12.93	8.2	NA	NA	NA	NA	NA	NA	10	1.05	0.54	0.20	0.34
12	Sulfate B Effluent	116.4	NA	NA	77.9	194.3	NA	NA	0.9	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	3.7	0.00	3.7	NA	NA	NA	NA	NA	NA	10	1.06	0.09	0.09	0.00
13	Calcite B Effluent	116.4	NA	NA	137.5	116.4	NA	NA	1.7	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	317.9	NA	NA	NA	NA	NA	NA	NA	6.3	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	60.4	NA	NA	0*	NA	NA	NA	0.0	NA	NA	NA	NA	NA	NA

Mine Water Treatment Trains Flow and Load Detail
Year 2 P90 Annual Average

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	100.0	2.9E-02	2.0E+02	3.4E-01	3.5E-02	1.4E+03	7.9E-02	1.6E+02	6.4E+00	1.8E-02	1.1E+01	2.2E+00	4.5E+02	4.8E+02	1.6E+01	2.0E+02	3.0E+01	1.4E-01	5.8E-01	1.1E-01	7.4E+03	1.3E-03	5.7E-02	8.8E+00	5.0
2	High Conc EQ Effluent to HDS A	50.0	2.9E-02	2.0E+02	3.4E-01	3.5E-02	1.4E+03	7.9E-02	1.6E+02	6.4E+00	1.8E-02	1.1E+01	2.2E+00	4.5E+02	4.8E+02	1.6E+01	2.0E+02	3.0E+01	1.4E-01	5.8E-01	1.1E-01	7.4E+03	1.3E-03	5.7E-02	8.8E+00	5.0
3	High Conc EQ Effluent to HDS B	50.0	2.9E-02	2.0E+02	3.4E-01	3.5E-02	1.4E+03	7.9E-02	1.6E+02	6.4E+00	1.8E-02	1.1E+01	2.2E+00	4.5E+02	4.8E+02	1.6E+01	2.0E+02	3.0E+01	1.4E-01	5.8E-01	1.1E-01	7.4E+03	1.3E-03	5.7E-02	8.8E+00	5.0
4	Combined HDS A Influent	132.4	1.8E-02	7.5E+01	3.0E-01	1.7E-02	1.9E+03	5.7E-02	9.8E+01	3.3E+00	4.7E-02	1.1E+01	2.5E+01	1.7E+02	8.6E+02	7.6E+00	8.8E+02	2.1E+01	6.3E-02	2.6E-01	8.0E-02	6.2E+03	6.4E-03	7.2E-02	6.0E+00	6.2
5	Sulfate A Influent	132.4	8.2E-03	7.3E+01	3.5E-06	8.6E-03	6.7E+02	4.2E-03	9.6E+01	3.5E-03	3.7E-02	3.5E-03	2.4E+01	7.5E-04	7.9E+02	7.5E-02	8.7E+02	9.1E-03	1.9E-04	2.5E-01	5.5E-02	3.3E+03	6.3E-03	3.1E-07	5.1E-01	10.4
6	Sulfate A Effluent	132.4	8.2E-03	7.3E-02	3.5E-06	8.6E-03	1.9E+03	4.2E-03	9.6E+01	4.1E-07	3.7E-02	3.5E-03	1.4E+00	7.5E-04	4.3E-01	7.5E-02	8.7E+02	6.4E-06	1.9E-04	1.3E-02	2.8E-02	1.2E+03	6.3E-03	3.1E-07	5.1E-01	12.4
7	Calcite A Effluent	132.4	8.3E-03	7.4E-02	3.5E-06	8.7E-03	8.0E+02	4.2E-03	9.7E+01	4.1E-07	3.8E-02	3.5E-03	1.5E+00	7.6E-04	4.3E-01	7.5E-02	8.8E+02	6.5E-06	1.9E-04	1.3E-02	2.8E-02	1.2E+03	6.3E-03	3.2E-07	5.1E-01	10.1
8	Calcite A Effluent to Final Effluent	53.0	8.3E-03	7.4E-02	3.5E-06	8.7E-03	8.0E+02	4.2E-03	9.6E+01	4.1E-07	3.8E-02	3.5E-03	1.4E+00	7.6E-04	4.3E-01	7.5E-02	8.7E+02	6.4E-06	1.9E-04	1.3E-02	2.8E-02	1.2E+03	6.3E-03	3.2E-07	5.1E-01	6.8
9	Calcite A Effluent to VSEP B	79.4	8.3E-03	7.4E-02	3.5E-06	8.7E-03	8.0E+02	4.2E-03	9.6E+01	4.1E-07	3.8E-02	3.5E-03	1.4E+00	7.6E-04	4.3E-01	7.5E-02	8.7E+02	6.4E-06	1.9E-04	1.3E-02	2.8E-02	1.2E+03	6.3E-03	3.2E-07	5.1E-01	6.8
10	Combined HDS B Influent	132.4	1.8E-02	7.5E+01	3.0E-01	1.7E-02	1.9E+03	5.7E-02	9.8E+01	3.3E+00	4.7E-02	1.1E+01	2.5E+01	1.7E+02	8.6E+02	7.6E+00	8.8E+02	2.1E+01	6.3E-02	2.6E-01	8.0E-02	6.2E+03	6.4E-03	7.2E-02	6.0E+00	6.2
11	Sulfate B Influent	132.4	8.2E-03	7.3E+01	3.5E-06	8.6E-03	6.7E+02	4.2E-03	9.6E+01	3.5E-03	3.7E-02	3.5E-03	2.4E+01	7.5E-04	7.9E+02	7.5E-02	8.7E+02	9.1E-03	1.9E-04	2.5E-01	5.5E-02	3.3E+03	6.3E-03	3.1E-07	5.1E-01	10.4
12	Sulfate B Effluent	132.4	8.2E-03	7.3E-02	3.5E-06	8.6E-03	1.9E+03	4.2E-03	9.6E+01	4.1E-07	3.7E-02	3.5E-03	1.4E+00	7.5E-04	4.3E-01	7.5E-02	8.7E+02	6.4E-06	1.9E-04	1.3E-02	2.8E-02	1.2E+03	6.3E-03	3.1E-07	5.1E-01	12.4
13	Calcite B Effluent	132.4	8.3E-03	7.4E-02	3.5E-06	8.7E-03	8.0E+02	4.2E-03	9.7E+01	4.1E-07	3.8E-02	3.5E-03	1.5E+00	7.6E-04	4.3E-01	7.5E-02	8.8E+02	6.5E-06	1.9E-04	1.3E-02	2.8E-02	1.2E+03	6.3E-03	3.2E-07	5.1E-01	10.1
14	Calcite B Effluent to Final Effluent	53.0	8.3E-03	7.4E-02	3.5E-06	8.7E-03	8.0E+02	4.2E-03	9.6E+01	4.1E-07	3.8E-02	3.5E-03	1.4E+00	7.6E-04	4.3E-01	7.5E-02	8.7E+02	6.4E-06	1.9E-04	1.3E-02	2.8E-02	1.2E+03	6.3E-03	3.2E-07	5.1E-01	6.8
15	Calcite B Effluent to VSEP B	79.4	8.3E-03	7.4E-02	3.5E-06	8.7E-03	8.0E+02	4.2E-03	9.6E+01	4.1E-07	3.8E-02	3.5E-03	1.4E+00	7.6E-04	4.3E-01	7.5E-02	8.7E+02	6.4E-06	1.9E-04	1.3E-02	2.8E-02	1.2E+03	6.3E-03	3.2E-07	5.1E-01	6.8
16	VSEP B Permeate to Final Effluent	152.5	3.3E-04	4.6E-04	2.2E-06	6.9E-03	5.7E+01	1.1E-04	1.0E+02	2.5E-08	4.0E-03	1.5E-04	8.7E-01	3.0E-05	1.0E-01	1.9E-02	4.9E+02	3.5E-07	4.3E-06	6.8E-04	1.7E-03	2.9E+01	3.4E-04	4.2E-08	3.3E-02	6.7
17	VSEP B Concentrate	38.1	4.1E-02	3.7E-01	9.0E-06	1.6E-02	3.8E+03	2.1E-02	6.4E+01	2.0E-06	1.7E-01	1.7E-02	3.8E+00	3.7E-03	1.8E+00	3.0E-01	2.5E+03	3.1E-05	9.5E-04	6.1E-02	1.3E-01	5.8E+03	3.1E-02	1.4E-06	2.5E+00	7.8
18	VSEP B Concentrate to HDS B	19.1	4.1E-02	3.7E-01	9.0E-06	1.6E-02	3.8E+03	2.1E-02	6.4E+01	2.0E-06	1.7E-01	1.7E-02	3.8E+00	3.7E-03	1.8E+00	3.0E-01	2.5E+03	3.1E-05	9.5E-04	6.1E-02	1.3E-01	5.8E+03	3.1E-02	1.4E-06	2.5E+00	7.8
19	VSEP B Concentrate to HDS A	19.1	4.1E-02	3.7E-01	9.0E-06	1.6E-02	3.8E+03	2.1E-02	6.4E+01	2.0E-06	1.7E-01	1.7E-02	3.8E+00	3.7E-03	1.8E+00	3.0E-01	2.5E+03	3.1E-05	9.5E-04	6.1E-02	1.3E-01	5.8E+03	3.1E-02	1.4E-06	2.5E+00	7.8
20	Low Conc EQ Effluent	688.2	1.8E-04	1.7E-03	7.8E-02	4.0E-04	2.7E+02	8.9E-03	7.7E+01	3.3E-01	5.0E-03	2.7E+00	1.2E+00	1.9E-01	9.6E+01	4.9E-01	9.4E+01	3.7E+00	4.0E-03	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	8.8E-01	7.4
21	GSF Backwash	34.4	1.8E-04	1.7E-03	1.3E+00	4.0E-04	2.7E+02	1.7E-01	7.7E+01	6.6E+00	5.0E-03	5.3E+01	1.2E+00	3.7E+00	9.6E+01	9.5E+00	9.4E+01	6.8E+01	7.5E-02	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	1.7E+01	7.0
22	GSF Backwash Solids	17.2	1.8E-04	1.7E-03	2.1E+00	4.0E-04	2.7E+02	3.1E-01	7.7E+01	1.3E+01	5.0E-03	1.0E+02	1.2E+00	7.1E+00	9.6E+01	1.8E+01	9.4E+01	1.2E+02	1.4E-01	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	3.3E+01	7.0
23	GSF Backwash Decant	17.2	1.8E-04	1.7E-03	3.9E-01	4.0E-04	2.7E+02	2.5E-02	7.7E+01	4.3E-01	5.0E-03	5.7E+00	1.2E+00	2.2E-01	9.6E+01	9.5E-01	9.4E+01	1.2E+01	1.1E-02	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	1.2E+00	7.0
24	GSF Permeate/NF Feed	653.8	1.8E-04	1.7E-03	2.4E-02	4.0E-04	2.7E+02	9.8E-04	7.7E+01	5.3E-03	5.0E-03	1.7E-01	1.2E+00	2.0E-03	9.6E+01	2.7E-02	9.4E+01	5.4E-01	4.4E-04	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	2.1E-02	7.4
25	NF Permeate	523.0	1.4E-04	1.2E-04	3.2E-04	2.8E-05	3.8E+01	6.8E-05	8.7E+01	1.9E-04	3.5E-04	1.3E-02	9.5E-01	0.0E+00	6.5E+00	2.9E-03	6.0E+01	1.9E-02	1.7E-05	5.8E-04	2.4E-04	7.9E+01	1.3E-05	6.9E-04	4.1E-04	7.5
26	NF Concentrate to VSEP A	130.8	3.6E-04	8.0E-03	1.2E-01	1.9E-03	1.2E+03	4.6E-03	3.6E+01	2.6E-02	2.4E-02	8.1E-01	2.4E+00	9.9E-03	4.6E+02	1.2E-01	2.3E+02	2.6E+00	2.1E-03	4.0E-02	2.9E-02	2.1E+03	9.0E-04	4.8E-02	1.0E-01	7.3
27	VSEP A Permeate to Final Effluent	104.6	1.4E-05	5.0E-05	7.2E-02	1.5E-03	8.5E+01	1.2E-04	3.9E+01	1.6E-03	2.5E-03	3.4E-02	1.4E+00	3.9E-04	1.1E+02	3.1E-02	1.3E+02	1.4E-01	4.8E-05	2.2E-03	1.8E-03	5.2E+01	4.8E-05	6.4E-03	6.5E-03	5.5
28	VSEP A Concentrate	26.2	1.8E-03	4.1E-02	3.1E-01	3.5E-03	5.8E+03	2.3E-02	2.4E+01	1.3E-01	1.1E-01	4.0E+00	6.4E+00	4.9E-02	1.9E+03	5.0E-01	6.5E+02	1.3E+01	1.1E-02	2.0E-01	1.4E-01	1.0E+04	4.4E-03	2.2E-01	5.0E-01	7.0
29	VSEP A Concentrate to HDS B	13.1	1.8E-03	4.1E-02	3.1E-01	3.5E-03	5.8E+03	2.3E-02	2.4E+01	1.3E-01	1.1E-01	4.0E+00	6.4E+00	4.9E-02	1.9E+03	5.0E-01	6.5E+02	1.3E+01	1.1E-02	2.0E-01	1.4E-01	1.0E+04	4.4E-03	2.2E-01	5.0E-01	7.0
30	VSEP A Concentrate to HDS A	13.1	1.8E-03	4.1E-02	3.1E-01	3.5E-03	5.8E+03	2.3E-02	2.4E+01	1.3E-01	1.1E-01	4.0E+00	6.4E+00	4.9E-02	1.9E+03	5.0E-01	6.5E+02	1.3E+01	1.1E-02	2.0E-01	1.4E-01	1.0E+04	4.4E-03	2.2E-01	5.0E-01	7.0
31	HDS A Underflow Sludge	5.6	2.2E-01	0.0E+00	7.0E+00	1.9E-01	9.4E+04	1.2E+00	1.5E+00	7.7E+01	2.1E-01	2.6E+02	1.3E-01	4.0E+03	1.2E+03	1.8E+02	0.0E+00	4.8E+02	1.5E+00	7.3E-06	5.6E-01	6.6E+04	0.0E+00	1.7E+00	1.3E+02	10.4
32	Sulfate A Underflow Sludge	11.7	0.0E+00	8.3E+02	0.0E+00	0.0E+00	3.1E+04	0.0E+00	7.0E-01	4.0E-02	0.0E+00	5.6E-05	2.6E+02	0.0E+00	8.9E+03	0.0E+00	0.0E+00	1.0E-01	0.0E+00	2.7E+00	3.1E-01	2.4E+04	0.0E+00	3.0E-12	0.0E+00	12.4
33	Calcite A Underflow Sludge	3.9	0.0E+00	1.8E-09	4.6E-11	0.0E+00	3.8E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.1E-05	9.2E-05	7.9E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.1E-10	1.7E-06	0.0E+00	0.0E+00	2.9E-12	3.6E-06	10.1
34	HDS B Underflow Sludge	5.6	2.2E-01	0.0E+00	7.0E+00	1.9E-01	9.4E+04	1.2E+00	1.5E+00	7.7E+01	2.1E-01	2.6E+02	1.3E-01	4.0E+03	1.2E+03	1.8E+02	0.0E+00	4.8E+02	1.5E+00	7.3E-06	5.6E-01	6.6E+04	0.0E+00	1.7E+00	1.3E+02	10.4
35	Sulfate B Underflow Sludge	11.7	0.0E+00	8.3E+02	0.0E+00	0.0E+00	3.1E+04	0.0E+00	7.0E-01	4.0E-02	0.0E+00	5.6E-05	2.6E+02	0.0E+00	8.9E+03	0.0E+00	0.0E+00	1.0E-01	0.0E+00	2.7E+00	3.1E-01	2.4E+04	0.0E+00	3.0E-12	0.0E+00	12.4
36	Calcite B Underflow Sludge	3.9	0.0E+00	1.8E-09	4.6E-11	0.0E+00	3.8E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.1E-05	9.2E-05	7.9E-09	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.1E-10	1.7E-06	0.0E+00	0.0E+00	2.9E-12	3.6E-06	10.1
37	Plant Site VSEP Concentrate	83.3	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
38	Plant Site Concentrate to HDS A	41.7	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
39	Plant Site Concentrate to HDS B	41.7	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
40	Final Effluent to CPS	854.3	8.6E-04	6.5E-03	9.0E-03	2.2E-03	1.1E+02	4.4E-04	8.5E+01	3.1E-04	4.5E-03	1.3E-02	1.0E+00	1.2E-04	1.7E+01	1.5E-02	2.2E+02	2.9E-02	3.4E-05	1.8E-03	3.1E-03	1.6E+02	6.2E-04	1.2E-03	5.1E-02	6.2

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	132.4	NA	NA	NA	145.7	3.0	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	18.9	13.34	5.6	NA	NA	NA	NA	NA	NA	25	1.18	1.40	0.41	0.99
5	Sulfate A Influent	132.4	NA	NA	NA	147.1	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	26.5	14.71	11.7	NA	NA	NA	NA	NA	NA	10	1.05	0.67	0.28	0.39
6	Sulfate A Effluent	132.4	NA	NA	82.5	214.9	NA	NA	1.0	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	3.9	0.00	3.9	NA	NA	NA	NA	NA	NA	10	1.06	0.09	0.09	0.00
7	Calcite A Effluent	132.4	NA	NA	36.7	169.1	NA	NA	0.4	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	132.4	NA	NA	NA	145.7	3.0	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	18.9	13.34	5.6	NA	NA	NA	NA	NA	NA	25	1.18	1.40	0.41	0.99
11	Sulfate B Influent	132.4	NA	NA		147.1	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	26.5	14.71	11.7	NA	NA	NA	NA	NA	NA	10	1.05	0.67	0.28	0.39
12	Sulfate B Effluent	132.4	NA	NA	82.5	214.9	NA	NA	1.0	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	3.9	0.00	3.9	NA	NA	NA	NA	NA	NA	10	1.06	0.09	0.09	0.00
13	Calcite B Effluent	132.4	NA	NA	36.7	132.4	NA	NA	0.4	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	688.2	NA	NA	NA	NA	NA	NA	NA	13.6	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	130.8	NA	NA	183.3*	NA	NA	NA	2.2	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 2 P90 Peak Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	188.0	2.9E-02	2.0E+02	3.4E-01	3.5E-02	1.4E+03	7.9E-02	1.6E+02	6.4E+00	1.8E-02	1.1E+01	2.2E+00	4.5E+02	4.8E+02	1.6E+01	2.0E+02	3.0E+01	1.4E-01	5.8E-01	1.1E-01	7.4E+03	1.3E-03	5.7E-02	8.8E+00	5.0
2	High Conc EQ Effluent to HDS A	94.0	2.9E-02	2.0E+02	3.4E-01	3.5E-02	1.4E+03	7.9E-02	1.6E+02	6.4E+00	1.8E-02	1.1E+01	2.2E+00	4.5E+02	4.8E+02	1.6E+01	2.0E+02	3.0E+01	1.4E-01	5.8E-01	1.1E-01	7.4E+03	1.3E-03	5.7E-02	8.8E+00	5.0
3	High Conc EQ Effluent to HDS B	94.0	2.9E-02	2.0E+02	3.4E-01	3.5E-02	1.4E+03	7.9E-02	1.6E+02	6.4E+00	1.8E-02	1.1E+01	2.2E+00	4.5E+02	4.8E+02	1.6E+01	2.0E+02	3.0E+01	1.4E-01	5.8E-01	1.1E-01	7.4E+03	1.3E-03	5.7E-02	8.8E+00	5.0
4	Combined HDS A Influent	181.2	1.6E-02	1.0E+02	3.4E-01	1.9E-02	1.6E+03	6.3E-02	1.1E+02	4.2E+00	2.3E-02	1.2E+01	1.9E+01	2.3E+02	7.9E+02	9.7E+00	4.6E+02	2.4E+01	8.1E-02	3.3E-01	7.5E-02	5.9E+03	1.9E-03	7.2E-02	6.7E+00	6.1
5	Sulfate A Influent	181.2	5.1E-03	1.0E+02	2.2E-06	7.1E-03	6.2E+02	2.0E-03	1.0E+02	1.3E-03	1.3E-02	3.7E-03	1.9E+01	8.9E-04	6.1E+02	9.5E-02	4.5E+02	3.4E-03	3.6E-05	3.2E-01	5.2E-02	3.1E+03	1.9E-03	1.8E-07	5.6E-01	10.5
6	Sulfate A Effluent	181.2	5.1E-03	1.0E-01	2.2E-06	7.1E-03	1.6E+03	2.0E-03	1.0E+02	2.0E-07	1.3E-02	3.7E-03	1.5E+00	8.9E-04	3.8E-01	9.5E-02	4.5E+02	3.1E-06	3.6E-05	1.6E-02	2.6E-02	1.2E+03	1.9E-03	1.8E-07	5.6E-01	12.4
7	Calcite A Effluent	181.2	5.1E-03	1.0E-01	2.3E-06	7.1E-03	3.0E+02	2.0E-03	1.0E+02	2.0E-07	1.4E-02	3.7E-03	1.5E+00	8.9E-04	3.8E-01	9.6E-02	4.6E+02	3.2E-06	3.6E-05	1.6E-02	2.6E-02	1.2E+03	1.9E-03	1.8E-07	5.6E-01	10.4
8	Calcite A Effluent to Final Effluent	72.5	5.1E-03	1.0E-01	2.2E-06	7.1E-03	3.0E+02	2.0E-03	1.0E+02	2.0E-07	1.4E-02	3.7E-03	1.5E+00	8.9E-04	3.8E-01	9.5E-02	4.5E+02	3.1E-06	3.6E-05	1.6E-02	2.6E-02	1.2E+03	1.9E-03	1.8E-07	5.6E-01	6.0
9	Calcite A Effluent to VSEP B	108.7	5.1E-03	1.0E-01	2.2E-06	7.1E-03	3.0E+02	2.0E-03	1.0E+02	2.0E-07	1.4E-02	3.7E-03	1.5E+00	8.9E-04	3.8E-01	9.5E-02	4.5E+02	3.1E-06	3.6E-05	1.6E-02	2.6E-02	1.2E+03	1.9E-03	1.8E-07	5.6E-01	6.0
10	Combined HDS B Influent	181.2	1.6E-02	1.0E+02	3.4E-01	1.9E-02	1.6E+03	6.3E-02	1.1E+02	4.2E+00	2.3E-02	1.2E+01	1.9E+01	2.3E+02	7.9E+02	9.7E+00	4.6E+02	2.4E+01	8.1E-02	3.3E-01	7.5E-02	5.9E+03	1.9E-03	7.2E-02	6.7E+00	6.1
11	Sulfate B Influent	181.2	5.1E-03	1.0E+02	2.2E-06	7.1E-03	6.2E+02	2.0E-03	1.0E+02	1.3E-03	1.3E-02	3.7E-03	1.9E+01	8.9E-04	6.1E+02	9.5E-02	4.5E+02	3.4E-03	3.6E-05	3.2E-01	5.2E-02	3.1E+03	1.9E-03	1.8E-07	5.6E-01	10.5
12	Sulfate B Effluent	181.2	5.1E-03	1.0E-01	2.2E-06	7.1E-03	1.6E+03	2.0E-03	1.0E+02	2.0E-07	1.3E-02	3.7E-03	1.5E+00	8.9E-04	3.8E-01	9.5E-02	4.5E+02	3.1E-06	3.6E-05	1.6E-02	2.6E-02	1.2E+03	1.9E-03	1.8E-07	5.6E-01	12.4
13	Calcite B Effluent	181.2	5.1E-03	1.0E-01	2.3E-06	7.1E-03	3.0E+02	2.0E-03	1.0E+02	2.0E-07	1.4E-02	3.7E-03	1.5E+00	8.9E-04	3.8E-01	9.6E-02	4.6E+02	3.2E-06	3.6E-05	1.6E-02	2.6E-02	1.2E+03	1.9E-03	1.8E-07	5.6E-01	10.4
14	Calcite B Effluent to Final Effluent	72.5	5.1E-03	1.0E-01	2.2E-06	7.1E-03	3.0E+02	2.0E-03	1.0E+02	2.0E-07	1.4E-02	3.7E-03	1.5E+00	8.9E-04	3.8E-01	9.5E-02	4.5E+02	3.1E-06	3.6E-05	1.6E-02	2.6E-02	1.2E+03	1.9E-03	1.8E-07	5.6E-01	6.0
15	Calcite B Effluent to VSEP B	108.7	5.1E-03	1.0E-01	2.2E-06	7.1E-03	3.0E+02	2.0E-03	1.0E+02	2.0E-07	1.4E-02	3.7E-03	1.5E+00	8.9E-04	3.8E-01	9.5E-02	4.5E+02	3.1E-06	3.6E-05	1.6E-02	2.6E-02	1.2E+03	1.9E-03	1.8E-07	5.6E-01	6.0
16	VSEP B Permeate to Final Effluent	130.5	1.9E-04	5.8E-04	1.3E-06	5.2E-03	2.1E+01	4.8E-05	1.0E+02	1.1E-08	1.3E-03	1.4E-04	8.3E-01	3.3E-05	8.4E-02	2.2E-02	2.3E+02	1.6E-07	7.4E-07	7.9E-04	1.5E-03	2.7E+01	9.2E-05	2.2E-08	3.3E-02	6.0
17	VSEP B Concentrate	32.6	2.5E-02	5.1E-01	5.7E-06	1.3E-02	1.4E+03	9.8E-03	6.8E+01	9.4E-07	6.2E-02	1.8E-02	3.9E+00	4.3E-03	1.6E+00	3.8E-01	1.3E+03	1.5E-05	1.8E-04	7.8E-02	1.2E-01	5.9E+03	9.0E-03	8.1E-07	2.7E+00	6.1
18	VSEP B Concentrate to HDS B	16.3	2.5E-02	5.1E-01	5.7E-06	1.3E-02	1.4E+03	9.8E-03	6.8E+01	9.4E-07	6.2E-02	1.8E-02	3.9E+00	4.3E-03	1.6E+00	3.8E-01	1.3E+03	1.5E-05	1.8E-04	7.8E-02	1.2E-01	5.9E+03	9.0E-03	8.1E-07	2.7E+00	6.1
19	VSEP B Concentrate to HDS A	16.3	2.5E-02	5.1E-01	5.7E-06	1.3E-02	1.4E+03	9.8E-03	6.8E+01	9.4E-07	6.2E-02	1.8E-02	3.9E+00	4.3E-03	1.6E+00	3.8E-01	1.3E+03	1.5E-05	1.8E-04	7.8E-02	1.2E-01	5.9E+03	9.0E-03	8.1E-07	2.7E+00	6.1
20	Low Conc EQ Effluent	885.1	1.8E-04	1.7E-03	7.8E-02	4.0E-04	2.7E+02	8.9E-03	7.7E+01	3.3E-01	5.0E-03	2.7E+00	1.2E+00	1.9E-01	9.6E+01	4.9E-01	9.4E+01	3.7E+00	4.0E-03	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	8.8E-01	7.4
21	GSF Backwash	44.3	1.8E-04	1.7E-03	1.3E+00	4.0E-04	2.7E+02	1.7E-01	7.7E+01	6.6E+00	5.0E-03	5.3E+01	1.2E+00	3.7E+00	9.6E+01	9.5E+00	9.4E+01	6.8E+01	7.5E-02	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	1.7E+01	7.0
22	GSF Backwash Solids	22.1	1.8E-04	1.7E-03	2.1E+00	4.0E-04	2.7E+02	3.1E-01	7.7E+01	1.3E+01	5.0E-03	1.0E+02	1.2E+00	7.1E+00	9.6E+01	1.8E+01	9.4E+01	1.2E+02	1.4E-01	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	3.3E+01	7.0
23	GSF Backwash Decant	22.1	1.8E-04	1.7E-03	3.9E-01	4.0E-04	2.7E+02	2.5E-02	7.7E+01	4.3E-01	5.0E-03	5.7E+00	1.2E+00	2.2E-01	9.6E+01	9.5E-01	9.4E+01	1.2E+01	1.1E-02	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	1.2E+00	7.0
24	GSF Permeate/NF Feed	840.9	1.8E-04	1.7E-03	2.4E-02	4.0E-04	2.7E+02	9.8E-04	7.7E+01	5.3E-03	5.0E-03	1.7E-01	1.2E+00	2.0E-03	9.6E+01	2.7E-02	9.4E+01	5.4E-01	4.4E-04	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	2.1E-02	7.4
25	NF Permeate	672.7	1.4E-04	1.2E-04	3.2E-04	2.8E-05	3.8E+01	6.8E-05	8.7E+01	1.9E-04	3.5E-04	1.3E-02	9.5E-01	0.0E+00	6.5E+00	2.9E-03	6.0E+01	1.9E-02	1.7E-05	5.8E-04	2.4E-04	7.9E+01	1.3E-05	6.9E-04	4.1E-04	7.5
26	NF Concentrate to VSEP A	168.2	3.6E-04	8.0E-03	1.2E-01	1.9E-03	1.2E+03	4.6E-03	3.6E+01	2.6E-02	2.4E-02	8.1E-01	2.4E+00	9.9E-03	4.6E+02	1.2E-01	2.3E+02	2.6E+00	2.1E-03	4.0E-02	2.9E-02	2.1E+03	9.0E-04	4.8E-02	1.0E-01	7.3
27	VSEP A Permeate to Final Effluent	134.5	1.4E-05	5.0E-05	7.2E-02	1.5E-03	8.5E+01	1.2E-04	3.9E+01	1.6E-03	2.5E-03	3.4E-02	1.4E+00	3.9E-04	1.1E+02	3.1E-02	1.3E+02	1.4E-01	4.8E-05	2.2E-03	1.8E-03	5.2E+01	4.8E-05	6.4E-03	6.5E-03	5.4
28	VSEP A Concentrate	33.6	1.8E-03	4.1E-02	3.1E-01	3.5E-03	5.8E+03	2.3E-02	2.4E+01	1.3E-01	1.1E-01	4.0E+00	6.4E+00	4.9E-02	1.9E+03	5.0E-01	6.6E+02	1.3E+01	1.1E-02	2.0E-01	1.4E-01	1.0E+04	4.5E-03	2.2E-01	5.0E-01	6.7
29	VSEP A Concentrate to HDS B	16.8	1.8E-03	4.1E-02	3.1E-01	3.5E-03	5.8E+03	2.3E-02	2.4E+01	1.3E-01	1.1E-01	4.0E+00	6.4E+00	4.9E-02	1.9E+03	5.0E-01	6.6E+02	1.3E+01	1.1E-02	2.0E-01	1.4E-01	1.0E+04	4.5E-03	2.2E-01	5.0E-01	6.7
30	VSEP A Concentrate to HDS A	16.8	1.8E-03	4.1E-02	3.1E-01	3.5E-03	5.8E+03	2.3E-02	2.4E+01	1.3E-01	1.1E-01	4.0E+00	6.4E+00	4.9E-02	1.9E+03	5.0E-01	6.6E+02	1.3E+01	1.1E-02	2.0E-01	1.4E-01	1.0E+04	4.5E-03	2.2E-01	5.0E-01	6.7
31	HDS A Underflow Sludge	7.5	2.9E-01	2.0E+02	8.1E+00	3.1E-01	8.4E+04	1.5E+00	2.5E+02	9.9E+01	3.0E-01	2.9E+02	3.9E+01	5.6E+03	5.3E+03	2.3E+02	1.8E+03	5.8E+02	1.9E+00	6.8E-01	7.2E-01	7.6E+04	1.2E-02	1.7E+00	1.5E+02	10.5
32	Sulfate A Underflow Sludge	13.6	0.0E+00	1.3E+03	0.0E+00	0.0E+00	3.3E+04	0.0E+00	0.0E+00	1.7E-02	0.0E+00	0.0E+00	2.3E+02	0.0E+00	8.2E+03	0.0E+00	0.0E+00	4.5E-02	0.0E+00	4.1E+00	3.4E-01	2.5E+04	0.0E+00	0.0E+00	0.0E+00	12.4
33	Calcite A Underflow Sludge	10.4	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.4
34	HDS B Underflow Sludge	7.5	2.9E-01	2.0E+02	8.1E+00	3.1E-01	8.4E+04	1.5E+00	2.5E+02	9.9E+01	3.0E-01	2.9E+02	3.9E+01	5.6E+03	5.3E+03	2.3E+02	1.8E+03	5.8E+02	1.9E+00	6.8E-01	7.2E-01	7.6E+04	1.2E-02	1.7E+00	1.5E+02	10.5
35	Sulfate B Underflow Sludge	13.6	0.0E+00	1.3E+03	0.0E+00	0.0E+00	3.3E+04	0.0E+00	0.0E+00	1.7E-02	0.0E+00	0.0E+00	2.3E+02	0.0E+00	8.2E+03	0.0E+00	0.0E+00	4.5E-02	0.0E+00	4.1E+00	3.4E-01	2.5E+04	0.0E+00	0.0E+00	0.0E+00	12.4
36	Calcite B Underflow Sludge	10.4	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.4
37	Plant Site VSEP Concentrate	86.0	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
38	Plant Site Concentrate to HDS A	43.0	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
39	Plant Site Concentrate to HDS B	43.0	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
40	Final Effluent to CPS	1137.0	8.7E-04	1.5E-02	8.7E-03	1.8E-03	8.5E+01	3.6E-04	8.2E+01	3.0E-04	2.7E-03	1.3E-02	1.0E+00	1.8E-04	1.7E+01	2.2E-02	1.4E+02	2.8E-02	2.1E-05	3.1E-03	4.4E-03	2.3E+02	3.1E-04	1.2E-03	8.8E-02	6.1

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	181.2	NA	NA	NA	191.4	3.8	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	17.7	10.25	7.5	NA	NA	NA	NA	NA	NA	25	1.18	1.31	0.55	0.76
5	Sulfate A Influent	181.2	NA	NA	NA	201.3	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	33.7	20.13	13.6	NA	NA	NA	NA	NA	NA	10	1.05	0.86	0.33	0.53
6	Sulfate A Effluent	181.2	NA	NA	117.3	298.5	NA	NA	1.4	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	10.4	0.00	10.4	NA	NA	NA	NA	NA	NA	10	1.06	0.25	0.25	0.00
7	Calcite A Effluent	181.2	NA	NA	41.3	222.4	NA	NA	0.5	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	181.2	NA	NA	NA	191.4	3.8	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	17.7	10.25	7.5	NA	NA	NA	NA	NA	NA	25	1.18	1.31	0.55	0.76
11	Sulfate B Influent	181.2	NA	NA		201.3	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	33.7	20.13	13.6	NA	NA	NA	NA	NA	NA	10	1.05	0.86	0.33	0.53
12	Sulfate B Effluent	181.2	NA	NA	117.3	298.5	NA	NA	1.4	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	10.4	0.00	10.4	NA	NA	NA	NA	NA	NA	10	1.06	0.25	0.25	0.00
13	Calcite B Effluent	181.2	NA	NA	41.3	181.2	NA	NA	0.5	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	885.1	NA	NA	NA	NA	NA	NA	NA	17.5	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	168.2	NA	NA	275*	NA	NA	NA	3.3	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 2 P90 Winter Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	39.0	2.9E-02	2.0E+02	3.4E-01	3.5E-02	1.4E+03	7.9E-02	1.6E+02	6.4E+00	1.8E-02	1.1E+01	2.2E+00	4.5E+02	4.8E+02	1.6E+01	2.0E+02	3.0E+01	1.4E-01	5.8E-01	1.1E-01	7.4E+03	1.3E-03	5.7E-02	8.8E+00	5.0
2	High Conc EQ Effluent to HDS A	19.5	2.9E-02	2.0E+02	3.4E-01	3.5E-02	1.4E+03	7.9E-02	1.6E+02	6.4E+00	1.8E-02	1.1E+01	2.2E+00	4.5E+02	4.8E+02	1.6E+01	2.0E+02	3.0E+01	1.4E-01	5.8E-01	1.1E-01	7.4E+03	1.3E-03	5.7E-02	8.8E+00	5.0
3	High Conc EQ Effluent to HDS B	19.5	2.9E-02	2.0E+02	3.4E-01	3.5E-02	1.4E+03	7.9E-02	1.6E+02	6.4E+00	1.8E-02	1.1E+01	2.2E+00	4.5E+02	4.8E+02	1.6E+01	2.0E+02	3.0E+01	1.4E-01	5.8E-01	1.1E-01	7.4E+03	1.3E-03	5.7E-02	8.8E+00	5.0
4	Combined HDS A Influent	123.3	1.5E-02	3.1E+01	1.7E-01	9.7E-03	1.6E+03	3.1E-02	6.9E+01	1.5E+00	7.9E-02	5.7E+00	2.5E+01	7.2E+01	7.2E+02	3.6E+00	1.1E+03	1.0E+01	2.9E-02	1.2E-01	4.6E-02	4.6E+03	2.3E-02	5.3E-02	3.2E+00	7.3
5	Sulfate A Influent	123.3	9.7E-03	3.1E+01	7.7E-06	6.2E-03	6.6E+02	4.8E-03	6.8E+01	2.1E-03	7.0E-02	3.8E-03	2.5E+01	8.8E-04	6.6E+02	3.5E-02	1.1E+03	6.1E-03	2.3E-04	1.1E-01	3.1E-02	3.3E+03	2.3E-02	8.2E-07	5.7E-01	10.5
6	Sulfate A Effluent	123.3	9.7E-03	3.1E-02	7.7E-06	6.2E-03	2.0E+03	4.8E-03	6.8E+01	3.0E-07	7.0E-02	3.8E-03	1.5E+00	8.8E-04	4.3E-01	3.5E-02	1.1E+03	5.5E-06	2.3E-04	5.7E-03	1.6E-02	1.2E+03	2.3E-02	8.2E-07	5.7E-01	12.4
7	Calcite A Effluent	123.3	9.8E-03	3.1E-02	7.8E-06	6.2E-03	8.4E+02	4.9E-03	6.9E+01	3.1E-07	7.1E-02	3.8E-03	1.5E+00	8.9E-04	4.4E-01	3.6E-02	1.1E+03	5.5E-06	2.3E-04	5.8E-03	1.6E-02	1.2E+03	2.3E-02	8.3E-07	5.8E-01	11.0
8	Calcite A Effluent to Final Effluent	49.3	9.8E-03	3.1E-02	7.8E-06	6.2E-03	8.4E+02	4.8E-03	6.9E+01	3.1E-07	7.1E-02	3.8E-03	1.5E+00	8.9E-04	4.4E-01	3.5E-02	1.1E+03	5.5E-06	2.3E-04	5.8E-03	1.6E-02	1.2E+03	2.3E-02	8.3E-07	5.8E-01	8.3
9	Calcite A Effluent to VSEP B	74.0	9.8E-03	3.1E-02	7.8E-06	6.2E-03	8.4E+02	4.8E-03	6.9E+01	3.1E-07	7.1E-02	3.8E-03	1.5E+00	8.9E-04	4.4E-01	3.5E-02	1.1E+03	5.5E-06	2.3E-04	5.8E-03	1.6E-02	1.2E+03	2.3E-02	8.3E-07	5.8E-01	8.3
10	Combined HDS B Influent	123.3	1.5E-02	3.1E+01	1.7E-01	9.7E-03	1.6E+03	3.1E-02	6.9E+01	1.5E+00	7.9E-02	5.7E+00	2.5E+01	7.2E+01	7.2E+02	3.6E+00	1.1E+03	1.0E+01	2.9E-02	1.2E-01	4.6E-02	4.6E+03	2.3E-02	5.3E-02	3.2E+00	7.3
11	Sulfate B Influent	123.3	9.7E-03	3.1E+01	7.7E-06	6.2E-03	6.6E+02	4.8E-03	6.8E+01	2.1E-03	7.0E-02	3.8E-03	2.5E+01	8.8E-04	6.6E+02	3.5E-02	1.1E+03	6.1E-03	2.3E-04	1.1E-01	3.1E-02	3.3E+03	2.3E-02	8.2E-07	5.7E-01	10.5
12	Sulfate B Effluent	123.3	9.7E-03	3.1E-02	7.7E-06	6.2E-03	2.0E+03	4.8E-03	6.8E+01	3.0E-07	7.0E-02	3.8E-03	1.5E+00	8.8E-04	4.3E-01	3.5E-02	1.1E+03	5.5E-06	2.3E-04	5.7E-03	1.6E-02	1.2E+03	2.3E-02	8.2E-07	5.7E-01	12.4
13	Calcite B Effluent	123.3	9.8E-03	3.1E-02	7.8E-06	6.2E-03	8.4E+02	4.9E-03	6.9E+01	3.1E-07	7.1E-02	3.8E-03	1.5E+00	8.9E-04	4.4E-01	3.6E-02	1.1E+03	5.5E-06	2.3E-04	5.8E-03	1.6E-02	1.2E+03	2.3E-02	8.3E-07	5.8E-01	11.0
14	Calcite B Effluent to Final Effluent	49.3	9.8E-03	3.1E-02	7.8E-06	6.2E-03	8.4E+02	4.8E-03	6.9E+01	3.1E-07	7.1E-02	3.8E-03	1.5E+00	8.9E-04	4.4E-01	3.5E-02	1.1E+03	5.5E-06	2.3E-04	5.8E-03	1.6E-02	1.2E+03	2.3E-02	8.3E-07	5.8E-01	8.3
15	Calcite B Effluent to VSEP B	74.0	9.8E-03	3.1E-02	7.8E-06	6.2E-03	8.4E+02	4.8E-03	6.9E+01	3.1E-07	7.1E-02	3.8E-03	1.5E+00	8.9E-04	4.4E-01	3.5E-02	1.1E+03	5.5E-06	2.3E-04	5.8E-03	1.6E-02	1.2E+03	2.3E-02	8.3E-07	5.8E-01	8.3
16	VSEP B Permeate to Final Effluent	197.3	3.9E-04	1.9E-04	4.8E-06	4.9E-03	5.9E+01	1.3E-04	7.4E+01	1.9E-08	7.5E-03	1.6E-04	8.9E-01	3.5E-05	1.0E-01	8.9E-03	6.2E+02	2.9E-07	5.1E-06	3.1E-04	9.7E-04	3.1E+01	1.2E-03	1.1E-07	3.7E-02	6.1
17	VSEP B Concentrate	49.3	4.9E-02	1.6E-01	2.0E-05	1.2E-02	4.1E+03	2.5E-02	4.6E+01	1.5E-06	3.4E-01	1.9E-02	4.0E+00	4.4E-03	1.8E+00	1.5E-01	3.2E+03	2.7E-05	1.2E-03	2.8E-02	7.8E-02	6.2E+03	1.1E-01	3.8E-06	2.8E+00	9.4
18	VSEP B Concentrate to HDS B	24.7	4.9E-02	1.6E-01	2.0E-05	1.2E-02	4.1E+03	2.5E-02	4.6E+01	1.5E-06	3.4E-01	1.9E-02	4.0E+00	4.4E-03	1.8E+00	1.5E-01	3.2E+03	2.7E-05	1.2E-03	2.8E-02	7.8E-02	6.2E+03	1.1E-01	3.8E-06	2.8E+00	9.4
19	VSEP B Concentrate to HDS A	24.7	4.9E-02	1.6E-01	2.0E-05	1.2E-02	4.1E+03	2.5E-02	4.6E+01	1.5E-06	3.4E-01	1.9E-02	4.0E+00	4.4E-03	1.8E+00	1.5E-01	3.2E+03	2.7E-05	1.2E-03	2.8E-02	7.8E-02	6.2E+03	1.1E-01	3.8E-06	2.8E+00	9.4
20	Low Conc EQ Effluent	360.0	1.8E-04	1.7E-03	7.8E-02	4.0E-04	2.7E+02	8.9E-03	7.7E+01	3.3E-01	5.0E-03	2.7E+00	1.2E+00	1.9E-01	9.6E+01	4.9E-01	9.4E+01	3.7E+00	4.0E-03	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	8.8E-01	7.4
21	GSF Backwash	18.0	1.8E-04	1.7E-03	1.3E+00	4.0E-04	2.7E+02	1.7E-01	7.7E+01	6.6E+00	5.0E-03	5.3E+01	1.2E+00	3.7E+00	9.6E+01	9.5E+00	9.4E+01	6.8E+01	7.5E-02	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	1.7E+01	7.0
22	GSF Backwash Solids	9.0	1.8E-04	1.7E-03	2.1E+00	4.0E-04	2.7E+02	3.1E-01	7.7E+01	1.3E+01	5.0E-03	1.0E+02	1.2E+00	7.1E+00	9.6E+01	1.8E+01	9.4E+01	1.2E+02	1.4E-01	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	3.3E+01	7.0
23	GSF Backwash Decant	9.0	1.8E-04	1.7E-03	3.9E-01	4.0E-04	2.7E+02	2.5E-02	7.7E+01	4.3E-01	5.0E-03	5.7E+00	1.2E+00	2.2E-01	9.6E+01	9.5E-01	9.4E+01	1.2E+01	1.1E-02	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	1.2E+00	7.0
24	GSF Permeate/NF Feed	342.0	1.8E-04	1.7E-03	2.4E-02	4.0E-04	2.7E+02	9.8E-04	7.7E+01	5.3E-03	5.0E-03	1.7E-01	1.2E+00	2.0E-03	9.6E+01	2.7E-02	9.4E+01	5.4E-01	4.4E-04	8.5E-03	6.0E-03	4.7E+02	1.9E-04	1.0E-02	2.1E-02	7.4
25	NF Permeate	273.6	1.4E-04	1.2E-04	3.2E-04	2.8E-05	3.8E+01	6.8E-05	8.7E+01	1.9E-04	3.5E-04	1.3E-02	9.4E-01	0.0E+00	6.5E+00	2.9E-03	6.0E+01	1.9E-02	1.7E-05	5.8E-04	2.4E-04	7.9E+01	1.3E-05	6.9E-04	4.1E-04	5.9
26	NF Concentrate to VSEP A	68.4	3.6E-04	8.0E-03	1.2E-01	1.9E-03	1.2E+03	4.7E-03	3.6E+01	2.6E-02	2.4E-02	8.1E-01	2.4E+00	9.9E-03	4.6E+02	1.2E-01	2.3E+02	2.6E+00	2.1E-03	4.0E-02	2.9E-02	2.1E+03	9.0E-04	4.8E-02	1.0E-01	9.6
27	VSEP A Permeate to Final Effluent	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	VSEP A Concentrate	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29	VSEP A Concentrate to HDS B	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30	VSEP A Concentrate to HDS A	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	4.4	1.4E-01	0.0E+00	4.6E+00	9.2E-02	9.9E+04	7.2E-01	1.2E+00	4.1E+01	2.1E-01	1.5E+02	2.0E-01	2.0E+03	1.1E+03	9.6E+01	0.0E+00	2.8E+02	7.7E-01	0.0E+00	3.7E-01	3.2E+04	0.0E+00	1.4E+00	7.2E+01	10.5
32	Sulfate A Underflow Sludge	10.0	0.0E+00	3.8E+02	5.1E-10	0.0E+00	3.3E+04	3.0E-07	5.5E-01	2.6E-02	0.0E+00	6.6E-05	2.9E+02	5.3E-08	8.2E+03	0.0E+00	0.0E+00	7.5E-02	0.0E+00	1.3E+00	1.9E-01	2.6E+04	0.0E+00	4.0E-11	2.7E-05	12.4
33	Calcite A Underflow Sludge	5.9	0.0E+00	0.0E+00	5.9E-10	0.0E+00	2.4E+04	6.1E-09	6.6E-08	0.0E+00	0.0E+00	6.0E-05	1.2E-04	5.4E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-01	0.0E+00	6.2E-11	3.4E-05	11.0
34	HDS B Underflow Sludge	4.4	1.4E-01	0.0E+00	4.6E+00	9.2E-02	9.9E+04	7.2E-01	1.2E+00	4.1E+01	2.1E-01	1.5E+02	2.0E-01	2.0E+03	1.1E+03	9.6E+01	0.0E+00	2.8E+02	7.7E-01	0.0E+00	3.7E-01	3.2E+04	0.0E+00	1.4E+00	7.2E+01	10.5
35	Sulfate B Underflow Sludge	10.0	0.0E+00	3.8E+02	5.1E-10	0.0E+00	3.3E+04	3.0E-07	5.5E-01	2.6E-02	0.0E+00	6.6E-05	2.9E+02	5.3E-08	8.2E+03	0.0E+00	0.0E+00	7.5E-02	0.0E+00	1.3E+00	1.9E-01	2.6E+04	0.0E+00	4.0E-11	2.7E-05	12.4
36	Calcite B Underflow Sludge	5.9	0.0E+00	0.0E+00	5.9E-10	0.0E+00	2.4E+04	6.1E-09	6.6E-08	0.0E+00	0.0E+00	6.0E-05	1.2E-04	5.4E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-01	0.0E+00	6.2E-11	3.4E-05	11.0
37	Plant Site VSEP Concentrate	80.9	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
38	Plant Site Concentrate to HDS A	40.5	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
39	Plant Site Concentrate to HDS B	40.5	2.6E-03	3.2E-01	7.2E-04	4.0E-03	8.8E+02	3.0E-03	6.8E+01	1.0E-03	1.2E-02	1.9E-02	7.2E+01	5.1E-01	1.5E+03	9.2E-01	1.2E+03	5.3E-02	3.0E-03	1.8E-02	1.2E-02	4.7E+03	3.4E-03	9.2E-02	5.9E-03	6.0
40	Final Effluent to CPS	470.9	2.4E-04	1.5E-04	2.0E-04	2.1E-03	4.7E+01	9.3E-05	8.2E+01	1.1E-04	3.3E-03	8.0E-03	9.2E-01	1.5E-05	3.8E+00	5.4E-03	2.9E+02	1.1E-02	1.2E-05	4.7E-04	5.4E-04	5.9E+01	5.2E-04	4.0E-04	1.6E-02	6.0

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	123.3	NA	NA	NA	161.7	2.8	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	42.8	38.36	4.4	NA	NA	NA	NA	NA	NA	25	1.19	3.17	0.33	2.84
5	Sulfate A Influent	123.3	NA	NA	NA	137.0	3.3	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	23.7	13.70	10.0	NA	NA	NA	NA	NA	NA	10	1.05	0.60	0.24	0.36
6	Sulfate A Effluent	123.3	NA	NA	77.9	201.2	NA	NA	0.9	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	5.9	0.00	5.9	NA	NA	NA	NA	NA	NA	10	1.06	0.14	0.14	0.00
7	Calcite A Effluent	123.3	NA	NA	119.2	242.5	NA	NA	1.4	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	123.3	NA	NA	NA	161.7	2.8	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	42.8	38.36	4.4	NA	NA	NA	NA	NA	NA	25	1.19	3.17	0.33	2.84
11	Sulfate B Influent	123.3	NA	NA		137.0	3.3	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	23.7	13.70	10.0	NA	NA	NA	NA	NA	NA	10	1.05	0.60	0.24	0.36
12	Sulfate B Effluent	123.3	NA	NA	77.9	201.2	NA	NA	0.9	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	5.9	0.00	5.9	NA	NA	NA	NA	NA	NA	10	1.06	0.14	0.14	0.00
13	Calcite B Effluent	123.3	NA	NA	119.2	123.3	NA	NA	1.4	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	360.0	NA	NA	NA	NA	NA	NA	NA	7.1	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	68.4	NA	NA	2.3*	NA	NA	NA	0.0	NA	NA	NA	NA	NA	NA

Mine Water Treatment Trains Flow and Load Detail
Year 3 P90 Annual Average Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	135.0	3.2E-02	2.1E+02	4.0E-01	3.6E-02	1.6E+03	8.4E-02	1.3E+02	6.9E+00	2.1E-02	1.1E+01	2.1E+00	4.9E+02	5.7E+02	1.9E+01	2.3E+02	3.3E+01	1.4E-01	6.8E-01	1.3E-01	8.5E+03	1.6E-03	5.8E-02	9.1E+00	5.0
2	High Conc EQ Effluent to HDS A	67.5	3.2E-02	2.1E+02	4.0E-01	3.6E-02	1.6E+03	8.4E-02	1.3E+02	6.9E+00	2.1E-02	1.1E+01	2.1E+00	4.9E+02	5.7E+02	1.9E+01	2.3E+02	3.3E+01	1.4E-01	6.8E-01	1.3E-01	8.5E+03	1.6E-03	5.8E-02	9.1E+00	5.0
3	High Conc EQ Effluent to HDS B	67.5	3.2E-02	2.1E+02	4.0E-01	3.6E-02	1.6E+03	8.4E-02	1.3E+02	6.9E+00	2.1E-02	1.1E+01	2.1E+00	4.9E+02	5.7E+02	1.9E+01	2.3E+02	3.3E+01	1.4E-01	6.8E-01	1.3E-01	8.5E+03	1.6E-03	5.8E-02	9.1E+00	5.0
4	Combined HDS A Influent	156.2	1.8E-02	9.0E+01	3.5E-01	1.9E-02	1.8E+03	6.0E-02	1.0E+02	3.9E+00	4.3E-02	1.1E+01	1.8E+01	2.2E+02	9.6E+02	9.7E+00	1.0E+03	2.5E+01	7.4E-02	4.2E-01	1.2E-01	7.4E+03	6.2E-03	7.5E-02	6.4E+00	6.3
5	Sulfate A Influent	156.2	5.2E-03	8.8E+01	4.6E-06	7.6E-03	5.4E+02	4.4E-04	9.8E+01	4.3E-04	2.7E-02	4.1E-03	1.8E+01	1.1E-03	4.8E+02	9.5E-02	9.9E+02	1.3E-03	2.7E-05	4.1E-01	8.0E-02	3.7E+03	6.1E-03	3.3E-07	6.6E-01	10.6
6	Sulfate A Effluent	156.2	5.2E-03	8.8E-02	4.6E-06	7.6E-03	1.3E+03	4.4E-04	9.8E+01	9.0E-08	2.7E-02	4.1E-03	1.7E+00	1.1E-03	3.2E-01	9.5E-02	9.9E+02	1.8E-06	2.7E-05	2.1E-02	4.0E-02	1.5E+03	6.1E-03	3.3E-07	6.6E-01	12.5
7	Calcite A Effluent	156.2	5.2E-03	8.9E-02	4.6E-06	7.6E-03	1.3E+02	4.4E-04	9.9E+01	9.1E-08	2.7E-02	4.2E-03	1.7E+00	1.1E-03	3.3E-01	9.6E-02	1.0E+03	1.8E-06	2.7E-05	2.1E-02	4.0E-02	1.5E+03	6.1E-03	3.3E-07	6.6E-01	10.9
8	Calcite A Effluent to Final Effluent	62.5	5.2E-03	8.8E-02	4.6E-06	7.6E-03	1.3E+02	4.4E-04	9.8E+01	9.1E-08	2.7E-02	4.1E-03	1.7E+00	1.1E-03	3.2E-01	9.6E-02	1.0E+03	1.8E-06	2.7E-05	2.1E-02	4.0E-02	1.5E+03	6.1E-03	3.3E-07	6.6E-01	6.7
9	Calcite A Effluent to VSEP B	93.7	5.2E-03	8.8E-02	4.6E-06	7.6E-03	1.3E+02	4.4E-04	9.8E+01	9.1E-08	2.7E-02	4.1E-03	1.7E+00	1.1E-03	3.2E-01	9.6E-02	1.0E+03	1.8E-06	2.7E-05	2.1E-02	4.0E-02	1.5E+03	6.1E-03	3.3E-07	6.6E-01	6.7
10	Combined HDS B Influent	156.2	1.8E-02	9.0E+01	3.5E-01	1.9E-02	1.8E+03	6.0E-02	1.0E+02	3.9E+00	4.3E-02	1.1E+01	1.8E+01	2.2E+02	9.6E+02	9.7E+00	1.0E+03	2.5E+01	7.4E-02	4.2E-01	1.2E-01	7.4E+03	6.2E-03	7.5E-02	6.4E+00	6.3
11	Sulfate B Influent	156.2	5.2E-03	8.8E+01	4.6E-06	7.6E-03	5.4E+02	4.4E-04	9.8E+01	4.3E-04	2.7E-02	4.1E-03	1.8E+01	1.1E-03	4.8E+02	9.5E-02	9.9E+02	1.3E-03	2.7E-05	4.1E-01	8.0E-02	3.7E+03	6.1E-03	3.3E-07	6.6E-01	10.6
12	Sulfate B Effluent	156.2	5.2E-03	8.8E-02	4.6E-06	7.6E-03	1.3E+03	4.4E-04	9.8E+01	9.0E-08	2.7E-02	4.1E-03	1.7E+00	1.1E-03	3.2E-01	9.5E-02	9.9E+02	1.8E-06	2.7E-05	2.1E-02	4.0E-02	1.5E+03	6.1E-03	3.3E-07	6.6E-01	12.5
13	Calcite B Effluent	156.2	5.2E-03	8.9E-02	4.6E-06	7.6E-03	1.3E+02	4.4E-04	9.9E+01	9.1E-08	2.7E-02	4.2E-03	1.7E+00	1.1E-03	3.3E-01	9.6E-02	1.0E+03	1.8E-06	2.7E-05	2.1E-02	4.0E-02	1.5E+03	6.1E-03	3.3E-07	6.6E-01	10.9
14	Calcite B Effluent to Final Effluent	62.5	5.2E-03	8.8E-02	4.6E-06	7.6E-03	1.3E+02	4.4E-04	9.8E+01	9.1E-08	2.7E-02	4.1E-03	1.7E+00	1.1E-03	3.2E-01	9.6E-02	1.0E+03	1.8E-06	2.7E-05	2.1E-02	4.0E-02	1.5E+03	6.1E-03	3.3E-07	6.6E-01	6.7
15	Calcite B Effluent to VSEP B	93.7	5.2E-03	8.8E-02	4.6E-06	7.6E-03	1.3E+02	4.4E-04	9.8E+01	9.1E-08	2.7E-02	4.1E-03	1.7E+00	1.1E-03	3.2E-01	9.6E-02	1.0E+03	1.8E-06	2.7E-05	2.1E-02	4.0E-02	1.5E+03	6.1E-03	3.3E-07	6.6E-01	6.7
16	VSEP B Permeate to Final Effluent	172.5	2.1E-04	5.5E-04	2.8E-06	6.1E-03	1.2E+01	1.2E-05	9.6E+01	5.6E-09	2.9E-03	1.8E-04	1.0E+00	4.4E-05	4.8E-02	2.4E-02	4.4E+02	2.9E-07	6.1E-07	1.1E-03	2.4E-03	1.3E+02	3.3E-04	4.4E-08	4.2E-02	6.5
17	VSEP B Concentrate	43.1	2.6E-02	4.4E-01	1.2E-05	1.4E-02	6.3E+02	2.2E-03	1.1E+02	4.4E-07	1.3E-01	2.0E-02	4.5E+00	5.3E-03	1.4E+00	3.9E-01	3.3E+03	8.1E-06	1.4E-04	1.0E-01	1.9E-01	7.0E+03	3.0E-02	1.5E-06	3.2E+00	7.5
18	VSEP B Concentrate to HDS B	21.6	2.6E-02	4.4E-01	1.2E-05	1.4E-02	6.3E+02	2.2E-03	1.1E+02	4.4E-07	1.3E-01	2.0E-02	4.5E+00	5.3E-03	1.4E+00	3.9E-01	3.3E+03	8.1E-06	1.4E-04	1.0E-01	1.9E-01	7.0E+03	3.0E-02	1.5E-06	3.2E+00	7.5
19	VSEP B Concentrate to HDS A	21.6	2.6E-02	4.4E-01	1.2E-05	1.4E-02	6.3E+02	2.2E-03	1.1E+02	4.4E-07	1.3E-01	2.0E-02	4.5E+00	5.3E-03	1.4E+00	3.9E-01	3.3E+03	8.1E-06	1.4E-04	1.0E-01	1.9E-01	7.0E+03	3.0E-02	1.5E-06	3.2E+00	7.5
20	Low Conc EQ Effluent	804.1	1.9E-04	1.7E-03	8.0E-02	4.0E-04	2.9E+02	8.3E-03	7.7E+01	3.4E-01	5.0E-03	2.4E+00	1.2E+00	1.9E-01	1.1E+02	5.0E-01	9.5E+01	4.1E+00	4.8E-03	4.0E-02	1.3E-02	5.5E+02	1.8E-04	1.0E-02	7.9E-01	7.0
21	GSF Backwash	40.2	1.9E-04	1.7E-03	1.3E+00	4.0E-04	2.9E+02	1.5E-01	7.7E+01	6.8E+00	5.0E-03	4.7E+01	1.2E+00	3.7E+00	1.1E+02	9.7E+00	9.4E+01	7.5E+01	9.0E-02	4.0E-02	1.3E-02	5.5E+02	1.8E-04	9.9E-03	1.6E+01	7.0
22	GSF Backwash Solids	20.1	1.9E-04	1.7E-03	2.2E+00	4.0E-04	2.9E+02	2.9E-01	7.7E+01	1.3E+01	5.0E-03	8.8E+01	1.2E+00	7.2E+00	1.1E+02	1.8E+01	9.4E+01	1.4E+02	1.7E-01	4.0E-02	1.3E-02	5.5E+02	1.8E-04	9.9E-03	3.0E+01	7.0
23	GSF Backwash Decant	20.1	1.9E-04	1.7E-03	4.0E-01	4.0E-04	2.9E+02	2.3E-02	7.7E+01	4.4E-01	5.0E-03	5.0E+00	1.2E+00	2.2E-01	1.1E+02	9.7E-01	9.4E+01	1.3E+01	1.4E-02	4.0E-02	1.3E-02	5.5E+02	1.8E-04	9.9E-03	1.1E+00	7.0
24	GSF Permeate/NF Feed	763.9	1.9E-04	1.7E-03	2.4E-02	4.0E-04	2.9E+02	9.1E-04	7.7E+01	5.5E-03	5.0E-03	1.5E-01	1.2E+00	2.0E-03	1.1E+02	2.7E-02	9.5E+01	5.9E-01	5.3E-04	4.0E-02	1.3E-02	5.5E+02	1.8E-04	1.0E-02	1.9E-02	7.0
25	NF Permeate	611.1	1.5E-04	1.2E-04	3.0E-04	2.8E-05	3.6E+01	6.5E-05	8.7E+01	2.0E-04	3.5E-04	1.2E-02	9.5E-01	0.0E+00	7.3E+00	7.4E-04	6.2E+01	2.1E-02	2.0E-05	2.8E-03	5.2E-04	2.3E+01	1.3E-05	7.1E-04	3.7E-04	6.0
26	NF Concentrate to VSEP A	152.8	3.5E-04	8.0E-03	1.2E-01	1.9E-03	1.3E+03	4.3E-03	3.7E+01	2.7E-02	2.4E-02	7.2E-01	2.1E+00	1.0E-02	5.2E+02	1.3E-01	2.3E+02	2.9E+00	2.6E-03	1.9E-01	6.3E-02	2.7E+03	8.6E-04	4.7E-02	9.2E-02	9.2
27	VSEP A Permeate to Final Effluent	122.2	1.4E-05	5.0E-05	7.4E-02	1.5E-03	1.2E+02	1.1E-04	3.6E+01	1.6E-03	2.5E-03	3.0E-02	1.3E+00	4.0E-04	7.6E+01	3.4E-02	1.0E+02	4.5E-01	5.8E-05	1.0E-02	3.8E-03	2.3E+02	4.6E-05	6.3E-03	5.8E-03	5.4
28	VSEP A Concentrate	30.6	1.8E-03	4.1E-02	3.2E-01	3.5E-03	6.3E+03	2.2E-02	4.1E+01	1.3E-01	1.1E-01	3.6E+00	5.8E+00	5.0E-02	2.4E+03	5.5E-01	7.6E+02	1.3E+01	1.3E-02	9.5E-01	3.1E-01	1.3E+04	4.3E-03	2.2E-01	4.5E-01	9.0
29	VSEP A Concentrate to HDS B	15.3	1.8E-03	4.1E-02	3.2E-01	3.5E-03	6.3E+03	2.2E-02	4.1E+01	1.3E-01	1.1E-01	3.6E+00	5.8E+00	5.0E-02	2.4E+03	5.5E-01	7.6E+02	1.3E+01	1.3E-02	9.5E-01	3.1E-01	1.3E+04	4.3E-03	2.2E-01	4.5E-01	9.0
30	VSEP A Concentrate to HDS A	15.3	1.8E-03	4.1E-02	3.2E-01	3.5E-03	6.3E+03	2.2E-02	4.1E+01	1.3E-01	1.1E-01	3.6E+00	5.8E+00	5.0E-02	2.4E+03	5.5E-01	7.6E+02	1.3E+01	1.3E-02	9.5E-01	3.1E-01	1.3E+04	4.3E-03	2.2E-01	4.5E-01	9.0
31	HDS A Underflow Sludge	8.3	2.4E-01	1.8E-04	6.5E+00	2.2E-01	8.6E+04	1.1E+00	1.2E+00	7.2E+01	2.9E-01	2.0E+02	8.0E-02	4.0E+03	8.8E+03	1.8E+02	0.0E+00	4.6E+02	1.4E+00	6.3E-06	6.5E-01	6.8E+04	0.0E+00	1.4E+00	1.1E+02	10.6
32	Sulfate A Underflow Sludge	13.1	0.0E+00	1.0E+03	0.0E+00	0.0E+00	4.0E+04	0.0E+00	7.6E-01	5.1E-03	4.3E-07	7.0E-05	1.9E+02	3.7E-08	5.7E+03	0.0E+00	0.0E+00	1.5E-02	0.0E+00	4.7E+00	4.8E-01	2.6E+04	0.0E+00	1.1E-12	0.0E+00	12.5
33	Calcite A Underflow Sludge	7.6	0.0E+00	0.0E+00	3.6E-11	1.4E-08	2.4E+04	0.0E+00	0.0E+00	0.0E+00	9.5E-08	6.5E-05	3.1E-05	2.9E-09	0.0E+00	0.0E+00	0.0E+00	8.6E-11	3.7E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.9E-12	1.5E-06	10.9
34	HDS B Underflow Sludge	8.3	2.4E-01	1.8E-04	6.5E+00	2.2E-01	8.6E+04	1.1E+00	1.2E+00	7.2E+01	2.9E-01	2.0E+02	8.0E-02	4.0E+03	8.8E+03	1.8E+02	0.0E+00	4.6E+02	1.4E+00	6.3E-06	6.5E-01	6.8E+04	0.0E+00	1.4E+00	1.1E+02	10.6
35	Sulfate B Underflow Sludge	13.1	0.0E+00	1.0E+03	0.0E+00	0.0E+00	4.0E+04	0.0E+00	7.6E-01	5.1E-03	4.3E-07	7.0E-05	1.9E+02	3.7E-08	5.7E+03	0.0E+00	0.0E+00	1.5E-02	0.0E+00	4.7E+00	4.8E-01	2.6E+04	0.0E+00	1.1E-12	0.0E+00	12.5
36	Calcite B Underflow Sludge	7.6	0.0E+00	0.0E+00	3.6E-11	1.4E-08	2.4E+04	0.0E+00	0.0E+00	0.0E+00	9.5E-08	6.5E-05	3.1E-05	2.9E-09	0.0E+00	0.0E+00	0.0E+00	8.6E-11	3.7E-11	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.9E-12	1.5E-06	10.9
37	Plant Site VSEP Concentrate	83.7	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
38	Plant Site Concentrate to HDS A	41.9	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
39	Plant Site Concentrate to HDS B	41.9	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
40	Final Effluent to CPS	1002.7	6.3E-04	8.7E-03	9.2E-03	2.0E-03	5.1E+01	9.8E-05	8.3E+01	3.2E-04	3.6E-03	1.1E-02	1.1E+00	1.6E-04	1.4E+01	1.8E-02	2.2E+02	6.7E-02	2.2E-05	5.2E-03	5.1E-03	2.1E+02	6.6E-04	1.2E-03	7.2E-02	5.8

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	156.2	NA	NA	NA	169.9	4.4	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	21.9	13.64	8.3	NA	NA	NA	NA	NA	NA	25	1.18	1.62	0.61	1.01
5	Sulfate A Influent	156.2	NA	NA	NA	173.6	3.9	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	30.4	17.36	13.1	NA	NA	NA	NA	NA	NA	10	1.05	0.77	0.31	0.46
6	Sulfate A Effluent	156.2	NA	NA	100.8	257.1	NA	NA	1.2	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	7.6	0.00	7.6	NA	NA	NA	NA	NA	NA	10	1.06	0.18	0.18	0.00
7	Calcite A Effluent	156.2	NA	NA	36.7	192.9	NA	NA	0.4	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	156.2	NA	NA	NA	169.9	4.4	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	21.9	13.64	8.3	NA	NA	NA	NA	NA	NA	25	1.18	1.62	0.61	1.01
11	Sulfate B Influent	156.2	NA	NA		173.6	3.9	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	30.4	17.36	13.1	NA	NA	NA	NA	NA	NA	10	1.05	0.77	0.31	0.46
12	Sulfate B Effluent	156.2	NA	NA	100.8	257.1	NA	NA	1.2	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	7.6	0.00	7.6	NA	NA	NA	NA	NA	NA	10	1.06	0.18	0.18	0.00
13	Calcite B Effluent	156.2	NA	NA	36.7	156.2	NA	NA	0.4	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	804.1	NA	NA	NA	NA	NA	NA	NA	15.9	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	152.8	NA	NA	275*	NA	NA	NA	3.3	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 3 P90 Peak Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	135.0	3.2E-02	2.1E+02	4.0E-01	3.6E-02	1.6E+03	8.4E-02	1.3E+02	6.9E+00	2.1E-02	1.1E+01	2.1E+00	4.9E+02	5.7E+02	1.9E+01	2.3E+02	3.3E+01	1.4E-01	6.8E-01	1.3E-01	8.5E+03	1.6E-03	5.8E-02	9.1E+00	5.0
2	High Conc EQ Effluent to HDS A	67.5	3.2E-02	2.1E+02	4.0E-01	3.6E-02	1.6E+03	8.4E-02	1.3E+02	6.9E+00	2.1E-02	1.1E+01	2.1E+00	4.9E+02	5.7E+02	1.9E+01	2.3E+02	3.3E+01	1.4E-01	6.8E-01	1.3E-01	8.5E+03	1.6E-03	5.8E-02	9.1E+00	5.0
3	High Conc EQ Effluent to HDS B	67.5	3.2E-02	2.1E+02	4.0E-01	3.6E-02	1.6E+03	8.4E-02	1.3E+02	6.9E+00	2.1E-02	1.1E+01	2.1E+00	4.9E+02	5.7E+02	1.9E+01	2.3E+02	3.3E+01	1.4E-01	6.8E-01	1.3E-01	8.5E+03	1.6E-03	5.8E-02	9.1E+00	5.0
4	Combined HDS A Influent	162.9	1.8E-02	8.6E+01	3.9E-01	1.8E-02	1.8E+03	6.4E-02	9.7E+01	4.0E+00	4.2E-02	1.2E+01	1.8E+01	2.1E+02	1.0E+03	9.7E+00	9.2E+02	2.7E+01	7.5E-02	4.3E-01	1.2E-01	7.4E+03	4.9E-03	7.9E-02	6.7E+00	6.5
5	Sulfate A Influent	162.9	5.9E-03	8.4E+01	5.2E-06	6.2E-03	5.0E+02	1.1E-03	9.5E+01	8.2E-04	2.6E-02	3.8E-03	1.8E+01	9.2E-04	7.3E+02	9.5E-02	9.0E+02	2.5E-03	2.7E-05	4.2E-01	8.2E-02	4.7E+03	4.8E-03	3.6E-07	5.9E-01	10.5
6	Sulfate A Effluent	162.9	5.9E-03	8.4E-02	5.2E-06	6.2E-03	1.2E+03	1.1E-03	9.5E+01	1.1E-07	2.6E-02	3.8E-03	1.7E+00	9.2E-04	3.1E-01	9.5E-02	9.0E+02	2.3E-06	2.7E-05	2.1E-02	4.1E-02	1.5E+03	4.8E-03	3.6E-07	5.9E-01	12.5
7	Calcite A Effluent	162.9	6.0E-03	8.5E-02	5.2E-06	6.3E-03	2.5E+01	1.1E-03	9.6E+01	1.1E-07	2.6E-02	3.8E-03	1.8E+00	9.3E-04	3.2E-01	9.6E-02	9.0E+02	2.3E-06	2.7E-05	2.1E-02	4.1E-02	1.5E+03	4.8E-03	3.6E-07	5.9E-01	10.0
8	Calcite A Effluent to Final Effluent	65.1	6.0E-03	8.5E-02	5.2E-06	6.2E-03	2.5E+01	1.1E-03	9.5E+01	1.1E-07	2.6E-02	3.8E-03	1.8E+00	9.2E-04	3.1E-01	9.6E-02	9.0E+02	2.3E-06	2.7E-05	2.1E-02	4.1E-02	1.5E+03	4.8E-03	3.6E-07	5.9E-01	6.0
9	Calcite A Effluent to VSEP B	97.7	6.0E-03	8.5E-02	5.2E-06	6.2E-03	2.5E+01	1.1E-03	9.5E+01	1.1E-07	2.6E-02	3.8E-03	1.8E+00	9.2E-04	3.1E-01	9.6E-02	9.0E+02	2.3E-06	2.7E-05	2.1E-02	4.1E-02	1.5E+03	4.8E-03	3.6E-07	5.9E-01	6.0
10	Combined HDS B Influent	162.9	1.8E-02	8.6E+01	3.9E-01	1.8E-02	1.8E+03	6.4E-02	9.7E+01	4.0E+00	4.2E-02	1.2E+01	1.8E+01	2.1E+02	1.0E+03	9.7E+00	9.2E+02	2.7E+01	7.5E-02	4.3E-01	1.2E-01	7.4E+03	4.9E-03	7.9E-02	6.7E+00	6.5
11	Sulfate B Influent	162.9	5.9E-03	8.4E+01	5.2E-06	6.2E-03	5.0E+02	1.1E-03	9.5E+01	8.2E-04	2.6E-02	3.8E-03	1.8E+01	9.2E-04	7.3E+02	9.5E-02	9.0E+02	2.5E-03	2.7E-05	4.2E-01	8.2E-02	4.7E+03	4.8E-03	3.6E-07	5.9E-01	10.5
12	Sulfate B Effluent	162.9	5.9E-03	8.4E-02	5.2E-06	6.2E-03	1.2E+03	1.1E-03	9.5E+01	1.1E-07	2.6E-02	3.8E-03	1.7E+00	9.2E-04	3.1E-01	9.5E-02	9.0E+02	2.3E-06	2.7E-05	2.1E-02	4.1E-02	1.5E+03	4.8E-03	3.6E-07	5.9E-01	12.5
13	Calcite B Effluent	162.9	6.0E-03	8.5E-02	5.2E-06	6.3E-03	2.5E+01	1.1E-03	9.6E+01	1.1E-07	2.6E-02	3.8E-03	1.8E+00	9.3E-04	3.2E-01	9.6E-02	9.0E+02	2.3E-06	2.7E-05	2.1E-02	4.1E-02	1.5E+03	4.8E-03	3.6E-07	5.9E-01	10.0
14	Calcite B Effluent to Final Effluent	65.1	6.0E-03	8.5E-02	5.2E-06	6.2E-03	2.5E+01	1.1E-03	9.5E+01	1.1E-07	2.6E-02	3.8E-03	1.8E+00	9.2E-04	3.1E-01	9.6E-02	9.0E+02	2.3E-06	2.7E-05	2.1E-02	4.1E-02	1.5E+03	4.8E-03	3.6E-07	5.9E-01	6.0
15	Calcite B Effluent to VSEP B	97.7	6.0E-03	8.5E-02	5.2E-06	6.2E-03	2.5E+01	1.1E-03	9.5E+01	1.1E-07	2.6E-02	3.8E-03	1.8E+00	9.2E-04	3.1E-01	9.6E-02	9.0E+02	2.3E-06	2.7E-05	2.1E-02	4.1E-02	1.5E+03	4.8E-03	3.6E-07	5.9E-01	6.0
16	VSEP B Permeate to Final Effluent	151.1	2.4E-04	5.3E-04	3.2E-06	5.0E-03	2.2E+00	2.8E-05	9.3E+01	7.0E-09	2.7E-03	1.6E-04	1.1E+00	3.7E-05	4.6E-02	2.4E-02	4.0E+02	3.6E-07	6.0E-07	1.1E-03	2.5E-03	1.3E+02	2.6E-04	4.8E-08	3.8E-02	5.9
17	VSEP B Concentrate	37.8	2.9E-02	4.3E-01	1.3E-05	1.1E-02	1.2E+02	5.3E-03	1.1E+02	5.5E-07	1.2E-01	1.9E-02	4.6E+00	4.5E-03	1.4E+00	3.9E-01	2.9E+03	1.0E-05	1.3E-04	1.0E-01	2.0E-01	7.1E+03	2.3E-02	1.6E-06	2.8E+00	6.4
18	VSEP B Concentrate to HDS B	18.9	2.9E-02	4.3E-01	1.3E-05	1.1E-02	1.2E+02	5.3E-03	1.1E+02	5.5E-07	1.2E-01	1.9E-02	4.6E+00	4.5E-03	1.4E+00	3.9E-01	2.9E+03	1.0E-05	1.3E-04	1.0E-01	2.0E-01	7.1E+03	2.3E-02	1.6E-06	2.8E+00	6.4
19	VSEP B Concentrate to HDS A	18.9	2.9E-02	4.3E-01	1.3E-05	1.1E-02	1.2E+02	5.3E-03	1.1E+02	5.5E-07	1.2E-01	1.9E-02	4.6E+00	4.5E-03	1.4E+00	3.9E-01	2.9E+03	1.0E-05	1.3E-04	1.0E-01	2.0E-01	7.1E+03	2.3E-02	1.6E-06	2.8E+00	6.4
20	Low Conc EQ Effluent	1073.8	1.9E-04	1.7E-03	8.0E-02	4.0E-04	2.9E+02	8.3E-03	7.7E+01	3.4E-01	5.0E-03	2.4E+00	1.2E+00	1.9E-01	1.1E+02	5.0E-01	9.5E+01	4.1E+00	4.8E-03	4.0E-02	1.3E-02	5.5E+02	1.8E-04	1.0E-02	7.9E-01	7.0
21	GSF Backwash	53.7	1.9E-04	1.7E-03	1.3E+00	4.0E-04	2.9E+02	1.5E-01	7.7E+01	6.8E+00	5.0E-03	4.7E+01	1.2E+00	3.7E+00	1.1E+02	9.7E+00	9.4E+01	7.5E+01	9.0E-02	4.0E-02	1.3E-02	5.5E+02	1.8E-04	9.9E-03	1.6E+01	7.0
22	GSF Backwash Solids	26.8	1.9E-04	1.7E-03	2.2E+00	4.0E-04	2.9E+02	2.9E-01	7.7E+01	1.3E+01	5.0E-03	8.8E+01	1.2E+00	7.2E+00	1.1E+02	1.8E+01	9.4E+01	1.4E+02	1.7E-01	4.0E-02	1.3E-02	5.5E+02	1.8E-04	9.9E-03	3.0E+01	7.0
23	GSF Backwash Decant	26.8	1.9E-04	1.7E-03	4.0E-01	4.0E-04	2.9E+02	2.3E-02	7.7E+01	4.4E-01	5.0E-03	5.0E+00	1.2E+00	2.2E-01	1.1E+02	9.7E-01	9.4E+01	1.3E+01	1.4E-02	4.0E-02	1.3E-02	5.5E+02	1.8E-04	9.9E-03	1.1E+00	7.0
24	GSF Permeate/NF Feed	1020.2	1.9E-04	1.7E-03	2.4E-02	4.0E-04	2.9E+02	9.1E-04	7.7E+01	5.5E-03	5.0E-03	1.5E-01	1.2E+00	2.0E-03	1.1E+02	2.7E-02	9.5E+01	5.9E-01	5.3E-04	4.0E-02	1.3E-02	5.5E+02	1.8E-04	1.0E-02	1.9E-02	7.0
25	NF Permeate	816.1	1.5E-04	1.2E-04	3.0E-04	2.8E-05	3.6E+01	6.5E-05	8.7E+01	2.0E-04	3.5E-04	1.2E-02	9.5E-01	6.8E-20	7.3E+00	7.4E-04	6.2E+01	2.1E-02	2.0E-05	2.8E-03	5.2E-04	2.3E+01	1.3E-05	7.1E-04	3.7E-04	5.8
26	NF Concentrate to VSEP A	204.0	3.5E-04	8.0E-03	1.2E-01	1.9E-03	1.3E+03	4.3E-03	3.7E+01	2.7E-02	2.4E-02	7.2E-01	2.1E+00	1.0E-02	5.2E+02	1.3E-01	2.3E+02	2.9E+00	2.6E-03	1.9E-01	6.3E-02	2.7E+03	8.6E-04	4.7E-02	9.2E-02	9.4
27	VSEP A Permeate to Final Effluent	163.2	1.4E-05	5.0E-05	7.4E-02	1.5E-03	1.2E+02	1.1E-04	3.6E+01	1.6E-03	2.5E-03	3.0E-02	1.3E+00	4.0E-04	7.6E+01	3.4E-02	1.0E+02	4.5E-01	5.8E-05	1.0E-02	3.8E-03	2.3E+02	4.6E-05	6.3E-03	5.8E-03	5.5
28	VSEP A Concentrate	40.8	1.8E-03	4.1E-02	3.2E-01	3.5E-03	6.3E+03	2.2E-02	4.1E+01	1.3E-01	1.1E-01	3.6E+00	5.8E+00	5.0E-02	2.4E+03	5.5E-01	7.6E+02	1.3E+01	1.3E-02	9.5E-01	3.1E-01	1.3E+04	4.3E-03	2.2E-01	4.5E-01	9.8
29	VSEP A Concentrate to HDS B	20.4	1.8E-03	4.1E-02	3.2E-01	3.5E-03	6.3E+03	2.2E-02	4.1E+01	1.3E-01	1.1E-01	3.6E+00	5.8E+00	5.0E-02	2.4E+03	5.5E-01	7.6E+02	1.3E+01	1.3E-02	9.5E-01	3.1E-01	1.3E+04	4.3E-03	2.2E-01	4.5E-01	9.8
30	VSEP A Concentrate to HDS A	20.4	1.8E-03	4.1E-02	3.2E-01	3.5E-03	6.3E+03	2.2E-02	4.1E+01	1.3E-01	1.1E-01	3.6E+00	5.8E+00	5.0E-02	2.4E+03	5.5E-01	7.6E+02	1.3E+01	1.3E-02	9.5E-01	3.1E-01	1.3E+04	4.3E-03	2.2E-01	4.5E-01	9.8
31	HDS A Underflow Sludge	7.4	2.5E-01	0.0E+00	8.5E+00	2.6E-01	9.1E+04	1.4E+00	1.4E+00	8.7E+01	3.5E-01	2.7E+02	8.8E-02	4.5E+03	5.6E+03	2.1E+02	0.0E+00	5.8E+02	1.6E+00	0.0E+00	7.7E-01	5.6E+04	0.0E+00	1.7E+00	1.3E+02	10.5
32	Sulfate A Underflow Sludge	15.7	6.3E-08	8.7E+02	0.0E+00	0.0E+00	2.9E+04	7.0E-08	6.4E-01	8.5E-03	0.0E+00	5.6E-05	1.7E+02	0.0E+00	7.5E+03	9.8E-07	0.0E+00	2.5E-02	4.5E-10	4.2E+00	4.2E-01	3.4E+04	0.0E+00	0.0E+00	0.0E+00	12.5
33	Calcite A Underflow Sludge	8.3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.4E+04	0.0E+00	7.7E-07	0.0E+00	0.0E+00	5.7E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.0
34	HDS B Underflow Sludge	7.4	2.5E-01	0.0E+00	8.5E+00	2.6E-01	9.1E+04	1.4E+00	1.4E+00	8.7E+01	3.5E-01	2.7E+02	8.8E-02	4.5E+03	5.6E+03	2.1E+02	0.0E+00	5.8E+02	1.6E+00	0.0E+00	7.7E-01	5.6E+04	0.0E+00	1.7E+00	1.3E+02	10.5
35	Sulfate B Underflow Sludge	15.7	6.3E-08	8.7E+02	0.0E+00	0.0E+00	2.9E+04	7.0E-08	6.4E-01	8.5E-03	0.0E+00	5.6E-05	1.7E+02	0.0E+00	7.5E+03	9.8E-07	0.0E+00	2.5E-02	4.5E-10	4.2E+00	4.2E-01	3.4E+04	0.0E+00	0.0E+00	0.0E+00	12.5
36	Calcite B Underflow Sludge	8.3	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.4E+04	0.0E+00	7.7E-07	0.0E+00	0.0E+00	5.7E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.0
37	Plant Site VSEP Concentrate	85.3	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
38	Plant Site Concentrate to HDS A	42.7	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
39	Plant Site Concentrate to HDS B	42.7	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
40	Final Effluent to CPS	1267.3	7.7E-04	9.3E-03	9.7E-03	1.5E-03	4.1E+01	1.7E-04	8.2E+01	3.4E-04	3.6E-03	1.2E-02	1.1E+00	1.5E-04	1.4E+01	1.8E-02	2.0E+02	7.1E-02	2.4E-05	5.6E-03	5.5E-03	2.2E+02	5.6E-04	1.3E-03	6.9E-02	5.7

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	162.9	NA	NA	NA	175.7	3.9	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	20.3	12.88	7.4	NA	NA	NA	NA	NA	NA	25	1.18	1.50	0.55	0.95
5	Sulfate A Influent	162.9	NA	NA	NA	181.0	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	33.8	18.10	15.7	NA	NA	NA	NA	NA	NA	10	1.05	0.85	0.38	0.48
6	Sulfate A Effluent	162.9	NA	NA	110.0	272.9	NA	NA	1.3	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	8.3	0.00	8.3	NA	NA	NA	NA	NA	NA	10	1.06	0.20	0.20	0.00
7	Calcite A Effluent	162.9	NA	NA	41.3	204.1	NA	NA	0.5	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	162.9	NA	NA	NA	175.7	3.9	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	20.3	12.88	7.4	NA	NA	NA	NA	NA	NA	25	1.18	1.50	0.55	0.95
11	Sulfate B Influent	162.9	NA	NA		181.0	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	33.8	18.10	15.7	NA	NA	NA	NA	NA	NA	10	1.05	0.85	0.38	0.48
12	Sulfate B Effluent	162.9	NA	NA	110.0	272.9	NA	NA	1.3	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	8.3	0.00	8.3	NA	NA	NA	NA	NA	NA	10	1.06	0.20	0.20	0.00
13	Calcite B Effluent	162.9	NA	NA	41.3	162.9	NA	NA	0.5	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1073.8	NA	NA	NA	NA	NA	NA	NA	21.2	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	204.0	NA	NA	275*	NA	NA	NA	3.3	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 3 P90 Winter Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	40.0	3.2E-02	2.1E+02	4.0E-01	3.6E-02	1.6E+03	8.4E-02	1.3E+02	6.9E+00	2.1E-02	1.1E+01	2.1E+00	4.9E+02	5.7E+02	1.9E+01	2.3E+02	3.3E+01	1.4E-01	6.8E-01	1.3E-01	8.5E+03	1.6E-03	5.8E-02	9.1E+00	5.0
2	High Conc EQ Effluent to HDS A	20.0	3.2E-02	2.1E+02	4.0E-01	3.6E-02	1.6E+03	8.4E-02	1.3E+02	6.9E+00	2.1E-02	1.1E+01	2.1E+00	4.9E+02	5.7E+02	1.9E+01	2.3E+02	3.3E+01	1.4E-01	6.8E-01	1.3E-01	8.5E+03	1.6E-03	5.8E-02	9.1E+00	5.0
3	High Conc EQ Effluent to HDS B	20.0	3.2E-02	2.1E+02	4.0E-01	3.6E-02	1.6E+03	8.4E-02	1.3E+02	6.9E+00	2.1E-02	1.1E+01	2.1E+00	4.9E+02	5.7E+02	1.9E+01	2.3E+02	3.3E+01	1.4E-01	6.8E-01	1.3E-01	8.5E+03	1.6E-03	5.8E-02	9.1E+00	5.0
4	Combined HDS A Influent	130.1	1.4E-02	3.2E+01	1.9E-01	9.1E-03	2.1E+03	2.8E-02	7.3E+01	1.6E+00	4.8E-02	5.4E+00	2.1E+01	7.7E+01	8.0E+02	4.0E+00	1.5E+03	1.1E+01	3.0E-02	2.0E-01	6.6E-02	5.0E+03	1.4E-02	5.6E-02	3.2E+00	6.3
5	Sulfate A Influent	130.1	8.5E-03	3.1E+01	6.8E-06	3.9E-03	8.5E+02	7.2E-04	7.2E+01	3.8E-04	3.3E-02	3.9E-03	2.0E+01	9.4E-04	5.7E+02	3.9E-02	1.5E+03	1.2E-03	1.7E-05	1.9E-01	4.6E-02	2.4E+03	1.4E-02	6.9E-07	6.0E-01	10.5
6	Sulfate A Effluent	130.1	8.5E-03	3.1E-02	6.8E-06	3.9E-03	2.1E+03	7.2E-04	7.2E+01	6.1E-08	3.3E-02	3.9E-03	1.4E+00	9.4E-04	4.5E-01	3.9E-02	1.5E+03	1.2E-06	1.7E-05	9.6E-03	2.3E-02	1.2E+03	1.4E-02	6.9E-07	6.0E-01	12.4
7	Calcite A Effluent	130.1	8.6E-03	3.2E-02	6.9E-06	3.9E-03	1.2E+03	7.2E-04	7.2E+01	6.2E-08	3.4E-02	3.9E-03	1.5E+00	9.5E-04	4.5E-01	4.0E-02	1.5E+03	1.2E-06	1.7E-05	9.7E-03	2.3E-02	1.2E+03	1.4E-02	7.0E-07	6.0E-01	10.9
8	Calcite A Effluent to Final Effluent	52.1	8.6E-03	3.2E-02	6.8E-06	3.9E-03	1.2E+03	7.2E-04	7.2E+01	6.2E-08	3.3E-02	3.9E-03	1.4E+00	9.4E-04	4.5E-01	4.0E-02	1.5E+03	1.2E-06	1.7E-05	9.6E-03	2.3E-02	1.2E+03	1.4E-02	7.0E-07	6.0E-01	7.2
9	Calcite A Effluent to VSEP B	78.1	8.6E-03	3.2E-02	6.8E-06	3.9E-03	1.2E+03	7.2E-04	7.2E+01	6.2E-08	3.3E-02	3.9E-03	1.4E+00	9.4E-04	4.5E-01	4.0E-02	1.5E+03	1.2E-06	1.7E-05	9.6E-03	2.3E-02	1.2E+03	1.4E-02	7.0E-07	6.0E-01	7.2
10	Combined HDS B Influent	130.1	1.4E-02	3.2E+01	1.9E-01	9.1E-03	2.1E+03	2.8E-02	7.3E+01	1.6E+00	4.8E-02	5.4E+00	2.1E+01	7.7E+01	8.0E+02	4.0E+00	1.5E+03	1.1E+01	3.0E-02	2.0E-01	6.6E-02	5.0E+03	1.4E-02	5.6E-02	3.2E+00	6.3
11	Sulfate B Influent	130.1	8.5E-03	3.1E+01	6.8E-06	3.9E-03	8.5E+02	7.2E-04	7.2E+01	3.8E-04	3.3E-02	3.9E-03	2.0E+01	9.4E-04	5.7E+02	3.9E-02	1.5E+03	1.2E-03	1.7E-05	1.9E-01	4.6E-02	2.4E+03	1.4E-02	6.9E-07	6.0E-01	10.5
12	Sulfate B Effluent	130.1	8.5E-03	3.1E-02	6.8E-06	3.9E-03	2.1E+03	7.2E-04	7.2E+01	6.1E-08	3.3E-02	3.9E-03	1.4E+00	9.4E-04	4.5E-01	3.9E-02	1.5E+03	1.2E-06	1.7E-05	9.6E-03	2.3E-02	1.2E+03	1.4E-02	6.9E-07	6.0E-01	12.4
13	Calcite B Effluent	130.1	8.6E-03	3.2E-02	6.9E-06	3.9E-03	1.2E+03	7.2E-04	7.2E+01	6.2E-08	3.4E-02	3.9E-03	1.5E+00	9.5E-04	4.5E-01	4.0E-02	1.5E+03	1.2E-06	1.7E-05	9.7E-03	2.3E-02	1.2E+03	1.4E-02	7.0E-07	6.0E-01	10.9
14	Calcite B Effluent to Final Effluent	52.1	8.6E-03	3.2E-02	6.8E-06	3.9E-03	1.2E+03	7.2E-04	7.2E+01	6.2E-08	3.3E-02	3.9E-03	1.4E+00	9.4E-04	4.5E-01	4.0E-02	1.5E+03	1.2E-06	1.7E-05	9.6E-03	2.3E-02	1.2E+03	1.4E-02	7.0E-07	6.0E-01	7.2
15	Calcite B Effluent to VSEP B	78.1	8.6E-03	3.2E-02	6.8E-06	3.9E-03	1.2E+03	7.2E-04	7.2E+01	6.2E-08	3.3E-02	3.9E-03	1.4E+00	9.4E-04	4.5E-01	4.0E-02	1.5E+03	1.2E-06	1.7E-05	9.6E-03	2.3E-02	1.2E+03	1.4E-02	7.0E-07	6.0E-01	7.2
16	VSEP B Permeate to Final Effluent	208.2	3.4E-04	2.0E-04	4.2E-06	3.1E-03	1.0E+02	1.9E-05	7.0E+01	3.8E-09	3.5E-03	1.6E-04	8.7E-01	3.8E-05	6.6E-02	1.0E-02	6.7E+02	1.9E-07	3.9E-07	5.2E-04	1.4E-03	1.0E+02	7.5E-04	9.3E-08	3.8E-02	9.1
17	VSEP B Concentrate	52.1	4.2E-02	1.6E-01	1.8E-05	7.1E-03	5.4E+03	3.6E-03	8.0E+01	3.0E-07	1.6E-01	1.9E-02	3.8E+00	4.6E-03	2.0E+00	1.6E-01	4.9E+03	5.4E-06	8.6E-05	4.7E-02	1.1E-01	5.6E+03	6.8E-02	3.2E-06	2.9E+00	5.3
18	VSEP B Concentrate to HDS B	26.0	4.2E-02	1.6E-01	1.8E-05	7.1E-03	5.4E+03	3.6E-03	8.0E+01	3.0E-07	1.6E-01	1.9E-02	3.8E+00	4.6E-03	2.0E+00	1.6E-01	4.9E+03	5.4E-06	8.6E-05	4.7E-02	1.1E-01	5.6E+03	6.8E-02	3.2E-06	2.9E+00	5.3
19	VSEP B Concentrate to HDS A	26.0	4.2E-02	1.6E-01	1.8E-05	7.1E-03	5.4E+03	3.6E-03	8.0E+01	3.0E-07	1.6E-01	1.9E-02	3.8E+00	4.6E-03	2.0E+00	1.6E-01	4.9E+03	5.4E-06	8.6E-05	4.7E-02	1.1E-01	5.6E+03	6.8E-02	3.2E-06	2.9E+00	5.3
20	Low Conc EQ Effluent	406.2	1.9E-04	1.7E-03	8.0E-02	4.0E-04	2.9E+02	8.3E-03	7.7E+01	3.4E-01	5.0E-03	2.4E+00	1.2E+00	1.9E-01	1.1E+02	5.0E-01	9.5E+01	4.1E+00	4.8E-03	4.0E-02	1.3E-02	5.5E+02	1.8E-04	1.0E-02	7.9E-01	7.0
21	GSF Backwash	20.2	1.9E-04	1.7E-03	1.3E+00	4.0E-04	2.9E+02	1.5E-01	7.7E+01	6.8E+00	5.0E-03	4.7E+01	1.2E+00	3.7E+00	1.1E+02	9.7E+00	9.4E+01	7.5E+01	9.0E-02	4.0E-02	1.3E-02	5.5E+02	1.8E-04	9.9E-03	1.6E+01	7.0
22	GSF Backwash Solids	10.2	1.9E-04	1.7E-03	2.2E+00	4.0E-04	2.9E+02	2.9E-01	7.7E+01	1.3E+01	5.0E-03	8.8E+01	1.2E+00	7.2E+00	1.1E+02	1.8E+01	9.4E+01	1.4E+02	1.7E-01	4.0E-02	1.3E-02	5.5E+02	1.8E-04	9.9E-03	3.0E+01	7.0
23	GSF Backwash Decant	10.2	1.9E-04	1.7E-03	4.0E-01	4.0E-04	2.9E+02	2.3E-02	7.7E+01	4.4E-01	5.0E-03	5.0E+00	1.2E+00	2.2E-01	1.1E+02	9.7E-01	9.4E+01	1.3E+01	1.4E-02	4.0E-02	1.3E-02	5.5E+02	1.8E-04	9.9E-03	1.1E+00	7.0
24	GSF Permeate/NF Feed	385.8	1.9E-04	1.7E-03	2.4E-02	4.0E-04	2.9E+02	9.1E-04	7.7E+01	5.5E-03	5.0E-03	1.5E-01	1.2E+00	2.0E-03	1.1E+02	2.7E-02	9.5E+01	5.9E-01	5.3E-04	4.0E-02	1.3E-02	5.5E+02	1.8E-04	1.0E-02	1.9E-02	7.0
25	NF Permeate	308.7	1.5E-04	1.2E-04	3.0E-04	2.8E-05	3.6E+01	6.5E-05	8.7E+01	2.0E-04	3.5E-04	1.2E-02	9.5E-01	0.0E+00	7.3E+00	7.4E-04	6.2E+01	2.1E-02	2.0E-05	2.8E-03	5.2E-04	2.3E+01	1.3E-05	7.1E-04	3.7E-04	6.0
26	NF Concentrate to VSEP A	77.2	3.5E-04	8.0E-03	1.2E-01	1.9E-03	1.3E+03	4.3E-03	3.7E+01	2.7E-02	2.4E-02	7.2E-01	2.1E+00	1.0E-02	5.2E+02	1.3E-01	2.3E+02	2.9E+00	2.6E-03	1.9E-01	6.3E-02	2.7E+03	8.6E-04	4.7E-02	9.2E-02	9.2
27	VSEP A Permeate to Final Effluent	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	VSEP A Concentrate	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29	VSEP A Concentrate to HDS B	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30	VSEP A Concentrate to HDS A	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	5.9	1.2E-01	8.7E-04	4.0E+00	1.1E-01	9.4E+04	6.0E-01	1.0E+00	3.5E+01	3.0E-01	1.2E+02	1.2E-01	1.7E+03	4.8E+03	8.6E+01	0.0E+00	2.5E+02	6.6E-01	0.0E+00	4.3E-01	5.4E+04	0.0E+00	1.2E+00	5.6E+01	10.5
32	Sulfate A Underflow Sludge	9.4	0.0E+00	4.3E+02	0.0E+00	0.0E+00	4.2E+04	0.0E+00	6.4E-01	5.2E-03	0.0E+00	7.5E-05	2.6E+02	0.0E+00	7.8E+03	1.8E-07	0.0E+00	1.7E-02	0.0E+00	2.5E+00	3.1E-01	1.7E+04	0.0E+00	0.0E+00	0.0E+00	12.4
33	Calcite A Underflow Sludge	3.0	0.0E+00	0.0E+00	0.0E+00	1.0E-07	3.8E+04	0.0E+00	1.1E-05	2.4E-12	0.0E+00	1.3E-04	2.6E-04	1.2E-07	0.0E+00	0.0E+00	0.0E+00	3.2E-10	0.0E+00	0.0E+00	0.0E+00	5.4E-01	0.0E+00	0.0E+00	7.3E-05	10.9
34	HDS B Underflow Sludge	5.9	1.2E-01	8.7E-04	4.0E+00	1.1E-01	9.4E+04	6.0E-01	1.0E+00	3.5E+01	3.0E-01	1.2E+02	1.2E-01	1.7E+03	4.8E+03	8.6E+01	0.0E+00	2.5E+02	6.6E-01	0.0E+00	4.3E-01	5.4E+04	0.0E+00	1.2E+00	5.6E+01	10.5
35	Sulfate B Underflow Sludge	9.4	0.0E+00	4.3E+02	0.0E+00	0.0E+00	4.2E+04	0.0E+00	6.4E-01	5.2E-03	0.0E+00	7.5E-05	2.6E+02	0.0E+00	7.8E+03	1.8E-07	0.0E+00	1.7E-02	0.0E+00	2.5E+00	3.1E-01	1.7E+04	0.0E+00	0.0E+00	0.0E+00	12.4
36	Calcite B Underflow Sludge	3.0	0.0E+00	0.0E+00	0.0E+00	1.0E-07	3.8E+04	0.0E+00	1.1E-05	2.4E-12	0.0E+00	1.3E-04	2.6E-04	1.2E-07	0.0E+00	0.0E+00	0.0E+00	3.2E-10	0.0E+00	0.0E+00	0.0E+00	5.4E-01	0.0E+00	0.0E+00	7.3E-05	10.9
37	Plant Site VSEP Concentrate	80.9	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
38	Plant Site Concentrate to HDS A	40.5	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
39	Plant Site Concentrate to HDS B	40.5	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
40	Final Effluent to CPS	516.9	2.3E-04	1.5E-04	1.9E-04	1.3E-03	6.3E+01	4.6E-05	8.0E+01	1.2E-04	1.6E-03	7.0E-03	9.2E-01	1.5E-05	4.4E+00	4.5E-03	3.1E+02	1.3E-02	1.2E-05	1.9E-03	8.7E-04	5.4E+01	3.1E-04	4.2E-04	1.6E-02	6.6

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	130.1	NA	NA	NA	180.5	3.3	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	56.3	50.40	5.9	NA	NA	NA	NA	NA	NA	25	1.18	4.17	0.44	3.73
5	Sulfate A Influent	130.1	NA	NA	NA	144.6	3.3	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	23.9	14.46	9.4	NA	NA	NA	NA	NA	NA	10	1.06	0.61	0.23	0.38
6	Sulfate A Effluent	130.1	NA	NA	64.2	194.3	NA	NA	0.8	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	3.0	0.00	3.0	NA	NA	NA	NA	NA	NA	10	1.06	0.07	0.07	0.00
7	Calcite A Effluent	130.1	NA	NA	36.7	166.8	NA	NA	0.4	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	130.1	NA	NA	NA	180.5	3.3	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	56.3	50.40	5.9	NA	NA	NA	NA	NA	NA	25	1.18	4.17	0.44	3.73
11	Sulfate B Influent	130.1	NA	NA		144.6	3.3	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	23.9	14.46	9.4	NA	NA	NA	NA	NA	NA	10	1.06	0.61	0.23	0.38
12	Sulfate B Effluent	130.1	NA	NA	64.2	194.3	NA	NA	0.8	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	3.0	0.00	3.0	NA	NA	NA	NA	NA	NA	10	1.06	0.07	0.07	0.00
13	Calcite B Effluent	130.1	NA	NA	36.7	130.1	NA	NA	0.4	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	406.2	NA	NA	NA	NA	NA	NA	NA	8.0	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	77.2	NA	NA	0*	NA	NA	NA	0.0	NA	NA	NA	NA	NA	NA

Mine Water Treatment Trains Flow and Load Detail
Year 4 P90 Annual Average Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	167.0	3.2E-02	2.1E+02	4.1E-01	3.8E-02	1.5E+03	8.7E-02	7.9E+01	7.2E+00	2.0E-02	1.1E+01	2.1E+00	5.1E+02	5.9E+02	1.8E+01	2.3E+02	3.1E+01	1.5E-01	6.7E-01	1.2E-01	8.4E+03	1.5E-03	6.1E-02	9.5E+00	5.0
2	High Conc EQ Effluent to HDS A	83.5	3.2E-02	2.1E+02	4.1E-01	3.8E-02	1.5E+03	8.7E-02	7.9E+01	7.2E+00	2.0E-02	1.1E+01	2.1E+00	5.1E+02	5.9E+02	1.8E+01	2.3E+02	3.1E+01	1.5E-01	6.7E-01	1.2E-01	8.4E+03	1.5E-03	6.1E-02	9.5E+00	5.0
3	High Conc EQ Effluent to HDS B	83.5	3.2E-02	2.1E+02	4.1E-01	3.8E-02	1.5E+03	8.7E-02	7.9E+01	7.2E+00	2.0E-02	1.1E+01	2.1E+00	5.1E+02	5.9E+02	1.8E+01	2.3E+02	3.1E+01	1.5E-01	6.7E-01	1.2E-01	8.4E+03	1.5E-03	6.1E-02	9.5E+00	5.0
4	Combined HDS A Influent	188.3	1.9E-02	9.6E+01	3.6E-01	2.1E-02	1.6E+03	6.2E-02	7.3E+01	4.0E+00	5.6E-02	1.1E+01	1.6E+01	2.3E+02	9.3E+02	9.6E+00	1.2E+03	2.4E+01	8.4E-02	4.2E-01	1.1E-01	7.8E+03	1.2E-02	7.1E-02	6.6E+00	6.4
5	Sulfate A Influent	188.3	4.8E-03	9.4E+01	4.7E-06	7.5E-03	4.8E+02	3.0E-03	7.1E+01	2.0E-03	3.8E-02	3.8E-03	1.6E+01	8.8E-04	8.1E+02	9.4E-02	1.2E+03	5.3E-03	5.8E-05	4.1E-01	7.8E-02	5.5E+03	1.1E-02	3.1E-07	5.8E-01	10.5
6	Sulfate A Effluent	188.3	4.8E-03	9.4E-02	4.7E-06	7.5E-03	1.2E+03	3.0E-03	7.1E+01	2.6E-07	3.8E-02	3.8E-03	1.8E+00	8.8E-04	3.0E-01	9.4E-02	1.2E+03	4.8E-06	5.8E-05	2.1E-02	3.9E-02	1.7E+03	1.1E-02	3.1E-07	5.8E-01	12.5
7	Calcite A Effluent	188.3	4.9E-03	9.5E-02	4.8E-06	7.6E-03	8.9E-01	3.0E-03	7.2E+01	2.6E-07	3.9E-02	3.8E-03	1.9E+00	8.9E-04	3.0E-01	9.5E-02	1.2E+03	4.8E-06	5.9E-05	2.1E-02	3.9E-02	1.7E+03	1.1E-02	3.1E-07	5.8E-01	10.2
8	Calcite A Effluent to Final Effluent	75.3	4.9E-03	9.4E-02	4.7E-06	7.6E-03	8.9E-01	3.0E-03	7.2E+01	2.6E-07	3.9E-02	3.8E-03	1.8E+00	8.9E-04	3.0E-01	9.4E-02	1.2E+03	4.8E-06	5.9E-05	2.1E-02	3.9E-02	1.7E+03	1.1E-02	3.1E-07	5.8E-01	6.9
9	Calcite A Effluent to VSEP B	113.0	4.9E-03	9.4E-02	4.7E-06	7.6E-03	8.9E-01	3.0E-03	7.2E+01	2.6E-07	3.9E-02	3.8E-03	1.8E+00	8.9E-04	3.0E-01	9.4E-02	1.2E+03	4.8E-06	5.9E-05	2.1E-02	3.9E-02	1.7E+03	1.1E-02	3.1E-07	5.8E-01	6.9
10	Combined HDS B Influent	188.3	1.9E-02	9.6E+01	3.6E-01	2.1E-02	1.6E+03	6.2E-02	7.3E+01	4.0E+00	5.6E-02	1.1E+01	1.6E+01	2.3E+02	9.3E+02	9.6E+00	1.2E+03	2.4E+01	8.4E-02	4.2E-01	1.1E-01	7.8E+03	1.2E-02	7.1E-02	6.6E+00	6.4
11	Sulfate B Influent	188.3	4.8E-03	9.4E+01	4.7E-06	7.5E-03	4.8E+02	3.0E-03	7.1E+01	2.0E-03	3.8E-02	3.8E-03	1.6E+01	8.8E-04	8.1E+02	9.4E-02	1.2E+03	5.3E-03	5.8E-05	4.1E-01	7.8E-02	5.5E+03	1.1E-02	3.1E-07	5.8E-01	10.5
12	Sulfate B Effluent	188.3	4.8E-03	9.4E-02	4.7E-06	7.5E-03	1.2E+03	3.0E-03	7.1E+01	2.6E-07	3.8E-02	3.8E-03	1.8E+00	8.8E-04	3.0E-01	9.4E-02	1.2E+03	4.8E-06	5.8E-05	2.1E-02	3.9E-02	1.7E+03	1.1E-02	3.1E-07	5.8E-01	12.5
13	Calcite B Effluent	188.3	4.9E-03	9.5E-02	4.8E-06	7.6E-03	8.9E-01	3.0E-03	7.2E+01	2.6E-07	3.9E-02	3.8E-03	1.9E+00	8.9E-04	3.0E-01	9.5E-02	1.2E+03	4.8E-06	5.9E-05	2.1E-02	3.9E-02	1.7E+03	1.1E-02	3.1E-07	5.8E-01	10.2
14	Calcite B Effluent to Final Effluent	75.3	4.9E-03	9.4E-02	4.7E-06	7.6E-03	8.9E-01	3.0E-03	7.2E+01	2.6E-07	3.9E-02	3.8E-03	1.8E+00	8.9E-04	3.0E-01	9.4E-02	1.2E+03	4.8E-06	5.9E-05	2.1E-02	3.9E-02	1.7E+03	1.1E-02	3.1E-07	5.8E-01	6.9
15	Calcite B Effluent to VSEP B	113.0	4.9E-03	9.4E-02	4.7E-06	7.6E-03	8.9E-01	3.0E-03	7.2E+01	2.6E-07	3.9E-02	3.8E-03	1.8E+00	8.9E-04	3.0E-01	9.4E-02	1.2E+03	4.8E-06	5.9E-05	2.1E-02	3.9E-02	1.7E+03	1.1E-02	3.1E-07	5.8E-01	6.9
16	VSEP B Permeate to Final Effluent	265.1	1.9E-04	5.9E-04	2.9E-06	6.1E-03	7.9E-02	7.8E-05	7.0E+01	1.6E-08	4.1E-03	1.6E-04	1.1E+00	3.5E-05	4.4E-02	2.4E-02	5.1E+02	7.5E-07	1.3E-06	1.1E-03	2.4E-03	1.4E+02	6.1E-04	4.1E-08	3.7E-02	8.9
17	VSEP B Concentrate	66.3	2.4E-02	4.8E-01	1.2E-05	1.4E-02	4.2E+00	1.5E-02	7.9E+01	1.3E-06	1.8E-01	1.8E-02	4.9E+00	4.3E-03	1.3E+00	3.8E-01	3.8E+03	2.1E-05	2.9E-04	1.0E-01	1.9E-01	7.8E+03	5.5E-02	1.4E-06	2.8E+00	5.4
18	VSEP B Concentrate to HDS B	33.1	2.4E-02	4.8E-01	1.2E-05	1.4E-02	4.2E+00	1.5E-02	7.9E+01	1.3E-06	1.8E-01	1.8E-02	4.9E+00	4.3E-03	1.3E+00	3.8E-01	3.8E+03	2.1E-05	2.9E-04	1.0E-01	1.9E-01	7.8E+03	5.5E-02	1.4E-06	2.8E+00	5.4
19	VSEP B Concentrate to HDS A	33.1	2.4E-02	4.8E-01	1.2E-05	1.4E-02	4.2E+00	1.5E-02	7.9E+01	1.3E-06	1.8E-01	1.8E-02	4.9E+00	4.3E-03	1.3E+00	3.8E-01	3.8E+03	2.1E-05	2.9E-04	1.0E-01	1.9E-01	7.8E+03	5.5E-02	1.4E-06	2.8E+00	5.4
20	Low Conc EQ Effluent	939.5	1.9E-04	1.7E-03	8.0E-02	4.0E-04	3.1E+02	7.8E-03	5.8E+01	3.2E-01	5.1E-03	2.3E+00	1.2E+00	1.9E-01	1.3E+02	4.6E-01	1.1E+02	4.0E+00	6.2E-03	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	7.3E-01	7.0
21	GSF Backwash	47.0	1.9E-04	1.7E-03	1.3E+00	4.0E-04	3.1E+02	1.5E-01	5.8E+01	6.3E+00	5.1E-03	4.5E+01	1.2E+00	3.8E+00	1.3E+02	8.9E+00	1.1E+02	7.4E+01	1.2E-01	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	1.4E+01	7.0
22	GSF Backwash Solids	23.5	1.9E-04	1.7E-03	2.2E+00	4.0E-04	3.1E+02	2.7E-01	5.8E+01	1.2E+01	5.1E-03	8.4E+01	1.2E+00	7.3E+00	1.3E+02	1.7E+01	1.1E+02	1.3E+02	2.2E-01	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	2.8E+01	7.0
23	GSF Backwash Decant	23.5	1.9E-04	1.7E-03	4.0E-01	4.0E-04	3.1E+02	2.2E-02	5.8E+01	4.1E-01	5.1E-03	4.8E+00	1.2E+00	2.3E-01	1.3E+02	8.9E-01	1.1E+02	1.3E+01	1.8E-02	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	1.0E+00	7.0
24	GSF Permeate/NF Feed	892.5	1.9E-04	1.7E-03	2.4E-02	4.0E-04	3.1E+02	8.6E-04	5.8E+01	5.1E-03	5.1E-03	1.4E-01	1.2E+00	2.0E-03	1.3E+02	2.5E-02	1.1E+02	5.8E-01	6.8E-04	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	1.7E-02	7.0
25	NF Permeate	714.0	1.5E-04	1.2E-04	3.0E-04	2.9E-05	3.9E+01	6.1E-05	6.6E+01	1.8E-04	3.6E-04	1.1E-02	9.6E-01	0.0E+00	8.8E+00	6.8E-04	6.9E+01	2.1E-02	2.6E-05	2.9E-03	3.9E-04	2.6E+01	1.3E-05	7.1E-04	3.4E-04	6.0
26	NF Concentrate to VSEP A	178.5	3.6E-04	8.1E-03	1.2E-01	1.9E-03	1.4E+03	4.1E-03	2.8E+01	2.5E-02	2.4E-02	6.9E-01	2.2E+00	1.0E-02	6.2E+02	1.2E-01	2.5E+02	2.8E+00	3.3E-03	1.9E-01	4.8E-02	3.1E+03	8.6E-04	4.7E-02	8.5E-02	9.2
27	VSEP A Permeate to Final Effluent	142.8	1.4E-05	5.0E-05	7.4E-02	1.5E-03	1.2E+02	1.1E-04	2.7E+01	1.5E-03	2.6E-03	2.9E-02	1.3E+00	4.1E-04	9.1E+01	3.1E-02	1.1E+02	4.4E-01	7.5E-05	1.0E-02	2.9E-03	2.6E+02	4.6E-05	6.3E-03	5.4E-03	5.5
28	VSEP A Concentrate	35.7	1.8E-03	4.2E-02	3.2E-01	3.6E-03	6.8E+03	2.1E-02	3.1E+01	1.2E-01	1.2E-01	3.5E+00	5.9E+00	5.1E-02	2.9E+03	5.1E-01	8.5E+02	1.3E+01	1.7E-02	9.5E-01	2.4E-01	1.5E+04	4.3E-03	2.2E-01	4.2E-01	10.0
29	VSEP A Concentrate to HDS B	17.9	1.8E-03	4.2E-02	3.2E-01	3.6E-03	6.8E+03	2.1E-02	3.1E+01	1.2E-01	1.2E-01	3.5E+00	5.9E+00	5.1E-02	2.9E+03	5.1E-01	8.5E+02	1.3E+01	1.7E-02	9.5E-01	2.4E-01	1.5E+04	4.3E-03	2.2E-01	4.2E-01	10.0
30	VSEP A Concentrate to HDS A	17.9	1.8E-03	4.2E-02	3.2E-01	3.6E-03	6.8E+03	2.1E-02	3.1E+01	1.2E-01	1.2E-01	3.5E+00	5.9E+00	5.1E-02	2.9E+03	5.1E-01	8.5E+02	1.3E+01	1.7E-02	9.5E-01	2.4E-01	1.5E+04	4.3E-03	2.2E-01	4.2E-01	10.0
31	HDS A Underflow Sludge	7.2	3.7E-01	0.0E+00	9.1E+00	3.4E-01	9.2E+04	1.5E+00	1.2E+00	1.0E+02	4.4E-01	2.7E+02	9.7E-02	5.9E+03	2.8E+03	2.4E+02	0.0E+00	6.1E+02	2.2E+00	0.0E+00	8.8E-01	5.6E+04	0.0E+00	1.8E+00	1.5E+02	10.5
32	Sulfate A Underflow Sludge	18.6	1.9E-07	9.5E+02	0.0E+00	3.3E-07	2.5E+04	1.1E-07	4.7E-01	2.0E-02	0.0E+00	5.4E-05	1.4E+02	3.7E-08	8.2E+03	3.9E-06	0.0E+00	5.3E-02	2.1E-09	4.0E+00	4.0E-01	3.9E+04	0.0E+00	0.0E+00	1.9E-05	12.5
33	Calcite A Underflow Sludge	10.1	6.0E-08	1.3E-06	0.0E+00	0.0E+00	2.2E+04	0.0E+00	1.5E-08	0.0E+00	0.0E+00	5.4E-05	0.0E+00	0.0E+00	0.0E+00	1.3E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.4E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.2
34	HDS B Underflow Sludge	7.2	3.7E-01	0.0E+00	9.1E+00	3.4E-01	9.2E+04	1.5E+00	1.2E+00	1.0E+02	4.4E-01	2.7E+02	9.7E-02	5.9E+03	2.8E+03	2.4E+02	0.0E+00	6.1E+02	2.2E+00	0.0E+00	8.8E-01	5.6E+04	0.0E+00	1.8E+00	1.5E+02	10.5
35	Sulfate B Underflow Sludge	18.6	1.9E-07	9.5E+02	0.0E+00	3.3E-07	2.5E+04	1.1E-07	4.7E-01	2.0E-02	0.0E+00	5.4E-05	1.4E+02	3.7E-08	8.2E+03	3.9E-06	0.0E+00	5.3E-02	2.1E-09	4.0E+00	4.0E-01	3.9E+04	0.0E+00	0.0E+00	1.9E-05	12.5
36	Calcite B Underflow Sludge	10.1	6.0E-08	1.3E-06	0.0E+00	0.0E+00	2.2E+04	0.0E+00	1.5E-08	0.0E+00	0.0E+00	5.4E-05	0.0E+00	0.0E+00	0.0E+00	1.3E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.4E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.2
37	Plant Site VSEP Concentrate	84.1	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
38	Plant Site Concentrate to HDS A	42.1	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
39	Plant Site Concentrate to HDS B	42.1	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
40	Final Effluent to CPS	1167.1	3.3E-04	3.9E-03	9.2E-03	1.9E-03	3.9E+01	1.8E-04	6.2E+01	3.0E-04	3.0E-03	1.1E-02	1.1E+00	9.2E-05	1.7E+01	1.3E-02	2.2E+02	6.7E-02	2.8E-05	4.1E-03	2.7E-03	1.4E+02	5.9E-04	1.2E-03	3.2E-02	6.0

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	188.3	NA	NA	NA	198.5	3.9	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	17.4	10.22	7.2	NA	NA	NA	NA	NA	NA	25	1.19	1.29	0.53	0.76
5	Sulfate A Influent	188.3	NA	NA	NA	209.2	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	39.5	20.92	18.6	NA	NA	NA	NA	NA	NA	10	1.05	1.00	0.45	0.55
6	Sulfate A Effluent	188.3	NA	NA	137.5	325.8	NA	NA	1.7	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	10.1	0.00	10.1	NA	NA	NA	NA	NA	NA	10	1.06	0.24	0.24	0.00
7	Calcite A Effluent	188.3	NA	NA	45.8	234.1	NA	NA	0.6	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	188.3	NA	NA	NA	198.5	3.9	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	17.4	10.22	7.2	NA	NA	NA	NA	NA	NA	25	1.19	1.29	0.53	0.76
11	Sulfate B Influent	188.3	NA	NA		209.2	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	39.5	20.92	18.6	NA	NA	NA	NA	NA	NA	10	1.05	1.00	0.45	0.55
12	Sulfate B Effluent	188.3	NA	NA	137.5	325.8	NA	NA	1.7	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	10.1	0.00	10.1	NA	NA	NA	NA	NA	NA	10	1.06	0.24	0.24	0.00
13	Calcite B Effluent	188.3	NA	NA	45.8	188.3	NA	NA	0.6	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	939.5	NA	NA	NA	NA	NA	NA	NA	18.6	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	178.5	NA	NA	229.2*	NA	NA	NA	2.8	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 4 P90 Peak Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	256.0	3.2E-02	2.1E+02	4.1E-01	3.8E-02	1.5E+03	8.7E-02	7.9E+01	7.2E+00	2.0E-02	1.1E+01	2.1E+00	5.1E+02	5.9E+02	1.8E+01	2.3E+02	3.1E+01	1.5E-01	6.7E-01	1.2E-01	8.4E+03	1.5E-03	6.1E-02	9.5E+00	5.0
2	High Conc EQ Effluent to HDS A	128.0	3.2E-02	2.1E+02	4.1E-01	3.8E-02	1.5E+03	8.7E-02	7.9E+01	7.2E+00	2.0E-02	1.1E+01	2.1E+00	5.1E+02	5.9E+02	1.8E+01	2.3E+02	3.1E+01	1.5E-01	6.7E-01	1.2E-01	8.4E+03	1.5E-03	6.1E-02	9.5E+00	5.0
3	High Conc EQ Effluent to HDS B	128.0	3.2E-02	2.1E+02	4.1E-01	3.8E-02	1.5E+03	8.7E-02	7.9E+01	7.2E+00	2.0E-02	1.1E+01	2.1E+00	5.1E+02	5.9E+02	1.8E+01	2.3E+02	3.1E+01	1.5E-01	6.7E-01	1.2E-01	8.4E+03	1.5E-03	6.1E-02	9.5E+00	5.0
4	Combined HDS A Influent	237.9	2.0E-02	1.2E+02	4.0E-01	2.5E-02	1.7E+03	6.9E-02	7.3E+01	4.7E+00	4.5E-02	1.2E+01	1.3E+01	2.8E+02	9.2E+02	1.1E+01	7.6E+02	2.7E+01	9.9E-02	4.8E-01	1.2E-01	7.8E+03	4.4E-03	7.3E-02	7.5E+00	6.5
5	Sulfate A Influent	237.9	2.5E-03	1.1E+02	5.1E-06	1.4E-02	5.4E+02	4.3E-04	7.1E+01	3.5E-04	3.3E-02	4.8E-03	1.3E+01	1.5E-03	2.4E+02	1.1E-01	7.4E+02	1.1E-03	6.0E-05	4.7E-01	7.9E-02	3.0E+03	4.3E-03	2.9E-07	8.2E-01	10.7
6	Sulfate A Effluent	237.9	2.5E-03	1.1E-01	5.1E-06	1.4E-02	1.2E+03	4.3E-04	7.1E+01	1.5E-07	3.3E-02	4.8E-03	1.8E+00	1.5E-03	3.1E-01	1.1E-01	7.4E+02	3.1E-06	6.0E-05	2.4E-02	4.0E-02	1.5E+03	4.3E-03	2.9E-07	8.2E-01	12.5
7	Calcite A Effluent	237.9	2.5E-03	1.1E-01	5.1E-06	1.4E-02	1.2E+00	4.3E-04	7.2E+01	1.5E-07	3.4E-02	4.9E-03	1.8E+00	1.5E-03	3.1E-01	1.1E-01	7.5E+02	3.1E-06	6.1E-05	2.4E-02	4.0E-02	1.5E+03	4.4E-03	3.0E-07	8.2E-01	10.0
8	Calcite A Effluent to Final Effluent	95.2	2.5E-03	1.1E-01	5.1E-06	1.4E-02	1.2E+00	4.3E-04	7.1E+01	1.5E-07	3.4E-02	4.8E-03	1.8E+00	1.5E-03	3.1E-01	1.1E-01	7.5E+02	3.1E-06	6.1E-05	2.4E-02	4.0E-02	1.5E+03	4.4E-03	3.0E-07	8.2E-01	6.6
9	Calcite A Effluent to VSEP B	142.7	2.5E-03	1.1E-01	5.1E-06	1.4E-02	1.2E+00	4.3E-04	7.1E+01	1.5E-07	3.4E-02	4.8E-03	1.8E+00	1.5E-03	3.1E-01	1.1E-01	7.5E+02	3.1E-06	6.1E-05	2.4E-02	4.0E-02	1.5E+03	4.4E-03	3.0E-07	8.2E-01	6.6
10	Combined HDS B Influent	237.9	2.0E-02	1.2E+02	4.0E-01	2.5E-02	1.7E+03	6.9E-02	7.3E+01	4.7E+00	4.5E-02	1.2E+01	1.3E+01	2.8E+02	9.2E+02	1.1E+01	7.6E+02	2.7E+01	9.9E-02	4.8E-01	1.2E-01	7.8E+03	4.4E-03	7.3E-02	7.5E+00	6.5
11	Sulfate B Influent	237.9	2.5E-03	1.1E+02	5.1E-06	1.4E-02	5.4E+02	4.3E-04	7.1E+01	3.5E-04	3.3E-02	4.8E-03	1.3E+01	1.5E-03	2.4E+02	1.1E-01	7.4E+02	1.1E-03	6.0E-05	4.7E-01	7.9E-02	3.0E+03	4.3E-03	2.9E-07	8.2E-01	10.7
12	Sulfate B Effluent	237.9	2.5E-03	1.1E-01	5.1E-06	1.4E-02	1.2E+03	4.3E-04	7.1E+01	1.5E-07	3.3E-02	4.8E-03	1.8E+00	1.5E-03	3.1E-01	1.1E-01	7.4E+02	3.1E-06	6.0E-05	2.4E-02	4.0E-02	1.5E+03	4.3E-03	2.9E-07	8.2E-01	12.5
13	Calcite B Effluent	237.9	2.5E-03	1.1E-01	5.1E-06	1.4E-02	1.2E+00	4.3E-04	7.2E+01	1.5E-07	3.4E-02	4.9E-03	1.8E+00	1.5E-03	3.1E-01	1.1E-01	7.5E+02	3.1E-06	6.1E-05	2.4E-02	4.0E-02	1.5E+03	4.4E-03	3.0E-07	8.2E-01	10.0
14	Calcite B Effluent to Final Effluent	95.2	2.5E-03	1.1E-01	5.1E-06	1.4E-02	1.2E+00	4.3E-04	7.1E+01	1.5E-07	3.4E-02	4.8E-03	1.8E+00	1.5E-03	3.1E-01	1.1E-01	7.5E+02	3.1E-06	6.1E-05	2.4E-02	4.0E-02	1.5E+03	4.4E-03	3.0E-07	8.2E-01	6.6
15	Calcite B Effluent to VSEP B	142.7	2.5E-03	1.1E-01	5.1E-06	1.4E-02	1.2E+00	4.3E-04	7.1E+01	1.5E-07	3.4E-02	4.8E-03	1.8E+00	1.5E-03	3.1E-01	1.1E-01	7.5E+02	3.1E-06	6.1E-05	2.4E-02	4.0E-02	1.5E+03	4.4E-03	3.0E-07	8.2E-01	6.6
16	VSEP B Permeate to Final Effluent	224.6	9.9E-05	7.1E-04	3.2E-06	1.1E-02	1.0E-01	1.1E-05	7.0E+01	9.2E-09	3.6E-03	2.0E-04	1.1E+00	5.9E-05	4.6E-02	2.8E-02	3.3E+02	4.9E-07	1.4E-06	1.3E-03	2.4E-03	1.3E+02	2.3E-04	3.9E-08	5.2E-02	7.5
17	VSEP B Concentrate	56.1	1.2E-02	5.7E-01	1.3E-05	2.6E-02	5.5E+00	2.1E-03	7.9E+01	7.2E-07	1.5E-01	2.4E-02	4.6E+00	7.2E-03	1.4E+00	4.5E-01	2.4E+03	1.4E-05	3.0E-04	1.2E-01	1.9E-01	7.1E+03	2.1E-02	1.3E-06	3.9E+00	5.3
18	VSEP B Concentrate to HDS B	28.1	1.2E-02	5.7E-01	1.3E-05	2.6E-02	5.5E+00	2.1E-03	7.9E+01	7.2E-07	1.5E-01	2.4E-02	4.6E+00	7.2E-03	1.4E+00	4.5E-01	2.4E+03	1.4E-05	3.0E-04	1.2E-01	1.9E-01	7.1E+03	2.1E-02	1.3E-06	3.9E+00	5.3
19	VSEP B Concentrate to HDS A	28.1	1.2E-02	5.7E-01	1.3E-05	2.6E-02	5.5E+00	2.1E-03	7.9E+01	7.2E-07	1.5E-01	2.4E-02	4.6E+00	7.2E-03	1.4E+00	4.5E-01	2.4E+03	1.4E-05	3.0E-04	1.2E-01	1.9E-01	7.1E+03	2.1E-02	1.3E-06	3.9E+00	5.3
20	Low Conc EQ Effluent	1262.6	1.9E-04	1.7E-03	8.0E-02	4.0E-04	3.1E+02	7.8E-03	5.8E+01	3.2E-01	5.1E-03	2.3E+00	1.2E+00	1.9E-01	1.3E+02	4.6E-01	1.1E+02	4.0E+00	6.2E-03	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	7.3E-01	7.0
21	GSF Backwash	63.1	1.9E-04	1.7E-03	1.3E+00	4.0E-04	3.1E+02	1.5E-01	5.8E+01	6.3E+00	5.1E-03	4.5E+01	1.2E+00	3.8E+00	1.3E+02	8.9E+00	1.1E+02	7.4E+01	1.2E-01	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	1.4E+01	7.0
22	GSF Backwash Solids	31.6	1.9E-04	1.7E-03	2.2E+00	4.0E-04	3.1E+02	2.7E-01	5.8E+01	1.2E+01	5.1E-03	8.4E+01	1.2E+00	7.3E+00	1.3E+02	1.7E+01	1.1E+02	1.3E+02	2.2E-01	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	2.8E+01	7.0
23	GSF Backwash Decant	31.6	1.9E-04	1.7E-03	4.0E-01	4.0E-04	3.1E+02	2.2E-02	5.8E+01	4.1E-01	5.1E-03	4.8E+00	1.2E+00	2.3E-01	1.3E+02	8.9E-01	1.1E+02	1.3E+01	1.8E-02	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	1.0E+00	7.0
24	GSF Permeate/NF Feed	1199.4	1.9E-04	1.7E-03	2.4E-02	4.0E-04	3.1E+02	8.6E-04	5.8E+01	5.1E-03	5.1E-03	1.4E-01	1.2E+00	2.0E-03	1.3E+02	2.5E-02	1.1E+02	5.8E-01	6.8E-04	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	1.7E-02	7.0
25	NF Permeate	959.5	1.5E-04	1.2E-04	3.0E-04	2.9E-05	3.9E+01	6.1E-05	6.6E+01	1.8E-04	3.6E-04	1.1E-02	9.6E-01	0.0E+00	8.8E+00	6.8E-04	6.9E+01	2.1E-02	2.6E-05	2.9E-03	3.9E-04	2.6E+01	1.3E-05	7.1E-04	3.4E-04	6.0
26	NF Concentrate to VSEP A	239.9	3.6E-04	8.1E-03	1.2E-01	1.9E-03	1.4E+03	4.1E-03	2.8E+01	2.5E-02	2.4E-02	6.9E-01	2.2E+00	1.0E-02	6.2E+02	1.2E-01	2.5E+02	2.8E+00	3.3E-03	1.9E-01	4.8E-02	3.1E+03	8.6E-04	4.7E-02	8.5E-02	9.2
27	VSEP A Permeate to Final Effluent	191.9	1.4E-05	5.0E-05	7.4E-02	1.5E-03	1.2E+02	1.1E-04	2.7E+01	1.5E-03	2.6E-03	2.9E-02	1.3E+00	4.0E-04	9.1E+01	3.1E-02	1.1E+02	4.4E-01	7.5E-05	1.0E-02	2.9E-03	2.6E+02	4.6E-05	6.3E-03	5.4E-03	5.5
28	VSEP A Concentrate	48.0	1.8E-03	4.2E-02	3.2E-01	3.6E-03	6.8E+03	2.1E-02	3.1E+01	1.2E-01	1.2E-01	3.4E+00	5.9E+00	5.1E-02	2.9E+03	5.1E-01	8.5E+02	1.3E+01	1.7E-02	9.5E-01	2.4E-01	1.5E+04	4.3E-03	2.2E-01	4.2E-01	10.7
29	VSEP A Concentrate to HDS B	24.0	1.8E-03	4.2E-02	3.2E-01	3.6E-03	6.8E+03	2.1E-02	3.1E+01	1.2E-01	1.2E-01	3.4E+00	5.9E+00	5.1E-02	2.9E+03	5.1E-01	8.5E+02	1.3E+01	1.7E-02	9.5E-01	2.4E-01	1.5E+04	4.3E-03	2.2E-01	4.2E-01	10.7
30	VSEP A Concentrate to HDS A	24.0	1.8E-03	4.2E-02	3.2E-01	3.6E-03	6.8E+03	2.1E-02	3.1E+01	1.2E-01	1.2E-01	3.4E+00	5.9E+00	5.1E-02	2.9E+03	5.1E-01	8.5E+02	1.3E+01	1.7E-02	9.5E-01	2.4E-01	1.5E+04	4.3E-03	2.2E-01	4.2E-01	10.7
31	HDS A Underflow Sludge	12.5	3.2E-01	8.0E-03	7.5E+00	2.0E-01	7.9E+04	1.3E+00	8.8E-01	8.8E+01	2.0E-01	2.2E+02	5.6E-02	5.2E+03	1.3E+04	2.1E+02	2.7E-03	5.1E+02	1.8E+00	0.0E+00	6.5E-01	8.9E+04	0.0E+00	1.4E+00	1.2E+02	10.7
32	Sulfate A Underflow Sludge	15.3	0.0E+00	1.8E+03	6.9E-11	1.3E-07	4.7E+04	1.4E-08	7.2E-01	5.5E-03	7.6E-07	1.1E-04	1.7E+02	0.0E+00	3.7E+03	2.0E-12	8.0E-09	1.7E-02	6.8E-10	7.0E+00	6.2E-01	2.3E+04	0.0E+00	0.0E+00	0.0E+00	12.5
33	Calcite A Underflow Sludge	7.9	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.6E+04	1.5E-08	1.1E-08	2.1E-13	0.0E+00	1.1E-04	5.0E-06	1.6E-08	0.0E+00	0.0E+00	0.0E+00	7.8E-12	0.0E+00	3.0E-06	3.0E-06	5.7E-03	0.0E+00	3.4E-12	7.3E-06	10.0
34	HDS B Underflow Sludge	12.5	3.2E-01	8.0E-03	7.5E+00	2.0E-01	7.9E+04	1.3E+00	8.8E-01	8.8E+01	2.0E-01	2.2E+02	5.6E-02	5.2E+03	1.3E+04	2.1E+02	2.7E-03	5.1E+02	1.8E+00	0.0E+00	6.5E-01	8.9E+04	0.0E+00	1.4E+00	1.2E+02	10.7
35	Sulfate B Underflow Sludge	15.3	0.0E+00	1.8E+03	6.9E-11	1.3E-07	4.7E+04	1.4E-08	7.2E-01	5.5E-03	7.6E-07	1.1E-04	1.7E+02	0.0E+00	3.7E+03	2.0E-12	8.0E-09	1.7E-02	6.8E-10	7.0E+00	6.2E-01	2.3E+04	0.0E+00	0.0E+00	0.0E+00	12.5
36	Calcite B Underflow Sludge	7.9	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.6E+04	1.5E-08	1.1E-08	2.1E-13	0.0E+00	1.1E-04	5.0E-06	1.6E-08	0.0E+00	0.0E+00	0.0E+00	7.8E-12	0.0E+00	3.0E-06	3.0E-06	5.7E-03	0.0E+00	3.4E-12	7.3E-06	10.0
37	Plant Site VSEP Concentrate	84.1	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
38	Plant Site Concentrate to HDS A	42.1	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
39	Plant Site Concentrate to HDS B	42.1	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
40	Final Effluent to CPS	1571.1	4.2E-04	1.4E-02	9.2E-03	3.6E-03	3.9E+01	1.1E-04	6.2E+01	3.0E-04	5.2E-03	1.1E-02	1.1E+00	2.4E-04	1.7E+01	2.2E-02	2.0E+02	6.7E-02	3.3E-05	6.1E-03	5.9E-03	2.5E+02	5.9E-04	1.2E-03	1.1E-01	5.9

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	237.9	NA	NA	NA	250.3	6.1	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	25.0	12.42	12.5	NA	NA	NA	NA	NA	NA	25	1.18	1.84	0.93	0.92
5	Sulfate A Influent	237.9	NA	NA	NA	264.3	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	41.7	26.43	15.3	NA	NA	NA	NA	NA	NA	10	1.05	1.06	0.37	0.70
6	Sulfate A Effluent	237.9	NA	NA	69.7	307.6	NA	NA	2.1	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	7.9	0.00	7.9	NA	NA	NA	NA	NA	NA	10	1.06	0.19	0.19	0.00
7	Calcite A Effluent	237.9	NA	NA	16.5	254.4	NA	NA	0.5	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	237.9	NA	NA	NA	250.3	6.1	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	25.0	12.42	12.5	NA	NA	NA	NA	NA	NA	25	1.18	1.84	0.93	0.92
11	Sulfate B Influent	237.9	NA	NA		264.3	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	41.7	26.43	15.3	NA	NA	NA	NA	NA	NA	10	1.05	1.06	0.37	0.70
12	Sulfate B Effluent	237.9	NA	NA	69.7	307.6	NA	NA	2.1	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	7.9	0.00	7.9	NA	NA	NA	NA	NA	NA	10	1.06	0.19	0.19	0.00
13	Calcite B Effluent	237.9	NA	NA	16.5	237.9	NA	NA	0.5	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1262.6	NA	NA	NA	NA	NA	NA	NA	25.0	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	239.9	NA	NA	110*	NA	NA	NA	3.3	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 4 P90 Winter Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	64.0	3.2E-02	2.1E+02	4.1E-01	3.8E-02	1.5E+03	8.7E-02	7.9E+01	7.2E+00	2.0E-02	1.1E+01	2.1E+00	5.1E+02	5.9E+02	1.8E+01	2.3E+02	3.1E+01	1.5E-01	6.7E-01	1.2E-01	8.4E+03	1.5E-03	6.1E-02	9.5E+00	5.0
2	High Conc EQ Effluent to HDS A	32.0	3.2E-02	2.1E+02	4.1E-01	3.8E-02	1.5E+03	8.7E-02	7.9E+01	7.2E+00	2.0E-02	1.1E+01	2.1E+00	5.1E+02	5.9E+02	1.8E+01	2.3E+02	3.1E+01	1.5E-01	6.7E-01	1.2E-01	8.4E+03	1.5E-03	6.1E-02	9.5E+00	5.0
3	High Conc EQ Effluent to HDS B	32.0	3.2E-02	2.1E+02	4.1E-01	3.8E-02	1.5E+03	8.7E-02	7.9E+01	7.2E+00	2.0E-02	1.1E+01	2.1E+00	5.1E+02	5.9E+02	1.8E+01	2.3E+02	3.1E+01	1.5E-01	6.7E-01	1.2E-01	8.4E+03	1.5E-03	6.1E-02	9.5E+00	5.0
4	Combined HDS A Influent	149.1	1.0E-02	4.6E+01	2.1E-01	1.3E-02	2.0E+03	3.2E-02	6.0E+01	2.0E+00	7.5E-02	5.7E+00	1.8E+01	1.1E+02	7.9E+02	4.9E+00	1.4E+03	1.3E+01	4.3E-02	2.3E-01	6.7E-02	5.3E+03	2.7E-02	5.5E-02	4.0E+00	6.3
5	Sulfate A Influent	149.1	2.3E-03	4.5E+01	1.1E-05	8.9E-03	1.0E+03	2.3E-04	5.9E+01	1.6E-04	6.3E-02	5.4E-03	1.8E+01	1.7E-03	1.5E+02	4.8E-02	1.4E+03	5.8E-04	4.0E-05	2.3E-01	4.6E-02	1.6E+03	2.6E-02	7.7E-07	9.6E-01	10.8
6	Sulfate A Effluent	149.1	2.3E-03	4.5E-02	1.1E-05	8.9E-03	1.9E+03	2.3E-04	5.9E+01	9.8E-08	6.3E-02	5.4E-03	1.5E+00	1.7E-03	4.2E-01	4.8E-02	1.4E+03	2.2E-06	4.0E-05	1.1E-02	2.3E-02	1.2E+03	2.6E-02	7.7E-07	9.6E-01	12.4
7	Calcite A Effluent	149.1	2.3E-03	4.6E-02	1.1E-05	9.0E-03	9.5E+02	2.3E-04	6.0E+01	9.9E-08	6.3E-02	5.5E-03	1.5E+00	1.7E-03	4.3E-01	4.9E-02	1.4E+03	2.2E-06	4.0E-05	1.1E-02	2.3E-02	1.2E+03	2.6E-02	7.8E-07	9.7E-01	11.0
8	Calcite A Effluent to Final Effluent	59.7	2.3E-03	4.6E-02	1.1E-05	9.0E-03	9.5E+02	2.3E-04	6.0E+01	9.9E-08	6.3E-02	5.4E-03	1.5E+00	1.7E-03	4.2E-01	4.9E-02	1.4E+03	2.2E-06	4.0E-05	1.1E-02	2.3E-02	1.2E+03	2.6E-02	7.8E-07	9.7E-01	7.5
9	Calcite A Effluent to VSEP B	89.5	2.3E-03	4.6E-02	1.1E-05	9.0E-03	9.5E+02	2.3E-04	6.0E+01	9.9E-08	6.3E-02	5.4E-03	1.5E+00	1.7E-03	4.2E-01	4.9E-02	1.4E+03	2.2E-06	4.0E-05	1.1E-02	2.3E-02	1.2E+03	2.6E-02	7.8E-07	9.7E-01	7.5
10	Combined HDS B Influent	149.1	1.0E-02	4.6E+01	2.1E-01	1.3E-02	2.0E+03	3.2E-02	6.0E+01	2.0E+00	7.5E-02	5.7E+00	1.8E+01	1.1E+02	7.9E+02	4.9E+00	1.4E+03	1.3E+01	4.3E-02	2.3E-01	6.7E-02	5.3E+03	2.7E-02	5.5E-02	4.0E+00	6.3
11	Sulfate B Influent	149.1	2.3E-03	4.5E+01	1.1E-05	8.9E-03	1.0E+03	2.3E-04	5.9E+01	1.6E-04	6.3E-02	5.4E-03	1.8E+01	1.7E-03	1.5E+02	4.8E-02	1.4E+03	5.8E-04	4.0E-05	2.3E-01	4.6E-02	1.6E+03	2.6E-02	7.7E-07	9.6E-01	10.8
12	Sulfate B Effluent	149.1	2.3E-03	4.5E-02	1.1E-05	8.9E-03	1.9E+03	2.3E-04	5.9E+01	9.8E-08	6.3E-02	5.4E-03	1.5E+00	1.7E-03	4.2E-01	4.8E-02	1.4E+03	2.2E-06	4.0E-05	1.1E-02	2.3E-02	1.2E+03	2.6E-02	7.7E-07	9.6E-01	12.4
13	Calcite B Effluent	149.1	2.3E-03	4.6E-02	1.1E-05	9.0E-03	9.5E+02	2.3E-04	6.0E+01	9.9E-08	6.3E-02	5.5E-03	1.5E+00	1.7E-03	4.3E-01	4.9E-02	1.4E+03	2.2E-06	4.0E-05	1.1E-02	2.3E-02	1.2E+03	2.6E-02	7.8E-07	9.7E-01	11.0
14	Calcite B Effluent to Final Effluent	59.7	2.3E-03	4.6E-02	1.1E-05	9.0E-03	9.5E+02	2.3E-04	6.0E+01	9.9E-08	6.3E-02	5.4E-03	1.5E+00	1.7E-03	4.2E-01	4.9E-02	1.4E+03	2.2E-06	4.0E-05	1.1E-02	2.3E-02	1.2E+03	2.6E-02	7.8E-07	9.7E-01	7.5
15	Calcite B Effluent to VSEP B	89.5	2.3E-03	4.6E-02	1.1E-05	9.0E-03	9.5E+02	2.3E-04	6.0E+01	9.9E-08	6.3E-02	5.4E-03	1.5E+00	1.7E-03	4.2E-01	4.9E-02	1.4E+03	2.2E-06	4.0E-05	1.1E-02	2.3E-02	1.2E+03	2.6E-02	7.8E-07	9.7E-01	7.5
16	VSEP B Permeate to Final Effluent	238.6	9.2E-05	2.9E-04	6.6E-06	7.2E-03	8.4E+01	6.1E-06	5.8E+01	6.0E-09	6.7E-03	2.3E-04	8.9E-01	6.9E-05	6.2E-02	1.2E-02	6.3E+02	3.4E-07	9.0E-07	6.1E-04	1.4E-03	1.1E+02	1.4E-03	1.0E-07	6.2E-02	9.3
17	VSEP B Concentrate	59.7	1.1E-02	2.3E-01	2.7E-05	1.6E-02	4.5E+03	1.2E-03	6.6E+01	4.8E-07	2.9E-01	2.7E-02	3.9E+00	8.5E-03	1.9E+00	2.0E-01	4.6E+03	9.8E-06	2.0E-04	5.5E-02	1.1E-01	5.8E+03	1.3E-01	3.5E-06	4.7E+00	5.3
18	VSEP B Concentrate to HDS B	29.8	1.1E-02	2.3E-01	2.7E-05	1.6E-02	4.5E+03	1.2E-03	6.6E+01	4.8E-07	2.9E-01	2.7E-02	3.9E+00	8.5E-03	1.9E+00	2.0E-01	4.6E+03	9.8E-06	2.0E-04	5.5E-02	1.1E-01	5.8E+03	1.3E-01	3.5E-06	4.7E+00	5.3
19	VSEP B Concentrate to HDS A	29.8	1.1E-02	2.3E-01	2.7E-05	1.6E-02	4.5E+03	1.2E-03	6.6E+01	4.8E-07	2.9E-01	2.7E-02	3.9E+00	8.5E-03	1.9E+00	2.0E-01	4.6E+03	9.8E-06	2.0E-04	5.5E-02	1.1E-01	5.8E+03	1.3E-01	3.5E-06	4.7E+00	5.3
20	Low Conc EQ Effluent	435.9	1.9E-04	1.7E-03	8.0E-02	4.0E-04	3.1E+02	7.8E-03	5.8E+01	3.2E-01	5.1E-03	2.3E+00	1.2E+00	1.9E-01	1.3E+02	4.6E-01	1.1E+02	4.0E+00	6.2E-03	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	7.3E-01	7.0
21	GSF Backwash	21.8	1.9E-04	1.7E-03	1.3E+00	4.0E-04	3.1E+02	1.5E-01	5.8E+01	6.3E+00	5.1E-03	4.5E+01	1.2E+00	3.8E+00	1.3E+02	8.9E+00	1.1E+02	7.4E+01	1.2E-01	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	1.4E+01	7.0
22	GSF Backwash Solids	10.9	1.9E-04	1.7E-03	2.2E+00	4.0E-04	3.1E+02	2.7E-01	5.8E+01	1.2E+01	5.1E-03	8.4E+01	1.2E+00	7.3E+00	1.3E+02	1.7E+01	1.1E+02	1.3E+02	2.2E-01	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	2.8E+01	7.0
23	GSF Backwash Decant	10.9	1.9E-04	1.7E-03	4.0E-01	4.0E-04	3.1E+02	2.2E-02	5.8E+01	4.1E-01	5.1E-03	4.8E+00	1.2E+00	2.3E-01	1.3E+02	8.9E-01	1.1E+02	1.3E+01	1.8E-02	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	1.0E+00	7.0
24	GSF Permeate/NF Feed	414.1	1.9E-04	1.7E-03	2.4E-02	4.0E-04	3.1E+02	8.6E-04	5.8E+01	5.1E-03	5.1E-03	1.4E-01	1.2E+00	2.0E-03	1.3E+02	2.5E-02	1.1E+02	5.8E-01	6.8E-04	4.0E-02	9.8E-03	6.3E+02	1.8E-04	9.9E-03	1.7E-02	7.0
25	NF Permeate	331.3	1.5E-04	1.2E-04	3.0E-04	2.9E-05	3.9E+01	6.1E-05	6.6E+01	1.8E-04	3.6E-04	1.1E-02	9.6E-01	0.0E+00	8.8E+00	6.8E-04	6.9E+01	2.1E-02	2.6E-05	2.9E-03	3.9E-04	2.6E+01	1.3E-05	7.1E-04	3.4E-04	6.0
26	NF Concentrate to VSEP A	82.8	3.6E-04	8.1E-03	1.2E-01	1.9E-03	1.4E+03	4.1E-03	2.8E+01	2.5E-02	2.4E-02	6.9E-01	2.2E+00	1.0E-02	6.2E+02	1.2E-01	2.5E+02	2.8E+00	3.3E-03	1.9E-01	4.8E-02	3.1E+03	8.6E-04	4.7E-02	8.5E-02	9.2
27	VSEP A Permeate to Final Effluent	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	VSEP A Concentrate	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29	VSEP A Concentrate to HDS B	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30	VSEP A Concentrate to HDS A	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	7.9	1.4E-01	6.2E-04	3.8E+00	8.1E-02	8.4E+04	5.9E-01	7.3E-01	3.8E+01	2.2E-01	1.1E+02	8.0E-02	2.1E+03	1.2E+04	9.1E+01	0.0E+00	2.4E+02	7.9E-01	0.0E+00	3.8E-01	6.8E+04	0.0E+00	1.0E+00	5.7E+01	10.8
32	Sulfate A Underflow Sludge	8.8	0.0E+00	7.7E+02	0.0E+00	0.0E+00	6.0E+04	0.0E+00	6.5E-01	2.7E-03	1.5E-06	1.3E-04	2.8E+02	0.0E+00	2.6E+03	2.2E-07	0.0E+00	9.7E-03	0.0E+00	3.6E+00	3.9E-01	7.1E+03	0.0E+00	1.4E-11	2.3E-05	12.4
33	Calcite A Underflow Sludge	3.7	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+04	0.0E+00	1.1E-08	0.0E+00	1.2E-07	1.7E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.6E-11	0.0E+00	0.0E+00	2.0E-06	1.0E-01	0.0E+00	0.0E+00	0.0E+00	11.0
34	HDS B Underflow Sludge	7.9	1.4E-01	6.2E-04	3.8E+00	8.1E-02	8.4E+04	5.9E-01	7.3E-01	3.8E+01	2.2E-01	1.1E+02	8.0E-02	2.1E+03	1.2E+04	9.1E+01	0.0E+00	2.4E+02	7.9E-01	0.0E+00	3.8E-01	6.8E+04	0.0E+00	1.0E+00	5.7E+01	10.8
35	Sulfate B Underflow Sludge	8.8	0.0E+00	7.7E+02	0.0E+00	0.0E+00	6.0E+04	0.0E+00	6.5E-01	2.7E-03	1.5E-06	1.3E-04	2.8E+02	0.0E+00	2.6E+03	2.2E-07	0.0E+00	9.7E-03	0.0E+00	3.6E+00	3.9E-01	7.1E+03	0.0E+00	1.4E-11	2.3E-05	12.4
36	Calcite B Underflow Sludge	3.7	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.8E+04	0.0E+00	1.1E-08	0.0E+00	1.2E-07	1.7E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.6E-11	0.0E+00	0.0E+00	2.0E-06	1.0E-01	0.0E+00	0.0E+00	0.0E+00	11.0
37	Plant Site VSEP Concentrate	80.9	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
38	Plant Site Concentrate to HDS A	40.5	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
39	Plant Site Concentrate to HDS B	40.5	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
40	Final Effluent to CPS	569.9	1.3E-04	1.9E-04	1.8E-04	3.0E-03	5.8E+01	3.8E-05	6.2E+01	1.1E-04	3.0E-03	7.0E-03	9.3E-01	2.9E-05	5.1E+00	5.6E-03	3.0E+02	1.2E-02	1.6E-05	1.9E-03	8.2E-04	5.9E+01	5.9E-04	4.1E-04	2.6E-02	6.6

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	149.1	NA	NA	NA	188.7	4.4	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	47.5	39.59	7.9	NA	NA	NA	NA	NA	NA	25	1.18	3.50	0.58	2.92
5	Sulfate A Influent	149.1	NA	NA	NA	165.7	3.9	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	25.4	16.57	8.8	NA	NA	NA	NA	NA	NA	10	1.05	0.65	0.21	0.44
6	Sulfate A Effluent	149.1	NA	NA	77.9	227.0	NA	NA	0.9	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	3.7	0.00	3.7	NA	NA	NA	NA	NA	NA	10	1.06	0.09	0.09	0.00
7	Calcite A Effluent	149.1	NA	NA	36.7	185.8	NA	NA	0.4	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	149.1	NA	NA	NA	188.7	4.4	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	47.5	39.59	7.9	NA	NA	NA	NA	NA	NA	25	1.18	3.50	0.58	2.92
11	Sulfate B Influent	149.1	NA	NA		165.7	3.9	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	25.4	16.57	8.8	NA	NA	NA	NA	NA	NA	10	1.05	0.65	0.21	0.44
12	Sulfate B Effluent	149.1	NA	NA	77.9	227.0	NA	NA	0.9	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	3.7	0.00	3.7	NA	NA	NA	NA	NA	NA	10	1.06	0.09	0.09	0.00
13	Calcite B Effluent	149.1	NA	NA	36.7	149.1	NA	NA	0.4	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	435.9	NA	NA	NA	NA	NA	NA	NA	8.6	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	82.8	NA	NA	0*	NA	NA	NA	0.0	NA	NA	NA	NA	NA	NA

Mine Water Treatment Trains Flow and Load Detail
Year 5 P90 Annual Average Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	168.0	3.4E-02	2.1E+02	4.1E-01	3.8E-02	3.8E+02	8.9E-02	5.1E+01	7.4E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	3.6E+02	1.0E+01	2.4E+02	3.5E+01	1.5E-01	4.2E-01	7.8E-02	5.0E+03	1.8E-03	6.0E-02	9.5E+00	5.0
2	High Conc EQ Effluent to HDS A	84.0	3.4E-02	2.1E+02	4.1E-01	3.8E-02	3.8E+02	8.9E-02	5.1E+01	7.4E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	3.6E+02	1.0E+01	2.4E+02	3.5E+01	1.5E-01	4.2E-01	7.8E-02	5.0E+03	1.8E-03	6.0E-02	9.5E+00	5.0
3	High Conc EQ Effluent to HDS B	84.0	3.4E-02	2.1E+02	4.1E-01	3.8E-02	3.8E+02	8.9E-02	5.1E+01	7.4E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	3.6E+02	1.0E+01	2.4E+02	3.5E+01	1.5E-01	4.2E-01	7.8E-02	5.0E+03	1.8E-03	6.0E-02	9.5E+00	5.0
4	Combined HDS A Influent	201.2	1.9E-02	9.1E+01	3.6E-01	2.1E-02	1.1E+03	5.4E-02	5.6E+01	3.8E+00	8.0E-02	8.5E+00	1.5E+01	2.3E+02	8.2E+02	5.9E+00	1.3E+03	2.4E+01	8.4E-02	3.0E-01	9.7E-02	5.9E+03	1.4E-02	7.0E-02	5.8E+00	6.6
5	Sulfate A Influent	201.2	4.0E-03	8.9E+01	5.5E-06	8.6E-03	4.8E+02	2.7E-03	5.5E+01	2.6E-03	6.0E-02	3.8E-03	1.5E+01	9.1E-04	7.3E+02	5.8E-02	1.3E+03	7.5E-03	1.1E-04	3.0E-01	6.6E-02	5.4E+03	1.4E-02	3.5E-07	5.9E-01	10.5
6	Sulfate A Effluent	201.2	4.0E-03	8.9E-02	5.5E-06	8.6E-03	1.1E+03	2.7E-03	5.5E+01	3.9E-07	6.0E-02	3.8E-03	1.9E+00	9.1E-04	2.9E-01	5.8E-02	1.3E+03	7.7E-06	1.1E-04	1.5E-02	3.3E-02	1.7E+03	1.4E-02	3.5E-07	5.9E-01	12.5
7	Calcite A Effluent	201.2	4.0E-03	9.0E-02	5.5E-06	8.7E-03	7.5E-01	2.7E-03	5.6E+01	3.9E-07	6.1E-02	3.9E-03	1.9E+00	9.2E-04	2.9E-01	5.8E-02	1.3E+03	7.8E-06	1.1E-04	1.5E-02	3.4E-02	1.7E+03	1.4E-02	3.5E-07	6.0E-01	10.4
8	Calcite A Effluent to Final Effluent	80.5	4.0E-03	9.0E-02	5.5E-06	8.7E-03	7.5E-01	2.7E-03	5.5E+01	3.9E-07	6.1E-02	3.8E-03	1.9E+00	9.1E-04	2.9E-01	5.8E-02	1.3E+03	7.7E-06	1.1E-04	1.5E-02	3.3E-02	1.7E+03	1.4E-02	3.5E-07	6.0E-01	7.0
9	Calcite A Effluent to VSEP B	120.7	4.0E-03	9.0E-02	5.5E-06	8.7E-03	7.5E-01	2.7E-03	5.5E+01	3.9E-07	6.1E-02	3.8E-03	1.9E+00	9.1E-04	2.9E-01	5.8E-02	1.3E+03	7.7E-06	1.1E-04	1.5E-02	3.3E-02	1.7E+03	1.4E-02	3.5E-07	6.0E-01	7.0
10	Combined HDS B Influent	201.2	1.9E-02	9.1E+01	3.6E-01	2.1E-02	1.1E+03	5.4E-02	5.6E+01	3.8E+00	8.0E-02	8.5E+00	1.5E+01	2.3E+02	8.2E+02	5.9E+00	1.3E+03	2.4E+01	8.4E-02	3.0E-01	9.7E-02	5.9E+03	1.4E-02	7.0E-02	5.8E+00	6.6
11	Sulfate B Influent	201.2	4.0E-03	8.9E+01	5.5E-06	8.6E-03	4.8E+02	2.7E-03	5.5E+01	2.6E-03	6.0E-02	3.8E-03	1.5E+01	9.1E-04	7.3E+02	5.8E-02	1.3E+03	7.5E-03	1.1E-04	3.0E-01	6.6E-02	5.4E+03	1.4E-02	3.5E-07	5.9E-01	10.5
12	Sulfate B Effluent	201.2	4.0E-03	8.9E-02	5.5E-06	8.6E-03	1.1E+03	2.7E-03	5.5E+01	3.9E-07	6.0E-02	3.8E-03	1.9E+00	9.1E-04	2.9E-01	5.8E-02	1.3E+03	7.7E-06	1.1E-04	1.5E-02	3.3E-02	1.7E+03	1.4E-02	3.5E-07	5.9E-01	12.5
13	Calcite B Effluent	201.2	4.0E-03	9.0E-02	5.5E-06	8.7E-03	7.5E-01	2.7E-03	5.6E+01	3.9E-07	6.1E-02	3.9E-03	1.9E+00	9.2E-04	2.9E-01	5.8E-02	1.3E+03	7.8E-06	1.1E-04	1.5E-02	3.4E-02	1.7E+03	1.4E-02	3.5E-07	6.0E-01	10.4
14	Calcite B Effluent to Final Effluent	80.5	4.0E-03	9.0E-02	5.5E-06	8.7E-03	7.5E-01	2.7E-03	5.5E+01	3.9E-07	6.1E-02	3.8E-03	1.9E+00	9.1E-04	2.9E-01	5.8E-02	1.3E+03	7.7E-06	1.1E-04	1.5E-02	3.3E-02	1.7E+03	1.4E-02	3.5E-07	6.0E-01	7.0
15	Calcite B Effluent to VSEP B	120.7	4.0E-03	9.0E-02	5.5E-06	8.7E-03	7.5E-01	2.7E-03	5.5E+01	3.9E-07	6.1E-02	3.8E-03	1.9E+00	9.1E-04	2.9E-01	5.8E-02	1.3E+03	7.7E-06	1.1E-04	1.5E-02	3.3E-02	1.7E+03	1.4E-02	3.5E-07	6.0E-01	7.0
16	VSEP B Permeate to Final Effluent	318.7	1.6E-04	5.6E-04	3.4E-06	6.9E-03	6.6E-02	7.0E-05	5.4E+01	2.4E-08	6.4E-03	1.6E-04	1.1E+00	3.6E-05	4.3E-02	1.5E-02	5.8E+02	1.2E-06	2.4E-06	8.1E-04	2.0E-03	1.5E+02	7.5E-04	4.6E-08	3.8E-02	9.0
17	VSEP B Concentrate	79.7	2.0E-02	4.5E-01	1.4E-05	1.6E-02	3.5E+00	1.3E-02	6.1E+01	1.9E-06	2.8E-01	1.9E-02	5.0E+00	4.5E-03	1.3E+00	2.3E-01	4.3E+03	3.4E-05	5.4E-04	7.3E-02	1.6E-01	8.2E+03	6.8E-02	1.6E-06	2.9E+00	5.4
18	VSEP B Concentrate to HDS B	39.8	2.0E-02	4.5E-01	1.4E-05	1.6E-02	3.5E+00	1.3E-02	6.1E+01	1.9E-06	2.8E-01	1.9E-02	5.0E+00	4.5E-03	1.3E+00	2.3E-01	4.3E+03	3.4E-05	5.4E-04	7.3E-02	1.6E-01	8.2E+03	6.8E-02	1.6E-06	2.9E+00	5.4
19	VSEP B Concentrate to HDS A	39.8	2.0E-02	4.5E-01	1.4E-05	1.6E-02	3.5E+00	1.3E-02	6.1E+01	1.9E-06	2.8E-01	1.9E-02	5.0E+00	4.5E-03	1.3E+00	2.3E-01	4.3E+03	3.4E-05	5.4E-04	7.3E-02	1.6E-01	8.2E+03	6.8E-02	1.6E-06	2.9E+00	5.4
20	Low Conc EQ Effluent	1117.9	1.9E-04	1.7E-03	7.8E-02	4.0E-04	3.0E+02	4.7E-03	5.6E+01	2.7E-01	5.0E-03	1.4E+00	1.1E+00	1.8E-01	1.3E+02	4.3E-01	1.1E+02	3.6E+00	7.0E-03	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	4.6E-01	7.0
21	GSF Backwash	55.9	1.9E-04	1.7E-03	1.3E+00	4.0E-04	3.0E+02	8.8E-02	5.6E+01	5.4E+00	5.0E-03	2.7E+01	1.1E+00	3.6E+00	1.3E+02	8.4E+00	1.1E+02	6.6E+01	1.3E-01	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	9.1E+00	7.0
22	GSF Backwash Solids	27.9	1.9E-04	1.7E-03	2.1E+00	4.0E-04	3.0E+02	1.6E-01	5.6E+01	1.0E+01	5.0E-03	5.2E+01	1.1E+00	6.9E+00	1.3E+02	1.6E+01	1.1E+02	1.2E+02	2.4E-01	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	1.8E+01	7.0
23	GSF Backwash Decant	27.9	1.9E-04	1.7E-03	3.9E-01	4.0E-04	3.0E+02	1.3E-02	5.6E+01	3.5E-01	5.0E-03	2.9E+00	1.1E+00	2.1E-01	1.3E+02	8.4E-01	1.1E+02	1.2E+01	2.0E-02	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	6.5E-01	7.0
24	GSF Permeate/NF Feed	1062.1	1.9E-04	1.7E-03	2.4E-02	4.0E-04	3.0E+02	5.2E-04	5.6E+01	4.3E-03	5.0E-03	8.9E-02	1.1E+00	1.9E-03	1.3E+02	2.3E-02	1.1E+02	5.2E-01	7.7E-04	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	1.1E-02	7.0
25	NF Permeate	849.6	1.5E-04	1.2E-04	2.9E-04	2.9E-05	3.8E+01	3.7E-05	6.3E+01	1.6E-04	3.6E-04	6.9E-03	8.8E-01	6.3E-20	8.7E+00	6.4E-04	7.0E+01	1.9E-02	3.0E-05	2.7E-03	4.4E-04	1.7E+01	1.4E-05	7.1E-04	2.2E-04	6.0
26	NF Concentrate to VSEP A	212.4	3.6E-04	8.1E-03	1.2E-01	1.9E-03	1.4E+03	2.5E-03	2.7E+01	2.1E-02	2.4E-02	4.2E-01	2.0E+00	9.7E-03	6.1E+02	1.1E-01	2.6E+02	2.6E+00	3.8E-03	1.8E-01	5.4E-02	2.0E+03	9.1E-04	4.7E-02	5.4E-02	9.2
27	VSEP A Permeate to Final Effluent	169.9	1.4E-05	5.1E-05	7.2E-02	1.5E-03	1.2E+02	6.5E-05	2.6E+01	1.3E-03	2.5E-03	1.8E-02	1.2E+00	3.8E-04	9.0E+01	2.9E-02	1.1E+02	4.0E-01	8.5E-05	9.7E-03	3.3E-03	1.7E+02	4.9E-05	6.3E-03	3.4E-03	5.5
28	VSEP A Concentrate	42.5	1.8E-03	4.2E-02	3.1E-01	3.6E-03	6.6E+03	1.3E-02	3.0E+01	1.0E-01	1.1E-01	2.1E+00	5.4E+00	4.9E-02	2.8E+03	4.8E-01	8.6E+02	1.2E+01	1.9E-02	9.1E-01	2.7E-01	9.7E+03	4.5E-03	2.2E-01	2.7E-01	11.5
29	VSEP A Concentrate to HDS B	21.2	1.8E-03	4.2E-02	3.1E-01	3.6E-03	6.6E+03	1.3E-02	3.0E+01	1.0E-01	1.1E-01	2.1E+00	5.4E+00	4.9E-02	2.8E+03	4.8E-01	8.6E+02	1.2E+01	1.9E-02	9.1E-01	2.7E-01	9.7E+03	4.5E-03	2.2E-01	2.7E-01	11.5
30	VSEP A Concentrate to HDS A	21.2	1.8E-03	4.2E-02	3.1E-01	3.6E-03	6.6E+03	1.3E-02	3.0E+01	1.0E-01	1.1E-01	2.1E+00	5.4E+00	4.9E-02	2.8E+03	4.8E-01	8.6E+02	1.2E+01	1.9E-02	9.1E-01	2.7E-01	9.7E+03	4.5E-03	2.2E-01	2.7E-01	11.5
31	HDS A Underflow Sludge	6.1	4.9E-01	0.0E+00	1.2E+01	3.8E-01	9.6E+04	1.7E+00	1.2E+00	1.2E+02	5.8E-01	2.8E+02	1.1E-01	7.4E+03	2.6E+03	1.9E+02	0.0E+00	7.9E+02	2.7E+00	0.0E+00	9.4E-01	1.4E+04	0.0E+00	2.3E+00	1.7E+02	10.5
32	Sulfate A Underflow Sludge	18.7	0.0E+00	9.6E+02	0.0E+00	0.0E+00	2.5E+04	0.0E+00	3.9E-01	2.9E-02	0.0E+00	5.9E-05	1.4E+02	0.0E+00	7.9E+03	0.0E+00	0.0E+00	8.1E-02	0.0E+00	3.1E+00	3.6E-01	4.0E+04	0.0E+00	0.0E+00	0.0E+00	12.5
33	Calcite A Underflow Sludge	10.7	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E+04	0.0E+00	7.9E-05	0.0E+00	0.0E+00	5.5E-05	0.0E+00	1.8E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.3E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.4
34	HDS B Underflow Sludge	6.1	4.9E-01	0.0E+00	1.2E+01	3.8E-01	9.6E+04	1.7E+00	1.2E+00	1.2E+02	5.8E-01	2.8E+02	1.1E-01	7.4E+03	2.6E+03	1.9E+02	0.0E+00	7.9E+02	2.7E+00	0.0E+00	9.4E-01	1.4E+04	0.0E+00	2.3E+00	1.7E+02	10.5
35	Sulfate B Underflow Sludge	18.7	0.0E+00	9.6E+02	0.0E+00	0.0E+00	2.5E+04	0.0E+00	3.9E-01	2.9E-02	0.0E+00	5.9E-05	1.4E+02	0.0E+00	7.9E+03	0.0E+00	0.0E+00	8.1E-02	0.0E+00	3.1E+00	3.6E-01	4.0E+04	0.0E+00	0.0E+00	0.0E+00	12.5
36	Calcite B Underflow Sludge	10.7	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.1E+04	0.0E+00	7.9E-05	0.0E+00	0.0E+00	5.5E-05	0.0E+00	1.8E-08	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.3E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.4
37	Plant Site VSEP Concentrate	84.3	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
38	Plant Site Concentrate to HDS A	42.2	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
39	Plant Site Concentrate to HDS B	42.2	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
40	Final Effluent to CPS	1342.3	1.5E-04	4.8E-04	9.3E-03	1.9E-03	3.9E+01	5.6E-05	5.7E+01	2.6E-04	2.2E-03	7.0E-03	9.9E-01	6.0E-05	1.7E+01	7.7E-03	2.0E+02	6.2E-02	3.1E-05	3.2E-03	1.3E-03	7.3E+01	2.3E-04	1.2E-03	1.1E-02	6.0

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	201.2	NA	NA	NA	209.7	3.9	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	14.6	8.47	6.1	NA	NA	NA	NA	NA	NA	25	1.19	1.09	0.46	0.63
5	Sulfate A Influent	201.2	NA	NA	NA	223.6	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	41.0	22.36	18.7	NA	NA	NA	NA	NA	NA	10	1.05	1.04	0.45	0.59
6	Sulfate A Effluent	201.2	NA	NA	146.7	347.9	NA	NA	1.8	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	10.7	0.00	10.7	NA	NA	NA	NA	NA	NA	10	1.06	0.26	0.26	0.00
7	Calcite A Effluent	201.2	NA	NA	59.6	260.8	NA	NA	0.7	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	201.2	NA	NA	NA	209.7	3.9	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	14.6	8.47	6.1	NA	NA	NA	NA	NA	NA	25	1.19	1.09	0.46	0.63
11	Sulfate B Influent	201.2	NA	NA		223.6	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	41.0	22.36	18.7	NA	NA	NA	NA	NA	NA	10	1.05	1.04	0.45	0.59
12	Sulfate B Effluent	201.2	NA	NA	146.7	347.9	NA	NA	1.8	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	10.7	0.00	10.7	NA	NA	NA	NA	NA	NA	10	1.06	0.26	0.26	0.00
13	Calcite B Effluent	201.2	NA	NA	59.6	201.2	NA	NA	0.7	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1117.9	NA	NA	NA	NA	NA	NA	NA	22.1	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	212.4	NA	NA	275*	NA	NA	NA	3.3	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 5 P90 Peak Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	287.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0
2	High Conc EQ Effluent to HDS A	143.5	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0
3	High Conc EQ Effluent to HDS B	143.5	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0
4	Combined HDS A Influent	268.1	2.1E-02	1.2E+02	4.0E-01	2.5E-02	1.1E+03	6.2E-02	5.4E+01	4.7E+00	4.8E-02	9.7E+00	1.2E+01	2.9E+02	7.7E+02	7.0E+00	7.9E+02	2.8E+01	1.0E-01	3.4E-01	1.3E-01	5.6E+03	5.7E-03	7.2E-02	6.8E+00	6.6
5	Sulfate A Influent	268.1	2.6E-03	1.1E+02	3.3E-06	1.1E-02	5.0E+02	9.8E-04	5.3E+01	1.0E-03	3.3E-02	4.1E-03	1.2E+01	1.1E-03	5.2E+02	6.9E-02	7.7E+02	2.9E-03	5.1E-05	3.4E-01	9.2E-02	4.2E+03	5.6E-03	2.0E-07	6.4E-01	10.6
6	Sulfate A Effluent	268.1	2.6E-03	1.1E-01	3.3E-06	1.1E-02	1.2E+03	9.8E-04	5.3E+01	2.0E-07	3.3E-02	4.1E-03	1.8E+00	1.1E-03	3.0E-01	6.9E-02	7.7E+02	3.9E-06	5.1E-05	1.7E-02	4.6E-02	1.5E+03	5.6E-03	2.0E-07	6.4E-01	12.5
7	Calcite A Effluent	268.1	2.6E-03	1.2E-01	3.3E-06	1.1E-02	8.4E-01	9.9E-04	5.4E+01	2.1E-07	3.3E-02	4.1E-03	1.8E+00	1.1E-03	3.0E-01	7.0E-02	7.8E+02	4.0E-06	5.1E-05	1.7E-02	4.6E-02	1.6E+03	5.7E-03	2.0E-07	6.5E-01	10.1
8	Calcite A Effluent to Final Effluent	107.2	2.6E-03	1.1E-01	3.3E-06	1.1E-02	8.4E-01	9.9E-04	5.3E+01	2.1E-07	3.3E-02	4.1E-03	1.8E+00	1.1E-03	3.0E-01	6.9E-02	7.8E+02	3.9E-06	5.1E-05	1.7E-02	4.6E-02	1.5E+03	5.6E-03	2.0E-07	6.4E-01	6.7
9	Calcite A Effluent to VSEP B	160.8	2.6E-03	1.1E-01	3.3E-06	1.1E-02	8.4E-01	9.9E-04	5.3E+01	2.1E-07	3.3E-02	4.1E-03	1.8E+00	1.1E-03	3.0E-01	6.9E-02	7.8E+02	3.9E-06	5.1E-05	1.7E-02	4.6E-02	1.5E+03	5.6E-03	2.0E-07	6.4E-01	6.7
10	Combined HDS B Influent	268.1	2.1E-02	1.2E+02	4.0E-01	2.5E-02	1.1E+03	6.2E-02	5.4E+01	4.7E+00	4.8E-02	9.7E+00	1.2E+01	2.9E+02	7.7E+02	7.0E+00	7.9E+02	2.8E+01	1.0E-01	3.4E-01	1.3E-01	5.6E+03	5.7E-03	7.2E-02	6.8E+00	6.6
11	Sulfate B Influent	268.1	2.6E-03	1.1E+02	3.3E-06	1.1E-02	5.0E+02	9.8E-04	5.3E+01	1.0E-03	3.3E-02	4.1E-03	1.2E+01	1.1E-03	5.2E+02	6.9E-02	7.7E+02	2.9E-03	5.1E-05	3.4E-01	9.2E-02	4.2E+03	5.6E-03	2.0E-07	6.4E-01	10.6
12	Sulfate B Effluent	268.1	2.6E-03	1.1E-01	3.3E-06	1.1E-02	1.2E+03	9.8E-04	5.3E+01	2.0E-07	3.3E-02	4.1E-03	1.8E+00	1.1E-03	3.0E-01	6.9E-02	7.7E+02	3.9E-06	5.1E-05	1.7E-02	4.6E-02	1.5E+03	5.6E-03	2.0E-07	6.4E-01	12.5
13	Calcite B Effluent	268.1	2.6E-03	1.2E-01	3.3E-06	1.1E-02	8.4E-01	9.9E-04	5.4E+01	2.1E-07	3.3E-02	4.1E-03	1.8E+00	1.1E-03	3.0E-01	7.0E-02	7.8E+02	4.0E-06	5.1E-05	1.7E-02	4.6E-02	1.6E+03	5.7E-03	2.0E-07	6.5E-01	10.1
14	Calcite B Effluent to Final Effluent	107.2	2.6E-03	1.1E-01	3.3E-06	1.1E-02	8.4E-01	9.9E-04	5.3E+01	2.1E-07	3.3E-02	4.1E-03	1.8E+00	1.1E-03	3.0E-01	6.9E-02	7.8E+02	3.9E-06	5.1E-05	1.7E-02	4.6E-02	1.5E+03	5.6E-03	2.0E-07	6.4E-01	6.7
15	Calcite B Effluent to VSEP B	160.8	2.6E-03	1.1E-01	3.3E-06	1.1E-02	8.4E-01	9.9E-04	5.3E+01	2.1E-07	3.3E-02	4.1E-03	1.8E+00	1.1E-03	3.0E-01	6.9E-02	7.8E+02	3.9E-06	5.1E-05	1.7E-02	4.6E-02	1.5E+03	5.6E-03	2.0E-07	6.4E-01	6.7
16	VSEP B Permeate to Final Effluent	287.4	1.0E-04	7.2E-04	2.0E-06	9.0E-03	7.4E-02	2.6E-05	5.2E+01	1.3E-08	3.5E-03	1.7E-04	1.1E+00	4.2E-05	4.5E-02	1.8E-02	3.5E+02	6.1E-07	1.2E-06	9.1E-04	2.8E-03	1.3E+02	3.0E-04	2.7E-08	4.1E-02	8.3
17	VSEP B Concentrate	71.8	1.3E-02	5.8E-01	8.5E-06	2.0E-02	3.9E+00	4.9E-03	5.9E+01	9.8E-07	1.5E-01	2.0E-02	4.7E+00	5.2E-03	1.3E+00	2.8E-01	2.5E+03	1.7E-05	2.5E-04	8.2E-02	2.2E-01	7.3E+03	2.7E-02	9.0E-07	3.1E+00	5.4
18	VSEP B Concentrate to HDS B	35.9	1.3E-02	5.8E-01	8.5E-06	2.0E-02	3.9E+00	4.9E-03	5.9E+01	9.8E-07	1.5E-01	2.0E-02	4.7E+00	5.2E-03	1.3E+00	2.8E-01	2.5E+03	1.7E-05	2.5E-04	8.2E-02	2.2E-01	7.3E+03	2.7E-02	9.0E-07	3.1E+00	5.4
19	VSEP B Concentrate to HDS A	35.9	1.3E-02	5.8E-01	8.5E-06	2.0E-02	3.9E+00	4.9E-03	5.9E+01	9.8E-07	1.5E-01	2.0E-02	4.7E+00	5.2E-03	1.3E+00	2.8E-01	2.5E+03	1.7E-05	2.5E-04	8.2E-02	2.2E-01	7.3E+03	2.7E-02	9.0E-07	3.1E+00	5.4
20	Low Conc EQ Effluent	1452.3	1.9E-04	1.7E-03	7.8E-02	4.0E-04	3.0E+02	4.7E-03	5.6E+01	2.7E-01	5.0E-03	1.4E+00	1.1E+00	1.8E-01	1.3E+02	4.3E-01	1.1E+02	3.6E+00	7.0E-03	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	4.6E-01	7.0
21	GSF Backwash	72.6	1.9E-04	1.7E-03	1.3E+00	4.0E-04	3.0E+02	8.8E-02	5.6E+01	5.4E+00	5.0E-03	2.7E+01	1.1E+00	3.6E+00	1.3E+02	8.4E+00	1.1E+02	6.6E+01	1.3E-01	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	9.1E+00	7.0
22	GSF Backwash Solids	36.3	1.9E-04	1.7E-03	2.1E+00	4.0E-04	3.0E+02	1.6E-01	5.6E+01	1.0E+01	5.0E-03	5.2E+01	1.1E+00	6.9E+00	1.3E+02	1.6E+01	1.1E+02	1.2E+02	2.4E-01	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	1.8E+01	7.0
23	GSF Backwash Decant	36.3	1.9E-04	1.7E-03	3.9E-01	4.0E-04	3.0E+02	1.3E-02	5.6E+01	3.5E-01	5.0E-03	2.9E+00	1.1E+00	2.1E-01	1.3E+02	8.4E-01	1.1E+02	1.2E+01	2.0E-02	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	6.5E-01	7.0
24	GSF Permeate/NF Feed	1379.7	1.9E-04	1.7E-03	2.4E-02	4.0E-04	3.0E+02	5.2E-04	5.6E+01	4.3E-03	5.0E-03	8.9E-02	1.1E+00	1.9E-03	1.3E+02	2.3E-02	1.1E+02	5.2E-01	7.7E-04	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	1.1E-02	7.0
25	NF Permeate	1103.8	1.5E-04	1.2E-04	2.9E-04	2.9E-05	3.8E+01	3.7E-05	6.3E+01	1.6E-04	3.6E-04	6.9E-03	8.8E-01	0.0E+00	8.7E+00	6.4E-04	7.0E+01	1.9E-02	3.0E-05	2.7E-03	4.4E-04	1.7E+01	1.4E-05	7.1E-04	2.2E-04	6.0
26	NF Concentrate to VSEP A	275.9	3.6E-04	8.1E-03	1.2E-01	1.9E-03	1.4E+03	2.5E-03	2.7E+01	2.1E-02	2.4E-02	4.2E-01	2.0E+00	9.7E-03	6.1E+02	1.1E-01	2.6E+02	2.6E+00	3.8E-03	1.8E-01	5.4E-02	2.0E+03	9.1E-04	4.7E-02	5.4E-02	9.2
27	VSEP A Permeate to Final Effluent	220.8	1.4E-05	5.1E-05	7.2E-02	1.5E-03	1.2E+02	6.5E-05	2.6E+01	1.3E-03	2.5E-03	1.8E-02	1.2E+00	3.8E-04	9.0E+01	2.9E-02	1.1E+02	4.0E-01	8.5E-05	9.7E-03	3.3E-03	1.7E+02	4.9E-05	6.3E-03	3.4E-03	5.5
28	VSEP A Concentrate	55.2	1.8E-03	4.2E-02	3.1E-01	3.6E-03	6.6E+03	1.3E-02	3.0E+01	1.0E-01	1.1E-01	2.1E+00	5.4E+00	4.9E-02	2.8E+03	4.8E-01	8.6E+02	1.2E+01	1.9E-02	9.1E-01	2.7E-01	9.7E+03	4.5E-03	2.2E-01	2.7E-01	11.4
29	VSEP A Concentrate to HDS B	27.6	1.8E-03	4.2E-02	3.1E-01	3.6E-03	6.6E+03	1.3E-02	3.0E+01	1.0E-01	1.1E-01	2.1E+00	5.4E+00	4.9E-02	2.8E+03	4.8E-01	8.6E+02	1.2E+01	1.9E-02	9.1E-01	2.7E-01	9.7E+03	4.5E-03	2.2E-01	2.7E-01	11.4
30	VSEP A Concentrate to HDS A	27.6	1.8E-03	4.2E-02	3.1E-01	3.6E-03	6.6E+03	1.3E-02	3.0E+01	1.0E-01	1.1E-01	2.1E+00	5.4E+00	4.9E-02	2.8E+03	4.8E-01	8.6E+02	1.2E+01	1.9E-02	9.1E-01	2.7E-01	9.7E+03	4.5E-03	2.2E-01	2.7E-01	11.4
31	HDS A Underflow Sludge	8.6	5.6E-01	1.3E-03	1.2E+01	4.0E-01	8.7E+04	1.9E+00	1.1E+00	1.4E+02	4.5E-01	3.0E+02	8.5E-02	9.0E+03	7.3E+03	2.1E+02	0.0E+00	8.7E+02	3.1E+00	9.3E-06	1.2E+00	4.1E+04	0.0E+00	2.2E+00	1.9E+02	10.6
32	Sulfate A Underflow Sludge	19.6	0.0E+00	1.6E+03	6.4E-11	0.0E+00	3.0E+04	0.0E+00	4.7E-01	1.4E-02	0.0E+00	7.9E-05	1.4E+02	0.0E+00	7.1E+03	0.0E+00	0.0E+00	4.0E-02	0.0E+00	4.4E+00	6.3E-01	3.6E+04	0.0E+00	0.0E+00	7.2E-06	12.5
33	Calcite A Underflow Sludge	8.8	0.0E+00	5.0E-11	1.2E-10	0.0E+00	3.6E+04	4.8E-13	5.3E-11	0.0E+00	0.0E+00	9.4E-05	0.0E+00	0.0E+00	1.8E-05	0.0E+00	0.0E+00	1.4E-10	0.0E+00	7.7E-12	1.8E-11	0.0E+00	0.0E+00	0.0E+00	8.5E-06	10.1
34	HDS B Underflow Sludge	8.6	5.6E-01	1.3E-03	1.2E+01	4.0E-01	8.7E+04	1.9E+00	1.1E+00	1.4E+02	4.5E-01	3.0E+02	8.5E-02	9.0E+03	7.3E+03	2.1E+02	0.0E+00	8.7E+02	3.1E+00	9.3E-06	1.2E+00	4.1E+04	0.0E+00	2.2E+00	1.9E+02	10.6
35	Sulfate B Underflow Sludge	19.6	0.0E+00	1.6E+03	6.4E-11	0.0E+00	3.0E+04	0.0E+00	4.7E-01	1.4E-02	0.0E+00	7.9E-05	1.4E+02	0.0E+00	7.1E+03	0.0E+00	0.0E+00	4.0E-02	0.0E+00	4.4E+00	6.3E-01	3.6E+04	0.0E+00	0.0E+00	7.2E-06	12.5
36	Calcite B Underflow Sludge	8.8	0.0E+00	5.0E-11	1.2E-10	0.0E+00	3.6E+04	4.8E-13	5.3E-11	0.0E+00	0.0E+00	9.4E-05	0.0E+00	0.0E+00	1.8E-05	0.0E+00	0.0E+00	1.4E-10	0.0E+00	7.7E-12	1.8E-11	0.0E+00	0.0E+00	0.0E+00	8.5E-06	10.1
37	Plant Site VSEP Concentrate	85.8	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
38	Plant Site Concentrate to HDS A	42.9	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
39	Plant Site Concentrate to HDS B	42.9	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
40	Final Effluent to CPS	1788.8	3.7E-04	1.2E-02	9.1E-03	2.8E-03	3.8E+01	1.3E-04	5.6E+01	2.5E-04	4.4E-03	7.0E-03	1.0E+00	1.6E-04	1.6E+01	1.4E-02	1.9E+02	6.1E-02	3.4E-05	4.7E-03	5.7E-03	2.1E+02	6.2E-04	1.2E-03	7.1E-02	5.9

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	268.1	NA	NA	NA	275.2	5.0	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	15.7	7.13	8.6	NA	NA	NA	NA	NA	NA	25	1.19	1.17	0.64	0.53
5	Sulfate A Influent	268.1	NA	NA	NA	297.9	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	49.4	29.79	19.6	NA	NA	NA	NA	NA	NA	10	1.05	1.26	0.47	0.79
6	Sulfate A Effluent	268.1	NA	NA	197.1	465.2	NA	NA	2.4	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	8.8	0.00	8.8	NA	NA	NA	NA	NA	NA	10	1.06	0.21	0.21	0.00
7	Calcite A Effluent	268.1	NA	NA	55.0	323.1	NA	NA	0.7	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	268.1	NA	NA	NA	275.2	5.0	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	15.7	7.13	8.6	NA	NA	NA	NA	NA	NA	25	1.19	1.17	0.64	0.53
11	Sulfate B Influent	268.1	NA	NA		297.9	4.4	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	49.4	29.79	19.6	NA	NA	NA	NA	NA	NA	10	1.05	1.26	0.47	0.79
12	Sulfate B Effluent	268.1	NA	NA	197.1	465.2	NA	NA	2.4	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	8.8	0.00	8.8	NA	NA	NA	NA	NA	NA	10	1.06	0.21	0.21	0.00
13	Calcite B Effluent	268.1	NA	NA	55.0	268.1	NA	NA	0.7	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1452.3	NA	NA	NA	NA	NA	NA	NA	28.7	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	275.9	NA	NA	366.7*	NA	NA	NA	4.4	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 5 P90 Winter Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	66.0	3.4E-02	2.1E+02	4.1E-01	3.8E-02	3.8E+02	8.9E-02	5.1E+01	7.4E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	3.6E+02	1.0E+01	2.4E+02	3.5E+01	1.5E-01	4.2E-01	1.4E-01	5.0E+03	1.8E-03	6.0E-02	9.5E+00	5.0
2	High Conc EQ Effluent to HDS A	33.0	3.4E-02	2.1E+02	4.1E-01	3.8E-02	3.8E+02	8.9E-02	5.1E+01	7.4E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	3.6E+02	1.0E+01	2.4E+02	3.5E+01	1.5E-01	4.2E-01	1.4E-01	5.0E+03	1.8E-03	6.0E-02	9.5E+00	5.0
3	High Conc EQ Effluent to HDS B	33.0	3.4E-02	2.1E+02	4.1E-01	3.8E-02	3.8E+02	8.9E-02	5.1E+01	7.4E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	3.6E+02	1.0E+01	2.4E+02	3.5E+01	1.5E-01	4.2E-01	1.4E-01	5.0E+03	1.8E-03	6.0E-02	9.5E+00	5.0
4	Combined HDS A Influent	161.5	1.0E-02	4.4E+01	2.1E-01	1.3E-02	1.6E+03	2.8E-02	5.1E+01	1.9E+00	7.0E-02	4.5E+00	1.7E+01	1.1E+02	7.1E+02	3.1E+00	1.4E+03	1.3E+01	4.3E-02	1.7E-01	7.4E-02	4.3E+03	2.7E-02	5.3E-02	3.5E+00	6.4
5	Sulfate A Influent	161.5	2.4E-03	4.4E+01	7.8E-06	7.8E-03	8.2E+02	2.2E-04	5.0E+01	2.0E-04	5.7E-02	4.9E-03	1.7E+01	1.5E-03	2.1E+02	3.1E-02	1.4E+03	7.1E-04	3.5E-05	1.7E-01	5.1E-02	2.0E+03	2.6E-02	6.0E-07	8.3E-01	10.7
6	Sulfate A Effluent	161.5	2.4E-03	4.4E-02	7.8E-06	7.8E-03	1.7E+03	2.2E-04	5.0E+01	8.8E-08	5.7E-02	4.9E-03	1.5E+00	1.5E-03	3.9E-01	3.1E-02	1.4E+03	2.0E-06	3.5E-05	8.4E-03	2.6E-02	1.3E+03	2.6E-02	6.0E-07	8.3E-01	12.4
7	Calcite A Effluent	161.5	2.4E-03	4.4E-02	7.9E-06	7.8E-03	7.4E+02	2.2E-04	5.0E+01	8.9E-08	5.7E-02	4.9E-03	1.6E+00	1.5E-03	3.9E-01	3.1E-02	1.4E+03	2.0E-06	3.5E-05	8.5E-03	2.6E-02	1.3E+03	2.7E-02	6.1E-07	8.4E-01	11.0
8	Calcite A Effluent to Final Effluent	64.6	2.4E-03	4.4E-02	7.9E-06	7.8E-03	7.4E+02	2.2E-04	5.0E+01	8.9E-08	5.7E-02	4.9E-03	1.6E+00	1.5E-03	3.9E-01	3.1E-02	1.4E+03	2.0E-06	3.5E-05	8.5E-03	2.6E-02	1.3E+03	2.6E-02	6.1E-07	8.4E-01	6.5
9	Calcite A Effluent to VSEP B	96.9	2.4E-03	4.4E-02	7.9E-06	7.8E-03	7.4E+02	2.2E-04	5.0E+01	8.9E-08	5.7E-02	4.9E-03	1.6E+00	1.5E-03	3.9E-01	3.1E-02	1.4E+03	2.0E-06	3.5E-05	8.5E-03	2.6E-02	1.3E+03	2.6E-02	6.1E-07	8.4E-01	6.5
10	Combined HDS B Influent	161.5	1.0E-02	4.4E+01	2.1E-01	1.3E-02	1.6E+03	2.8E-02	5.1E+01	1.9E+00	7.0E-02	4.5E+00	1.7E+01	1.1E+02	7.1E+02	3.1E+00	1.4E+03	1.3E+01	4.3E-02	1.7E-01	7.4E-02	4.3E+03	2.7E-02	5.3E-02	3.5E+00	6.4
11	Sulfate B Influent	161.5	2.4E-03	4.4E+01	7.8E-06	7.8E-03	8.2E+02	2.2E-04	5.0E+01	2.0E-04	5.7E-02	4.9E-03	1.7E+01	1.5E-03	2.1E+02	3.1E-02	1.4E+03	7.1E-04	3.5E-05	1.7E-01	5.1E-02	2.0E+03	2.6E-02	6.0E-07	8.3E-01	10.7
12	Sulfate B Effluent	161.5	2.4E-03	4.4E-02	7.8E-06	7.8E-03	1.7E+03	2.2E-04	5.0E+01	8.8E-08	5.7E-02	4.9E-03	1.5E+00	1.5E-03	3.9E-01	3.1E-02	1.4E+03	2.0E-06	3.5E-05	8.4E-03	2.6E-02	1.3E+03	2.6E-02	6.0E-07	8.3E-01	12.4
13	Calcite B Effluent	161.5	2.4E-03	4.4E-02	7.9E-06	7.8E-03	7.4E+02	2.2E-04	5.0E+01	8.9E-08	5.7E-02	4.9E-03	1.6E+00	1.5E-03	3.9E-01	3.1E-02	1.4E+03	2.0E-06	3.5E-05	8.5E-03	2.6E-02	1.3E+03	2.7E-02	6.1E-07	8.4E-01	11.0
14	Calcite B Effluent to Final Effluent	64.6	2.4E-03	4.4E-02	7.9E-06	7.8E-03	7.4E+02	2.2E-04	5.0E+01	8.9E-08	5.7E-02	4.9E-03	1.6E+00	1.5E-03	3.9E-01	3.1E-02	1.4E+03	2.0E-06	3.5E-05	8.5E-03	2.6E-02	1.3E+03	2.6E-02	6.1E-07	8.4E-01	6.5
15	Calcite B Effluent to VSEP B	96.9	2.4E-03	4.4E-02	7.9E-06	7.8E-03	7.4E+02	2.2E-04	5.0E+01	8.9E-08	5.7E-02	4.9E-03	1.6E+00	1.5E-03	3.9E-01	3.1E-02	1.4E+03	2.0E-06	3.5E-05	8.5E-03	2.6E-02	1.3E+03	2.6E-02	6.1E-07	8.4E-01	6.5
16	VSEP B Permeate to Final Effluent	258.5	9.6E-05	2.7E-04	4.8E-06	6.2E-03	6.6E+01	5.9E-06	4.9E+01	5.4E-09	6.0E-03	2.1E-04	9.3E-01	5.9E-05	5.8E-02	7.9E-03	6.0E+02	3.1E-07	7.8E-07	4.5E-04	1.6E-03	1.1E+02	1.4E-03	8.1E-08	5.3E-02	7.3
17	VSEP B Concentrate	64.6	1.2E-02	2.2E-01	2.0E-05	1.4E-02	3.5E+03	1.1E-03	5.5E+01	4.3E-07	2.6E-01	2.4E-02	4.1E+00	7.3E-03	1.8E+00	1.3E-01	4.4E+03	8.9E-06	1.7E-04	4.1E-02	1.2E-01	6.1E+03	1.3E-01	2.7E-06	4.0E+00	5.2
18	VSEP B Concentrate to HDS B	32.3	1.2E-02	2.2E-01	2.0E-05	1.4E-02	3.5E+03	1.1E-03	5.5E+01	4.3E-07	2.6E-01	2.4E-02	4.1E+00	7.3E-03	1.8E+00	1.3E-01	4.4E+03	8.9E-06	1.7E-04	4.1E-02	1.2E-01	6.1E+03	1.3E-01	2.7E-06	4.0E+00	5.2
19	VSEP B Concentrate to HDS A	32.3	1.2E-02	2.2E-01	2.0E-05	1.4E-02	3.5E+03	1.1E-03	5.5E+01	4.3E-07	2.6E-01	2.4E-02	4.1E+00	7.3E-03	1.8E+00	1.3E-01	4.4E+03	8.9E-06	1.7E-04	4.1E-02	1.2E-01	6.1E+03	1.3E-01	2.7E-06	4.0E+00	5.2
20	Low Conc EQ Effluent	519.0	1.9E-04	1.7E-03	7.8E-02	4.0E-04	3.0E+02	4.7E-03	5.6E+01	2.7E-01	5.0E-03	1.4E+00	1.1E+00	1.8E-01	1.3E+02	4.3E-01	1.1E+02	3.6E+00	7.0E-03	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	4.6E-01	7.0
21	GSF Backwash	26.0	1.9E-04	1.7E-03	1.3E+00	4.0E-04	3.0E+02	8.8E-02	5.6E+01	5.4E+00	5.0E-03	2.7E+01	1.1E+00	3.6E+00	1.3E+02	8.4E+00	1.1E+02	6.6E+01	1.3E-01	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	9.1E+00	7.0
22	GSF Backwash Solids	13.0	1.9E-04	1.7E-03	2.1E+00	4.0E-04	3.0E+02	1.6E-01	5.6E+01	1.0E+01	5.0E-03	5.2E+01	1.1E+00	6.9E+00	1.3E+02	1.6E+01	1.1E+02	1.2E+02	2.4E-01	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	1.8E+01	7.0
23	GSF Backwash Decant	13.0	1.9E-04	1.7E-03	3.9E-01	4.0E-04	3.0E+02	1.3E-02	5.6E+01	3.5E-01	5.0E-03	2.9E+00	1.1E+00	2.1E-01	1.3E+02	8.4E-01	1.1E+02	1.2E+01	2.0E-02	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	6.5E-01	7.0
24	GSF Permeate/NF Feed	493.0	1.9E-04	1.7E-03	2.4E-02	4.0E-04	3.0E+02	5.2E-04	5.6E+01	4.3E-03	5.0E-03	8.9E-02	1.1E+00	1.9E-03	1.3E+02	2.3E-02	1.1E+02	5.2E-01	7.7E-04	3.8E-02	1.1E-02	4.1E+02	1.9E-04	9.9E-03	1.1E-02	7.0
25	NF Permeate	394.4	1.5E-04	1.2E-04	2.9E-04	2.9E-05	3.8E+01	3.7E-05	6.3E+01	1.6E-04	3.6E-04	6.9E-03	8.8E-01	0.0E+00	8.7E+00	6.4E-04	7.0E+01	1.9E-02	3.0E-05	2.7E-03	4.4E-04	1.7E+01	1.4E-05	7.1E-04	2.2E-04	6.0
26	NF Concentrate to VSEP A	98.6	3.6E-04	8.1E-03	1.2E-01	1.9E-03	1.4E+03	2.5E-03	2.7E+01	2.1E-02	2.4E-02	4.2E-01	2.0E+00	9.7E-03	6.1E+02	1.1E-01	2.6E+02	2.6E+00	3.8E-03	1.8E-01	5.4E-02	2.0E+03	9.1E-04	4.7E-02	5.4E-02	9.2
27	VSEP A Permeate to Final Effluent	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	VSEP A Concentrate	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29	VSEP A Concentrate to HDS B	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30	VSEP A Concentrate to HDS A	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	7.3	1.7E-01	0.0E+00	4.6E+00	1.0E-01	8.7E+04	5.9E-01	7.2E-01	4.2E+01	2.7E-01	9.9E+01	8.7E-02	2.4E+03	1.1E+04	6.8E+01	0.0E+00	2.8E+02	9.4E-01	0.0E+00	4.8E-01	4.8E+04	0.0E+00	1.2E+00	5.8E+01	10.7
32	Sulfate A Underflow Sludge	9.7	0.0E+00	7.3E+02	0.0E+00	0.0E+00	5.4E+04	0.0E+00	5.4E-01	3.3E-03	0.0E+00	1.2E-04	2.5E+02	0.0E+00	3.6E+03	0.0E+00	0.0E+00	1.2E-02	0.0E+00	2.7E+00	4.3E-01	1.2E+04	0.0E+00	0.0E+00	0.0E+00	12.4
33	Calcite A Underflow Sludge	4.0	0.0E+00	0.0E+00	0.0E+00	4.5E-07	3.8E+04	0.0E+00	1.7E-08	0.0E+00	4.2E-06	1.5E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.2E-01	1.8E-10	0.0E+00	0.0E+00	2.1E-06	0.0E+00	0.0E+00	0.0E+00	6.7E-05	11.0
34	HDS B Underflow Sludge	7.3	1.7E-01	0.0E+00	4.6E+00	1.0E-01	8.7E+04	5.9E-01	7.2E-01	4.2E+01	2.7E-01	9.9E+01	8.7E-02	2.4E+03	1.1E+04	6.8E+01	0.0E+00	2.8E+02	9.4E-01	0.0E+00	4.8E-01	4.8E+04	0.0E+00	1.2E+00	5.8E+01	10.7
35	Sulfate B Underflow Sludge	9.7	0.0E+00	7.3E+02	0.0E+00	0.0E+00	5.4E+04	0.0E+00	5.4E-01	3.3E-03	0.0E+00	1.2E-04	2.5E+02	0.0E+00	3.6E+03	0.0E+00	0.0E+00	1.2E-02	0.0E+00	2.7E+00	4.3E-01	1.2E+04	0.0E+00	0.0E+00	0.0E+00	12.4
36	Calcite B Underflow Sludge	4.0	0.0E+00	0.0E+00	0.0E+00	4.5E-07	3.8E+04	0.0E+00	1.7E-08	0.0E+00	4.2E-06	1.5E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.2E-01	1.8E-10	0.0E+00	0.0E+00	2.1E-06	0.0E+00	0.0E+00	0.0E+00	6.7E-05	11.0
37	Plant Site VSEP Concentrate	80.9	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
38	Plant Site Concentrate to HDS A	40.5	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
39	Plant Site Concentrate to HDS B	40.5	2.8E-03	3.4E-01	1.2E-03	4.9E-03	1.4E+03	6.4E-03	7.6E+01	4.0E-03	2.1E-02	4.6E-02	6.1E+01	5.8E-01	1.8E+03	1.1E+00	1.4E+03	3.7E-01	3.6E-03	7.3E-02	1.8E-02	5.6E+03	3.8E-03	1.0E-01	9.8E-03	6.0
40	Final Effluent to CPS	652.9	1.3E-04	1.8E-04	1.9E-04	2.5E-03	4.9E+01	2.5E-05	5.8E+01	9.4E-05	2.6E-03	4.0E-03	9.0E-01	2.3E-05	5.3E+00	3.5E-03	2.8E+02	1.1E-02	1.8E-05	1.8E-03	8.8E-04	5.4E+01	5.7E-04	4.3E-04	2.1E-02	6.3

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	161.5	NA	NA	NA	195.8	4.4	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	41.5	34.21	7.3	NA	NA	NA	NA	NA	NA	25	1.18	3.07	0.54	2.53
5	Sulfate A Influent	161.5	NA	NA	NA	179.5	3.9	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	27.6	17.95	9.7	NA	NA	NA	NA	NA	NA	10	1.05	0.71	0.23	0.47
6	Sulfate A Effluent	161.5	NA	NA	85.9	247.5	NA	NA	1.0	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	4.0	0.00	4.0	NA	NA	NA	NA	NA	NA	10	1.06	0.10	0.10	0.00
7	Calcite A Effluent	161.5	NA	NA	55.0	216.5	NA	NA	0.7	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	161.5	NA	NA	NA	195.8	4.4	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	41.5	34.21	7.3	NA	NA	NA	NA	NA	NA	25	1.18	3.07	0.54	2.53
11	Sulfate B Influent	161.5	NA	NA		179.5	3.9	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	27.6	17.95	9.7	NA	NA	NA	NA	NA	NA	10	1.05	0.71	0.23	0.47
12	Sulfate B Effluent	161.5	NA	NA	85.9	247.5	NA	NA	1.0	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	4.0	0.00	4.0	NA	NA	NA	NA	NA	NA	10	1.06	0.10	0.10	0.00
13	Calcite B Effluent	161.5	NA	NA	55.0	161.5	NA	NA	0.7	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	519.0	NA	NA	NA	NA	NA	NA	NA	10.3	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	98.6	NA	NA	0*	NA	NA	NA	0.0	NA	NA	NA	NA	NA	NA

Mine Water Treatment Trains Flow and Load Detail
Year 6 P90 Annual Average Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	189.0	3.2E-01	2.0E+02	3.9E-01	2.5E-02	1.7E+03	8.3E-02	7.1E+01	7.0E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	6.6E+02	2.3E+01	2.5E+02	3.5E+01	1.3E-01	7.9E-01	1.4E-01	9.2E+03	1.9E-03	5.6E-02	8.8E+00	5.0
2	High Conc EQ Effluent to HDS A	94.5	3.2E-01	2.0E+02	3.9E-01	2.5E-02	1.7E+03	8.3E-02	7.1E+01	7.0E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	6.6E+02	2.3E+01	2.5E+02	3.5E+01	1.3E-01	7.9E-01	1.4E-01	9.2E+03	1.9E-03	5.6E-02	8.8E+00	5.0
3	High Conc EQ Effluent to HDS B	94.5	3.2E-01	2.0E+02	3.9E-01	2.5E-02	1.7E+03	8.3E-02	7.1E+01	7.0E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	6.6E+02	2.3E+01	2.5E+02	3.5E+01	1.3E-01	7.9E-01	1.4E-01	9.2E+03	1.9E-03	5.6E-02	8.8E+00	5.0
4	Combined HDS A Influent	217.5	1.7E-01	8.7E+01	3.5E-01	1.5E-02	1.8E+03	5.9E-02	6.6E+01	3.8E+00	9.4E-02	1.1E+01	7.3E+00	2.4E+02	1.1E+03	1.2E+01	1.1E+03	2.5E+01	8.0E-02	4.9E-01	1.3E-01	1.0E+04	1.1E-02	7.9E-02	6.5E+00	6.8
5	Sulfate A Influent	217.5	2.8E-02	8.6E+01	6.6E-06	7.8E-03	4.5E+02	4.5E-04	6.5E+01	3.0E-04	6.9E-02	4.6E-03	7.1E+00	1.3E-03	4.1E+02	1.2E-01	1.1E+03	1.0E-03	4.4E-05	4.8E-01	8.8E-02	4.9E+03	1.1E-02	4.3E-07	7.6E-01	10.6
6	Sulfate A Effluent	217.5	2.8E-02	8.6E-02	6.6E-06	7.8E-03	9.7E+02	4.5E-04	6.5E+01	8.3E-08	6.9E-02	4.5E-03	2.1E+00	1.3E-03	2.6E-01	1.2E-01	1.1E+03	2.1E-06	4.4E-05	2.4E-02	4.4E-02	2.0E+03	1.1E-02	4.3E-07	7.6E-01	12.6
7	Calcite A Effluent	217.5	2.8E-02	8.6E-02	6.6E-06	7.8E-03	4.5E-01	4.5E-04	6.6E+01	8.4E-08	6.9E-02	4.6E-03	2.1E+00	1.3E-03	2.6E-01	1.2E-01	1.1E+03	2.1E-06	4.5E-05	2.4E-02	4.5E-02	2.0E+03	1.1E-02	4.3E-07	7.7E-01	10.2
8	Calcite A Effluent to Final Effluent	87.0	2.8E-02	8.6E-02	6.6E-06	7.8E-03	4.5E-01	4.5E-04	6.5E+01	8.4E-08	6.9E-02	4.6E-03	2.1E+00	1.3E-03	2.6E-01	1.2E-01	1.1E+03	2.1E-06	4.5E-05	2.4E-02	4.4E-02	2.0E+03	1.1E-02	4.3E-07	7.6E-01	7.8
9	Calcite A Effluent to VSEP B	130.5	2.8E-02	8.6E-02	6.6E-06	7.8E-03	4.5E-01	4.5E-04	6.5E+01	8.4E-08	6.9E-02	4.6E-03	2.1E+00	1.3E-03	2.6E-01	1.2E-01	1.1E+03	2.1E-06	4.5E-05	2.4E-02	4.4E-02	2.0E+03	1.1E-02	4.3E-07	7.6E-01	7.8
10	Combined HDS B Influent	217.5	1.7E-01	8.7E+01	3.5E-01	1.5E-02	1.8E+03	5.9E-02	6.6E+01	3.8E+00	9.4E-02	1.1E+01	7.3E+00	2.4E+02	1.1E+03	1.2E+01	1.1E+03	2.5E+01	8.0E-02	4.9E-01	1.3E-01	1.0E+04	1.1E-02	7.9E-02	6.5E+00	6.8
11	Sulfate B Influent	217.5	2.8E-02	8.6E+01	6.6E-06	7.8E-03	4.5E+02	4.5E-04	6.5E+01	3.0E-04	6.9E-02	4.6E-03	7.1E+00	1.3E-03	4.1E+02	1.2E-01	1.1E+03	1.0E-03	4.4E-05	4.8E-01	8.8E-02	4.9E+03	1.1E-02	4.3E-07	7.6E-01	10.6
12	Sulfate B Effluent	217.5	2.8E-02	8.6E-02	6.6E-06	7.8E-03	9.7E+02	4.5E-04	6.5E+01	8.3E-08	6.9E-02	4.5E-03	2.1E+00	1.3E-03	2.6E-01	1.2E-01	1.1E+03	2.1E-06	4.4E-05	2.4E-02	4.4E-02	2.0E+03	1.1E-02	4.3E-07	7.6E-01	12.6
13	Calcite B Effluent	217.5	2.8E-02	8.6E-02	6.6E-06	7.8E-03	4.5E-01	4.5E-04	6.6E+01	8.4E-08	6.9E-02	4.6E-03	2.1E+00	1.3E-03	2.6E-01	1.2E-01	1.1E+03	2.1E-06	4.5E-05	2.4E-02	4.5E-02	2.0E+03	1.1E-02	4.3E-07	7.7E-01	10.2
14	Calcite B Effluent to Final Effluent	87.0	2.8E-02	8.6E-02	6.6E-06	7.8E-03	4.5E-01	4.5E-04	6.5E+01	8.4E-08	6.9E-02	4.6E-03	2.1E+00	1.3E-03	2.6E-01	1.2E-01	1.1E+03	2.1E-06	4.5E-05	2.4E-02	4.4E-02	2.0E+03	1.1E-02	4.3E-07	7.6E-01	7.8
15	Calcite B Effluent to VSEP B	130.5	2.8E-02	8.6E-02	6.6E-06	7.8E-03	4.5E-01	4.5E-04	6.5E+01	8.4E-08	6.9E-02	4.6E-03	2.1E+00	1.3E-03	2.6E-01	1.2E-01	1.1E+03	2.1E-06	4.5E-05	2.4E-02	4.4E-02	2.0E+03	1.1E-02	4.3E-07	7.6E-01	7.8
16	VSEP B Permeate to Final Effluent	299.3	1.1E-03	5.4E-04	4.1E-06	6.2E-03	4.0E-02	1.2E-05	6.4E+01	5.1E-09	7.3E-03	1.9E-04	1.2E+00	5.1E-05	3.8E-02	3.0E-02	4.7E+02	3.2E-07	1.0E-06	1.3E-03	2.7E-03	1.7E+02	5.8E-04	5.8E-08	4.9E-02	9.6
17	VSEP B Concentrate	74.8	1.4E-01	4.3E-01	1.7E-05	1.4E-02	2.1E+00	2.2E-03	7.2E+01	4.0E-07	3.2E-01	2.2E-02	5.4E+00	6.3E-03	1.2E+00	4.9E-01	3.4E+03	9.2E-06	2.2E-04	1.2E-01	2.1E-01	9.3E+03	5.2E-02	2.0E-06	3.7E+00	5.5
18	VSEP B Concentrate to HDS B	37.4	1.4E-01	4.3E-01	1.7E-05	1.4E-02	2.1E+00	2.2E-03	7.2E+01	4.0E-07	3.2E-01	2.2E-02	5.4E+00	6.3E-03	1.2E+00	4.9E-01	3.4E+03	9.2E-06	2.2E-04	1.2E-01	2.1E-01	9.3E+03	5.2E-02	2.0E-06	3.7E+00	5.5
19	VSEP B Concentrate to HDS A	37.4	1.4E-01	4.3E-01	1.7E-05	1.4E-02	2.1E+00	2.2E-03	7.2E+01	4.0E-07	3.2E-01	2.2E-02	5.4E+00	6.3E-03	1.2E+00	4.9E-01	3.4E+03	9.2E-06	2.2E-04	1.2E-01	2.1E-01	9.3E+03	5.2E-02	2.0E-06	3.7E+00	5.5
20	Low Conc EQ Effluent	1357.9	1.9E-04	1.7E-03	6.9E-02	4.0E-04	2.7E+02	6.0E-03	5.0E+01	2.3E-01	4.6E-03	1.9E+00	9.5E-01	1.9E-01	1.2E+02	4.0E-01	1.0E+02	3.2E+00	5.4E-03	3.4E-02	8.4E-03	5.5E+02	1.9E-04	1.0E-02	6.6E-01	7.0
21	GSF Backwash	67.9	1.9E-04	1.7E-03	1.1E+00	4.0E-04	2.7E+02	1.1E-01	4.9E+01	4.6E+00	4.5E-03	3.7E+01	9.5E-01	3.7E+00	1.2E+02	7.8E+00	1.0E+02	5.9E+01	1.0E-01	3.4E-02	8.3E-03	5.5E+02	1.9E-04	9.9E-03	1.3E+01	7.0
22	GSF Backwash Solids	33.9	1.9E-04	1.7E-03	1.9E+00	3.9E-04	2.7E+02	2.1E-01	4.9E+01	8.9E+00	4.5E-03	7.0E+01	9.5E-01	7.2E+00	1.2E+02	1.5E+01	1.0E+02	1.1E+02	1.9E-01	3.4E-02	8.3E-03	5.5E+02	1.9E-04	9.9E-03	2.5E+01	7.0
23	GSF Backwash Decant	33.9	1.9E-04	1.7E-03	3.5E-01	4.0E-04	2.7E+02	1.7E-02	4.9E+01	3.0E-01	4.5E-03	4.0E+00	9.5E-01	2.2E-01	1.2E+02	7.8E-01	1.0E+02	1.1E+01	1.5E-02	3.4E-02	8.3E-03	5.5E+02	1.9E-04	9.9E-03	9.4E-01	7.0
24	GSF Permeate/NF Feed	1290.1	1.9E-04	1.7E-03	2.1E-02	4.0E-04	2.7E+02	6.5E-04	5.0E+01	3.7E-03	4.6E-03	1.2E-01	9.5E-01	2.0E-03	1.2E+02	2.2E-02	1.0E+02	4.6E-01	6.0E-04	3.4E-02	8.4E-03	5.5E+02	1.9E-04	1.0E-02	1.5E-02	7.0
25	NF Permeate	1032.0	1.5E-04	1.2E-04	2.6E-04	2.8E-05	3.4E+01	4.7E-05	5.6E+01	1.3E-04	3.2E-04	9.3E-03	7.6E-01	5.4E-20	8.2E+00	6.0E-04	6.6E+01	1.7E-02	2.3E-05	2.4E-03	3.3E-04	2.3E+01	1.3E-05	7.1E-04	3.1E-04	6.0
26	NF Concentrate to VSEP A	258.0	3.6E-04	8.1E-03	1.0E-01	1.9E-03	1.2E+03	3.1E-03	2.4E+01	1.8E-02	2.2E-02	5.7E-01	1.7E+00	1.0E-02	5.8E+02	1.1E-01	2.4E+02	2.3E+00	2.9E-03	1.6E-01	4.1E-02	2.7E+03	8.9E-04	4.7E-02	7.7E-02	9.2
27	VSEP A Permeate to Final Effluent	206.4	1.4E-05	5.0E-05	6.4E-02	1.5E-03	1.1E+02	8.1E-05	2.3E+01	1.1E-03	2.3E-03	2.4E-02	1.0E+00	4.0E-04	8.6E+01	2.7E-02	1.1E+02	3.5E-01	6.5E-05	8.7E-03	2.5E-03	2.3E+02	4.8E-05	6.3E-03	4.9E-03	5.5
28	VSEP A Concentrate	51.6	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.6E-02	2.7E+01	8.9E-02	1.0E-01	2.9E+00	4.7E+00	5.0E-02	2.7E+03	4.4E-01	8.1E+02	1.0E+01	1.5E-02	8.1E-01	2.0E-01	1.3E+04	4.4E-03	2.2E-01	3.8E-01	9.6
29	VSEP A Concentrate to HDS B	25.8	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.6E-02	2.7E+01	8.9E-02	1.0E-01	2.9E+00	4.7E+00	5.0E-02	2.7E+03	4.4E-01	8.1E+02	1.0E+01	1.5E-02	8.1E-01	2.0E-01	1.3E+04	4.4E-03	2.2E-01	3.8E-01	9.6
30	VSEP A Concentrate to HDS A	25.8	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.6E-02	2.7E+01	8.9E-02	1.0E-01	2.9E+00	4.7E+00	5.0E-02	2.7E+03	4.4E-01	8.1E+02	1.0E+01	1.5E-02	8.1E-01	2.0E-01	1.3E+04	4.4E-03	2.2E-01	3.8E-01	9.6
31	HDS A Underflow Sludge	10.5	2.8E+00	0.0E+00	7.1E+00	1.5E-01	7.8E+04	1.2E+00	8.7E-01	7.6E+01	4.8E-01	2.2E+02	3.3E-02	4.8E+03	1.3E+04	2.4E+02	0.0E+00	5.1E+02	1.6E+00	0.0E+00	7.8E-01	1.0E+05	0.0E+00	1.6E+00	1.2E+02	10.6
32	Sulfate A Underflow Sludge	16.5	0.0E+00	1.1E+03	0.0E+00	0.0E+00	3.2E+04	0.0E+00	5.5E-01	3.9E-03	0.0E+00	8.5E-05	6.7E+01	0.0E+00	5.4E+03	0.0E+00	0.0E+00	1.3E-02	0.0E+00	6.0E+00	5.8E-01	3.8E+04	0.0E+00	0.0E+00	0.0E+00	12.6
33	Calcite A Underflow Sludge	12.1	0.0E+00	0.0E+00	0.0E+00	2.0E-07	1.7E+04	0.0E+00	2.3E-05	0.0E+00	0.0E+00	6.3E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.2
34	HDS B Underflow Sludge	10.5	2.8E+00	0.0E+00	7.1E+00	1.5E-01	7.8E+04	1.2E+00	8.7E-01	7.6E+01	4.8E-01	2.2E+02	3.3E-02	4.8E+03	1.3E+04	2.4E+02	0.0E+00	5.1E+02	1.6E+00	0.0E+00	7.8E-01	1.0E+05	0.0E+00	1.6E+00	1.2E+02	10.6
35	Sulfate B Underflow Sludge	16.5	0.0E+00	1.1E+03	0.0E+00	0.0E+00	3.2E+04	0.0E+00	5.5E-01	3.9E-03	0.0E+00	8.5E-05	6.7E+01	0.0E+00	5.4E+03	0.0E+00	0.0E+00	1.3E-02	0.0E+00	6.0E+00	5.8E-01	3.8E+04	0.0E+00	0.0E+00	0.0E+00	12.6
36	Calcite B Underflow Sludge	12.1	0.0E+00	0.0E+00	0.0E+00	2.0E-07	1.7E+04	0.0E+00	2.3E-05	0.0E+00	0.0E+00	6.3E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.2
37	Plant Site VSEP Concentrate	85.7	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
38	Plant Site Concentrate to HDS A	42.9	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
39	Plant Site Concentrate to HDS B	42.9	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
40	Final Effluent to CPS	1598.7	1.4E-03	3.5E-03	8.3E-03	1.7E-03	3.6E+01	6.0E-05	5.4E+01	2.3E-04	4.5E-03	9.0E-03	9.4E-01	1.1E-04	1.6E+01	1.4E-02	1.8E+02	5.6E-02	2.5E-05	3.8E-03	2.7E-03	1.5E+02	5.3E-04	1.3E-03	3.9E-02	6.1

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	217.5	NA	NA	NA	231.9	4.4	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	24.9	14.32	10.5	NA	NA	NA	NA	NA	NA	25	1.18	1.83	0.78	1.06
5	Sulfate A Influent	217.5	NA	NA	NA	241.7	3.9	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	40.6	24.17	16.5	NA	NA	NA	NA	NA	NA	10	1.05	1.03	0.39	0.64
6	Sulfate A Effluent	217.5	NA	NA	174.2	391.7	NA	NA	2.1	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	12.1	0.00	12.1	NA	NA	NA	NA	NA	NA	10	1.06	0.29	0.29	0.00
7	Calcite A Effluent	217.5	NA	NA	64.2	281.7	NA	NA	0.8	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	217.5	NA	NA	NA	231.9	4.4	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	24.9	14.32	10.5	NA	NA	NA	NA	NA	NA	25	1.18	1.83	0.78	1.06
11	Sulfate B Influent	217.5	NA	NA		241.7	3.9	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	40.6	24.17	16.5	NA	NA	NA	NA	NA	NA	10	1.05	1.03	0.39	0.64
12	Sulfate B Effluent	217.5	NA	NA	174.2	391.7	NA	NA	2.1	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	12.1	0.00	12.1	NA	NA	NA	NA	NA	NA	10	1.06	0.29	0.29	0.00
13	Calcite B Effluent	217.5	NA	NA	64.2	217.5	NA	NA	0.8	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1357.9	NA	NA	NA	NA	NA	NA	NA	26.9	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	258.0	NA	NA	366.7*	NA	NA	NA	4.4	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 6 P90 Peak Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	292.0	3.2E-01	2.0E+02	3.9E-01	2.5E-02	1.7E+03	8.3E-02	7.1E+01	7.0E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	6.6E+02	2.3E+01	2.5E+02	3.5E+01	1.3E-01	7.9E-01	1.4E-01	9.2E+03	1.9E-03	5.6E-02	8.8E+00	5.0
2	High Conc EQ Effluent to HDS A	146.0	3.2E-01	2.0E+02	3.9E-01	2.5E-02	1.7E+03	8.3E-02	7.1E+01	7.0E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	6.6E+02	2.3E+01	2.5E+02	3.5E+01	1.3E-01	7.9E-01	1.4E-01	9.2E+03	1.9E-03	5.6E-02	8.8E+00	5.0
3	High Conc EQ Effluent to HDS B	146.0	3.2E-01	2.0E+02	3.9E-01	2.5E-02	1.7E+03	8.3E-02	7.1E+01	7.0E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	6.6E+02	2.3E+01	2.5E+02	3.5E+01	1.3E-01	7.9E-01	1.4E-01	9.2E+03	1.9E-03	5.6E-02	8.8E+00	5.0
4	Combined HDS A Influent	274.3	1.8E-01	1.1E+02	3.9E-01	1.9E-02	1.9E+03	6.9E-02	6.6E+01	4.4E+00	8.1E-02	1.2E+01	6.1E+00	2.9E+02	1.0E+03	1.4E+01	7.2E+02	2.8E+01	1.0E-01	5.5E-01	1.3E-01	9.8E+03	5.4E-03	7.8E-02	1.5E+01	7.0
5	Sulfate A Influent	274.3	6.1E-03	1.0E+02	2.3E-04	1.8E-02	5.6E+02	5.5E-03	6.5E+01	2.5E-04	7.9E-02	4.7E-02	6.0E+00	1.9E-02	2.2E+00	1.4E-01	7.1E+02	4.4E-03	1.4E-02	5.4E-01	8.8E-02	2.6E+03	5.3E-03	2.2E-06	1.5E+01	11.9
6	Sulfate A Effluent	274.3	6.1E-03	1.0E-01	2.3E-04	1.8E-02	1.0E+03	5.5E-03	6.5E+01	1.3E-05	7.9E-02	4.6E-02	1.9E+00	1.9E-02	2.7E-01	1.4E-01	7.1E+02	1.3E-03	1.4E-02	2.7E-02	4.4E-02	1.8E+03	5.3E-03	2.2E-06	1.5E+01	12.5
7	Calcite A Effluent	274.3	6.1E-03	1.1E-01	2.3E-04	1.9E-02	4.4E-01	5.5E-03	6.5E+01	1.3E-05	8.0E-02	4.7E-02	2.0E+00	2.0E-02	2.7E-01	1.4E-01	7.1E+02	1.3E-03	1.4E-02	2.7E-02	4.5E-02	1.8E+03	5.3E-03	2.2E-06	1.5E+01	10.9
8	Calcite A Effluent to Final Effluent	109.7	6.1E-03	1.1E-01	2.3E-04	1.9E-02	4.4E-01	5.5E-03	6.5E+01	1.3E-05	8.0E-02	4.7E-02	2.0E+00	2.0E-02	2.7E-01	1.4E-01	7.1E+02	1.3E-03	1.4E-02	2.7E-02	4.4E-02	1.8E+03	5.3E-03	2.2E-06	1.5E+01	7.1
9	Calcite A Effluent to VSEP B	164.6	6.1E-03	1.1E-01	2.3E-04	1.9E-02	4.4E-01	5.5E-03	6.5E+01	1.3E-05	8.0E-02	4.7E-02	2.0E+00	2.0E-02	2.7E-01	1.4E-01	7.1E+02	1.3E-03	1.4E-02	2.7E-02	4.4E-02	1.8E+03	5.3E-03	2.2E-06	1.5E+01	7.1
10	Combined HDS B Influent	274.3	1.8E-01	1.1E+02	3.9E-01	1.9E-02	1.9E+03	6.9E-02	6.6E+01	4.4E+00	8.1E-02	1.2E+01	6.1E+00	2.9E+02	1.0E+03	1.4E+01	7.2E+02	2.8E+01	1.0E-01	5.5E-01	1.3E-01	9.8E+03	5.4E-03	7.8E-02	1.5E+01	7.0
11	Sulfate B Influent	274.3	6.1E-03	1.0E+02	2.3E-04	1.8E-02	5.6E+02	5.5E-03	6.5E+01	2.5E-04	7.9E-02	4.7E-02	6.0E+00	1.9E-02	2.2E+00	1.4E-01	7.1E+02	4.4E-03	1.4E-02	5.4E-01	8.8E-02	2.6E+03	5.3E-03	2.2E-06	1.5E+01	11.9
12	Sulfate B Effluent	274.3	6.1E-03	1.0E-01	2.3E-04	1.8E-02	1.0E+03	5.5E-03	6.5E+01	1.3E-05	7.9E-02	4.6E-02	1.9E+00	1.9E-02	2.7E-01	1.4E-01	7.1E+02	1.3E-03	1.4E-02	2.7E-02	4.4E-02	1.8E+03	5.3E-03	2.2E-06	1.5E+01	12.5
13	Calcite B Effluent	274.3	6.1E-03	1.1E-01	2.3E-04	1.9E-02	4.4E-01	5.5E-03	6.5E+01	1.3E-05	8.0E-02	4.7E-02	2.0E+00	2.0E-02	2.7E-01	1.4E-01	7.1E+02	1.3E-03	1.4E-02	2.7E-02	4.5E-02	1.8E+03	5.3E-03	2.2E-06	1.5E+01	10.9
14	Calcite B Effluent to Final Effluent	109.7	6.1E-03	1.1E-01	2.3E-04	1.9E-02	4.4E-01	5.5E-03	6.5E+01	1.3E-05	8.0E-02	4.7E-02	2.0E+00	2.0E-02	2.7E-01	1.4E-01	7.1E+02	1.3E-03	1.4E-02	2.7E-02	4.4E-02	1.8E+03	5.3E-03	2.2E-06	1.5E+01	7.1
15	Calcite B Effluent to VSEP B	164.6	6.1E-03	1.1E-01	2.3E-04	1.9E-02	4.4E-01	5.5E-03	6.5E+01	1.3E-05	8.0E-02	4.7E-02	2.0E+00	2.0E-02	2.7E-01	1.4E-01	7.1E+02	1.3E-03	1.4E-02	2.7E-02	4.4E-02	1.8E+03	5.3E-03	2.2E-06	1.5E+01	7.1
16	VSEP B Permeate to Final Effluent	259.0	2.4E-04	6.6E-04	1.4E-04	1.5E-02	3.9E-02	1.4E-04	6.3E+01	8.1E-07	8.5E-03	2.0E-03	1.2E+00	7.8E-04	4.0E-02	3.6E-02	3.2E+02	2.0E-04	3.1E-04	1.5E-03	2.7E-03	1.5E+02	2.8E-04	3.0E-07	9.5E-01	6.9
17	VSEP B Concentrate	64.7	3.0E-02	5.3E-01	5.9E-04	3.4E-02	2.1E+00	2.7E-02	7.2E+01	6.4E-05	3.7E-01	2.3E-01	5.2E+00	9.6E-02	1.2E+00	5.7E-01	2.3E+03	5.6E-03	6.9E-02	1.3E-01	2.1E-01	8.3E+03	2.6E-02	1.0E-05	7.1E+01	8.0
18	VSEP B Concentrate to HDS B	32.4	3.0E-02	5.3E-01	5.9E-04	3.4E-02	2.1E+00	2.7E-02	7.2E+01	6.4E-05	3.7E-01	2.3E-01	5.2E+00	9.6E-02	1.2E+00	5.7E-01	2.3E+03	5.6E-03	6.9E-02	1.3E-01	2.1E-01	8.3E+03	2.6E-02	1.0E-05	7.1E+01	8.0
19	VSEP B Concentrate to HDS A	32.4	3.0E-02	5.3E-01	5.9E-04	3.4E-02	2.1E+00	2.7E-02	7.2E+01	6.4E-05	3.7E-01	2.3E-01	5.2E+00	9.6E-02	1.2E+00	5.7E-01	2.3E+03	5.6E-03	6.9E-02	1.3E-01	2.1E-01	8.3E+03	2.6E-02	1.0E-05	7.1E+01	8.0
20	Low Conc EQ Effluent	1687.2	1.9E-04	1.7E-03	6.9E-02	4.0E-04	2.7E+02	6.0E-03	5.0E+01	2.3E-01	4.6E-03	1.9E+00	9.5E-01	1.9E-01	1.2E+02	4.0E-01	1.0E+02	3.2E+00	5.4E-03	3.4E-02	8.4E-03	5.5E+02	1.9E-04	1.0E-02	6.6E-01	7.0
21	GSF Backwash	84.4	1.9E-04	1.7E-03	1.1E+00	3.9E-04	2.7E+02	1.1E-01	5.0E+01	4.6E+00	4.5E-03	3.7E+01	9.5E-01	3.7E+00	1.2E+02	7.8E+00	1.0E+02	5.9E+01	1.0E-01	3.4E-02	8.4E-03	5.5E+02	1.9E-04	9.9E-03	1.3E+01	7.0
22	GSF Backwash Solids	42.2	1.9E-04	1.7E-03	1.9E+00	3.9E-04	2.7E+02	2.1E-01	4.9E+01	8.9E+00	4.5E-03	7.0E+01	9.5E-01	7.2E+00	1.2E+02	1.5E+01	1.0E+02	1.1E+02	1.9E-01	3.4E-02	8.3E-03	5.5E+02	1.9E-04	9.9E-03	2.5E+01	7.0
23	GSF Backwash Decant	42.2	1.9E-04	1.7E-03	3.5E-01	3.9E-04	2.7E+02	1.7E-02	5.0E+01	3.0E-01	4.5E-03	4.0E+00	9.5E-01	2.2E-01	1.2E+02	7.8E-01	1.0E+02	1.1E+01	1.5E-02	3.4E-02	8.4E-03	5.5E+02	1.9E-04	9.9E-03	9.4E-01	7.0
24	GSF Permeate/NF Feed	1602.8	1.9E-04	1.7E-03	2.1E-02	4.0E-04	2.7E+02	6.5E-04	5.0E+01	3.7E-03	4.6E-03	1.2E-01	9.5E-01	2.0E-03	1.2E+02	2.2E-02	1.0E+02	4.6E-01	6.0E-04	3.4E-02	8.4E-03	5.5E+02	1.9E-04	1.0E-02	1.5E-02	7.0
25	NF Permeate	1282.3	1.5E-04	1.2E-04	2.6E-04	2.8E-05	3.4E+01	4.7E-05	5.6E+01	1.3E-04	3.2E-04	9.3E-03	7.6E-01	4.3E-20	8.2E+00	6.0E-04	6.6E+01	1.7E-02	2.3E-05	2.4E-03	3.3E-04	2.3E+01	1.3E-05	7.1E-04	3.1E-04	6.0
26	NF Concentrate to VSEP A	320.6	3.6E-04	8.1E-03	1.0E-01	1.9E-03	1.2E+03	3.1E-03	2.4E+01	1.8E-02	2.2E-02	5.7E-01	1.7E+00	1.0E-02	5.8E+02	1.1E-01	2.4E+02	2.3E+00	2.9E-03	1.6E-01	4.1E-02	2.7E+03	8.9E-04	4.7E-02	7.7E-02	9.2
27	VSEP A Permeate to Final Effluent	256.5	1.4E-05	5.0E-05	6.4E-02	1.5E-03	1.1E+02	8.1E-05	2.3E+01	1.1E-03	2.3E-03	2.4E-02	1.0E+00	4.0E-04	8.6E+01	2.7E-02	1.1E+02	3.5E-01	6.5E-05	8.7E-03	2.5E-03	2.3E+02	4.8E-05	6.3E-03	4.9E-03	5.5
28	VSEP A Concentrate	64.1	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.6E-02	2.7E+01	8.9E-02	1.0E-01	2.9E+00	4.7E+00	5.0E-02	2.7E+03	4.4E-01	8.1E+02	1.0E+01	1.5E-02	8.1E-01	2.0E-01	1.3E+04	4.4E-03	2.2E-01	3.8E-01	9.6
29	VSEP A Concentrate to HDS B	32.1	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.6E-02	2.7E+01	8.9E-02	1.0E-01	2.9E+00	4.7E+00	5.0E-02	2.7E+03	4.4E-01	8.1E+02	1.0E+01	1.5E-02	8.1E-01	2.0E-01	1.3E+04	4.4E-03	2.2E-01	3.8E-01	9.6
30	VSEP A Concentrate to HDS A	32.1	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.6E-02	2.7E+01	8.9E-02	1.0E-01	2.9E+00	4.7E+00	5.0E-02	2.7E+03	4.4E-01	8.1E+02	1.0E+01	1.5E-02	8.1E-01	2.0E-01	1.3E+04	4.4E-03	2.2E-01	3.8E-01	9.6
31	HDS A Underflow Sludge	16.6	2.8E+00	6.0E-03	6.3E+00	9.5E-04	7.3E+04	1.0E+00	6.9E-01	7.2E+01	7.4E-03	1.9E+02	2.2E-02	4.7E+03	1.7E+04	2.3E+02	0.0E+00	4.6E+02	1.4E+00	5.1E-06	6.3E-01	1.2E+05	0.0E+00	1.3E+00	0.0E+00	11.9
32	Sulfate A Underflow Sludge	14.5	0.0E+00	2.0E+03	0.0E+00	1.0E-06	5.9E+04	0.0E+00	8.0E-01	4.5E-03	8.5E-03	1.2E-03	7.6E+01	0.0E+00	3.7E+01	6.2E-07	0.0E+00	6.0E-02	0.0E+00	9.7E+00	8.4E-01	1.6E+04	0.0E+00	0.0E+00	0.0E+00	12.5
33	Calcite A Underflow Sludge	14.4	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.9E+04	0.0E+00	6.0E-07	0.0E+00	6.1E-06	6.8E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.9
34	HDS B Underflow Sludge	16.6	2.8E+00	6.0E-03	6.3E+00	9.5E-04	7.3E+04	1.0E+00	6.9E-01	7.2E+01	7.4E-03	1.9E+02	2.2E-02	4.7E+03	1.7E+04	2.3E+02	0.0E+00	4.6E+02	1.4E+00	5.1E-06	6.3E-01	1.2E+05	0.0E+00	1.3E+00	0.0E+00	11.9
35	Sulfate B Underflow Sludge	14.5	0.0E+00	2.0E+03	0.0E+00	1.0E-06	5.9E+04	0.0E+00	8.0E-01	4.5E-03	8.5E-03	1.2E-03	7.6E+01	0.0E+00	3.7E+01	6.2E-07	0.0E+00	6.0E-02	0.0E+00	9.7E+00	8.4E-01	1.6E+04	0.0E+00	0.0E+00	0.0E+00	12.5
36	Calcite B Underflow Sludge	14.4	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.9E+04	0.0E+00	6.0E-07	0.0E+00	6.1E-06	6.8E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.9
37	Plant Site VSEP Concentrate	85.6	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
38	Plant Site Concentrate to HDS A	42.8	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
39	Plant Site Concentrate to HDS B	42.8	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
40	Final Effluent to CPS	2022.6	8.1E-04	1.2E-02	8.2E-03	4.2E-03	3.6E+01	6.7E-04	5.4E+01	2.3E-04	1.0E-02	1.4E-02	9.8E-01	2.3E-03	1.6E+01	2.4E-02	1.8E+02	5.6E-02	1.6E-03	5.8E-03	5.8E-03	2.6E+02	6.4E-04	1.2E-03	1.8E+00	6.0

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	274.3	NA	NA	NA	289.4	7.2	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	31.7	15.05	16.6	NA	NA	NA	NA	NA	NA	25	1.18	2.33	1.22	1.11
5	Sulfate A Influent	274.3	NA	NA	NA	304.8	5.5	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	45.0	30.48	14.5	NA	NA	NA	NA	NA	NA	10	1.05	1.15	0.35	0.80
6	Sulfate A Effluent	274.3	NA	NA	201.7	476.0	NA	NA	2.4	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	14.4	0.00	14.4	NA	NA	NA	NA	NA	NA	10	1.06	0.35	0.35	0.00
7	Calcite A Effluent	274.3	NA	NA	96.3	370.6	NA	NA	1.2	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	274.3	NA	NA	NA	289.4	7.2	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	31.7	15.05	16.6	NA	NA	NA	NA	NA	NA	25	1.18	2.33	1.22	1.11
11	Sulfate B Influent	274.3	NA	NA		304.8	5.5	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	45.0	30.48	14.5	NA	NA	NA	NA	NA	NA	10	1.05	1.15	0.35	0.80
12	Sulfate B Effluent	274.3	NA	NA	201.7	476.0	NA	NA	2.4	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	14.4	0.00	14.4	NA	NA	NA	NA	NA	NA	10	1.06	0.35	0.35	0.00
13	Calcite B Effluent	274.3	NA	NA	96.3	274.3	NA	NA	1.2	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1687.2	NA	NA	NA	NA	NA	NA	NA	33.4	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	320.6	NA	NA	458.3*	NA	NA	NA	5.5	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 6 P90 Winter Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	65.0	3.2E-01	2.0E+02	3.9E-01	2.5E-02	1.7E+03	8.3E-02	7.1E+01	7.0E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	6.6E+02	2.3E+01	2.5E+02	3.5E+01	1.3E-01	7.9E-01	1.4E-01	9.2E+03	1.9E-03	5.6E-02	8.8E+00	5.0
2	High Conc EQ Effluent to HDS A	32.5	3.2E-01	2.0E+02	3.9E-01	2.5E-02	1.7E+03	8.3E-02	7.1E+01	7.0E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	6.6E+02	2.3E+01	2.5E+02	3.5E+01	1.3E-01	7.9E-01	1.4E-01	9.2E+03	1.9E-03	5.6E-02	8.8E+00	5.0
3	High Conc EQ Effluent to HDS B	32.5	3.2E-01	2.0E+02	3.9E-01	2.5E-02	1.7E+03	8.3E-02	7.1E+01	7.0E+00	2.3E-02	1.1E+01	2.0E+00	5.4E+02	6.6E+02	2.3E+01	2.5E+02	3.5E+01	1.3E-01	7.9E-01	1.4E-01	9.2E+03	1.9E-03	5.6E-02	8.8E+00	5.0
4	Combined HDS A Influent	199.7	8.1E-02	3.3E+01	2.0E-01	8.4E-03	1.2E+03	2.9E-02	5.1E+01	1.6E+00	1.5E-01	5.7E+00	7.9E+00	8.9E+01	8.3E+02	5.4E+00	9.4E+02	1.2E+01	3.9E-02	2.3E-01	7.0E-02	9.6E+03	2.4E-02	5.8E-02	3.6E+00	6.8
5	Sulfate A Influent	199.7	2.6E-02	3.2E+01	2.0E-05	5.4E-03	3.9E+02	4.1E-04	5.0E+01	2.0E-04	1.2E-01	5.0E-03	7.8E+00	1.4E-03	4.1E+02	5.3E-02	9.3E+02	8.2E-04	3.7E-05	2.3E-01	4.8E-02	7.0E+03	2.3E-02	1.4E-06	8.7E-01	10.7
6	Sulfate A Effluent	199.7	2.6E-02	3.2E-02	2.0E-05	5.4E-03	5.0E+02	4.1E-04	5.0E+01	4.3E-08	1.2E-01	5.0E-03	3.2E+00	1.4E-03	5.2E-01	5.3E-02	9.3E+02	1.0E-06	3.7E-05	1.1E-02	2.4E-02	4.1E+03	2.3E-02	1.4E-06	8.7E-01	12.3
7	Calcite A Effluent	199.7	2.7E-02	3.2E-02	2.0E-05	5.4E-03	1.5E+00	4.2E-04	5.1E+01	4.3E-08	1.3E-01	5.0E-03	3.2E+00	1.4E-03	5.2E-01	5.3E-02	9.3E+02	1.0E-06	3.8E-05	1.2E-02	2.4E-02	4.2E+03	2.3E-02	1.4E-06	8.7E-01	9.1
8	Calcite A Effluent to Final Effluent	79.9	2.7E-02	3.2E-02	2.0E-05	5.4E-03	1.5E+00	4.2E-04	5.1E+01	4.3E-08	1.3E-01	5.0E-03	3.2E+00	1.4E-03	5.2E-01	5.3E-02	9.3E+02	1.0E-06	3.8E-05	1.2E-02	2.4E-02	4.2E+03	2.3E-02	1.4E-06	8.7E-01	6.5
9	Calcite A Effluent to VSEP B	119.8	2.7E-02	3.2E-02	2.0E-05	5.4E-03	1.5E+00	4.2E-04	5.1E+01	4.3E-08	1.3E-01	5.0E-03	3.2E+00	1.4E-03	5.2E-01	5.3E-02	9.3E+02	1.0E-06	3.8E-05	1.2E-02	2.4E-02	4.2E+03	2.3E-02	1.4E-06	8.7E-01	6.5
10	Combined HDS B Influent	199.7	8.1E-02	3.3E+01	2.0E-01	8.4E-03	1.2E+03	2.9E-02	5.1E+01	1.6E+00	1.5E-01	5.7E+00	7.9E+00	8.9E+01	8.3E+02	5.4E+00	9.4E+02	1.2E+01	3.9E-02	2.3E-01	7.0E-02	9.6E+03	2.4E-02	5.8E-02	3.6E+00	6.8
11	Sulfate B Influent	199.7	2.6E-02	3.2E+01	2.0E-05	5.4E-03	3.9E+02	4.1E-04	5.0E+01	2.0E-04	1.2E-01	5.0E-03	7.8E+00	1.4E-03	4.1E+02	5.3E-02	9.3E+02	8.2E-04	3.7E-05	2.3E-01	4.8E-02	7.0E+03	2.3E-02	1.4E-06	8.7E-01	10.7
12	Sulfate B Effluent	199.7	2.6E-02	3.2E-02	2.0E-05	5.4E-03	5.0E+02	4.1E-04	5.0E+01	4.3E-08	1.2E-01	5.0E-03	3.2E+00	1.4E-03	5.2E-01	5.3E-02	9.3E+02	1.0E-06	3.7E-05	1.1E-02	2.4E-02	4.1E+03	2.3E-02	1.4E-06	8.7E-01	12.3
13	Calcite B Effluent	199.7	2.7E-02	3.2E-02	2.0E-05	5.4E-03	1.5E+00	4.2E-04	5.1E+01	4.3E-08	1.3E-01	5.0E-03	3.2E+00	1.4E-03	5.2E-01	5.3E-02	9.3E+02	1.0E-06	3.8E-05	1.2E-02	2.4E-02	4.2E+03	2.3E-02	1.4E-06	8.7E-01	9.1
14	Calcite B Effluent to Final Effluent	79.9	2.7E-02	3.2E-02	2.0E-05	5.4E-03	1.5E+00	4.2E-04	5.1E+01	4.3E-08	1.3E-01	5.0E-03	3.2E+00	1.4E-03	5.2E-01	5.3E-02	9.3E+02	1.0E-06	3.8E-05	1.2E-02	2.4E-02	4.2E+03	2.3E-02	1.4E-06	8.7E-01	6.5
15	Calcite B Effluent to VSEP B	119.8	2.7E-02	3.2E-02	2.0E-05	5.4E-03	1.5E+00	4.2E-04	5.1E+01	4.3E-08	1.3E-01	5.0E-03	3.2E+00	1.4E-03	5.2E-01	5.3E-02	9.3E+02	1.0E-06	3.8E-05	1.2E-02	2.4E-02	4.2E+03	2.3E-02	1.4E-06	8.7E-01	6.5
16	VSEP B Permeate to Final Effluent	319.4	1.1E-03	2.0E-04	1.3E-05	4.3E-03	1.4E-01	1.1E-05	4.9E+01	2.6E-09	1.3E-02	2.1E-04	1.9E+00	5.8E-05	7.7E-02	1.3E-02	4.1E+02	1.6E-07	8.4E-07	6.2E-04	1.5E-03	3.6E+02	1.3E-03	1.9E-07	5.6E-02	7.0
17	VSEP B Concentrate	79.9	1.3E-01	1.6E-01	5.3E-05	9.9E-03	7.3E+00	2.1E-03	5.6E+01	2.1E-07	5.9E-01	2.5E-02	8.5E+00	7.1E-03	2.4E+00	2.2E-01	3.1E+03	4.7E-06	1.9E-04	5.6E-02	1.2E-01	2.0E+04	1.1E-01	6.5E-06	4.2E+00	5.3
18	VSEP B Concentrate to HDS B	39.9	1.3E-01	1.6E-01	5.3E-05	9.9E-03	7.3E+00	2.1E-03	5.6E+01	2.1E-07	5.9E-01	2.5E-02	8.5E+00	7.1E-03	2.4E+00	2.2E-01	3.1E+03	4.7E-06	1.9E-04	5.6E-02	1.2E-01	2.0E+04	1.1E-01	6.5E-06	4.2E+00	5.3
19	VSEP B Concentrate to HDS A	39.9	1.3E-01	1.6E-01	5.3E-05	9.9E-03	7.3E+00	2.1E-03	5.6E+01	2.1E-07	5.9E-01	2.5E-02	8.5E+00	7.1E-03	2.4E+00	2.2E-01	3.1E+03	4.7E-06	1.9E-04	5.6E-02	1.2E-01	2.0E+04	1.1E-01	6.5E-06	4.2E+00	5.3
20	Low Conc EQ Effluent	787.7	1.9E-04	1.7E-03	6.9E-02	4.0E-04	2.7E+02	6.0E-03	5.0E+01	2.3E-01	4.6E-03	1.9E+00	9.5E-01	1.9E-01	1.2E+02	4.0E-01	1.1E+00	3.2E+00	5.4E-03	3.4E-02	8.4E-03	5.5E+02	1.9E-04	1.0E-02	6.6E-01	7.0
21	GSF Backwash	39.4	1.9E-04	1.7E-03	1.1E+00	4.0E-04	2.7E+02	1.1E-01	5.0E+01	4.6E+00	4.5E-03	3.7E+01	9.5E-01	3.7E+00	1.2E+02	7.8E+00	1.1E+00	5.9E+01	1.0E-01	3.4E-02	8.3E-03	5.5E+02	1.9E-04	1.0E-02	1.3E+01	7.0
22	GSF Backwash Solids	19.7	1.9E-04	1.7E-03	1.9E+00	4.0E-04	2.7E+02	2.1E-01	5.0E+01	8.9E+00	4.5E-03	7.0E+01	9.5E-01	7.2E+00	1.2E+02	1.5E+01	1.1E+00	1.1E+02	1.9E-01	3.4E-02	8.3E-03	5.5E+02	1.9E-04	1.0E-02	2.5E+01	7.0
23	GSF Backwash Decant	19.7	1.9E-04	1.7E-03	3.5E-01	4.0E-04	2.7E+02	1.7E-02	5.0E+01	3.0E-01	4.5E-03	4.0E+00	9.5E-01	2.2E-01	1.2E+02	7.8E-01	1.1E+00	1.1E+01	1.5E-02	3.4E-02	8.3E-03	5.5E+02	1.9E-04	1.0E-02	9.4E-01	7.0
24	GSF Permeate/NF Feed	748.3	1.9E-04	1.7E-03	2.1E-02	4.0E-04	2.7E+02	6.5E-04	5.0E+01	3.7E-03	4.6E-03	1.2E-01	9.5E-01	2.0E-03	1.2E+02	2.2E-02	1.1E+00	4.6E-01	6.0E-04	3.4E-02	8.4E-03	5.5E+02	1.9E-04	1.0E-02	1.5E-02	7.0
25	NF Permeate	598.6	1.5E-04	1.2E-04	2.6E-04	2.8E-05	3.4E+01	4.7E-05	5.6E+01	1.3E-04	3.2E-04	9.3E-03	7.6E-01	0.0E+00	8.2E+00	6.0E-04	7.2E-01	1.7E-02	2.3E-05	2.4E-03	3.3E-04	2.3E+01	1.3E-05	7.1E-04	3.1E-04	5.8
26	NF Concentrate to VSEP A	149.7	3.6E-04	8.1E-03	1.0E-01	1.9E-03	1.2E+03	3.1E-03	2.4E+01	1.8E-02	2.2E-02	5.7E-01	1.7E+00	1.0E-02	5.8E+02	1.1E-01	2.6E+00	2.3E+00	2.9E-03	1.6E-01	4.1E-02	2.7E+03	8.9E-04	4.7E-02	7.7E-02	9.4
27	VSEP A Permeate to Final Effluent	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	VSEP A Concentrate	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29	VSEP A Concentrate to HDS B	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30	VSEP A Concentrate to HDS A	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	6.6	1.6E+00	4.3E-04	5.9E+00	8.7E-02	8.3E+04	8.6E-01	9.9E-01	4.8E+01	5.6E-01	1.7E+02	0.0E+00	2.7E+03	1.2E+04	1.6E+02	0.0E+00	3.6E+02	1.2E+00	0.0E+00	6.3E-01	7.6E+04	0.0E+00	1.7E+00	8.0E+01	10.7
32	Sulfate A Underflow Sludge	13.3	0.0E+00	4.8E+02	0.0E+00	0.0E+00	3.0E+04	0.0E+00	4.9E-01	3.0E-03	0.0E+00	1.1E-04	7.0E+01	0.0E+00	6.2E+03	3.5E-07	0.0E+00	1.2E-02	0.0E+00	3.3E+00	3.6E-01	4.3E+04	0.0E+00	0.0E+00	0.0E+00	12.3
33	Calcite A Underflow Sludge	8.2	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.3E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.1
34	HDS B Underflow Sludge	6.6	1.6E+00	4.3E-04	5.9E+00	8.7E-02	8.3E+04	8.6E-01	9.9E-01	4.8E+01	5.6E-01	1.7E+02	0.0E+00	2.7E+03	1.2E+04	1.6E+02	0.0E+00	3.6E+02	1.2E+00	0.0E+00	6.3E-01	7.6E+04	0.0E+00	1.7E+00	8.0E+01	10.7
35	Sulfate B Underflow Sludge	13.3	0.0E+00	4.8E+02	0.0E+00	0.0E+00	3.0E+04	0.0E+00	4.9E-01	3.0E-03	0.0E+00	1.1E-04	7.0E+01	0.0E+00	6.2E+03	3.5E-07	0.0E+00	1.2E-02	0.0E+00	3.3E+00	3.6E-01	4.3E+04	0.0E+00	0.0E+00	0.0E+00	12.3
36	Calcite B Underflow Sludge	8.2	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.3E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.2E-10	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.1
37	Plant Site VSEP Concentrate	85.1	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
38	Plant Site Concentrate to HDS A	42.6	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
39	Plant Site Concentrate to HDS B	42.6	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
40	Final Effluent to CPS	918.1	4.7E-04	1.5E-04	1.8E-04	1.5E-03	2.2E+01	3.4E-05	5.4E+01	8.7E-05	4.8E-03	6.0E-03	1.2E+00	2.0E-05	5.4E+00	5.0E-03	1.4E+02	1.1E-02	1.5E-05	1.8E-03	7.3E-04	1.4E+02	4.4E-04	4.6E-04	1.9E-02	6.4

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	199.7	NA	NA	NA	239.8	3.3	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	46.7	40.16	6.6	NA	NA	NA	NA	NA	NA	25	1.18	3.45	0.49	2.96
5	Sulfate A Influent	199.7	NA	NA	NA	221.8	2.2	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	35.5	22.18	13.3	NA	NA	NA	NA	NA	NA	10	1.05	0.90	0.32	0.59
6	Sulfate A Effluent	199.7	NA	NA	126.0	325.7	NA	NA	1.5	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	8.2	0.00	8.2	NA	NA	NA	NA	NA	NA	10	1.06	0.20	0.20	0.00
7	Calcite A Effluent	199.7	NA	NA	68.8	268.4	NA	NA	0.8	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	199.7	NA	NA	NA	239.8	3.3	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	46.7	40.16	6.6	NA	NA	NA	NA	NA	NA	25	1.18	3.45	0.49	2.96
11	Sulfate B Influent	199.7	NA	NA		221.8	2.2	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	35.5	22.18	13.3	NA	NA	NA	NA	NA	NA	10	1.05	0.90	0.32	0.59
12	Sulfate B Effluent	199.7	NA	NA	126.0	325.7	NA	NA	1.5	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	8.2	0.00	8.2	NA	NA	NA	NA	NA	NA	10	1.06	0.20	0.20	0.00
13	Calcite B Effluent	199.7	NA	NA	68.8	199.7	NA	NA	0.8	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	787.7	NA	NA	NA	NA	NA	NA	NA	15.6	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	149.7	NA	NA	0*	NA	NA	NA	0.0	NA	NA	NA	NA	NA	NA

Mine Water Treatment Trains Flow and Load Detail
Year 7 P90 Annual Average Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	221.0	2.9E-02	1.9E+02	3.5E-01	3.1E-02	1.5E+03	7.7E-02	3.8E+01	7.1E+00	2.3E-02	2.0E+01	2.0E+00	4.7E+02	6.5E+02	2.4E+01	2.4E+02	5.1E+01	1.3E-01	8.1E-01	1.3E-01	8.8E+03	2.4E-03	5.1E-02	8.2E+00	5.0
2	High Conc EQ Effluent to HDS A	110.5	2.9E-02	1.9E+02	3.5E-01	3.1E-02	1.5E+03	7.7E-02	3.8E+01	7.1E+00	2.3E-02	2.0E+01	2.0E+00	4.7E+02	6.5E+02	2.4E+01	2.4E+02	5.1E+01	1.3E-01	8.1E-01	1.3E-01	8.8E+03	2.4E-03	5.1E-02	8.2E+00	5.0
3	High Conc EQ Effluent to HDS B	110.5	2.9E-02	1.9E+02	3.5E-01	3.1E-02	1.5E+03	7.7E-02	3.8E+01	7.1E+00	2.3E-02	2.0E+01	2.0E+00	4.7E+02	6.5E+02	2.4E+01	2.4E+02	5.1E+01	1.3E-01	8.1E-01	1.3E-01	8.8E+03	2.4E-03	5.1E-02	8.2E+00	5.0
4	Combined HDS A Influent	238.3	1.8E-02	9.0E+01	3.3E-01	1.9E-02	1.8E+03	5.7E-02	4.5E+01	4.0E+00	8.8E-02	1.5E+01	7.3E+00	2.2E+02	1.0E+03	1.3E+01	1.0E+03	3.4E+01	8.6E-02	5.2E-01	1.3E-01	1.1E+04	1.4E-02	7.3E-02	6.2E+00	6.5
5	Sulfate A Influent	238.3	2.9E-03	8.9E+01	7.1E-06	8.3E-03	4.1E+02	8.5E-04	4.4E+01	6.6E-04	6.3E-02	4.2E-03	7.1E+00	1.0E-03	6.9E+02	1.3E-01	1.0E+03	2.6E-03	4.1E-05	5.1E-01	9.0E-02	6.7E+03	1.4E-02	4.5E-07	6.7E-01	10.6
6	Sulfate A Effluent	238.3	2.9E-03	8.9E-02	7.1E-06	8.3E-03	5.2E+02	8.5E-04	4.4E+01	6.7E-08	6.3E-02	4.2E-03	2.9E+00	1.0E-03	1.0E+00	1.3E-01	1.0E+03	1.2E-06	4.1E-05	2.5E-02	4.5E-02	3.4E+03	1.4E-02	4.5E-07	6.7E-01	12.1
7	Calcite A Effluent	238.3	3.0E-03	8.9E-02	7.2E-06	8.4E-03	1.1E+00	8.6E-04	4.4E+01	6.8E-08	6.4E-02	4.2E-03	2.9E+00	1.1E-03	1.0E+00	1.3E-01	1.0E+03	1.2E-06	4.1E-05	2.6E-02	4.5E-02	3.5E+03	1.4E-02	4.5E-07	6.7E-01	10.2
8	Calcite A Effluent to Final Effluent	95.3	3.0E-03	8.9E-02	7.2E-06	8.4E-03	1.1E+00	8.6E-04	4.4E+01	6.8E-08	6.4E-02	4.2E-03	2.9E+00	1.1E-03	1.0E+00	1.3E-01	1.0E+03	1.2E-06	4.1E-05	2.6E-02	4.5E-02	3.5E+03	1.4E-02	4.5E-07	6.7E-01	6.4
9	Calcite A Effluent to VSEP B	143.0	3.0E-03	8.9E-02	7.2E-06	8.4E-03	1.1E+00	8.6E-04	4.4E+01	6.8E-08	6.4E-02	4.2E-03	2.9E+00	1.1E-03	1.0E+00	1.3E-01	1.0E+03	1.2E-06	4.1E-05	2.6E-02	4.5E-02	3.5E+03	1.4E-02	4.5E-07	6.7E-01	6.4
10	Combined HDS B Influent	238.3	1.8E-02	9.0E+01	3.3E-01	1.9E-02	1.8E+03	5.7E-02	4.5E+01	4.0E+00	8.8E-02	1.5E+01	7.3E+00	2.2E+02	1.0E+03	1.3E+01	1.0E+03	3.4E+01	8.6E-02	5.2E-01	1.3E-01	1.1E+04	1.4E-02	7.3E-02	6.2E+00	6.5
11	Sulfate B Influent	238.3	2.9E-03	8.9E+01	7.1E-06	8.3E-03	4.1E+02	8.5E-04	4.4E+01	6.6E-04	6.3E-02	4.2E-03	7.1E+00	1.0E-03	6.9E+02	1.3E-01	1.0E+03	2.6E-03	4.1E-05	5.1E-01	9.0E-02	6.7E+03	1.4E-02	4.5E-07	6.7E-01	10.6
12	Sulfate B Effluent	238.3	2.9E-03	8.9E-02	7.1E-06	8.3E-03	5.2E+02	8.5E-04	4.4E+01	6.7E-08	6.3E-02	4.2E-03	2.9E+00	1.0E-03	1.0E+00	1.3E-01	1.0E+03	1.2E-06	4.1E-05	2.5E-02	4.5E-02	3.4E+03	1.4E-02	4.5E-07	6.7E-01	12.1
13	Calcite B Effluent	238.3	3.0E-03	8.9E-02	7.2E-06	8.4E-03	1.1E+00	8.6E-04	4.4E+01	6.8E-08	6.4E-02	4.2E-03	2.9E+00	1.1E-03	1.0E+00	1.3E-01	1.0E+03	1.2E-06	4.1E-05	2.6E-02	4.5E-02	3.5E+03	1.4E-02	4.5E-07	6.7E-01	10.2
14	Calcite B Effluent to Final Effluent	95.3	3.0E-03	8.9E-02	7.2E-06	8.4E-03	1.1E+00	8.6E-04	4.4E+01	6.8E-08	6.4E-02	4.2E-03	2.9E+00	1.1E-03	1.0E+00	1.3E-01	1.0E+03	1.2E-06	4.1E-05	2.6E-02	4.5E-02	3.5E+03	1.4E-02	4.5E-07	6.7E-01	6.4
15	Calcite B Effluent to VSEP B	143.0	3.0E-03	8.9E-02	7.2E-06	8.4E-03	1.1E+00	8.6E-04	4.4E+01	6.8E-08	6.4E-02	4.2E-03	2.9E+00	1.1E-03	1.0E+00	1.3E-01	1.0E+03	1.2E-06	4.1E-05	2.6E-02	4.5E-02	3.5E+03	1.4E-02	4.5E-07	6.7E-01	6.4
16	VSEP B Permeate to Final Effluent	328.0	1.2E-04	5.6E-04	4.4E-06	6.7E-03	9.6E-02	2.2E-05	4.3E+01	4.2E-09	6.8E-03	1.8E-04	1.7E+00	4.2E-05	1.5E-01	3.3E-02	4.5E+02	1.8E-07	9.2E-07	1.4E-03	2.8E-03	3.0E+02	7.6E-04	6.0E-08	4.3E-02	6.8
17	VSEP B Concentrate	82.0	1.5E-02	4.5E-01	1.8E-05	1.5E-02	5.1E+00	4.3E-03	4.9E+01	3.3E-07	3.0E-01	2.0E-02	7.6E+00	5.2E-03	4.6E+00	5.3E-01	3.3E+03	5.2E-06	2.0E-04	1.2E-01	2.2E-01	1.6E+04	6.9E-02	2.0E-06	3.3E+00	5.6
18	VSEP B Concentrate to HDS B	41.0	1.5E-02	4.5E-01	1.8E-05	1.5E-02	5.1E+00	4.3E-03	4.9E+01	3.3E-07	3.0E-01	2.0E-02	7.6E+00	5.2E-03	4.6E+00	5.3E-01	3.3E+03	5.2E-06	2.0E-04	1.2E-01	2.2E-01	1.6E+04	6.9E-02	2.0E-06	3.3E+00	5.6
19	VSEP B Concentrate to HDS A	41.0	1.5E-02	4.5E-01	1.8E-05	1.5E-02	5.1E+00	4.3E-03	4.9E+01	3.3E-07	3.0E-01	2.0E-02	7.6E+00	5.2E-03	4.6E+00	5.3E-01	3.3E+03	5.2E-06	2.0E-04	1.2E-01	2.2E-01	1.6E+04	6.9E-02	2.0E-06	3.3E+00	5.6
20	Low Conc EQ Effluent	1396.9	1.9E-04	1.7E-03	6.9E-02	3.9E-04	2.8E+02	6.1E-03	3.2E+01	2.3E-01	4.6E-03	1.8E+00	1.0E+00	1.9E-01	1.2E+02	4.0E-01	1.0E+02	3.4E+00	6.4E-03	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	6.2E-01	7.0
21	GSF Backwash	69.8	1.9E-04	1.7E-03	1.1E+00	3.9E-04	2.8E+02	1.1E-01	3.1E+01	4.6E+00	4.6E-03	3.5E+01	9.9E-01	3.7E+00	1.2E+02	7.7E+00	1.0E+02	6.2E+01	1.2E-01	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	1.2E+01	7.0
22	GSF Backwash Solids	34.9	1.9E-04	1.7E-03	1.9E+00	3.9E-04	2.8E+02	2.1E-01	3.1E+01	8.9E+00	4.6E-03	6.6E+01	9.9E-01	7.1E+00	1.2E+02	1.5E+01	1.0E+02	1.1E+02	2.2E-01	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	2.3E+01	7.0
23	GSF Backwash Decant	34.9	1.9E-04	1.7E-03	3.5E-01	3.9E-04	2.8E+02	1.7E-02	3.1E+01	3.0E-01	4.6E-03	3.8E+00	9.9E-01	2.2E-01	1.2E+02	7.7E-01	1.0E+02	1.1E+01	1.8E-02	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	8.7E-01	7.0
24	GSF Permeate/NF Feed	1327.1	1.9E-04	1.7E-03	2.1E-02	3.9E-04	2.8E+02	6.7E-04	3.2E+01	3.7E-03	4.6E-03	1.1E-01	1.0E+00	2.0E-03	1.2E+02	2.1E-02	1.0E+02	4.9E-01	7.1E-04	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	1.4E-02	7.0
25	NF Permeate	1061.7	1.5E-04	1.2E-04	2.6E-04	2.8E-05	3.6E+01	4.7E-05	3.6E+01	1.3E-04	3.3E-04	8.8E-03	8.0E-01	0.0E+00	8.3E+00	5.9E-04	6.5E+01	1.8E-02	2.7E-05	2.5E-03	3.6E-04	2.5E+01	1.3E-05	7.1E-04	2.9E-04	6.3
26	NF Concentrate to VSEP A	265.4	3.5E-04	8.1E-03	1.0E-01	1.9E-03	1.3E+03	3.2E-03	1.5E+01	1.8E-02	2.2E-02	5.4E-01	1.8E+00	9.9E-03	5.9E+02	1.1E-01	2.4E+02	2.4E+00	3.5E-03	1.7E-01	4.4E-02	3.0E+03	8.6E-04	4.7E-02	7.1E-02	8.8
27	VSEP A Permeate to Final Effluent	212.3	1.4E-05	5.1E-05	6.4E-02	1.5E-03	1.1E+02	8.3E-05	1.5E+01	1.1E-03	2.3E-03	2.3E-02	1.1E+00	3.9E-04	8.7E+01	2.7E-02	1.1E+02	3.8E-01	7.7E-05	8.9E-03	2.7E-03	2.6E+02	4.6E-05	6.3E-03	4.5E-03	5.7
28	VSEP A Concentrate	53.1	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.2E+03	1.6E-02	1.7E+01	8.9E-02	1.0E-01	2.7E+00	4.8E+00	5.0E-02	2.7E+03	4.4E-01	8.0E+02	1.1E+01	1.8E-02	8.3E-01	2.2E-01	1.4E+04	4.3E-03	2.2E-01	3.5E-01	8.8
29	VSEP A Concentrate to HDS B	26.5	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.2E+03	1.6E-02	1.7E+01	8.9E-02	1.0E-01	2.7E+00	4.8E+00	5.0E-02	2.7E+03	4.4E-01	8.0E+02	1.1E+01	1.8E-02	8.3E-01	2.2E-01	1.4E+04	4.3E-03	2.2E-01	3.5E-01	8.8
30	VSEP A Concentrate to HDS A	26.5	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.2E+03	1.6E-02	1.7E+01	8.9E-02	1.0E-01	2.7E+00	4.8E+00	5.0E-02	2.7E+03	4.4E-01	8.0E+02	1.1E+01	1.8E-02	8.3E-01	2.2E-01	1.4E+04	4.3E-03	2.2E-01	3.5E-01	8.8
31	HDS A Underflow Sludge	9.5	3.6E-01	0.0E+00	8.3E+00	2.6E-01	8.2E+04	1.4E+00	7.2E-01	9.8E+01	5.9E-01	3.6E+02	4.2E-02	5.4E+03	7.9E+03	3.2E+02	0.0E+00	8.3E+02	2.1E+00	0.0E+00	9.8E-01	1.1E+05	0.0E+00	1.8E+00	1.4E+02	10.6
32	Sulfate A Underflow Sludge	18.9	0.0E+00	1.1E+03	0.0E+00	0.0E+00	2.4E+04	0.0E+00	3.6E-01	8.3E-03	0.0E+00	7.4E-05	5.4E+01	0.0E+00	8.7E+03	0.0E+00	4.0E+00	3.3E-02	0.0E+00	6.1E+00	5.7E-01	4.2E+04	0.0E+00	0.0E+00	0.0E+00	12.1
33	Calcite A Underflow Sludge	6.5	1.5E-07	3.7E-06	0.0E+00	5.4E-07	1.9E+04	0.0E+00	7.6E-09	3.3E-13	0.0E+00	1.2E-04	0.0E+00	0.0E+00	5.1E-05	3.5E-09	2.7E-05	0.0E+00	0.0E+00	6.8E-10	1.8E-06	6.9E-02	0.0E+00	0.0E+00	0.0E+00	10.2
34	HDS B Underflow Sludge	9.5	3.6E-01	0.0E+00	8.3E+00	2.6E-01	8.2E+04	1.4E+00	7.2E-01	9.8E+01	5.9E-01	3.6E+02	4.2E-02	5.4E+03	7.9E+03	3.2E+02	0.0E+00	8.3E+02	2.1E+00	0.0E+00	9.8E-01	1.1E+05	0.0E+00	1.8E+00	1.4E+02	10.6
35	Sulfate B Underflow Sludge	18.9	0.0E+00	1.1E+03	0.0E+00	0.0E+00	2.4E+04	0.0E+00	3.6E-01	8.3E-03	0.0E+00	7.4E-05	5.4E+01	0.0E+00	8.7E+03	0.0E+00	4.0E+00	3.3E-02	0.0E+00	6.1E+00	5.7E-01	4.2E+04	0.0E+00	0.0E+00	0.0E+00	12.1
36	Calcite B Underflow Sludge	6.5	1.5E-07	3.7E-06	0.0E+00	5.4E-07	1.9E+04	0.0E+00	7.6E-09	3.3E-13	0.0E+00	1.2E-04	0.0E+00	0.0E+00	5.1E-05	3.5E-09	2.7E-05	0.0E+00	0.0E+00	6.8E-10	1.8E-06	6.9E-02	0.0E+00	0.0E+00	0.0E+00	10.2
37	Plant Site VSEP Concentrate	85.7	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
38	Plant Site Concentrate to HDS A	42.9	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
39	Plant Site Concentrate to HDS B	42.9	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
40	Final Effluent to CPS	1668.7	2.4E-04	3.8E-03	8.3E-03	1.9E-03	3.7E+01	7.9E-05	3.5E+01	2.2E-04	4.4E-03	9.0E-03	1.1E+00	1.0E-04	1.6E+01	1.5E-02	1.8E+02	5.9E-02	2.9E-05	4.0E-03	2.9E-03	2.4E+02	7.3E-04	1.2E-03	3.6E-02	6.1

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	238.3	NA	NA	NA	253.0	3.9	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	24.1	14.62	9.5	NA	NA	NA	NA	NA	NA	25	1.18	1.78	0.70	1.08
5	Sulfate A Influent	238.3	NA	NA	NA	264.8	3.0	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	45.4	26.48	18.9	NA	NA	NA	NA	NA	NA	10	1.05	1.15	0.45	0.70
6	Sulfate A Effluent	238.3	NA	NA	91.7	330.0	NA	NA	1.1	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	6.5	0.00	6.5	NA	NA	NA	NA	NA	NA	10	1.06	0.16	0.16	0.00
7	Calcite A Effluent	238.3	NA	NA	87.1	325.4	NA	NA	1.0	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	238.3	NA	NA	NA	253.0	3.9	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	24.1	14.62	9.5	NA	NA	NA	NA	NA	NA	25	1.18	1.78	0.70	1.08
11	Sulfate B Influent	238.3	NA	NA		264.8	3.0	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	45.4	26.48	18.9	NA	NA	NA	NA	NA	NA	10	1.05	1.15	0.45	0.70
12	Sulfate B Effluent	238.3	NA	NA	91.7	330.0	NA	NA	1.1	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	6.5	0.00	6.5	NA	NA	NA	NA	NA	NA	10	1.06	0.16	0.16	0.00
13	Calcite B Effluent	238.3	NA	NA	87.1	238.3	NA	NA	1.0	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1396.9	NA	NA	NA	NA	NA	NA	NA	27.6	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	265.4	NA	NA	366.7*	NA	NA	NA	4.4	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 7 P90 Peak Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	339.0	2.9E-02	1.9E+02	3.5E-01	3.1E-02	1.5E+03	7.7E-02	3.8E+01	7.1E+00	2.3E-02	2.0E+01	2.0E+00	4.7E+02	6.5E+02	2.4E+01	2.4E+02	5.1E+01	1.3E-01	8.1E-01	1.3E-01	8.8E+03	2.4E-03	5.1E-02	8.2E+00	5.0
2	High Conc EQ Effluent to HDS A	169.5	2.9E-02	1.9E+02	3.5E-01	3.1E-02	1.5E+03	7.7E-02	3.8E+01	7.1E+00	2.3E-02	2.0E+01	2.0E+00	4.7E+02	6.5E+02	2.4E+01	2.4E+02	5.1E+01	1.3E-01	8.1E-01	1.3E-01	8.8E+03	2.4E-03	5.1E-02	8.2E+00	5.0
3	High Conc EQ Effluent to HDS B	169.5	2.9E-02	1.9E+02	3.5E-01	3.1E-02	1.5E+03	7.7E-02	3.8E+01	7.1E+00	2.3E-02	2.0E+01	2.0E+00	4.7E+02	6.5E+02	2.4E+01	2.4E+02	5.1E+01	1.3E-01	8.1E-01	1.3E-01	8.8E+03	2.4E-03	5.1E-02	8.2E+00	5.0
4	Combined HDS A Influent	306.6	1.8E-02	1.1E+02	3.8E-01	2.1E-02	1.9E+03	6.4E-02	4.2E+01	4.7E+00	6.0E-02	1.7E+01	5.8E+00	2.6E+02	1.0E+03	1.5E+01	6.6E+02	3.9E+01	9.7E-02	5.8E-01	1.3E-01	9.6E+03	5.4E-03	7.4E-02	6.9E+00	7.0
5	Sulfate A Influent	306.6	1.8E-03	1.1E+02	4.7E-06	1.2E-02	4.6E+02	5.1E-04	4.1E+01	3.8E-04	4.5E-02	4.5E-03	5.7E+00	1.3E-03	3.8E+02	1.5E-01	6.5E+02	1.6E-03	6.1E-05	5.7E-01	8.9E-02	4.3E+03	5.3E-03	2.9E-07	7.4E-01	10.6
6	Sulfate A Effluent	306.6	1.8E-03	1.1E-01	4.7E-06	1.2E-02	1.0E+03	5.1E-04	4.1E+01	1.1E-07	4.5E-02	4.5E-03	1.9E+00	1.3E-03	2.7E-01	1.5E-01	6.5E+02	3.3E-06	6.1E-05	2.9E-02	4.5E-02	1.8E+03	5.3E-03	2.9E-07	7.4E-01	12.5
7	Calcite A Effluent	306.6	1.8E-03	1.1E-01	4.7E-06	1.2E-02	4.3E-01	5.2E-04	4.1E+01	1.1E-07	4.5E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.6E+02	3.3E-06	6.2E-05	2.9E-02	4.5E-02	1.8E+03	5.4E-03	3.0E-07	7.5E-01	10.6
8	Calcite A Effluent to Final Effluent	122.6	1.8E-03	1.1E-01	4.7E-06	1.2E-02	4.3E-01	5.2E-04	4.1E+01	1.1E-07	4.5E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.5E+02	3.3E-06	6.2E-05	2.9E-02	4.5E-02	1.8E+03	5.4E-03	2.9E-07	7.4E-01	7.1
9	Calcite A Effluent to VSEP B	184.0	1.8E-03	1.1E-01	4.7E-06	1.2E-02	4.3E-01	5.2E-04	4.1E+01	1.1E-07	4.5E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.5E+02	3.3E-06	6.2E-05	2.9E-02	4.5E-02	1.8E+03	5.4E-03	2.9E-07	7.4E-01	7.1
10	Combined HDS B Influent	306.6	1.8E-02	1.1E+02	3.8E-01	2.1E-02	1.9E+03	6.4E-02	4.2E+01	4.7E+00	6.0E-02	1.7E+01	5.8E+00	2.6E+02	1.0E+03	1.5E+01	6.6E+02	3.9E+01	9.7E-02	5.8E-01	1.3E-01	9.6E+03	5.4E-03	7.4E-02	6.9E+00	7.0
11	Sulfate B Influent	306.6	1.8E-03	1.1E+02	4.7E-06	1.2E-02	4.6E+02	5.1E-04	4.1E+01	3.8E-04	4.5E-02	4.5E-03	5.7E+00	1.3E-03	3.8E+02	1.5E-01	6.5E+02	1.6E-03	6.1E-05	5.7E-01	8.9E-02	4.3E+03	5.3E-03	2.9E-07	7.4E-01	10.6
12	Sulfate B Effluent	306.6	1.8E-03	1.1E-01	4.7E-06	1.2E-02	1.0E+03	5.1E-04	4.1E+01	1.1E-07	4.5E-02	4.5E-03	1.9E+00	1.3E-03	2.7E-01	1.5E-01	6.5E+02	3.3E-06	6.1E-05	2.9E-02	4.5E-02	1.8E+03	5.3E-03	2.9E-07	7.4E-01	12.5
13	Calcite B Effluent	306.6	1.8E-03	1.1E-01	4.7E-06	1.2E-02	4.3E-01	5.2E-04	4.1E+01	1.1E-07	4.5E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.6E+02	3.3E-06	6.2E-05	2.9E-02	4.5E-02	1.8E+03	5.4E-03	3.0E-07	7.5E-01	10.6
14	Calcite B Effluent to Final Effluent	122.6	1.8E-03	1.1E-01	4.7E-06	1.2E-02	4.3E-01	5.2E-04	4.1E+01	1.1E-07	4.5E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.5E+02	3.3E-06	6.2E-05	2.9E-02	4.5E-02	1.8E+03	5.4E-03	2.9E-07	7.4E-01	7.1
15	Calcite B Effluent to VSEP B	184.0	1.8E-03	1.1E-01	4.7E-06	1.2E-02	4.3E-01	5.2E-04	4.1E+01	1.1E-07	4.5E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.5E+02	3.3E-06	6.2E-05	2.9E-02	4.5E-02	1.8E+03	5.4E-03	2.9E-07	7.4E-01	7.1
16	VSEP B Permeate to Final Effluent	269.8	7.2E-05	6.6E-04	2.9E-06	9.4E-03	3.8E-02	1.4E-05	4.0E+01	6.7E-09	4.8E-03	1.9E-04	1.2E+00	5.1E-05	4.0E-02	3.8E-02	2.9E+02	5.1E-07	1.4E-06	1.5E-03	2.7E-03	1.5E+02	2.9E-04	3.9E-08	4.7E-02	7.1
17	VSEP B Concentrate	67.5	8.9E-03	5.3E-01	1.2E-05	2.1E-02	2.0E+00	2.6E-03	4.5E+01	5.3E-07	2.1E-01	2.2E-02	5.2E+00	6.2E-03	1.2E+00	6.1E-01	2.1E+03	1.5E-05	3.1E-04	1.4E-01	2.2E-01	8.3E+03	2.6E-02	1.3E-06	3.6E+00	7.0
18	VSEP B Concentrate to HDS B	33.7	8.9E-03	5.3E-01	1.2E-05	2.1E-02	2.0E+00	2.6E-03	4.5E+01	5.3E-07	2.1E-01	2.2E-02	5.2E+00	6.2E-03	1.2E+00	6.1E-01	2.1E+03	1.5E-05	3.1E-04	1.4E-01	2.2E-01	8.3E+03	2.6E-02	1.3E-06	3.6E+00	7.0
19	VSEP B Concentrate to HDS A	33.7	8.9E-03	5.3E-01	1.2E-05	2.1E-02	2.0E+00	2.6E-03	4.5E+01	5.3E-07	2.1E-01	2.2E-02	5.2E+00	6.2E-03	1.2E+00	6.1E-01	2.1E+03	1.5E-05	3.1E-04	1.4E-01	2.2E-01	8.3E+03	2.6E-02	1.3E-06	3.6E+00	7.0
20	Low Conc EQ Effluent	1922.1	1.9E-04	1.7E-03	6.9E-02	3.9E-04	2.8E+02	6.1E-03	3.2E+01	2.3E-01	4.6E-03	1.8E+00	1.0E+00	1.9E-01	1.2E+02	4.0E-01	1.0E+02	3.4E+00	6.4E-03	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	6.2E-01	7.0
21	GSF Backwash	96.1	1.9E-04	1.7E-03	1.1E+00	3.9E-04	2.8E+02	1.1E-01	3.1E+01	4.6E+00	4.6E-03	3.5E+01	9.9E-01	3.7E+00	1.2E+02	7.7E+00	1.0E+02	6.2E+01	1.2E-01	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	1.2E+01	7.0
22	GSF Backwash Solids	48.1	1.9E-04	1.7E-03	1.9E+00	3.9E-04	2.8E+02	2.1E-01	3.1E+01	8.9E+00	4.6E-03	6.6E+01	9.9E-01	7.1E+00	1.2E+02	1.5E+01	1.0E+02	1.1E+02	2.2E-01	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	2.3E+01	7.0
23	GSF Backwash Decant	48.1	1.9E-04	1.7E-03	3.5E-01	3.9E-04	2.8E+02	1.7E-02	3.2E+01	3.0E-01	4.6E-03	3.8E+00	9.9E-01	2.2E-01	1.2E+02	7.7E-01	1.0E+02	1.1E+01	1.8E-02	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	8.7E-01	7.0
24	GSF Permeate/NF Feed	1825.9	1.9E-04	1.7E-03	2.1E-02	3.9E-04	2.8E+02	6.7E-04	3.2E+01	3.7E-03	4.6E-03	1.1E-01	1.0E+00	2.0E-03	1.2E+02	2.1E-02	1.0E+02	4.9E-01	7.1E-04	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	1.4E-02	7.0
25	NF Permeate	1460.8	1.5E-04	1.2E-04	2.6E-04	2.8E-05	3.6E+01	4.7E-05	3.6E+01	1.3E-04	3.3E-04	8.8E-03	8.0E-01	3.8E-20	8.3E+00	5.9E-04	6.5E+01	1.8E-02	2.7E-05	2.5E-03	3.6E-04	2.5E+01	1.3E-05	7.1E-04	2.9E-04	6.0
26	NF Concentrate to VSEP A	365.2	3.5E-04	8.1E-03	1.0E-01	1.9E-03	1.3E+03	3.2E-03	1.5E+01	1.8E-02	2.2E-02	5.4E-01	1.8E+00	9.9E-03	5.9E+02	1.1E-01	2.4E+02	2.4E+00	3.5E-03	1.7E-01	4.4E-02	3.0E+03	8.6E-04	4.7E-02	7.1E-02	9.2
27	VSEP A Permeate to Final Effluent	292.2	1.4E-05	5.0E-05	6.4E-02	1.5E-03	1.1E+02	8.3E-05	1.5E+01	1.1E-03	2.3E-03	2.3E-02	1.1E+00	3.9E-04	8.6E+01	2.7E-02	1.1E+02	3.7E-01	7.7E-05	8.9E-03	2.7E-03	2.6E+02	4.6E-05	6.3E-03	4.5E-03	5.5
28	VSEP A Concentrate	73.0	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.2E+03	1.6E-02	1.7E+01	8.9E-02	1.0E-01	2.7E+00	4.9E+00	5.0E-02	2.7E+03	4.4E-01	8.0E+02	1.1E+01	1.8E-02	8.3E-01	2.2E-01	1.5E+04	4.3E-03	2.2E-01	3.5E-01	9.6
29	VSEP A Concentrate to HDS B	36.5	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.2E+03	1.6E-02	1.7E+01	8.9E-02	1.0E-01	2.7E+00	4.9E+00	5.0E-02	2.7E+03	4.4E-01	8.0E+02	1.1E+01	1.8E-02	8.3E-01	2.2E-01	1.5E+04	4.3E-03	2.2E-01	3.5E-01	9.6
30	VSEP A Concentrate to HDS A	36.5	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.2E+03	1.6E-02	1.7E+01	8.9E-02	1.0E-01	2.7E+00	4.9E+00	5.0E-02	2.7E+03	4.4E-01	8.0E+02	1.1E+01	1.8E-02	8.3E-01	2.2E-01	1.5E+04	4.3E-03	2.2E-01	3.5E-01	9.6
31	HDS A Underflow Sludge	14.2	3.5E-01	0.0E+00	8.0E+00	2.0E-01	7.6E+04	1.4E+00	5.8E-01	9.9E+01	3.0E-01	3.5E+02	2.8E-02	5.5E+03	1.3E+04	3.2E+02	0.0E+00	8.3E+02	2.1E+00	2.8E-06	8.3E-01	1.1E+05	0.0E+00	1.6E+00	1.3E+02	10.6
32	Sulfate A Underflow Sludge	20.8	4.0E-08	1.6E+03	0.0E+00	0.0E+00	3.1E+04	0.0E+00	3.9E-01	5.6E-03	0.0E+00	9.3E-05	5.5E+01	0.0E+00	5.5E+03	0.0E+00	0.0E+00	2.4E-02	0.0E+00	8.0E+00	6.5E-01	3.7E+04	0.0E+00	0.0E+00	0.0E+00	12.5
33	Calcite A Underflow Sludge	16.3	8.4E-08	4.9E-06	0.0E+00	0.0E+00	1.9E+04	2.4E-08	0.0E+00	0.0E+00	0.0E+00	6.5E-05	0.0E+00	0.0E+00	0.0E+00	4.6E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.6
34	HDS B Underflow Sludge	14.2	3.5E-01	0.0E+00	8.0E+00	2.0E-01	7.6E+04	1.4E+00	5.8E-01	9.9E+01	3.0E-01	3.5E+02	2.8E-02	5.5E+03	1.3E+04	3.2E+02	0.0E+00	8.3E+02	2.1E+00	2.8E-06	8.3E-01	1.1E+05	0.0E+00	1.6E+00	1.3E+02	10.6
35	Sulfate B Underflow Sludge	20.8	4.0E-08	1.6E+03	0.0E+00	0.0E+00	3.1E+04	0.0E+00	3.9E-01	5.6E-03	0.0E+00	9.3E-05	5.5E+01	0.0E+00	5.5E+03	0.0E+00	0.0E+00	2.4E-02	0.0E+00	8.0E+00	6.5E-01	3.7E+04	0.0E+00	0.0E+00	0.0E+00	12.5
36	Calcite B Underflow Sludge	16.3	8.4E-08	4.9E-06	0.0E+00	0.0E+00	1.9E+04	2.4E-08	0.0E+00	0.0E+00	0.0E+00	6.5E-05	0.0E+00	0.0E+00	0.0E+00	4.6E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.0E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.6
37	Plant Site VSEP Concentrate	85.7	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
38	Plant Site Concentrate to HDS A	42.9	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
39	Plant Site Concentrate to HDS B	42.9	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
40	Final Effluent to CPS	2298.7	3.2E-04	1.3E-02	8.3E-03	2.7E-03	3.7E+01	1.0E-04	3.4E+01	2.2E-04	6.5E-03	9.0E-03	1.0E+00	2.1E-04	1.6E+01	2.6E-02	1.7E+02	5.9E-02	3.5E-05	6.4E-03	6.3E-03	2.8E+02	6.9E-04	1.2E-03	9.5E-02	6.0

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	306.6	NA	NA	NA	322.4	5.5	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	30.0	15.79	14.2	NA	NA	NA	NA	NA	NA	25	1.18	2.21	1.04	1.16
5	Sulfate A Influent	306.6	NA	NA	NA	340.7	5.1	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	54.9	34.07	20.8	NA	NA	NA	NA	NA	NA	10	1.05	1.40	0.50	0.90
6	Sulfate A Effluent	306.6	NA	NA	229.2	535.8	NA	NA	2.8	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	16.3	0.00	16.3	NA	NA	NA	NA	NA	NA	10	1.06	0.39	0.39	0.00
7	Calcite A Effluent	306.6	NA	NA	96.3	402.9	NA	NA	1.2	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	306.6	NA	NA	NA	322.4	5.5	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	30.0	15.79	14.2	NA	NA	NA	NA	NA	NA	25	1.18	2.21	1.04	1.16
11	Sulfate B Influent	306.6	NA	NA		340.7	5.1	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	54.9	34.07	20.8	NA	NA	NA	NA	NA	NA	10	1.05	1.40	0.50	0.90
12	Sulfate B Effluent	306.6	NA	NA	229.2	535.8	NA	NA	2.8	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	16.3	0.00	16.3	NA	NA	NA	NA	NA	NA	10	1.06	0.39	0.39	0.00
13	Calcite B Effluent	306.6	NA	NA	96.3	306.6	NA	NA	1.2	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1922.1	NA	NA	NA	NA	NA	NA	NA	38.0	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	365.2	NA	NA	504.2*	NA	NA	NA	6.1	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 7 P90 Summer Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	339.0	2.9E-02	1.9E+02	3.5E-01	3.1E-02	1.5E+03	7.7E-02	3.8E+01	7.1E+00	2.3E-02	2.0E+01	2.0E+00	4.7E+02	6.5E+02	2.4E+01	2.4E+02	5.1E+01	1.3E-01	8.1E-01	1.3E-01	8.8E+03	2.4E-03	5.1E-02	8.2E+00	5.0
2	High Conc EQ Effluent to HDS A	169.5	2.9E-02	1.9E+02	3.5E-01	3.1E-02	1.5E+03	7.7E-02	3.8E+01	7.1E+00	2.3E-02	2.0E+01	2.0E+00	4.7E+02	6.5E+02	2.4E+01	2.4E+02	5.1E+01	1.3E-01	8.1E-01	1.3E-01	8.8E+03	2.4E-03	5.1E-02	8.2E+00	5.0
3	High Conc EQ Effluent to HDS B	169.5	2.9E-02	1.9E+02	3.5E-01	3.1E-02	1.5E+03	7.7E-02	3.8E+01	7.1E+00	2.3E-02	2.0E+01	2.0E+00	4.7E+02	6.5E+02	2.4E+01	2.4E+02	5.1E+01	1.3E-01	8.1E-01	1.3E-01	8.8E+03	2.4E-03	5.1E-02	8.2E+00	5.0
4	Combined HDS A Influent	305.2	1.9E-02	1.1E+02	3.7E-01	2.2E-02	1.8E+03	6.3E-02	4.2E+01	4.6E+00	6.2E-02	1.6E+01	5.8E+00	2.6E+02	9.9E+02	1.5E+01	6.8E+02	3.8E+01	9.7E-02	5.8E-01	1.3E-01	9.6E+03	5.8E-03	7.3E-02	6.8E+00	6.9
5	Sulfate A Influent	305.2	1.8E-03	1.1E+02	4.6E-06	1.2E-02	4.6E+02	5.1E-04	4.1E+01	3.9E-04	4.7E-02	4.5E-03	5.7E+00	1.3E-03	3.8E+02	1.5E-01	6.7E+02	1.6E-03	6.1E-05	5.7E-01	9.0E-02	4.4E+03	5.7E-03	2.9E-07	7.4E-01	10.6
6	Sulfate A Effluent	305.2	1.8E-03	1.1E-01	4.6E-06	1.2E-02	1.0E+03	5.1E-04	4.1E+01	1.1E-07	4.7E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.7E+02	3.3E-06	6.1E-05	2.9E-02	4.5E-02	1.8E+03	5.7E-03	2.9E-07	7.4E-01	12.5
7	Calcite A Effluent	305.2	1.8E-03	1.1E-01	4.7E-06	1.2E-02	4.2E-01	5.1E-04	4.2E+01	1.1E-07	4.7E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.8E+02	3.4E-06	6.1E-05	2.9E-02	4.5E-02	1.8E+03	5.8E-03	2.9E-07	7.5E-01	10.7
8	Calcite A Effluent to Final Effluent	122.1	1.8E-03	1.1E-01	4.7E-06	1.2E-02	4.2E-01	5.1E-04	4.2E+01	1.1E-07	4.7E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.7E+02	3.4E-06	6.1E-05	2.9E-02	4.5E-02	1.8E+03	5.8E-03	2.9E-07	7.5E-01	7.2
9	Calcite A Effluent to VSEP B	183.1	1.8E-03	1.1E-01	4.7E-06	1.2E-02	4.2E-01	5.1E-04	4.2E+01	1.1E-07	4.7E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.7E+02	3.4E-06	6.1E-05	2.9E-02	4.5E-02	1.8E+03	5.8E-03	2.9E-07	7.5E-01	7.2
10	Combined HDS B Influent	305.2	1.9E-02	1.1E+02	3.7E-01	2.2E-02	1.8E+03	6.3E-02	4.2E+01	4.6E+00	6.2E-02	1.6E+01	5.8E+00	2.6E+02	9.9E+02	1.5E+01	6.8E+02	3.8E+01	9.7E-02	5.8E-01	1.3E-01	9.6E+03	5.8E-03	7.3E-02	6.8E+00	6.9
11	Sulfate B Influent	305.2	1.8E-03	1.1E+02	4.6E-06	1.2E-02	4.6E+02	5.1E-04	4.1E+01	3.9E-04	4.7E-02	4.5E-03	5.7E+00	1.3E-03	3.8E+02	1.5E-01	6.7E+02	1.6E-03	6.1E-05	5.7E-01	9.0E-02	4.4E+03	5.7E-03	2.9E-07	7.4E-01	10.6
12	Sulfate B Effluent	305.2	1.8E-03	1.1E-01	4.6E-06	1.2E-02	1.0E+03	5.1E-04	4.1E+01	1.1E-07	4.7E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.7E+02	3.3E-06	6.1E-05	2.9E-02	4.5E-02	1.8E+03	5.7E-03	2.9E-07	7.4E-01	12.5
13	Calcite B Effluent	305.2	1.8E-03	1.1E-01	4.7E-06	1.2E-02	4.2E-01	5.1E-04	4.2E+01	1.1E-07	4.7E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.8E+02	3.4E-06	6.1E-05	2.9E-02	4.5E-02	1.8E+03	5.8E-03	2.9E-07	7.5E-01	10.7
14	Calcite B Effluent to Final Effluent	122.1	1.8E-03	1.1E-01	4.7E-06	1.2E-02	4.2E-01	5.1E-04	4.2E+01	1.1E-07	4.7E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.7E+02	3.4E-06	6.1E-05	2.9E-02	4.5E-02	1.8E+03	5.8E-03	2.9E-07	7.5E-01	7.2
15	Calcite B Effluent to VSEP B	183.1	1.8E-03	1.1E-01	4.7E-06	1.2E-02	4.2E-01	5.1E-04	4.2E+01	1.1E-07	4.7E-02	4.5E-03	2.0E+00	1.3E-03	2.7E-01	1.5E-01	6.7E+02	3.4E-06	6.1E-05	2.9E-02	4.5E-02	1.8E+03	5.8E-03	2.9E-07	7.5E-01	7.2
16	VSEP B Permeate to Final Effluent	288.1	7.3E-05	6.7E-04	2.9E-06	9.5E-03	3.7E-02	1.3E-05	4.0E+01	6.9E-09	5.0E-03	1.9E-04	1.2E+00	5.1E-05	3.9E-02	3.8E-02	3.0E+02	5.2E-07	1.4E-06	1.5E-03	2.7E-03	1.5E+02	3.1E-04	3.9E-08	4.8E-02	7.2
17	VSEP B Concentrate	72.0	8.9E-03	5.4E-01	1.2E-05	2.2E-02	2.0E+00	2.5E-03	4.6E+01	5.4E-07	2.2E-01	2.2E-02	5.2E+00	6.2E-03	1.2E+00	6.1E-01	2.2E+03	1.5E-05	3.0E-04	1.4E-01	2.2E-01	8.4E+03	2.8E-02	1.3E-06	3.6E+00	7.1
18	VSEP B Concentrate to HDS B	36.0	8.9E-03	5.4E-01	1.2E-05	2.2E-02	2.0E+00	2.5E-03	4.6E+01	5.4E-07	2.2E-01	2.2E-02	5.2E+00	6.2E-03	1.2E+00	6.1E-01	2.2E+03	1.5E-05	3.0E-04	1.4E-01	2.2E-01	8.4E+03	2.8E-02	1.3E-06	3.6E+00	7.1
19	VSEP B Concentrate to HDS A	36.0	8.9E-03	5.4E-01	1.2E-05	2.2E-02	2.0E+00	2.5E-03	4.6E+01	5.4E-07	2.2E-01	2.2E-02	5.2E+00	6.2E-03	1.2E+00	6.1E-01	2.2E+03	1.5E-05	3.0E-04	1.4E-01	2.2E-01	8.4E+03	2.8E-02	1.3E-06	3.6E+00	7.1
20	Low Conc EQ Effluent	1805.1	1.9E-04	1.7E-03	6.9E-02	3.9E-04	2.8E+02	6.1E-03	3.2E+01	2.3E-01	4.6E-03	1.8E+00	1.0E+00	1.9E-01	1.2E+02	4.0E-01	1.0E+02	3.4E+00	6.4E-03	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	6.2E-01	7.0
21	GSF Backwash	45.1	1.9E-04	1.7E-03	1.1E+00	3.9E-04	2.8E+02	1.1E-01	3.2E+01	4.6E+00	4.6E-03	3.5E+01	9.9E-01	3.7E+00	1.2E+02	7.7E+00	1.0E+02	6.2E+01	1.2E-01	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	1.2E+01	7.0
22	GSF Backwash Solids	45.1	1.9E-04	1.7E-03	1.9E+00	3.9E-04	2.8E+02	2.1E-01	3.1E+01	8.9E+00	4.6E-03	6.6E+01	9.9E-01	7.1E+00	1.2E+02	1.5E+01	1.0E+02	1.1E+02	2.2E-01	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	2.3E+01	7.0
23	GSF Backwash Decant	45.1	1.9E-04	1.7E-03	3.5E-01	3.9E-04	2.8E+02	1.7E-02	3.2E+01	3.0E-01	4.6E-03	3.8E+00	9.9E-01	2.2E-01	1.2E+02	7.7E-01	1.0E+02	1.1E+01	1.8E-02	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	8.7E-01	7.0
24	GSF Permeate/NF Feed	1714.9	1.9E-04	1.7E-03	2.1E-02	3.9E-04	2.8E+02	6.7E-04	3.2E+01	3.7E-03	4.6E-03	1.1E-01	1.0E+00	2.0E-03	1.2E+02	2.1E-02	1.0E+02	4.9E-01	7.1E-04	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	1.4E-02	7.0
25	NF Permeate	1371.9	1.5E-04	1.2E-04	2.6E-04	2.8E-05	3.6E+01	4.7E-05	3.6E+01	1.3E-04	3.3E-04	8.8E-03	8.0E-01	4.0E-20	8.3E+00	5.9E-04	6.5E+01	1.8E-02	2.7E-05	2.5E-03	3.6E-04	2.5E+01	1.3E-05	7.1E-04	2.9E-04	6.0
26	NF Concentrate to VSEP A	343.0	3.5E-04	8.1E-03	1.0E-01	1.9E-03	1.3E+03	3.2E-03	1.5E+01	1.8E-02	2.2E-02	5.4E-01	1.8E+00	9.9E-03	5.9E+02	1.1E-01	2.4E+02	2.4E+00	3.5E-03	1.7E-01	4.4E-02	3.0E+03	8.6E-04	4.7E-02	7.1E-02	9.2
27	VSEP A Permeate to Final Effluent	274.4	1.4E-05	5.1E-05	6.4E-02	1.5E-03	1.1E+02	8.3E-05	1.5E+01	1.1E-03	2.3E-03	2.3E-02	1.1E+00	3.9E-04	8.7E+01	2.7E-02	1.1E+02	3.7E-01	7.7E-05	8.9E-03	2.7E-03	2.6E+02	4.6E-05	6.3E-03	4.5E-03	5.4
28	VSEP A Concentrate	68.6	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.2E+03	1.6E-02	1.7E+01	8.9E-02	1.0E-01	2.7E+00	4.9E+00	5.0E-02	2.7E+03	4.4E-01	8.0E+02	1.1E+01	1.8E-02	8.3E-01	2.2E-01	1.5E+04	4.3E-03	2.2E-01	3.5E-01	9.5
29	VSEP A Concentrate to HDS B	34.3	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.2E+03	1.6E-02	1.7E+01	8.9E-02	1.0E-01	2.7E+00	4.9E+00	5.0E-02	2.7E+03	4.4E-01	8.0E+02	1.1E+01	1.8E-02	8.3E-01	2.2E-01	1.5E+04	4.3E-03	2.2E-01	3.5E-01	9.5
30	VSEP A Concentrate to HDS A	34.3	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.2E+03	1.6E-02	1.7E+01	8.9E-02	1.0E-01	2.7E+00	4.9E+00	5.0E-02	2.7E+03	4.4E-01	8.0E+02	1.1E+01	1.8E-02	8.3E-01	2.2E-01	1.5E+04	4.3E-03	2.2E-01	3.5E-01	9.5
31	HDS A Underflow Sludge	14.0	3.6E-01	0.0E+00	7.9E+00	2.1E-01	7.6E+04	1.3E+00	5.9E-01	9.9E+01	3.1E-01	3.5E+02	2.8E-02	5.6E+03	1.3E+04	3.2E+02	0.0E+00	8.2E+02	2.1E+00	0.0E+00	8.4E-01	1.1E+05	0.0E+00	1.6E+00	1.3E+02	10.6
32	Sulfate A Underflow Sludge	20.9	0.0E+00	1.5E+03	0.0E+00	0.0E+00	3.1E+04	0.0E+00	3.9E-01	5.7E-03	0.0E+00	9.3E-05	5.4E+01	0.0E+00	5.5E+03	0.0E+00	0.0E+00	2.4E-02	0.0E+00	7.9E+00	6.5E-01	3.8E+04	0.0E+00	0.0E+00	0.0E+00	12.5
33	Calcite A Underflow Sludge	16.2	0.0E+00	5.5E-09	0.0E+00	0.0E+00	1.9E+04	1.1E-10	0.0E+00	0.0E+00	0.0E+00	6.5E-05	0.0E+00	0.0E+00	3.3E-06	5.5E-06	0.0E+00	0.0E+00	0.0E+00	9.4E-07	9.4E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.7
34	HDS B Underflow Sludge	14.0	3.6E-01	0.0E+00	7.9E+00	2.1E-01	7.6E+04	1.3E+00	5.9E-01	9.9E+01	3.1E-01	3.5E+02	2.8E-02	5.6E+03	1.3E+04	3.2E+02	0.0E+00	8.2E+02	2.1E+00	0.0E+00	8.4E-01	1.1E+05	0.0E+00	1.6E+00	1.3E+02	10.6
35	Sulfate B Underflow Sludge	20.9	0.0E+00	1.5E+03	0.0E+00	0.0E+00	3.1E+04	0.0E+00	3.9E-01	5.7E-03	0.0E+00	9.3E-05	5.4E+01	0.0E+00	5.5E+03	0.0E+00	0.0E+00	2.4E-02	0.0E+00	7.9E+00	6.5E-01	3.8E+04	0.0E+00	0.0E+00	0.0E+00	12.5
36	Calcite B Underflow Sludge	16.2	0.0E+00	5.5E-09	0.0E+00	0.0E+00	1.9E+04	1.1E-10	0.0E+00	0.0E+00	0.0E+00	6.5E-05	0.0E+00	0.0E+00	3.3E-06	5.5E-06	0.0E+00	0.0E+00	0.0E+00	9.4E-07	9.4E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.7
37	Plant Site VSEP Concentrate	85.7	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
38	Plant Site Concentrate to HDS A	42.9	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
39	Plant Site Concentrate to HDS B	42.9	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
40	Final Effluent to CPS	2184.7	3.1E-04	1.2E-02	8.2E-03	2.8E-03	3.7E+01	1.0E-04	3.4E+01	2.2E-04	6.5E-03	9.0E-03	1.0E+00	2.0E-04	1.6E+01	2.6E-02	1.7E+02	5.8E-02	3.4E-05	6.2E-03	6.1E-03	2.7E+02	7.1E-04	1.2E-03	9.2E-02	6.0

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	305.2	NA	NA	NA	320.7	5.5	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	29.4	15.44	14.0	NA	NA	NA	NA	NA	NA	25	1.18	2.17	1.03	1.14
5	Sulfate A Influent	305.2	NA	NA	NA	339.1	5.1	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	54.8	33.91	20.9	NA	NA	NA	NA	NA	NA	10	1.05	1.40	0.50	0.90
6	Sulfate A Effluent	305.2	NA	NA	229.2	534.4	NA	NA	2.8	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	16.2	0.00	16.2	NA	NA	NA	NA	NA	NA	10	1.06	0.39	0.39	0.00
7	Calcite A Effluent	305.2	NA	NA	96.3	401.5	NA	NA	1.2	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	305.2	NA	NA	NA	320.7	5.5	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	29.4	15.44	14.0	NA	NA	NA	NA	NA	NA	25	1.18	2.17	1.03	1.14
11	Sulfate B Influent	305.2	NA	NA		339.1	5.1	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	54.8	33.91	20.9	NA	NA	NA	NA	NA	NA	10	1.05	1.40	0.50	0.90
12	Sulfate B Effluent	305.2	NA	NA	229.2	534.4	NA	NA	2.8	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	16.2	0.00	16.2	NA	NA	NA	NA	NA	NA	10	1.06	0.39	0.39	0.00
13	Calcite B Effluent	305.2	NA	NA	96.3	305.2	NA	NA	1.2	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1805.1	NA	NA	NA	NA	NA	NA	NA	35.7	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	343.0	NA	NA	504.2*	NA	NA	NA	6.1	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 7 P90 Winter Flows

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	82.0	2.9E-02	1.9E+02	3.5E-01	3.1E-02	1.5E+03	7.7E-02	3.8E+01	7.1E+00	2.3E-02	2.0E+01	2.0E+00	4.7E+02	6.5E+02	2.4E+01	2.4E+02	5.1E+01	1.3E-01	8.1E-01	1.3E-01	8.8E+03	2.4E-03	5.1E-02	8.2E+00	5.0
2	High Conc EQ Effluent to HDS A	41.0	2.9E-02	1.9E+02	3.5E-01	3.1E-02	1.5E+03	7.7E-02	3.8E+01	7.1E+00	2.3E-02	2.0E+01	2.0E+00	4.7E+02	6.5E+02	2.4E+01	2.4E+02	5.1E+01	1.3E-01	8.1E-01	1.3E-01	8.8E+03	2.4E-03	5.1E-02	8.2E+00	5.0
3	High Conc EQ Effluent to HDS B	41.0	2.9E-02	1.9E+02	3.5E-01	3.1E-02	1.5E+03	7.7E-02	3.8E+01	7.1E+00	2.3E-02	2.0E+01	2.0E+00	4.7E+02	6.5E+02	2.4E+01	2.4E+02	5.1E+01	1.3E-01	8.1E-01	1.3E-01	8.8E+03	2.4E-03	5.1E-02	8.2E+00	5.0
4	Combined HDS A Influent	215.9	1.1E-02	3.7E+01	1.8E-01	1.0E-02	1.3E+03	3.2E-02	3.6E+01	1.8E+00	5.5E-02	7.1E+00	7.0E+00	9.0E+01	8.0E+02	6.0E+00	6.7E+02	1.6E+01	4.2E-02	2.5E-01	7.3E-02	7.5E+03	3.5E-03	5.5E-02	3.3E+00	6.9
5	Sulfate A Influent	215.9	4.0E-03	3.6E+01	6.9E-06	5.5E-03	4.3E+02	2.7E-03	3.6E+01	1.0E-03	4.4E-02	4.0E-03	6.9E+00	9.9E-04	7.0E+02	6.0E-02	6.6E+02	4.3E-03	5.0E-05	2.5E-01	5.0E-02	5.9E+03	3.4E-03	6.7E-07	6.2E-01	10.5
6	Sulfate A Effluent	215.9	4.0E-03	3.6E-02	6.9E-06	5.5E-03	8.3E+02	2.7E-03	2.9E+01	1.5E-07	2.8E-02	4.0E-03	2.1E+00	9.9E-04	3.1E-01	6.0E-02	4.0E+02	4.1E-06	5.0E-05	1.2E-02	2.4E-02	1.9E+03	1.8E-03	6.7E-07	6.2E-01	12.5
7	Calcite A Effluent	215.9	4.1E-03	3.7E-02	7.0E-06	5.5E-03	1.4E+02	2.7E-03	2.9E+01	1.5E-07	2.9E-02	4.0E-03	2.1E+00	9.9E-04	1.3E-02	6.0E-02	4.0E+02	4.1E-06	5.0E-05	1.2E-02	2.4E-02	1.9E+03	1.8E-03	6.8E-07	6.3E-01	12.0
8	Calcite A Effluent to Final Effluent	86.4	4.0E-03	3.6E-02	6.9E-06	5.5E-03	1.4E+02	2.7E-03	2.9E+01	1.5E-07	2.8E-02	4.0E-03	2.1E+00	9.9E-04	1.3E-02	6.0E-02	4.0E+02	4.1E-06	5.0E-05	1.2E-02	2.4E-02	1.9E+03	1.8E-03	6.8E-07	6.3E-01	9.2
9	Calcite A Effluent to VSEP B	129.6	4.0E-03	3.6E-02	6.9E-06	5.5E-03	1.4E+02	2.7E-03	2.9E+01	1.5E-07	2.8E-02	4.0E-03	2.1E+00	9.9E-04	1.3E-02	6.0E-02	4.0E+02	4.1E-06	5.0E-05	1.2E-02	2.4E-02	1.9E+03	1.8E-03	6.8E-07	6.3E-01	9.2
10	Combined HDS B Influent	215.9	1.1E-02	3.7E+01	1.8E-01	1.0E-02	1.3E+03	3.2E-02	3.6E+01	1.8E+00	5.5E-02	7.1E+00	7.0E+00	9.0E+01	8.0E+02	6.0E+00	6.7E+02	1.6E+01	4.2E-02	2.5E-01	7.3E-02	7.5E+03	3.5E-03	5.5E-02	3.3E+00	6.9
11	Sulfate B Influent	215.9	4.0E-03	3.6E+01	6.9E-06	5.5E-03	4.3E+02	2.7E-03	3.6E+01	1.0E-03	4.4E-02	4.0E-03	6.9E+00	9.9E-04	7.0E+02	6.0E-02	6.6E+02	4.3E-03	5.0E-05	2.5E-01	5.0E-02	5.9E+03	3.4E-03	6.7E-07	6.2E-01	10.5
12	Sulfate B Effluent	215.9	4.0E-03	3.6E-02	6.9E-06	5.5E-03	8.3E+02	2.7E-03	2.9E+01	1.5E-07	2.8E-02	4.0E-03	2.1E+00	9.9E-04	3.1E-01	6.0E-02	4.0E+02	4.1E-06	5.0E-05	1.2E-02	2.4E-02	1.9E+03	1.8E-03	6.7E-07	6.2E-01	12.5
13	Calcite B Effluent	215.9	4.1E-03	3.7E-02	7.0E-06	5.5E-03	1.4E+02	2.7E-03	2.9E+01	1.5E-07	2.9E-02	4.0E-03	2.1E+00	9.9E-04	1.3E-02	6.0E-02	4.0E+02	4.1E-06	5.0E-05	1.2E-02	2.4E-02	1.9E+03	1.8E-03	6.8E-07	6.3E-01	12.0
14	Calcite B Effluent to Final Effluent	86.4	4.0E-03	3.6E-02	6.9E-06	5.5E-03	1.4E+02	2.7E-03	2.9E+01	1.5E-07	2.8E-02	4.0E-03	2.1E+00	9.9E-04	1.3E-02	6.0E-02	4.0E+02	4.1E-06	5.0E-05	1.2E-02	2.4E-02	1.9E+03	1.8E-03	6.8E-07	6.3E-01	9.2
15	Calcite B Effluent to VSEP B	129.6	4.0E-03	3.6E-02	6.9E-06	5.5E-03	1.4E+02	2.7E-03	2.9E+01	1.5E-07	2.8E-02	4.0E-03	2.1E+00	9.9E-04	1.3E-02	6.0E-02	4.0E+02	4.1E-06	5.0E-05	1.2E-02	2.4E-02	1.9E+03	1.8E-03	6.8E-07	6.3E-01	9.2
16	VSEP B Permeate to Final Effluent	345.5	1.6E-04	2.3E-04	4.3E-06	4.4E-03	1.2E+01	7.2E-05	2.9E+01	9.2E-09	3.0E-03	1.7E-04	1.3E+00	4.0E-05	2.0E-03	1.5E-02	1.8E+02	6.4E-07	1.1E-06	6.5E-04	1.5E-03	1.6E+02	9.5E-05	9.0E-08	4.0E-02	10.2
17	VSEP B Concentrate	86.4	2.0E-02	1.8E-01	1.8E-05	1.0E-02	6.6E+02	1.4E-02	3.2E+01	7.2E-07	1.3E-01	1.9E-02	5.5E+00	4.9E-03	5.9E-02	2.4E-01	1.3E+03	1.8E-05	2.5E-04	5.8E-02	1.2E-01	9.0E+03	8.5E-03	3.0E-06	3.0E+00	5.6
18	VSEP B Concentrate to HDS B	43.2	2.0E-02	1.8E-01	1.8E-05	1.0E-02	6.6E+02	1.4E-02	3.2E+01	7.2E-07	1.3E-01	1.9E-02	5.5E+00	4.9E-03	5.9E-02	2.4E-01	1.3E+03	1.8E-05	2.5E-04	5.8E-02	1.2E-01	9.0E+03	8.5E-03	3.0E-06	3.0E+00	5.6
19	VSEP B Concentrate to HDS A	43.2	2.0E-02	1.8E-01	1.8E-05	1.0E-02	6.6E+02	1.4E-02	3.2E+01	7.2E-07	1.3E-01	1.9E-02	5.5E+00	4.9E-03	5.9E-02	2.4E-01	1.3E+03	1.8E-05	2.5E-04	5.8E-02	1.2E-01	9.0E+03	8.5E-03	3.0E-06	3.0E+00	5.6
20	Low Conc EQ Effluent	829.7	1.9E-04	1.7E-03	6.9E-02	3.9E-04	2.8E+02	6.1E-03	3.2E+01	2.3E-01	4.6E-03	1.8E+00	1.0E+00	1.9E-01	1.2E+02	4.0E-01	1.0E+02	3.4E+00	6.4E-03	3.5E-02	9.1E-03	6.1E+02	1.8E-04	9.9E-03	6.2E-01	7.0
21	GSF Backwash	41.4	1.9E-04	1.7E-03	1.0E+00	3.8E-04	2.7E+02	1.1E-01	3.1E+01	4.4E+00	4.5E-03	3.3E+01	9.7E-01	3.6E+00	1.2E+02	7.3E+00	9.7E+01	5.8E+01	1.1E-01	3.4E-02	8.8E-03	6.0E+02	1.8E-04	9.7E-03	1.2E+01	6.8
22	GSF Backwash Solids	20.7	1.9E-04	1.7E-03	1.7E+00	3.8E-04	2.7E+02	2.0E-01	3.1E+01	8.6E+00	4.5E-03	6.3E+01	9.7E-01	6.9E+00	1.2E+02	1.4E+01	9.7E+01	1.0E+02	2.1E-01	3.4E-02	8.8E-03	6.0E+02	1.8E-04	9.7E-03	2.3E+01	6.8
23	GSF Backwash Decant	20.7	1.9E-04	1.7E-03	3.1E-01	3.8E-04	2.7E+02	1.6E-02	3.1E+01	2.9E-01	4.5E-03	3.6E+00	9.7E-01	2.1E-01	1.2E+02	7.3E-01	9.7E+01	1.0E+01	1.7E-02	3.4E-02	8.8E-03	6.0E+02	1.8E-04	9.7E-03	8.4E-01	6.8
24	GSF Permeate/NF Feed	788.3	1.9E-04	1.7E-03	1.8E-02	3.8E-04	2.7E+02	6.2E-04	3.1E+01	3.6E-03	4.5E-03	1.1E-01	9.7E-01	1.9E-03	1.2E+02	2.0E-02	9.7E+01	4.5E-01	6.6E-04	3.4E-02	8.9E-03	6.0E+02	1.8E-04	9.7E-03	1.4E-02	7.0
25	NF Permeate	630.6	1.5E-04	1.2E-04	2.3E-04	2.7E-05	3.5E+01	4.4E-05	3.5E+01	1.3E-04	3.2E-04	8.4E-03	7.8E-01	0.0E+00	8.1E+00	5.6E-04	6.4E+01	1.6E-02	2.5E-05	2.4E-03	3.5E-04	2.5E+01	1.3E-05	6.9E-04	2.8E-04	6.0
26	NF Concentrate to VSEP A	157.7	3.5E-04	7.9E-03	9.2E-02	1.8E-03	1.2E+03	3.0E-03	1.5E+01	1.7E-02	2.1E-02	5.1E-01	1.8E+00	9.6E-03	5.7E+02	1.0E-01	2.3E+02	2.2E+00	3.2E-03	1.6E-01	4.3E-02	2.9E+03	8.4E-04	4.6E-02	6.9E-02	9.2
27	VSEP A Permeate to Final Effluent	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	VSEP A Concentrate	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29	VSEP A Concentrate to HDS B	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30	VSEP A Concentrate to HDS A	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	3.3	1.9E-01	0.0E+00	1.2E+01	1.7E-01	1.2E+05	1.7E+00	0.0E+00	1.1E+02	0.0E+00	4.6E+02	0.0E+00	5.8E+03	5.7E+03	3.8E+02	0.0E+00	1.0E+03	2.7E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.5E+00	1.3E+02	10.5
32	Sulfate A Underflow Sludge	16.7	0.0E+00	4.7E+02	7.1E-12	2.5E-08	1.5E+04	0.0E+00	2.5E-01	1.4E-02	0.0E+00	7.3E-05	4.8E+01	1.6E-09	9.0E+03	5.1E-07	0.0E+00	5.5E-02	7.4E-10	2.9E+00	3.1E-01	4.8E+04	0.0E+00	2.3E-12	0.0E+00	12.5
33	Calcite A Underflow Sludge	6.2	0.0E+00	1.2E-14	2.1E-18	1.7E-15	2.4E+04	0.0E+00	4.5E-11	0.0E+00	9.2E-15	1.1E-04	0.0E+00	3.0E-16	1.0E+01	1.8E-14	1.2E-10	0.0E+00	4.7E-17	4.5E-14	7.7E-15	0.0E+00	0.0E+00	2.1E-19	0.0E+00	12.0
34	HDS B Underflow Sludge	3.3	1.9E-01	0.0E+00	1.2E+01	1.7E-01	1.2E+05	1.7E+00	0.0E+00	1.1E+02	0.0E+00	4.6E+02	0.0E+00	5.8E+03	5.7E+03	3.8E+02	0.0E+00	1.0E+03	2.7E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.5E+00	1.3E+02	10.5
35	Sulfate B Underflow Sludge	16.7	0.0E+00	4.7E+02	7.1E-12	2.5E-08	1.5E+04	0.0E+00	2.5E-01	1.4E-02	0.0E+00	7.3E-05	4.8E+01	1.6E-09	9.0E+03	5.1E-07	0.0E+00	5.5E-02	7.4E-10	2.9E+00	3.1E-01	4.8E+04	0.0E+00	2.3E-12	0.0E+00	12.5
36	Calcite B Underflow Sludge	6.2	0.0E+00	1.2E-14	2.1E-18	1.7E-15	2.4E+04	0.0E+00	4.5E-11	0.0E+00	9.2E-15	1.1E-04	0.0E+00	3.0E-16	1.0E+01	1.8E-14	1.2E-10	0.0E+00	4.7E-17	4.5E-14	7.7E-15	0.0E+00	0.0E+00	2.1E-19	0.0E+00	12.0
37	Plant Site VSEP Concentrate	85.1	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
38	Plant Site Concentrate to HDS A	42.6	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
39	Plant Site Concentrate to HDS B	42.6	6.9E-03	3.0E-01	2.4E-03	7.8E-03	2.0E+03	1.9E-02	8.0E+01	7.6E-03	8.4E-02	3.3E-01	2.5E+01	2.1E+00	2.3E+03	3.3E+00	1.4E+03	8.3E-01	3.1E-02	1.4E-01	3.9E-02	1.5E+04	5.2E-03	1.4E-01	2.7E-02	6.3
40	Final Effluent to CPS	976.1	1.5E-04	1.6E-04	1.6E-04	1.6E-03	2.7E+01	5.4E-05	3.3E+01	8.4E-05	1.3E-03	5.0E-03	9.5E-01	1.4E-05	5.2E+00	5.7E-03	1.0E+02	1.1E-02	1.7E-05	1.8E-03	7.6E-04	7.4E+01	4.2E-05	4.5E-04	1.4E-02	6.8

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	215.9	NA	NA	NA	233.6	2.1	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	21.0	17.66	3.3	NA	NA	NA	NA	NA	NA	25	1.19	1.56	0.25	1.31
5	Sulfate A Influent	215.9	NA	NA	NA	239.9	3.6	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	40.7	23.99	16.7	NA	NA	NA	NA	NA	NA	10	1.05	1.03	0.40	0.63
6	Sulfate A Effluent	215.9	NA	NA	82.5	298.4	NA	NA	1.0	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	6.2	0.00	6.2	NA	NA	NA	NA	NA	NA	10	1.06	0.15	0.15	0.00
7	Calcite A Effluent	215.9	NA	NA	64.2	280.1	NA	NA	0.8	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	215.9	NA	NA	NA	233.6	2.1	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	21.0	17.66	3.3	NA	NA	NA	NA	NA	NA	25	1.19	1.56	0.25	1.31
11	Sulfate B Influent	215.9	NA	NA		239.9	3.6	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	40.7	23.99	16.7	NA	NA	NA	NA	NA	NA	10	1.05	1.03	0.40	0.63
12	Sulfate B Effluent	215.9	NA	NA	82.5	298.4	NA	NA	1.0	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	6.2	0.00	6.2	NA	NA	NA	NA	NA	NA	10	1.06	0.15	0.15	0.00
13	Calcite B Effluent	215.9	NA	NA	64.2	215.9	NA	NA	0.8	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	829.7	NA	NA	NA	NA	NA	NA	NA	16.4	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	157.7	NA	NA	0*	NA	NA	NA	0.0	NA	NA	NA	NA	NA	NA

Mine Water Treatment Trains Flow and Load Detail
Year 8 P90 Annual Average Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	210.0	3.4E-02	2.5E+02	3.4E-01	3.3E-02	1.6E+03	9.0E-02	5.4E+01	9.5E+00	2.5E-02	3.7E+01	1.9E+00	5.0E+02	7.7E+02	3.2E+01	2.4E+02	1.1E+02	1.8E-01	1.1E+00	1.4E-01	9.9E+03	4.2E-03	5.6E-02	9.7E+00	5.0
2	High Conc EQ Effluent to HDS A	105.0	3.4E-02	2.5E+02	3.4E-01	3.3E-02	1.6E+03	9.0E-02	5.4E+01	9.5E+00	2.5E-02	3.7E+01	1.9E+00	5.0E+02	7.7E+02	3.2E+01	2.4E+02	1.1E+02	1.8E-01	1.1E+00	1.4E-01	9.9E+03	4.2E-03	5.6E-02	9.7E+00	5.0
3	High Conc EQ Effluent to HDS B	105.0	3.4E-02	2.5E+02	3.4E-01	3.3E-02	1.6E+03	9.0E-02	5.4E+01	9.5E+00	2.5E-02	3.7E+01	1.9E+00	5.0E+02	7.7E+02	3.2E+01	2.4E+02	1.1E+02	1.8E-01	1.1E+00	1.4E-01	9.9E+03	4.2E-03	5.6E-02	9.7E+00	5.0
4	Combined HDS A Influent	257.8	2.0E-02	1.2E+02	3.5E-01	2.0E-02	2.0E+03	6.7E-02	4.0E+01	5.3E+00	7.3E-02	2.4E+01	6.6E+00	2.4E+02	1.2E+03	1.7E+01	7.6E+02	6.1E+01	1.2E-01	6.9E-01	1.2E-01	1.0E+04	7.2E-03	9.0E-02	6.9E+00	6.5
5	Sulfate A Influent	257.8	1.8E-03	7.9E+01	2.5E-06	6.0E-03	3.1E+02	5.7E-04	2.6E+01	4.5E-04	3.3E-02	2.5E-03	4.3E+00	6.1E-04	5.0E+02	1.1E-01	5.0E+02	2.3E-03	4.1E-05	4.5E-01	5.6E-02	3.5E+03	4.7E-03	2.1E-07	3.9E-01	10.5
6	Sulfate A Effluent	257.8	1.8E-03	7.9E-02	2.5E-06	6.0E-03	6.2E+02	5.7E-04	2.6E+01	5.3E-08	3.3E-02	2.5E-03	1.3E+00	6.1E-04	2.7E-01	1.1E-01	5.0E+02	1.7E-06	4.1E-05	2.2E-02	2.8E-02	1.2E+03	4.7E-03	2.1E-07	3.9E-01	12.4
7	Calcite A Effluent	257.8	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.3E-01	8.7E-04	4.0E+01	8.1E-08	5.1E-02	3.8E-03	2.0E+00	9.2E-04	4.2E-01	1.7E-01	7.5E+02	2.5E-06	6.3E-05	3.4E-02	4.3E-02	1.8E+03	7.1E-03	3.3E-07	5.9E-01	10.2
8	Calcite A Effluent to Final Effluent	103.1	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.3E-01	8.6E-04	4.0E+01	8.1E-08	5.1E-02	3.8E-03	1.9E+00	9.2E-04	4.1E-01	1.7E-01	7.5E+02	2.5E-06	6.2E-05	3.4E-02	4.2E-02	1.7E+03	7.1E-03	3.3E-07	5.9E-01	6.4
9	Calcite A Effluent to VSEP B	154.7	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.3E-01	8.6E-04	4.0E+01	8.1E-08	5.1E-02	3.8E-03	1.9E+00	9.2E-04	4.1E-01	1.7E-01	7.5E+02	2.5E-06	6.2E-05	3.4E-02	4.2E-02	1.7E+03	7.1E-03	3.3E-07	5.9E-01	6.4
10	Combined HDS B Influent	257.8	2.0E-02	1.2E+02	3.5E-01	2.0E-02	2.0E+03	6.7E-02	4.0E+01	5.3E+00	7.3E-02	2.4E+01	6.6E+00	2.4E+02	1.2E+03	1.7E+01	7.6E+02	6.1E+01	1.2E-01	6.9E-01	1.2E-01	1.0E+04	7.2E-03	9.0E-02	6.9E+00	6.5
11	Sulfate B Influent	257.8	1.8E-03	7.9E+01	2.5E-06	6.0E-03	3.1E+02	5.7E-04	2.6E+01	4.5E-04	3.3E-02	2.5E-03	4.3E+00	6.1E-04	5.0E+02	1.1E-01	5.0E+02	2.3E-03	4.1E-05	4.5E-01	5.6E-02	3.5E+03	4.7E-03	2.1E-07	3.9E-01	10.5
12	Sulfate B Effluent	257.8	1.8E-03	7.9E-02	2.5E-06	6.0E-03	6.2E+02	5.7E-04	2.6E+01	5.3E-08	3.3E-02	2.5E-03	1.3E+00	6.1E-04	2.7E-01	1.1E-01	5.0E+02	1.7E-06	4.1E-05	2.2E-02	2.8E-02	1.2E+03	4.7E-03	2.1E-07	3.9E-01	12.4
13	Calcite B Effluent	257.8	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.3E-01	8.7E-04	4.0E+01	8.1E-08	5.1E-02	3.8E-03	2.0E+00	9.2E-04	4.2E-01	1.7E-01	7.5E+02	2.5E-06	6.3E-05	3.4E-02	4.3E-02	1.8E+03	7.1E-03	3.3E-07	5.9E-01	10.2
14	Calcite B Effluent to Final Effluent	103.1	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.3E-01	8.6E-04	4.0E+01	8.1E-08	5.1E-02	3.8E-03	1.9E+00	9.2E-04	4.1E-01	1.7E-01	7.5E+02	2.5E-06	6.2E-05	3.4E-02	4.2E-02	1.7E+03	7.1E-03	3.3E-07	5.9E-01	6.4
15	Calcite B Effluent to VSEP B	154.7	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.3E-01	8.6E-04	4.0E+01	8.1E-08	5.1E-02	3.8E-03	1.9E+00	9.2E-04	4.1E-01	1.7E-01	7.5E+02	2.5E-06	6.2E-05	3.4E-02	4.2E-02	1.7E+03	7.1E-03	3.3E-07	5.9E-01	6.4
16	VSEP B Permeate to Final Effluent	387.8	7.1E-05	4.7E-04	1.5E-06	4.6E-03	5.2E-02	1.4E-05	2.4E+01	3.1E-09	3.4E-03	1.0E-04	7.4E-01	2.3E-05	3.8E-02	2.7E-02	2.1E+02	2.5E-07	8.8E-07	1.1E-03	1.6E-03	9.5E+01	2.2E-04	2.7E-08	2.4E-02	11.7
17	VSEP B Concentrate	97.0	9.0E-03	4.0E-01	6.4E-06	1.1E-02	2.9E+00	2.8E-03	2.9E+01	2.6E-07	1.5E-01	1.2E-02	3.4E+00	3.0E-03	1.2E+00	4.5E-01	1.6E+03	7.3E-06	2.0E-04	1.1E-01	1.3E-01	5.4E+03	2.1E-02	9.7E-07	1.9E+00	9.3
18	VSEP B Concentrate to HDS B	48.5	9.0E-03	4.0E-01	6.4E-06	1.1E-02	2.9E+00	2.8E-03	2.9E+01	2.6E-07	1.5E-01	1.2E-02	3.4E+00	3.0E-03	1.2E+00	4.5E-01	1.6E+03	7.3E-06	2.0E-04	1.1E-01	1.3E-01	5.4E+03	2.1E-02	9.7E-07	1.9E+00	9.3
19	VSEP B Concentrate to HDS A	48.5	9.0E-03	4.0E-01	6.4E-06	1.1E-02	2.9E+00	2.8E-03	2.9E+01	2.6E-07	1.5E-01	1.2E-02	3.4E+00	3.0E-03	1.2E+00	4.5E-01	1.6E+03	7.3E-06	2.0E-04	1.1E-01	1.3E-01	5.4E+03	2.1E-02	9.7E-07	1.9E+00	9.3
20	Low Conc EQ Effluent	1361.0	1.9E-04	1.7E-03	6.9E-02	3.9E-04	2.8E+02	5.7E-03	4.0E+01	2.3E-01	4.5E-03	1.8E+00	8.6E-01	1.9E-01	1.2E+02	3.9E-01	9.9E+01	3.3E+00	6.1E-03	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	6.0E-01	7.0
21	GSF Backwash	68.1	1.9E-04	1.7E-03	1.1E+00	3.9E-04	2.8E+02	1.1E-01	4.0E+01	4.6E+00	4.5E-03	3.4E+01	8.5E-01	3.7E+00	1.2E+02	7.6E+00	9.9E+01	6.1E+01	1.1E-01	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	1.2E+01	7.0
22	GSF Backwash Solids	34.0	1.9E-04	1.7E-03	1.9E+00	3.9E-04	2.8E+02	2.0E-01	4.0E+01	8.8E+00	4.5E-03	6.5E+01	8.5E-01	7.1E+00	1.2E+02	1.4E+01	9.9E+01	1.1E+02	2.1E-01	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	2.3E+01	7.0
23	GSF Backwash Decant	34.0	1.9E-04	1.7E-03	3.5E-01	3.9E-04	2.8E+02	1.6E-02	4.0E+01	3.0E-01	4.5E-03	3.7E+00	8.5E-01	2.2E-01	1.2E+02	7.6E-01	9.9E+01	1.1E+01	1.7E-02	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	8.5E-01	7.0
24	GSF Permeate/NF Feed	1293.0	1.9E-04	1.7E-03	2.1E-02	3.9E-04	2.8E+02	6.2E-04	4.0E+01	3.7E-03	4.5E-03	1.1E-01	8.6E-01	2.0E-03	1.2E+02	2.1E-02	9.9E+01	4.8E-01	6.7E-04	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	1.4E-02	7.0
25	NF Permeate	1034.4	1.5E-04	1.2E-04	2.6E-04	2.8E-05	3.5E+01	4.4E-05	4.5E+01	1.3E-04	3.2E-04	8.7E-03	6.9E-01	3.3E-20	8.1E+00	5.8E-04	6.5E+01	1.7E-02	2.6E-05	2.5E-03	3.5E-04	2.5E+01	1.3E-05	7.1E-04	2.8E-04	6.1
26	NF Concentrate to VSEP A	258.6	3.5E-04	8.1E-03	1.0E-01	1.9E-03	1.3E+03	3.0E-03	1.9E+01	1.8E-02	2.1E-02	5.3E-01	1.5E+00	9.9E-03	5.8E+02	1.0E-01	2.4E+02	2.3E+00	3.3E-03	1.7E-01	4.3E-02	3.0E+03	8.6E-04	4.7E-02	7.0E-02	9.0
27	VSEP A Permeate to Final Effluent	206.9	1.4E-05	5.0E-05	6.4E-02	1.5E-03	1.1E+02	7.8E-05	1.8E+01	1.1E-03	2.3E-03	2.2E-02	9.2E-01	3.9E-04	8.5E+01	2.6E-02	1.1E+02	3.6E-01	7.4E-05	8.9E-03	2.6E-03	2.6E+02	4.6E-05	6.3E-03	4.4E-03	5.5
28	VSEP A Concentrate	51.7	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.5E-02	2.1E+01	8.9E-02	1.0E-01	2.6E+00	4.2E+00	5.0E-02	2.6E+03	4.3E-01	7.9E+02	1.1E+01	1.7E-02	8.3E-01	2.1E-01	1.4E+04	4.3E-03	2.2E-01	3.4E-01	9.7
29	VSEP A Concentrate to HDS B	25.9	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.5E-02	2.1E+01	8.9E-02	1.0E-01	2.6E+00	4.2E+00	5.0E-02	2.6E+03	4.3E-01	7.9E+02	1.1E+01	1.7E-02	8.3E-01	2.1E-01	1.4E+04	4.3E-03	2.2E-01	3.4E-01	9.7
30	VSEP A Concentrate to HDS A	25.9	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.5E-02	2.1E+01	8.9E-02	1.0E-01	2.6E+00	4.2E+00	5.0E-02	2.6E+03	4.3E-01	7.9E+02	1.1E+01	1.7E-02	8.3E-01	2.1E-01	1.4E+04	4.3E-03	2.2E-01	3.4E-01	9.7
31	HDS A Underflow Sludge	11.8	3.1E-01	2.1E+03	6.4E+00	2.1E-01	7.5E+04	1.2E+00	5.2E+02	9.7E+01	4.2E-01	4.3E+02	9.3E+01	4.4E+03	1.3E+04	3.2E+02	1.2E+03	1.1E+03	2.2E+00	1.1E+01	7.5E-01	1.2E+05	9.6E-06	1.8E+00	1.1E+02	10.5
32	Sulfate A Underflow Sludge	18.9	0.0E+00	1.1E+03	0.0E+00	0.0E+00	3.4E+04	0.0E+00	2.6E+02	6.1E-03	0.0E+00	4.5E-05	4.1E+01	0.0E+00	6.8E+03	0.0E+00	8.7E-03	3.2E-02	0.0E+00	5.8E+00	3.8E-01	3.1E+04	0.0E+00	0.0E+00	0.0E+00	12.4
33	Calcite A Underflow Sludge	12.6	4.3E-06	1.9E-04	5.7E-09	1.4E-05	1.3E+04	1.3E-06	4.0E-02	1.3E-10	7.8E-05	7.9E-05	9.0E-03	1.4E-06	6.4E-04	2.6E-04	1.2E+00	3.9E-09	9.6E-08	5.2E-05	6.4E-05	2.5E+00	0.0E+00	4.9E-10	9.1E-04	10.2
34	HDS B Underflow Sludge	11.8	3.1E-01	2.1E+03	6.4E+00	2.1E-01	7.5E+04	1.2E+00	5.2E+02	9.7E+01	4.2E-01	4.3E+02	9.3E+01	4.4E+03	1.3E+04	3.2E+02	1.2E+03	1.1E+03	2.2E+00	1.1E+01	7.5E-01	1.2E+05	9.6E-06	1.8E+00	1.1E+02	10.5
35	Sulfate B Underflow Sludge	18.9	0.0E+00	1.1E+03	0.0E+00	0.0E+00	3.4E+04	0.0E+00	2.6E+02	6.1E-03	0.0E+00	4.5E-05	4.1E+01	0.0E+00	6.8E+03	0.0E+00	8.7E-03	3.2E-02	0.0E+00	5.8E+00	3.8E-01	3.1E+04	0.0E+00	0.0E+00	0.0E+00	12.4
36	Calcite B Underflow Sludge	12.6	4.3E-06	1.9E-04	5.7E-09	1.4E-05	1.3E+04	1.3E-06	4.0E-02	1.3E-10	7.8E-05	7.9E-05	9.0E-03	1.4E-06	6.4E-04	2.6E-04	1.2E+00	3.9E-09	9.6E-08	5.2E-05	6.4E-05	2.5E+00	0.0E+00	4.9E-10	9.1E-04	10.2
37	Plant Site VSEP Concentrate	123.0	6.9E-03	2.6E-01	3.1E-03	8.2E-03	2.0E+03	2.3E-02	2.1E+01	8.0E-03	1.1E-01	4.5E-01	2.1E+01	1.8E+00	2.2E+03	3.3E+00	1.4E+03	9.0E-01	5.1E-02	1.5E-01	4.4E-02	1.4E+04	5.1E-03	1.7E-01	3.5E-02	6.2
38	Plant Site Concentrate to HDS A	61.5	6.9E-03	2.6E-01	3.1E-03	8.2E-03	2.0E+03	2.3E-02	2.1E+01	8.0E-03	1.1E-01	4.5E-01	2.1E+01	1.8E+00	2.2E+03	3.3E+00	1.4E+03	9.0E-01	5.1E-02	1.5E-01	4.4E-02	1.4E+04	5.1E-03	1.7E-01	3.5E-02	6.2
39	Plant Site Concentrate to HDS B	61.5	6.9E-03	2.6E-01	3.1E-03	8.2E-03	2.0E+03	2.3E-02	2.1E+01	8.0E-03	1.1E-01	4.5E-01	2.1E+01	1.8E+00	2.2E+03	3.3E+00	1.4E+03	9.0E-01	5.1E-02	1.5E-01	4.4E-02	1.4E+04	5.1E-03	1.7E-01	3.5E-02	6.2
40	Final Effluent to CPS	1660.0	1.4E-04	1.5E-03	8.1E-03	1.3E-03	3.6E+01	5.0E-05	3.6E+01	2.2E-04	1.8E-03	8.0E-03	7.2E-01	6.4E-05	1.6E+01	1.1E-02	1.1E+02	5.6E-02	2.6E-05	3.3E-03	1.4E-03	8.8E+01	1.3E-04	1.2E-03	1.3E-02	6.0

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	257.8	NA	NA	NA	276.3	4.4	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	30.2	18.45	11.8	NA	NA	NA	NA	NA	NA	25	1.18	2.22	0.87	1.36
5	Sulfate A Influent	257.8	NA	NA	NA	286.5	5.0	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	47.6	28.65	18.9	NA	NA	NA	NA	NA	NA	10	1.05	1.21	0.45	0.76
6	Sulfate A Effluent	257.8	NA	NA	192.5	450.3	NA	NA	2.3	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	12.6	0.00	12.6	NA	NA	NA	NA	NA	NA	10	1.06	0.30	0.30	0.00
7	Calcite A Effluent	257.8	NA	NA	100.8	358.7	NA	NA	1.2	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	257.8	NA	NA	NA	276.3	4.4	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	30.2	18.45	11.8	NA	NA	NA	NA	NA	NA	25	1.18	2.22	0.87	1.36
11	Sulfate B Influent	257.8	NA	NA		286.5	5.0	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	47.6	28.65	18.9	NA	NA	NA	NA	NA	NA	10	1.05	1.21	0.45	0.76
12	Sulfate B Effluent	257.8	NA	NA	192.5	450.3	NA	NA	2.3	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	12.6	0.00	12.6	NA	NA	NA	NA	NA	NA	10	1.06	0.30	0.30	0.00
13	Calcite B Effluent	257.8	NA	NA	100.8	257.8	NA	NA	1.2	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1361.0	NA	NA	NA	NA	NA	NA	NA	26.9	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	258.6	NA	NA	412.5*	NA	NA	NA	5.0	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 8 P90 Peak Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	322.0	3.4E-02	2.5E+02	3.4E-01	3.3E-02	1.6E+03	9.0E-02	5.4E+01	9.5E+00	2.5E-02	3.7E+01	1.9E+00	5.0E+02	7.7E+02	3.2E+01	2.4E+02	1.1E+02	1.8E-01	1.1E+00	1.4E-01	9.9E+03	4.2E-03	5.6E-02	9.7E+00	5.0
2	High Conc EQ Effluent to HDS A	161.0	3.4E-02	2.5E+02	3.4E-01	3.3E-02	1.6E+03	9.0E-02	5.4E+01	9.5E+00	2.5E-02	3.7E+01	1.9E+00	5.0E+02	7.7E+02	3.2E+01	2.4E+02	1.1E+02	1.8E-01	1.1E+00	1.4E-01	9.9E+03	4.2E-03	5.6E-02	9.7E+00	5.0
3	High Conc EQ Effluent to HDS B	161.0	3.4E-02	2.5E+02	3.4E-01	3.3E-02	1.6E+03	9.0E-02	5.4E+01	9.5E+00	2.5E-02	3.7E+01	1.9E+00	5.0E+02	7.7E+02	3.2E+01	2.4E+02	1.1E+02	1.8E-01	1.1E+00	1.4E-01	9.9E+03	4.2E-03	5.6E-02	9.7E+00	5.0
4	Combined HDS A Influent	337.7	2.0E-02	1.2E+02	3.5E-01	2.0E-02	2.0E+03	6.7E-02	4.0E+01	5.3E+00	7.3E-02	2.4E+01	6.6E+00	2.4E+02	1.2E+03	1.7E+01	7.6E+02	6.1E+01	1.2E-01	6.9E-01	1.2E-01	1.0E+04	7.2E-03	9.0E-02	6.9E+00	6.5
5	Sulfate A Influent	337.7	2.8E-03	1.2E+02	3.8E-06	9.1E-03	4.7E+02	8.6E-04	4.0E+01	6.8E-04	5.0E-02	3.8E-03	6.5E+00	9.1E-04	7.5E+02	1.7E-01	7.5E+02	3.5E-03	6.2E-05	6.7E-01	8.5E-02	5.2E+03	7.1E-03	3.2E-07	5.9E-01	10.5
6	Sulfate A Effluent	337.7	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.4E+02	8.6E-04	4.0E+01	8.0E-08	5.0E-02	3.8E-03	1.9E+00	9.1E-04	4.1E-01	1.7E-01	7.5E+02	2.5E-06	6.2E-05	3.4E-02	4.2E-02	1.7E+03	7.1E-03	3.2E-07	5.9E-01	12.4
7	Calcite A Effluent	337.7	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.3E-01	8.7E-04	4.0E+01	8.1E-08	5.1E-02	3.8E-03	2.0E+00	9.2E-04	4.2E-01	1.7E-01	7.5E+02	2.5E-06	6.3E-05	3.4E-02	4.3E-02	1.8E+03	7.1E-03	3.3E-07	5.9E-01	10.2
8	Calcite A Effluent to Final Effluent	135.1	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.3E-01	8.6E-04	4.0E+01	8.1E-08	5.1E-02	3.8E-03	1.9E+00	9.2E-04	4.1E-01	1.7E-01	7.5E+02	2.5E-06	6.2E-05	3.4E-02	4.2E-02	1.7E+03	7.1E-03	3.3E-07	5.9E-01	6.4
9	Calcite A Effluent to VSEP B	202.6	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.3E-01	8.6E-04	4.0E+01	8.1E-08	5.1E-02	3.8E-03	1.9E+00	9.2E-04	4.1E-01	1.7E-01	7.5E+02	2.5E-06	6.2E-05	3.4E-02	4.2E-02	1.7E+03	7.1E-03	3.3E-07	5.9E-01	6.4
10	Combined HDS B Influent	337.7	2.0E-02	1.2E+02	3.5E-01	2.0E-02	2.0E+03	6.7E-02	4.0E+01	5.3E+00	7.3E-02	2.4E+01	6.6E+00	2.4E+02	1.2E+03	1.7E+01	7.6E+02	6.1E+01	1.2E-01	6.9E-01	1.2E-01	1.0E+04	7.2E-03	9.0E-02	6.9E+00	6.5
11	Sulfate B Influent	337.7	2.8E-03	1.2E+02	3.8E-06	9.1E-03	4.7E+02	8.6E-04	4.0E+01	6.8E-04	5.0E-02	3.8E-03	6.5E+00	9.1E-04	7.5E+02	1.7E-01	7.5E+02	3.5E-03	6.2E-05	6.7E-01	8.5E-02	5.2E+03	7.1E-03	3.2E-07	5.9E-01	10.5
12	Sulfate B Effluent	337.7	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.4E+02	8.6E-04	4.0E+01	8.0E-08	5.0E-02	3.8E-03	1.9E+00	9.1E-04	4.1E-01	1.7E-01	7.5E+02	2.5E-06	6.2E-05	3.4E-02	4.2E-02	1.7E+03	7.1E-03	3.2E-07	5.9E-01	12.4
13	Calcite B Effluent	337.7	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.3E-01	8.7E-04	4.0E+01	8.1E-08	5.1E-02	3.8E-03	2.0E+00	9.2E-04	4.2E-01	1.7E-01	7.5E+02	2.5E-06	6.3E-05	3.4E-02	4.3E-02	1.8E+03	7.1E-03	3.3E-07	5.9E-01	10.2
14	Calcite B Effluent to Final Effluent	135.1	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.3E-01	8.6E-04	4.0E+01	8.1E-08	5.1E-02	3.8E-03	1.9E+00	9.2E-04	4.1E-01	1.7E-01	7.5E+02	2.5E-06	6.2E-05	3.4E-02	4.2E-02	1.7E+03	7.1E-03	3.3E-07	5.9E-01	6.4
15	Calcite B Effluent to VSEP B	202.6	2.8E-03	1.2E-01	3.8E-06	9.1E-03	9.3E-01	8.6E-04	4.0E+01	8.1E-08	5.1E-02	3.8E-03	1.9E+00	9.2E-04	4.1E-01	1.7E-01	7.5E+02	2.5E-06	6.2E-05	3.4E-02	4.2E-02	1.7E+03	7.1E-03	3.3E-07	5.9E-01	6.4
16	VSEP B Permeate to Final Effluent	270.2	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0
17	VSEP B Concentrate	67.5	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0
18	VSEP B Concentrate to HDS B	33.8	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0
19	VSEP B Concentrate to HDS A	33.8	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0
20	Low Conc EQ Effluent	2156.9	1.9E-04	1.7E-03	6.9E-02	3.9E-04	2.8E+02	5.7E-03	4.0E+01	2.3E-01	4.5E-03	1.8E+00	8.6E-01	1.9E-01	1.2E+02	3.9E-01	9.9E+01	3.3E+00	6.1E-03	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	6.0E-01	7.0
21	GSF Backwash	107.8	1.9E-04	1.7E-03	1.1E+00	3.9E-04	2.8E+02	1.1E-01	4.0E+01	4.6E+00	4.5E-03	3.4E+01	8.5E-01	3.7E+00	1.2E+02	7.6E+00	9.9E+01	6.1E+01	1.1E-01	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	1.2E+01	7.0
22	GSF Backwash Solids	53.9	1.9E-04	1.7E-03	1.9E+00	3.9E-04	2.8E+02	2.0E-01	4.0E+01	8.8E+00	4.5E-03	6.5E+01	8.5E-01	7.1E+00	1.2E+02	1.4E+01	9.9E+01	1.1E+02	2.1E-01	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	2.3E+01	7.0
23	GSF Backwash Decant	53.9	1.9E-04	1.7E-03	3.5E-01	3.9E-04	2.8E+02	1.6E-02	4.0E+01	3.0E-01	4.5E-03	3.7E+00	8.5E-01	2.2E-01	1.2E+02	7.6E-01	9.9E+01	1.1E+01	1.7E-02	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	8.5E-01	7.0
24	GSF Permeate/NF Feed	2049.1	1.9E-04	1.7E-03	2.1E-02	3.9E-04	2.8E+02	6.2E-04	4.0E+01	3.7E-03	4.5E-03	1.1E-01	8.6E-01	2.0E-03	1.2E+02	2.1E-02	9.9E+01	4.8E-01	6.7E-04	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	1.4E-02	7.0
25	NF Permeate	1639.3	1.5E-04	1.2E-04	2.6E-04	2.8E-05	3.5E+01	4.4E-05	4.5E+01	1.3E-04	3.2E-04	8.7E-03	6.9E-01	3.3E-20	8.1E+00	5.8E-04	6.5E+01	1.7E-02	2.6E-05	2.5E-03	3.5E-04	2.5E+01	1.3E-05	7.1E-04	2.8E-04	6.1
26	NF Concentrate to VSEP A	409.8	3.5E-04	8.1E-03	1.0E-01	1.9E-03	1.3E+03	3.0E-03	1.9E+01	1.8E-02	2.1E-02	5.3E-01	1.5E+00	9.9E-03	5.8E+02	1.0E-01	2.4E+02	2.3E+00	3.3E-03	1.7E-01	4.3E-02	3.0E+03	8.6E-04	4.7E-02	7.0E-02	9.0
27	VSEP A Permeate to Final Effluent	327.9	1.4E-05	5.0E-05	6.4E-02	1.5E-03	1.1E+02	7.8E-05	1.8E+01	1.1E-03	2.3E-03	2.2E-02	9.2E-01	3.9E-04	8.5E+01	2.6E-02	1.1E+02	3.6E-01	7.4E-05	8.9E-03	2.6E-03	2.6E+02	4.6E-05	6.3E-03	4.4E-03	5.5
28	VSEP A Concentrate	82.0	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.5E-02	2.1E+01	8.9E-02	1.0E-01	2.6E+00	4.2E+00	5.0E-02	2.6E+03	4.3E-01	7.9E+02	1.1E+01	1.7E-02	8.3E-01	2.1E-01	1.4E+04	4.3E-03	2.2E-01	3.4E-01	9.7
29	VSEP A Concentrate to HDS B	41.0	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.5E-02	2.1E+01	8.9E-02	1.0E-01	2.6E+00	4.2E+00	5.0E-02	2.6E+03	4.3E-01	7.9E+02	1.1E+01	1.7E-02	8.3E-01	2.1E-01	1.4E+04	4.3E-03	2.2E-01	3.4E-01	9.7
30	VSEP A Concentrate to HDS A	41.0	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.5E-02	2.1E+01	8.9E-02	1.0E-01	2.6E+00	4.2E+00	5.0E-02	2.6E+03	4.3E-01	7.9E+02	1.1E+01	1.7E-02	8.3E-01	2.1E-01	1.4E+04	4.3E-03	2.2E-01	3.4E-01	9.7
31	HDS A Underflow Sludge	14.5	3.8E-01	2.4E+00	8.1E+00	2.4E-01	7.9E+04	1.5E+00	0.0E+00	1.2E+02	4.9E-01	5.4E+02	0.0E+00	5.5E+03	9.3E+03	3.9E+02	0.0E+00	1.4E+03	2.7E+00	1.2E-03	8.4E-01	1.2E+05	1.3E-03	2.0E+00	1.4E+02	10.5
32	Sulfate A Underflow Sludge	28.7	0.0E+00	1.4E+03	5.7E-11	0.0E+00	2.3E+04	0.0E+00	0.0E+00	8.0E-03	4.5E-07	6.4E-05	5.3E+01	0.0E+00	8.8E+03	0.0E+00	0.0E+00	4.2E-02	6.8E-10	7.5E+00	5.0E-01	4.1E+04	3.6E-06	0.0E+00	0.0E+00	12.4
33	Calcite A Underflow Sludge	9.8	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E-04	0.0E+00	0.0E+00	0.0E+00	1.7E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.2
34	HDS B Underflow Sludge	14.5	3.8E-01	2.4E+00	8.1E+00	2.4E-01	7.9E+04	1.5E+00	0.0E+00	1.2E+02	4.9E-01	5.4E+02	0.0E+00	5.5E+03	9.3E+03	3.9E+02	0.0E+00	1.4E+03	2.7E+00	1.2E-03	8.4E-01	1.2E+05	1.3E-03	2.0E+00	1.4E+02	10.5
35	Sulfate B Underflow Sludge	28.7	0.0E+00	1.4E+03	5.7E-11	0.0E+00	2.3E+04	0.0E+00	0.0E+00	8.0E-03	4.5E-07	6.4E-05	5.3E+01	0.0E+00	8.8E+03	0.0E+00	0.0E+00	4.2E-02	6.8E-10	7.5E+00	5.0E-01	4.1E+04	3.6E-06	0.0E+00	0.0E+00	12.4
36	Calcite B Underflow Sludge	9.8	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E-04	0.0E+00	0.0E+00	0.0E+00	1.7E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.2
37	Plant Site VSEP Concentrate	150.0	6.9E-03	2.6E-01	3.1E-03	8.2E-03	2.0E+03	2.3E-02	2.1E+01	8.0E-03	1.1E-01	4.5E-01	2.1E+01	1.8E+00	2.2E+03	3.3E+00	1.4E+03	9.0E-01	5.1E-02	1.5E-01	4.4E-02	1.4E+04	5.1E-03	1.7E-01	3.5E-02	6.2
38	Plant Site Concentrate to HDS A	75.0	6.9E-03	2.6E-01	3.1E-03	8.2E-03	2.0E+03	2.3E-02	2.1E+01	8.0E-03	1.1E-01	4.5E-01	2.1E+01	1.8E+00	2.2E+03	3.3E+00	1.4E+03	9.0E-01	5.1E-02	1.5E-01	4.4E-02	1.4E+04	5.1E-03	1.7E-01	3.5E-02	6.2
39	Plant Site Concentrate to HDS B	75.0	6.9E-03	2.6E-01	3.1E-03	8.2E-03	2.0E+03	2.3E-02	2.1E+01	8.0E-03	1.1E-01	4.5E-01	2.1E+01	1.8E+00	2.2E+03	3.3E+00	1.4E+03	9.0E-01	5.1E-02	1.5E-01	4.4E-02	1.4E+04	5.1E-03	1.7E-01	3.5E-02	6.2
40	Final Effluent to CPS	2575.0	1.4E-04	1.5E-03	8.1E-03	1.3E-03	3.6E+01	5.0E-05	3.6E+01	2.2E-04	1.8E-03	8.0E-03	7.2E-01	6.4E-05	1.6E+01	1.1E-02	1.1E+02	5.6E-02	2.6E-05	3.3E-03	1.4E-03	8.8E+01	1.3E-04	1.2E-03	1.3E-02	6.0
	Effluent Target		1.0E-03	1.3E-01	1.0E-02	4.0E-03		5.1E-03	2.3E+02	5.0E-03	1.1E-02	3.0E-02	2.0E+00	3.0E-01		5.0E-02		1.1E-01	1.0E-02	3.1E-02	5.0E-03	2.5E+02	5.6E-02		2.6E-01	
	Targets Met?	NA	Yes	Yes	Yes	Yes	NA	Yes	Yes	Yes	Yes	Yes	Yes	Yes	NA	Yes	NA	Yes	Yes	Yes	Yes	Yes	Yes	NA	Yes	No

Chemical Addition, Flow Recycle, and Sludge Detail

Item	Description	Flows					Chemical Additions				Solids Balance				
		Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	337.7	NA	NA	NA	356.7	5.5	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	33.5	18.97	14.5	NA	NA	NA	NA	NA	NA	25	1.18	2.47	1.07	1.40
5	Sulfate A Influent	337.7	NA	NA	NA	375.2	5.5	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	66.2	37.52	28.7	NA	NA	NA	NA	NA	NA	10	1.05	1.68	0.69	0.99
6	Sulfate A Effluent	337.7	NA	NA	206.3	544.0	NA	NA	2.5	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	9.8	0.00	9.8	NA	NA	NA	NA	NA	NA	10	1.06	0.24	0.24	0.00
7	Calcite A Effluent	337.7	NA	NA	100.8	438.5	NA	NA	1.2	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	337.7	NA	NA	NA	356.7	5.5	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	33.5	18.97	14.5	NA	NA	NA	NA	NA	NA	25	1.18	2.47	1.07	1.40
11	Sulfate B Influent	337.7	NA	NA		375.2	5.5	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	66.2	37.52	28.7	NA	NA	NA	NA	NA	NA	10	1.05	1.68	0.69	0.99
12	Sulfate B Effluent	337.7	NA	NA	206.3	544.0	NA	NA	2.5	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	9.8	0.00	9.8	NA	NA	NA	NA	NA	NA	10	1.06	0.24	0.24	0.00
13	Calcite B Effluent	337.7	NA	NA	100.8	337.7	NA	NA	1.2	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	2156.9	NA	NA	NA	NA	NA	NA	NA	42.7	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	409.8	NA	NA	412.5*	NA	NA	NA	5.0	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 8 P90 Summer Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	322.0	3.4E-02	2.5E+02	3.4E-01	3.3E-02	1.6E+03	9.0E-02	5.4E+01	9.5E+00	2.5E-02	3.7E+01	1.9E+00	5.0E+02	7.7E+02	3.2E+01	2.4E+02	1.1E+02	1.8E-01	1.1E+00	1.4E-01	9.9E+03	4.2E-03	5.6E-02	9.7E+00	5.0
2	High Conc EQ Effluent to HDS A	161.0	3.4E-02	2.5E+02	3.4E-01	3.3E-02	1.6E+03	9.0E-02	5.4E+01	9.5E+00	2.5E-02	3.7E+01	1.9E+00	5.0E+02	7.7E+02	3.2E+01	2.4E+02	1.1E+02	1.8E-01	1.1E+00	1.4E-01	9.9E+03	4.2E-03	5.6E-02	9.7E+00	5.0
3	High Conc EQ Effluent to HDS B	161.0	3.4E-02	2.5E+02	3.4E-01	3.3E-02	1.6E+03	9.0E-02	5.4E+01	9.5E+00	2.5E-02	3.7E+01	1.9E+00	5.0E+02	7.7E+02	3.2E+01	2.4E+02	1.1E+02	1.8E-01	1.1E+00	1.4E-01	9.9E+03	4.2E-03	5.6E-02	9.7E+00	5.0
4	Combined HDS A Influent	332.6	2.0E-02	1.2E+02	3.2E-01	2.1E-02	1.9E+03	6.5E-02	4.1E+01	5.3E+00	8.0E-02	2.3E+01	6.7E+00	2.4E+02	1.1E+03	1.7E+01	8.3E+02	6.1E+01	1.2E-01	6.8E-01	1.3E-01	1.1E+04	8.6E-03	8.6E-02	6.7E+00	6.4
5	Sulfate A Influent	332.6	2.9E-03	1.2E+02	3.7E-06	9.3E-03	4.6E+02	8.9E-04	4.0E+01	7.4E-04	5.5E-02	3.8E-03	6.6E+00	9.2E-04	7.5E+02	1.7E-01	8.2E+02	3.9E-03	6.1E-05	6.7E-01	8.7E-02	5.4E+03	8.4E-03	3.1E-07	5.9E-01	10.5
6	Sulfate A Effluent	332.6	2.9E-03	1.2E-01	3.7E-06	9.3E-03	9.1E+02	8.9E-04	4.0E+01	9.0E-08	5.5E-02	3.8E-03	2.0E+00	9.2E-04	3.9E-01	1.7E-01	8.2E+02	2.9E-06	6.1E-05	3.3E-02	4.3E-02	1.8E+03	8.4E-03	3.1E-07	5.9E-01	12.4
7	Calcite A Effluent	332.6	2.9E-03	1.2E-01	3.7E-06	9.4E-03	6.2E-01	9.0E-04	4.1E+01	9.0E-08	5.6E-02	3.9E-03	2.0E+00	9.3E-04	4.0E-01	1.7E-01	8.2E+02	2.9E-06	6.1E-05	3.4E-02	4.4E-02	1.8E+03	8.5E-03	3.2E-07	6.0E-01	10.1
8	Calcite A Effluent to Final Effluent	133.0	2.9E-03	1.2E-01	3.7E-06	9.4E-03	6.2E-01	8.9E-04	4.0E+01	9.0E-08	5.6E-02	3.9E-03	2.0E+00	9.3E-04	4.0E-01	1.7E-01	8.2E+02	2.9E-06	6.1E-05	3.4E-02	4.4E-02	1.8E+03	8.5E-03	3.2E-07	6.0E-01	6.7
9	Calcite A Effluent to VSEP B	199.6	2.9E-03	1.2E-01	3.7E-06	9.4E-03	6.2E-01	8.9E-04	4.0E+01	9.0E-08	5.6E-02	3.9E-03	2.0E+00	9.3E-04	4.0E-01	1.7E-01	8.2E+02	2.9E-06	6.1E-05	3.4E-02	4.4E-02	1.8E+03	8.5E-03	3.2E-07	6.0E-01	6.7
10	Combined HDS B Influent	332.6	2.0E-02	1.2E+02	3.2E-01	2.1E-02	1.9E+03	6.5E-02	4.1E+01	5.3E+00	8.0E-02	2.3E+01	6.7E+00	2.4E+02	1.1E+03	1.7E+01	8.3E+02	6.1E+01	1.2E-01	6.8E-01	1.3E-01	1.1E+04	8.6E-03	8.6E-02	6.7E+00	6.4
11	Sulfate B Influent	332.6	2.9E-03	1.2E+02	3.7E-06	9.3E-03	4.6E+02	8.9E-04	4.0E+01	7.4E-04	5.5E-02	3.8E-03	6.6E+00	9.2E-04	7.5E+02	1.7E-01	8.2E+02	3.9E-03	6.1E-05	6.7E-01	8.7E-02	5.4E+03	8.4E-03	3.1E-07	5.9E-01	10.5
12	Sulfate B Effluent	332.6	2.9E-03	1.2E-01	3.7E-06	9.3E-03	9.1E+02	8.9E-04	4.0E+01	9.0E-08	5.5E-02	3.8E-03	2.0E+00	9.2E-04	3.9E-01	1.7E-01	8.2E+02	2.9E-06	6.1E-05	3.3E-02	4.3E-02	1.8E+03	8.4E-03	3.1E-07	5.9E-01	12.4
13	Calcite B Effluent	332.6	2.9E-03	1.2E-01	3.7E-06	9.4E-03	6.2E-01	9.0E-04	4.1E+01	9.0E-08	5.6E-02	3.9E-03	2.0E+00	9.3E-04	4.0E-01	1.7E-01	8.2E+02	2.9E-06	6.1E-05	3.4E-02	4.4E-02	1.8E+03	8.5E-03	3.2E-07	6.0E-01	10.1
14	Calcite B Effluent to Final Effluent	133.0	2.9E-03	1.2E-01	3.7E-06	9.4E-03	6.2E-01	8.9E-04	4.0E+01	9.0E-08	5.6E-02	3.9E-03	2.0E+00	9.3E-04	4.0E-01	1.7E-01	8.2E+02	2.9E-06	6.1E-05	3.4E-02	4.4E-02	1.8E+03	8.5E-03	3.2E-07	6.0E-01	6.7
15	Calcite B Effluent to VSEP B	199.6	2.9E-03	1.2E-01	3.7E-06	9.4E-03	6.2E-01	8.9E-04	4.0E+01	9.0E-08	5.6E-02	3.9E-03	2.0E+00	9.3E-04	4.0E-01	1.7E-01	8.2E+02	2.9E-06	6.1E-05	3.4E-02	4.4E-02	1.8E+03	8.5E-03	3.2E-07	6.0E-01	6.7
16	VSEP B Permeate to Final Effluent	324.6	1.1E-04	7.6E-04	2.3E-06	7.5E-03	5.5E-02	2.3E-05	3.9E+01	5.5E-09	5.9E-03	1.6E-04	1.2E+00	3.7E-05	5.8E-02	4.3E-02	3.7E+02	4.5E-07	1.4E-06	1.8E-03	2.7E-03	1.6E+02	4.5E-04	4.2E-08	3.8E-02	7.3
17	VSEP B Concentrate	81.2	1.4E-02	6.2E-01	9.4E-06	1.7E-02	2.9E+00	4.4E-03	4.5E+01	4.3E-07	2.6E-01	1.9E-02	5.3E+00	4.6E-03	1.8E+00	6.9E-01	2.7E+03	1.3E-05	3.0E-04	1.6E-01	2.1E-01	8.7E+03	4.1E-02	1.4E-06	2.9E+00	6.0
18	VSEP B Concentrate to HDS B	40.6	1.4E-02	6.2E-01	9.4E-06	1.7E-02	2.9E+00	4.4E-03	4.5E+01	4.3E-07	2.6E-01	1.9E-02	5.3E+00	4.6E-03	1.8E+00	6.9E-01	2.7E+03	1.3E-05	3.0E-04	1.6E-01	2.1E-01	8.7E+03	4.1E-02	1.4E-06	2.9E+00	6.0
19	VSEP B Concentrate to HDS A	40.6	1.4E-02	6.2E-01	9.4E-06	1.7E-02	2.9E+00	4.4E-03	4.5E+01	4.3E-07	2.6E-01	1.9E-02	5.3E+00	4.6E-03	1.8E+00	6.9E-01	2.7E+03	1.3E-05	3.0E-04	1.6E-01	2.1E-01	8.7E+03	4.1E-02	1.4E-06	2.9E+00	6.0
20	Low Conc EQ Effluent	1778.5	1.9E-04	1.7E-03	6.9E-02	3.9E-04	2.8E+02	5.7E-03	4.0E+01	2.3E-01	4.5E-03	1.8E+00	8.6E-01	1.9E-01	1.2E+02	3.9E-01	9.9E+01	3.3E+00	6.1E-03	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	6.0E-01	7.0
21	GSF Backwash	88.9	1.9E-04	1.7E-03	1.1E+00	3.9E-04	2.8E+02	1.1E-01	4.0E+01	4.6E+00	4.5E-03	3.4E+01	8.5E-01	3.7E+00	1.2E+02	7.6E+00	9.9E+01	6.1E+01	1.1E-01	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	1.2E+01	7.0
22	GSF Backwash Solids	44.5	1.9E-04	1.7E-03	1.9E+00	3.9E-04	2.8E+02	2.0E-01	4.0E+01	8.8E+00	4.5E-03	6.5E+01	8.5E-01	7.1E+00	1.2E+02	1.4E+01	9.9E+01	1.1E+02	2.1E-01	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	2.3E+01	7.0
23	GSF Backwash Decant	44.5	1.9E-04	1.7E-03	3.5E-01	3.9E-04	2.8E+02	1.6E-02	4.0E+01	3.0E-01	4.5E-03	3.7E+00	8.5E-01	2.2E-01	1.2E+02	7.6E-01	9.9E+01	1.1E+01	1.7E-02	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	8.5E-01	7.0
24	GSF Permeate/NF Feed	1689.5	1.9E-04	1.7E-03	2.1E-02	3.9E-04	2.8E+02	6.2E-04	4.0E+01	3.7E-03	4.5E-03	1.1E-01	8.6E-01	2.0E-03	1.2E+02	2.1E-02	9.9E+01	4.8E-01	6.7E-04	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	1.4E-02	7.0
25	NF Permeate	1351.6	1.5E-04	1.2E-04	2.6E-04	2.8E-05	3.5E+01	4.4E-05	4.5E+01	1.3E-04	3.2E-04	8.7E-03	6.9E-01	4.0E-20	8.1E+00	5.8E-04	6.5E+01	1.7E-02	2.6E-05	2.5E-03	3.5E-04	2.5E+01	1.3E-05	7.1E-04	2.8E-04	6.1
26	NF Concentrate to VSEP A	337.9	3.5E-04	8.1E-03	1.0E-01	1.9E-03	1.3E+03	3.0E-03	1.9E+01	1.8E-02	2.1E-02	5.3E-01	1.5E+00	9.9E-03	5.8E+02	1.0E-01	2.4E+02	2.3E+00	3.3E-03	1.7E-01	4.3E-02	3.0E+03	8.6E-04	4.7E-02	7.0E-02	9.0
27	VSEP A Permeate to Final Effluent	270.3	1.4E-05	5.0E-05	6.4E-02	1.5E-03	1.1E+02	7.8E-05	1.8E+01	1.1E-03	2.3E-03	2.2E-02	9.2E-01	3.9E-04	8.5E+01	2.6E-02	1.1E+02	3.6E-01	7.4E-05	8.9E-03	2.6E-03	2.6E+02	4.6E-05	6.3E-03	4.4E-03	5.4
28	VSEP A Concentrate	67.6	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.5E-02	2.1E+01	8.9E-02	1.0E-01	2.7E+00	4.2E+00	5.0E-02	2.6E+03	4.3E-01	7.9E+02	1.1E+01	1.7E-02	8.3E-01	2.1E-01	1.4E+04	4.3E-03	2.2E-01	3.4E-01	9.3
29	VSEP A Concentrate to HDS B	33.8	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.5E-02	2.1E+01	8.9E-02	1.0E-01	2.7E+00	4.2E+00	5.0E-02	2.6E+03	4.3E-01	7.9E+02	1.1E+01	1.7E-02	8.3E-01	2.1E-01	1.4E+04	4.3E-03	2.2E-01	3.4E-01	9.3
30	VSEP A Concentrate to HDS A	33.8	1.8E-03	4.2E-02	2.7E-01	3.5E-03	6.0E+03	1.5E-02	2.1E+01	8.9E-02	1.0E-01	2.7E+00	4.2E+00	5.0E-02	2.6E+03	4.3E-01	7.9E+02	1.1E+01	1.7E-02	8.3E-01	2.1E-01	1.4E+04	4.3E-03	2.2E-01	3.4E-01	9.3
31	HDS A Underflow Sludge	14.0	4.0E-01	7.0E-04	7.6E+00	2.6E-01	7.9E+04	1.5E+00	6.2E-01	1.2E+02	5.4E-01	5.3E+02	3.5E-02	5.7E+03	8.6E+03	4.0E+02	0.0E+00	1.4E+03	2.7E+00	8.2E-06	8.8E-01	1.2E+05	0.0E+00	2.0E+00	1.4E+02	10.5
32	Sulfate A Underflow Sludge	28.8	0.0E+00	1.4E+03	0.0E+00	3.4E-08	2.3E+04	0.0E+00	3.0E-01	8.5E-03	0.0E+00	6.3E-05	5.3E+01	8.3E-09	8.6E+03	0.0E+00	0.0E+00	4.4E-02	0.0E+00	7.3E+00	5.0E-01	4.1E+04	0.0E+00	0.0E+00	0.0E+00	12.4
33	Calcite A Underflow Sludge	9.2	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E+04	0.0E+00	9.7E-07	0.0E+00	0.0E+00	1.1E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.2E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.1
34	HDS B Underflow Sludge	14.0	4.0E-01	7.0E-04	7.6E+00	2.6E-01	7.9E+04	1.5E+00	6.2E-01	1.2E+02	5.4E-01	5.3E+02	3.5E-02	5.7E+03	8.6E+03	4.0E+02	0.0E+00	1.4E+03	2.7E+00	8.2E-06	8.8E-01	1.2E+05	0.0E+00	2.0E+00	1.4E+02	10.5
35	Sulfate B Underflow Sludge	28.8	0.0E+00	1.4E+03	0.0E+00	3.4E-08	2.3E+04	0.0E+00	3.0E-01	8.5E-03	0.0E+00	6.3E-05	5.3E+01	8.3E-09	8.6E+03	0.0E+00	0.0E+00	4.4E-02	0.0E+00	7.3E+00	5.0E-01	4.1E+04	0.0E+00	0.0E+00	0.0E+00	12.4
36	Calcite B Underflow Sludge	9.2	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.3E+04	0.0E+00	9.7E-07	0.0E+00	0.0E+00	1.1E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.2E-07	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.1
37	Plant Site VSEP Concentrate	150.0	6.9E-03	2.6E-01	3.1E-03	8.2E-03	2.0E+03	2.3E-02	2.1E+01	8.0E-03	1.1E-01	4.5E-01	2.1E+01	1.8E+00	2.2E+03	3.3E+00	1.4E+03	9.0E-01	5.1E-02	1.5E-01	4.4E-02	1.4E+04	5.1E-03	1.7E-01	3.5E-02	6.2
38	Plant Site Concentrate to HDS A	75.0	6.9E-03	2.6E-01	3.1E-03	8.2E-03	2.0E+03	2.3E-02	2.1E+01	8.0E-03	1.1E-01	4.5E-01	2.1E+01	1.8E+00	2.2E+03	3.3E+00	1.4E+03	9.0E-01	5.1E-02	1.5E-01	4.4E-02	1.4E+04	5.1E-03	1.7E-01	3.5E-02	6.2
39	Plant Site Concentrate to HDS B	75.0	6.9E-03	2.6E-01	3.1E-03	8.2E-03	2.0E+03	2.3E-02	2.1E+01	8.0E-03	1.1E-01	4.5E-01	2.1E+01	1.8E+00	2.2E+03	3.3E+00	1.4E+03	9.0E-01	5.1E-02	1.5E-01	4.4E-02	1.4E+04	5.1E-03	1.7E-01	3.5E-02	6.2
40	Final Effluent to CPS	2206.0	4.5E-04	1.5E-02	8.0E-03	2.4E-03	3.5E+01	1.5E-04	4.1E+01	2.2E-04	7.9E-03	9.0E-03	9.5E-01	1.6E-04	1.5E+01	3.0E-02	2.0E+02	5.5E-02	3.2E-05	6.8E-03	6.0E-03	2.9E+02	1.1E-03	1.2E-03	7.7E-02	6.1

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	332.6	NA	NA	NA	350.3	5.5	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	31.7	17.74	14.0	NA	NA	NA	NA	NA	NA	25	1.18	2.34	1.03	1.31
5	Sulfate A Influent	332.6	NA	NA	NA	369.6	5.5	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	65.8	36.96	28.8	NA	NA	NA	NA	NA	NA	10	1.05	1.67	0.69	0.98
6	Sulfate A Effluent	332.6	NA	NA	215.4	548.0	NA	NA	2.6	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	9.2	0.00	9.2	NA	NA	NA	NA	NA	NA	10	1.06	0.22	0.22	0.00
7	Calcite A Effluent	332.6	NA	NA	96.3	428.8	NA	NA	1.2	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	332.6	NA	NA	NA	350.3	5.5	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	31.7	17.74	14.0	NA	NA	NA	NA	NA	NA	25	1.18	2.34	1.03	1.31
11	Sulfate B Influent	332.6	NA	NA		369.6	5.5	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	65.8	36.96	28.8	NA	NA	NA	NA	NA	NA	10	1.05	1.67	0.69	0.98
12	Sulfate B Effluent	332.6	NA	NA	215.4	548.0	NA	NA	2.6	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	9.2	0.00	9.2	NA	NA	NA	NA	NA	NA	10	1.06	0.22	0.22	0.00
13	Calcite B Effluent	332.6	NA	NA	96.3	332.6	NA	NA	1.2	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1778.5	NA	NA	NA	NA	NA	NA	NA	35.2	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	337.9	NA	NA	412.5*	NA	NA	NA	5.0	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 8 P90 Winter Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	82.0	3.4E-02	2.5E+02	3.4E-01	3.3E-02	1.6E+03	9.0E-02	5.4E+01	9.5E+00	2.5E-02	3.7E+01	1.9E+00	5.0E+02	7.7E+02	3.2E+01	2.4E+02	1.1E+02	1.8E-01	1.1E+00	1.4E-01	9.9E+03	4.2E-03	5.6E-02	9.7E+00	5.0
2	High Conc EQ Effluent to HDS A	41.0	3.4E-02	2.5E+02	3.4E-01	3.3E-02	1.6E+03	9.0E-02	5.4E+01	9.5E+00	2.5E-02	3.7E+01	1.9E+00	5.0E+02	7.7E+02	3.2E+01	2.4E+02	1.1E+02	1.8E-01	1.1E+00	1.4E-01	9.9E+03	4.2E-03	5.6E-02	9.7E+00	5.0
3	High Conc EQ Effluent to HDS B	41.0	3.4E-02	2.5E+02	3.4E-01	3.3E-02	1.6E+03	9.0E-02	5.4E+01	9.5E+00	2.5E-02	3.7E+01	1.9E+00	5.0E+02	7.7E+02	3.2E+01	2.4E+02	1.1E+02	1.8E-01	1.1E+00	1.4E-01	9.9E+03	4.2E-03	5.6E-02	9.7E+00	5.0
4	Combined HDS A Influent	211.7	1.2E-02	4.9E+01	2.0E-01	1.1E-02	1.2E+03	3.4E-02	3.0E+01	2.3E+00	1.4E-01	1.1E+01	6.3E+00	9.8E+01	8.0E+02	7.6E+00	1.1E+03	2.7E+01	5.7E-02	3.2E-01	7.8E-02	8.0E+03	3.6E-02	6.1E-02	3.7E+00	6.5
5	Sulfate A Influent	211.7	3.6E-03	4.9E+01	9.1E-06	5.9E-03	4.4E+02	1.4E-03	2.9E+01	7.0E-04	1.1E-01	4.1E-03	6.2E+00	1.1E-03	6.2E+02	7.5E-02	1.1E+03	3.9E-03	4.5E-05	3.2E-01	5.4E-02	5.8E+03	3.5E-02	8.7E-07	6.6E-01	10.6
6	Sulfate A Effluent	211.7	3.6E-03	4.9E-02	9.1E-06	5.9E-03	8.1E+02	1.4E-03	2.9E+01	1.1E-07	1.1E-01	4.1E-03	2.2E+00	1.1E-03	3.5E-01	7.5E-02	1.1E+03	4.0E-06	4.5E-05	1.6E-02	2.7E-02	2.2E+03	3.5E-02	8.7E-07	6.6E-01	12.4
7	Calcite A Effluent	211.7	3.6E-03	4.9E-02	9.2E-06	5.9E-03	7.4E-01	1.4E-03	3.0E+01	1.1E-07	1.1E-01	4.2E-03	2.2E+00	1.1E-03	3.5E-01	7.6E-02	1.1E+03	4.1E-06	4.5E-05	1.6E-02	2.7E-02	2.3E+03	3.6E-02	8.7E-07	6.7E-01	10.8
8	Calcite A Effluent to Final Effluent	84.7	3.6E-03	4.9E-02	9.2E-06	5.9E-03	7.3E-01	1.4E-03	2.9E+01	1.1E-07	1.1E-01	4.1E-03	2.2E+00	1.1E-03	3.5E-01	7.6E-02	1.1E+03	4.1E-06	4.5E-05	1.6E-02	2.7E-02	2.3E+03	3.5E-02	8.7E-07	6.7E-01	6.9
9	Calcite A Effluent to VSEP B	127.0	3.6E-03	4.9E-02	9.2E-06	5.9E-03	7.3E-01	1.4E-03	2.9E+01	1.1E-07	1.1E-01	4.1E-03	2.2E+00	1.1E-03	3.5E-01	7.6E-02	1.1E+03	4.1E-06	4.5E-05	1.6E-02	2.7E-02	2.3E+03	3.5E-02	8.7E-07	6.7E-01	6.9
10	Combined HDS B Influent	211.7	1.2E-02	4.9E+01	2.0E-01	1.1E-02	1.2E+03	3.4E-02	3.0E+01	2.3E+00	1.4E-01	1.1E+01	6.3E+00	9.8E+01	8.0E+02	7.6E+00	1.1E+03	2.7E+01	5.7E-02	3.2E-01	7.8E-02	8.0E+03	3.6E-02	6.1E-02	3.7E+00	6.5
11	Sulfate B Influent	211.7	3.6E-03	4.9E+01	9.1E-06	5.9E-03	4.4E+02	1.4E-03	2.9E+01	7.0E-04	1.1E-01	4.1E-03	6.2E+00	1.1E-03	6.2E+02	7.5E-02	1.1E+03	3.9E-03	4.5E-05	3.2E-01	5.4E-02	5.8E+03	3.5E-02	8.7E-07	6.6E-01	10.6
12	Sulfate B Effluent	211.7	3.6E-03	4.9E-02	9.1E-06	5.9E-03	8.1E+02	1.4E-03	2.9E+01	1.1E-07	1.1E-01	4.1E-03	2.2E+00	1.1E-03	3.5E-01	7.5E-02	1.1E+03	4.0E-06	4.5E-05	1.6E-02	2.7E-02	2.2E+03	3.5E-02	8.7E-07	6.6E-01	12.4
13	Calcite B Effluent	211.7	3.6E-03	4.9E-02	9.2E-06	5.9E-03	7.4E-01	1.4E-03	3.0E+01	1.1E-07	1.1E-01	4.2E-03	2.2E+00	1.1E-03	3.5E-01	7.6E-02	1.1E+03	4.1E-06	4.5E-05	1.6E-02	2.7E-02	2.3E+03	3.6E-02	8.7E-07	6.7E-01	10.8
14	Calcite B Effluent to Final Effluent	84.7	3.6E-03	4.9E-02	9.2E-06	5.9E-03	7.3E-01	1.4E-03	2.9E+01	1.1E-07	1.1E-01	4.1E-03	2.2E+00	1.1E-03	3.5E-01	7.6E-02	1.1E+03	4.1E-06	4.5E-05	1.6E-02	2.7E-02	2.3E+03	3.5E-02	8.7E-07	6.7E-01	6.9
15	Calcite B Effluent to VSEP B	127.0	3.6E-03	4.9E-02	9.2E-06	5.9E-03	7.3E-01	1.4E-03	2.9E+01	1.1E-07	1.1E-01	4.1E-03	2.2E+00	1.1E-03	3.5E-01	7.6E-02	1.1E+03	4.1E-06	4.5E-05	1.6E-02	2.7E-02	2.3E+03	3.5E-02	8.7E-07	6.7E-01	6.9
16	VSEP B Permeate to Final Effluent	338.6	1.5E-04	3.1E-04	5.7E-06	4.7E-03	6.5E-02	3.7E-05	2.9E+01	6.8E-09	1.2E-02	1.8E-04	1.3E+00	4.2E-05	5.2E-02	1.9E-02	5.1E+02	6.3E-07	1.0E-06	8.6E-04	1.7E-03	1.9E+02	1.9E-03	1.2E-07	4.2E-02	8.9
17	VSEP B Concentrate	84.7	1.8E-02	2.5E-01	2.4E-05	1.1E-02	3.5E+00	7.1E-03	3.3E+01	5.4E-07	5.3E-01	2.0E-02	5.9E+00	5.2E-03	1.6E+00	3.1E-01	3.7E+03	1.8E-05	2.2E-04	7.8E-02	1.3E-01	1.1E+04	1.7E-01	3.9E-06	3.2E+00	5.4
18	VSEP B Concentrate to HDS B	42.3	1.8E-02	2.5E-01	2.4E-05	1.1E-02	3.5E+00	7.1E-03	3.3E+01	5.4E-07	5.3E-01	2.0E-02	5.9E+00	5.2E-03	1.6E+00	3.1E-01	3.7E+03	1.8E-05	2.2E-04	7.8E-02	1.3E-01	1.1E+04	1.7E-01	3.9E-06	3.2E+00	5.4
19	VSEP B Concentrate to HDS A	42.3	1.8E-02	2.5E-01	2.4E-05	1.1E-02	3.5E+00	7.1E-03	3.3E+01	5.4E-07	5.3E-01	2.0E-02	5.9E+00	5.2E-03	1.6E+00	3.1E-01	3.7E+03	1.8E-05	2.2E-04	7.8E-02	1.3E-01	1.1E+04	1.7E-01	3.9E-06	3.2E+00	5.4
20	Low Conc EQ Effluent	797.9	1.9E-04	1.7E-03	6.9E-02	3.9E-04	2.8E+02	5.7E-03	4.0E+01	2.3E-01	4.5E-03	1.8E+00	8.6E-01	1.9E-01	1.2E+02	3.9E-01	9.9E+01	3.3E+00	6.1E-03	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	6.0E-01	7.0
21	GSF Backwash	39.8	1.9E-04	1.7E-03	1.1E+00	3.9E-04	2.8E+02	1.1E-01	4.0E+01	4.6E+00	4.5E-03	3.4E+01	8.5E-01	3.7E+00	1.2E+02	7.6E+00	9.9E+01	6.1E+01	1.1E-01	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	1.2E+01	7.0
22	GSF Backwash Solids	19.9	1.9E-04	1.7E-03	1.9E+00	3.9E-04	2.8E+02	2.0E-01	4.0E+01	8.8E+00	4.5E-03	6.5E+01	8.5E-01	7.1E+00	1.2E+02	1.4E+01	9.9E+01	1.1E+02	2.1E-01	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	2.3E+01	7.0
23	GSF Backwash Decant	19.9	1.9E-04	1.7E-03	3.5E-01	3.9E-04	2.8E+02	1.6E-02	4.0E+01	3.0E-01	4.5E-03	3.7E+00	8.5E-01	2.2E-01	1.2E+02	7.6E-01	9.9E+01	1.1E+01	1.7E-02	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	8.5E-01	7.0
24	GSF Permeate/NF Feed	758.1	1.9E-04	1.7E-03	2.1E-02	3.9E-04	2.8E+02	6.2E-04	4.0E+01	3.7E-03	4.5E-03	1.1E-01	8.6E-01	2.0E-03	1.2E+02	2.1E-02	9.9E+01	4.8E-01	6.7E-04	3.5E-02	8.8E-03	6.1E+02	1.8E-04	9.9E-03	1.4E-02	7.0
25	NF Permeate	606.4	1.5E-04	1.2E-04	2.6E-04	2.8E-05	3.5E+01	4.4E-05	4.5E+01	1.3E-04	3.2E-04	8.7E-03	6.9E-01	0.0E+00	8.1E+00	5.8E-04	6.5E+01	1.7E-02	2.6E-05	2.5E-03	3.5E-04	2.5E+01	1.3E-05	7.1E-04	2.8E-04	6.1
26	NF Concentrate to VSEP A	151.6	3.5E-04	8.1E-03	1.0E-01	1.9E-03	1.3E+03	3.0E-03	1.9E+01	1.8E-02	2.1E-02	5.3E-01	1.5E+00	9.9E-03	5.8E+02	1.0E-01	2.4E+02	2.3E+00	3.3E-03	1.7E-01	4.3E-02	3.0E+03	8.6E-04	4.7E-02	7.0E-02	9.0
27	VSEP A Permeate to Final Effluent	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	VSEP A Concentrate	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29	VSEP A Concentrate to HDS B	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30	VSEP A Concentrate to HDS A	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	5.3	3.2E-01	0.0E+00	7.7E+00	2.0E-01	8.7E+04	1.3E+00	7.6E-01	8.9E+01	1.0E+00	4.2E+02	5.7E-02	3.8E+03	6.5E+03	3.0E+02	0.0E+00	1.1E+03	2.2E+00	0.0E+00	9.2E-01	8.2E+04	0.0E+00	2.4E+00	1.2E+02	10.6
32	Sulfate A Underflow Sludge	16.1	0.0E+00	6.4E+02	0.0E+00	0.0E+00	1.9E+04	0.0E+00	2.5E-01	9.2E-03	0.0E+00	7.7E-05	5.2E+01	0.0E+00	8.1E+03	0.0E+00	0.0E+00	5.2E-02	0.0E+00	4.0E+00	3.5E-01	4.6E+04	0.0E+00	0.0E+00	0.0E+00	12.4
33	Calcite A Underflow Sludge	5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.4E+04	0.0E+00	0.0E+00	1.6E-11	0.0E+00	1.3E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.9E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.8
34	HDS B Underflow Sludge	5.3	3.2E-01	0.0E+00	7.7E+00	2.0E-01	8.7E+04	1.3E+00	7.6E-01	8.9E+01	1.0E+00	4.2E+02	5.7E-02	3.8E+03	6.5E+03	3.0E+02	0.0E+00	1.1E+03	2.2E+00	0.0E+00	9.2E-01	8.2E+04	0.0E+00	2.4E+00	1.2E+02	10.6
35	Sulfate B Underflow Sludge	16.1	0.0E+00	6.4E+02	0.0E+00	0.0E+00	1.9E+04	0.0E+00	2.5E-01	9.2E-03	0.0E+00	7.7E-05	5.2E+01	0.0E+00	8.1E+03	0.0E+00	0.0E+00	5.2E-02	0.0E+00	4.0E+00	3.5E-01	4.6E+04	0.0E+00	0.0E+00	0.0E+00	12.4
36	Calcite B Underflow Sludge	5.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.4E+04	0.0E+00	0.0E+00	1.6E-11	0.0E+00	1.3E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.9E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.8
37	Plant Site VSEP Concentrate	85.1	6.9E-03	2.6E-01	3.1E-03	8.2E-03	2.0E+03	2.3E-02	2.1E+01	8.0E-03	1.1E-01	4.5E-01	2.1E+01	1.8E+00	2.2E+03	3.3E+00	1.4E+03	9.0E-01	5.1E-02	1.5E-01	4.4E-02	1.4E+04	5.1E-03	1.7E-01	3.5E-02	6.2
38	Plant Site Concentrate to HDS A	42.6	6.9E-03	2.6E-01	3.1E-03	8.2E-03	2.0E+03	2.3E-02	2.1E+01	8.0E-03	1.1E-01	4.5E-01	2.1E+01	1.8E+00	2.2E+03	3.3E+00	1.4E+03	9.0E-01	5.1E-02	1.5E-01	4.4E-02	1.4E+04	5.1E-03	1.7E-01	3.5E-02	6.2
39	Plant Site Concentrate to HDS B	42.6	6.9E-03	2.6E-01	3.1E-03	8.2E-03	2.0E+03	2.3E-02	2.1E+01	8.0E-03	1.1E-01	4.5E-01	2.1E+01	1.8E+00	2.2E+03	3.3E+00	1.4E+03	9.0E-01	5.1E-02	1.5E-01	4.4E-02	1.4E+04	5.1E-03	1.7E-01	3.5E-02	6.2
40	Final Effluent to CPS	945.1	1.5E-04	1.9E-04	1.8E-04	1.7E-03	2.2E+01	4.2E-05	3.9E+01	8.5E-05	4.5E-03	6.0E-03	9.2E-01	1.5E-05	5.3E+00	7.2E-03	2.2E+02	1.1E-02	1.7E-05	1.9E-03	8.2E-04	8.6E+01	6.9E-04	4.5E-04	1.5E-02	6.7

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	211.7	NA	NA	NA	238.7	2.6	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	32.4	27.04	5.3	NA	NA	NA	NA	NA	NA	25	1.18	2.39	0.39	2.00
5	Sulfate A Influent	211.7	NA	NA	NA	235.2	3.3	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	39.6	23.52	16.1	NA	NA	NA	NA	NA	NA	10	1.05	1.01	0.39	0.62
6	Sulfate A Effluent	211.7	NA	NA	114.6	326.2	NA	NA	1.4	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	5.0	0.00	5.0	NA	NA	NA	NA	NA	NA	10	1.06	0.12	0.12	0.00
7	Calcite A Effluent	211.7	NA	NA	73.3	285.0	NA	NA	0.9	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	211.7	NA	NA	NA	238.7	2.6	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	32.4	27.04	5.3	NA	NA	NA	NA	NA	NA	25	1.18	2.39	0.39	2.00
11	Sulfate B Influent	211.7	NA	NA		235.2	3.3	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	39.6	23.52	16.1	NA	NA	NA	NA	NA	NA	10	1.05	1.01	0.39	0.62
12	Sulfate B Effluent	211.7	NA	NA	114.6	326.2	NA	NA	1.4	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	5.0	0.00	5.0	NA	NA	NA	NA	NA	NA	10	1.06	0.12	0.12	0.00
13	Calcite B Effluent	211.7	NA	NA	73.3	211.7	NA	NA	0.9	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	797.9	NA	NA	NA	NA	NA	NA	NA	15.8	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	151.6	NA	NA	0*	NA	NA	NA	0.0	NA	NA	NA	NA	NA	NA

Mine Water Treatment Trains Flow and Load Detail
Year 9 P90 Annual Average Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	211.0	4.0E-02	3.2E+02	3.4E-01	3.5E-02	1.6E+03	1.1E-01	5.4E+01	1.2E+01	2.7E-02	5.1E+01	1.8E+00	5.2E+02	8.6E+02	3.8E+01	2.3E+02	1.7E+02	2.2E-01	1.3E+00	1.4E-01	1.1E+04	6.1E-03	6.1E-02	1.2E+01	5.0
2	High Conc EQ Effluent to HDS A	105.5	4.0E-02	3.2E+02	3.4E-01	3.5E-02	1.6E+03	1.1E-01	5.4E+01	1.2E+01	2.7E-02	5.1E+01	1.8E+00	5.2E+02	8.6E+02	3.8E+01	2.3E+02	1.7E+02	2.2E-01	1.3E+00	1.4E-01	1.1E+04	6.1E-03	6.1E-02	1.2E+01	5.0
3	High Conc EQ Effluent to HDS B	105.5	4.0E-02	3.2E+02	3.4E-01	3.5E-02	1.6E+03	1.1E-01	5.4E+01	1.2E+01	2.7E-02	5.1E+01	1.8E+00	5.2E+02	8.6E+02	3.8E+01	2.3E+02	1.7E+02	2.2E-01	1.3E+00	1.4E-01	1.1E+04	6.1E-03	6.1E-02	1.2E+01	5.0
4	Combined HDS A Influent	282.8	2.1E-02	1.2E+02	2.8E-01	2.1E-02	1.8E+03	6.5E-02	5.0E+01	5.1E+00	1.4E-01	2.4E+01	5.7E+00	2.0E+02	1.1E+03	1.6E+01	1.1E+03	7.2E+01	1.3E-01	6.4E-01	1.5E-01	9.8E+03	1.6E-02	9.8E-02	7.1E+00	6.2
5	Sulfate A Influent	282.8	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0
6	Sulfate A Effluent	282.8	7.3E-09	1.6E-07	7.1E-12	2.1E-08	8.5E+02	1.8E-09	6.5E-05	1.4E-09	1.3E-07	8.5E-09	7.3E-06	2.1E-09	1.4E-03	4.2E-07	1.5E-03	8.7E-09	1.8E-10	4.2E-08	9.0E-08	9.5E-03	1.8E-08	6.9E-13	1.3E-06	12.5
7	Calcite A Effluent	282.8	1.5E-08	3.2E-07	1.4E-11	4.3E-08	7.1E-02	3.7E-09	1.3E-04	1.4E-09	2.6E-07	1.7E-08	1.0E-05	4.1E-09	1.4E-03	8.5E-07	3.0E-03	8.7E-09	3.5E-10	8.3E-08	1.8E-07	1.2E-02	3.7E-08	1.4E-12	2.6E-06	6.3
8	Calcite A Effluent to Final Effluent	113.1	2.2E-08	4.8E-07	2.1E-11	6.4E-08	7.1E-02	5.5E-09	1.9E-04	1.4E-09	3.9E-07	2.5E-08	1.3E-05	6.2E-09	1.4E-03	1.3E-06	4.5E-03	8.7E-09	5.3E-10	1.3E-07	2.7E-07	1.5E-02	5.5E-08	2.1E-12	3.9E-06	6.7
9	Calcite A Effluent to VSEP B	169.7	2.2E-08	4.8E-07	2.1E-11	6.4E-08	7.1E-02	5.5E-09	1.9E-04	1.4E-09	3.9E-07	2.5E-08	1.3E-05	6.2E-09	1.4E-03	1.3E-06	4.5E-03	8.7E-09	5.3E-10	1.3E-07	2.7E-07	1.5E-02	5.5E-08	2.1E-12	3.9E-06	6.7
10	Combined HDS B Influent	282.8	2.1E-02	1.2E+02	2.8E-01	2.1E-02	1.8E+03	6.5E-02	5.0E+01	5.1E+00	1.4E-01	2.4E+01	5.7E+00	2.0E+02	1.1E+03	1.6E+01	1.1E+03	7.2E+01	1.3E-01	6.4E-01	1.5E-01	9.8E+03	1.6E-02	9.8E-02	7.1E+00	6.2
11	Sulfate B Influent	282.8	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0
12	Sulfate B Effluent	282.8	7.3E-09	1.6E-07	7.1E-12	2.1E-08	8.5E+02	1.8E-09	6.5E-05	1.4E-09	1.3E-07	8.5E-09	7.3E-06	2.1E-09	1.4E-03	4.2E-07	1.5E-03	8.7E-09	1.8E-10	4.2E-08	9.0E-08	9.5E-03	1.8E-08	6.9E-13	1.3E-06	12.5
13	Calcite B Effluent	282.8	1.5E-08	3.2E-07	1.4E-11	4.3E-08	7.1E-02	3.7E-09	1.3E-04	1.4E-09	2.6E-07	1.7E-08	1.0E-05	4.1E-09	1.4E-03	8.5E-07	3.0E-03	8.7E-09	3.5E-10	8.3E-08	1.8E-07	1.2E-02	3.7E-08	1.4E-12	2.6E-06	6.3
14	Calcite B Effluent to Final Effluent	113.1	2.2E-08	4.8E-07	2.1E-11	6.4E-08	7.1E-02	5.5E-09	1.9E-04	1.4E-09	3.9E-07	2.5E-08	1.3E-05	6.2E-09	1.4E-03	1.3E-06	4.5E-03	8.7E-09	5.3E-10	1.3E-07	2.7E-07	1.5E-02	5.5E-08	2.1E-12	3.9E-06	6.7
15	Calcite B Effluent to VSEP B	169.7	2.2E-08	4.8E-07	2.1E-11	6.4E-08	7.1E-02	5.5E-09	1.9E-04	1.4E-09	3.9E-07	2.5E-08	1.3E-05	6.2E-09	1.4E-03	1.3E-06	4.5E-03	8.7E-09	5.3E-10	1.3E-07	2.7E-07	1.5E-02	5.5E-08	2.1E-12	3.9E-06	6.7
16	VSEP B Permeate to Final Effluent	411.7	2.8E-05	9.7E-05	4.2E-07	1.6E-03	1.3E-02	4.7E-06	6.2E+00	7.6E-10	1.4E-03	3.3E-05	1.7E-01	7.6E-06	8.8E-03	9.8E-03	6.5E+01	6.6E-08	3.6E-07	2.2E-04	5.2E-04	2.4E+01	1.1E-04	9.1E-09	7.7E-03	6.6
17	VSEP B Concentrate	102.9	1.1E-07	2.4E-06	5.4E-11	1.2E-07	3.3E-01	2.7E-08	2.1E-04	6.5E-09	1.8E-06	1.2E-07	3.4E-05	3.0E-08	6.4E-03	5.1E-06	1.4E-02	3.8E-08	2.6E-09	6.0E-07	1.3E-06	7.1E-02	2.6E-07	9.3E-12	1.9E-05	7.8
18	VSEP B Concentrate to HDS B	51.5	1.1E-07	2.4E-06	5.4E-11	1.2E-07	3.3E-01	2.7E-08	2.1E-04	6.5E-09	1.8E-06	1.2E-07	3.4E-05	3.0E-08	6.4E-03	5.1E-06	1.4E-02	3.8E-08	2.6E-09	6.0E-07	1.3E-06	7.1E-02	2.6E-07	9.3E-12	1.9E-05	7.8
19	VSEP B Concentrate to HDS A	51.5	1.1E-07	2.4E-06	5.4E-11	1.2E-07	3.3E-01	2.7E-08	2.1E-04	6.5E-09	1.8E-06	1.2E-07	3.4E-05	3.0E-08	6.4E-03	5.1E-06	1.4E-02	3.8E-08	2.6E-09	6.0E-07	1.3E-06	7.1E-02	2.6E-07	9.3E-12	1.9E-05	7.8
20	Low Conc EQ Effluent	1549.7	1.9E-04	1.7E-03	6.3E-02	3.9E-04	2.5E+02	5.5E-03	3.4E+01	2.1E-01	4.1E-03	1.7E+00	7.8E-01	1.9E-01	1.1E+02	3.7E-01	9.2E+01	3.1E+00	6.4E-03	3.1E-02	9.7E-03	6.6E+02	1.8E-04	9.9E-03	5.6E-01	7.0
21	GSF Backwash	77.5	1.9E-04	1.7E-03	1.0E+00	3.9E-04	2.5E+02	1.0E-01	3.4E+01	4.2E+00	4.1E-03	3.3E+01	7.7E-01	3.7E+00	1.1E+02	7.2E+00	9.2E+01	5.6E+01	1.2E-01	3.1E-02	9.7E-03	6.5E+02	1.8E-04	9.8E-03	1.1E+01	7.0
22	GSF Backwash Solids	38.7	1.9E-04	1.7E-03	1.7E+00	3.9E-04	2.5E+02	1.9E-01	3.4E+01	8.1E+00	4.1E-03	6.3E+01	7.7E-01	7.2E+00	1.1E+02	1.4E+01	9.2E+01	1.0E+02	2.2E-01	3.1E-02	9.7E-03	6.5E+02	1.8E-04	9.8E-03	2.1E+01	7.0
23	GSF Backwash Decant	38.7	1.9E-04	1.7E-03	3.2E-01	3.9E-04	2.5E+02	1.5E-02	3.4E+01	2.7E-01	4.1E-03	3.6E+00	7.7E-01	2.2E-01	1.1E+02	7.2E-01	9.2E+01	1.0E+01	1.8E-02	3.1E-02	9.7E-03	6.5E+02	1.8E-04	9.8E-03	8.0E-01	7.0
24	GSF Permeate/NF Feed	1472.3	1.9E-04	1.7E-03	1.9E-02	3.9E-04	2.5E+02	6.1E-04	3.4E+01	3.4E-03	4.1E-03	1.1E-01	7.8E-01	2.0E-03	1.1E+02	2.0E-02	9.2E+01	4.4E-01	7.1E-04	3.1E-02	9.7E-03	6.6E+02	1.8E-04	9.9E-03	1.3E-02	7.0
25	NF Permeate	1177.8	1.4E-04	1.2E-04	2.4E-04	2.8E-05	3.0E+01	4.3E-05	3.8E+01	1.2E-04	2.9E-04	8.4E-03	6.1E-01	0.0E+00	7.2E+00	3.0E-03	5.9E+01	1.6E-02	2.8E-05	2.2E-03	3.9E-04	2.7E+01	1.3E-05	7.0E-04	2.6E-04	6.0
26	NF Concentrate to VSEP A	294.5	3.8E-04	8.1E-03	9.5E-02	1.9E-03	1.1E+03	2.9E-03	1.6E+01	1.7E-02	2.0E-02	5.1E-01	1.5E+00	9.9E-03	5.1E+02	8.9E-02	2.3E+02	2.2E+00	3.5E-03	1.5E-01	4.7E-02	3.2E+03	8.7E-04	4.7E-02	6.5E-02	9.1
27	VSEP A Permeate to Final Effluent	235.6	1.5E-05	5.0E-05	5.8E-02	1.5E-03	1.0E+02	7.5E-05	1.6E+01	1.0E-03	2.1E-03	2.2E-02	8.7E-01	4.0E-04	7.5E+01	2.3E-02	1.0E+02	3.4E-01	7.8E-05	8.0E-03	2.9E-03	2.7E+02	4.6E-05	6.2E-03	4.1E-03	5.6
28	VSEP A Concentrate	58.9	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0
29	VSEP A Concentrate to HDS B	29.4	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0
30	VSEP A Concentrate to HDS A	29.4	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0
31	HDS A Underflow Sludge	23.2	2.4E-01	2.6E+03	3.3E+00	2.2E-01	5.9E+04	7.7E-01	8.4E+02	6.1E+01	1.6E+00	2.9E+02	8.2E+01	2.3E+03	1.2E+04	1.9E+02	1.2E+04	8.6E+02	1.5E+00	1.3E+01	1.7E+00	1.1E+05	2.2E-01	1.2E+00	8.2E+01	0.0
32	Sulfate A Underflow Sludge	12.2	6.0E-07	4.2E-01	7.2E-10	2.1E-06	7.5E+04	2.8E-07	3.1E-03	3.6E-06	1.3E-05	3.9E-07	1.2E-02	1.9E-07	3.8E+00	2.9E-05	6.9E-02	2.3E-05	1.9E-08	2.1E-03	2.4E-04	1.8E+01	3.1E-06	7.0E-11	1.1E-04	12.5
33	Calcite A Underflow Sludge	9.5	1.1E-04	2.3E-03	1.0E-07	3.1E-04	3.6E+00	2.7E-05	3.9E-03	1.6E-09	1.9E-03	5.1E-07	2.7E-02	3.0E-05	8.6E-03	6.2E-03	2.2E+01	6.1E-08	2.6E-06	6.1E-04	1.3E-03	4.2E+01	2.7E-04	1.0E-08	1.9E-02	6.3
34	HDS B Underflow Sludge	23.2	2.4E-01	2.6E+03	3.3E+00	2.2E-01	5.9E+04	7.7E-01	8.4E+02	6.1E+01	1.6E+00	2.9E+02	8.2E+01	2.3E+03	1.2E+04	1.9E+02	1.2E+04	8.6E+02	1.5E+00	1.3E+01	1.7E+00	1.1E+05	2.2E-01	1.2E+00	8.2E+01	0.0
35	Sulfate B Underflow Sludge	12.2	6.0E-07	4.2E-01	7.2E-10	2.1E-06	7.5E+04	2.8E-07	3.1E-03	3.6E-06	1.3E-05	3.9E-07	1.2E-02	1.9E-07	3.8E+00	2.9E-05	6.9E-02	2.3E-05	1.9E-08	2.1E-03	2.4E-04	1.8E+01	3.1E-06	7.0E-11	1.1E-04	12.5
36	Calcite B Underflow Sludge	9.5	1.1E-04	2.3E-03	1.0E-07	3.1E-04	3.6E+00	2.7E-05	3.9E-03	1.6E-09	1.9E-03	5.1E-07	2.7E-02	3.0E-05	8.6E-03	6.2E-03	2.2E+01	6.1E-08	2.6E-06	6.1E-04	1.3E-03	4.2E+01	2.7E-04	1.0E-08	1.9E-02	6.3
37	Plant Site VSEP Concentrate	154.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
38	Plant Site Concentrate to HDS A	77.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
39	Plant Site Concentrate to HDS B	77.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
40	Final Effluent to CPS	1876.0	1.4E-04	9.3E-04	7.4E-03	1.1E-03	3.2E+01	4.8E-05	3.0E+01	2.0E-04	1.9E-03	8.0E-03	6.0E-01	6.3E-05	1.4E+01	1.2E-02	9.5E+01	5.2E-02	2.8E-05	2.7E-03	1.3E-03	7.9E+01	1.9E-04	1.2E-03	1.1E-02	6.0

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	282.8	NA	NA	NA	333.1	7.7	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	73.5	50.31	23.2	NA	NA	NA	NA	NA	NA	25	1.18	5.41	1.71	3.70
5	Sulfate A Influent	282.8	NA	NA	NA	314.2	5.0	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	43.6	31.42	12.2	NA	NA	NA	NA	NA	NA	10	1.05	1.12	0.29	0.83
6	Sulfate A Effluent	282.8	NA	NA	165.0	447.8	NA	NA	2.0	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	9.5	0.00	9.5	NA	NA	NA	NA	NA	NA	10	1.06	0.23	0.23	0.00
7	Calcite A Effluent	282.8	NA	NA	77.9	360.7	NA	NA	0.9	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	282.8	NA	NA	NA	333.1	7.7	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	73.5	50.31	23.2	NA	NA	NA	NA	NA	NA	25	1.18	5.41	1.71	3.70
11	Sulfate B Influent	282.8	NA	NA		314.2	5.0	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	43.6	31.42	12.2	NA	NA	NA	NA	NA	NA	10	1.05	1.12	0.29	0.83
12	Sulfate B Effluent	282.8	NA	NA	165.0	447.8	NA	NA	2.0	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	9.5	0.00	9.5	NA	NA	NA	NA	NA	NA	10	1.06	0.23	0.23	0.00
13	Calcite B Effluent	282.8	NA	NA	77.9	282.8	NA	NA	0.9	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1549.7	NA	NA	NA	NA	NA	NA	NA	30.7	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	294.5	NA	NA	275*	NA	NA	NA	3.3	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 9 P90 Peak Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	323.0	4.0E-02	3.2E+02	3.4E-01	3.5E-02	1.6E+03	1.1E-01	5.4E+01	1.2E+01	2.7E-02	5.1E+01	1.8E+00	5.2E+02	8.6E+02	3.8E+01	2.3E+02	1.7E+02	2.2E-01	1.3E+00	1.4E-01	1.1E+04	6.1E-03	6.1E-02	1.2E+01	5.0
2	High Conc EQ Effluent to HDS A	161.5	4.0E-02	3.2E+02	3.4E-01	3.5E-02	1.6E+03	1.1E-01	5.4E+01	1.2E+01	2.7E-02	5.1E+01	1.8E+00	5.2E+02	8.6E+02	3.8E+01	2.3E+02	1.7E+02	2.2E-01	1.3E+00	1.4E-01	1.1E+04	6.1E-03	6.1E-02	1.2E+01	5.0
3	High Conc EQ Effluent to HDS B	161.5	4.0E-02	3.2E+02	3.4E-01	3.5E-02	1.6E+03	1.1E-01	5.4E+01	1.2E+01	2.7E-02	5.1E+01	1.8E+00	5.2E+02	8.6E+02	3.8E+01	2.3E+02	1.7E+02	2.2E-01	1.3E+00	1.4E-01	1.1E+04	6.1E-03	6.1E-02	1.2E+01	5.0
4	Combined HDS A Influent	351.7	2.1E-02	1.5E+02	3.4E-01	2.0E-02	1.9E+03	7.5E-02	4.8E+01	6.3E+00	8.4E-02	2.9E+01	4.7E+00	2.4E+02	1.2E+03	1.9E+01	6.8E+02	8.8E+01	1.4E-01	7.5E-01	1.3E-01	9.5E+03	8.1E-03	9.9E-02	8.0E+00	6.2
5	Sulfate A Influent	351.7	3.3E-03	1.5E+02	3.1E-06	9.6E-03	5.1E+02	8.3E-04	4.7E+01	6.1E-04	5.8E-02	3.8E-03	4.6E+00	9.3E-04	6.5E+02	1.9E-01	6.6E+02	3.9E-03	7.9E-05	7.3E-01	8.9E-02	4.3E+03	7.9E-03	3.1E-07	5.8E-01	10.5
6	Sulfate A Effluent	351.7	3.3E-03	1.5E-01	3.1E-06	9.6E-03	1.3E+03	8.3E-04	4.7E+01	9.4E-08	5.8E-02	3.8E-03	1.7E+00	9.3E-04	3.2E-01	1.9E-01	6.6E+02	4.0E-06	7.9E-05	3.7E-02	4.5E-02	1.4E+03	7.8E-03	3.1E-07	5.8E-01	12.5
7	Calcite A Effluent	351.7	3.3E-03	1.5E-01	3.2E-06	9.6E-03	1.4E+00	8.3E-04	4.7E+01	9.5E-08	5.8E-02	3.8E-03	1.7E+00	9.3E-04	3.2E-01	1.9E-01	6.7E+02	4.0E-06	8.0E-05	3.7E-02	4.5E-02	1.4E+03	7.9E-03	3.1E-07	5.9E-01	10.8
8	Calcite A Effluent to Final Effluent	140.7	3.3E-03	1.5E-01	3.2E-06	9.6E-03	1.4E+00	8.3E-04	4.7E+01	9.5E-08	5.8E-02	3.8E-03	1.7E+00	9.3E-04	3.2E-01	1.9E-01	6.6E+02	4.0E-06	8.0E-05	3.7E-02	4.5E-02	1.4E+03	7.8E-03	3.1E-07	5.9E-01	6.4
9	Calcite A Effluent to VSEP B	211.0	3.3E-03	1.5E-01	3.2E-06	9.6E-03	1.4E+00	8.3E-04	4.7E+01	9.5E-08	5.8E-02	3.8E-03	1.7E+00	9.3E-04	3.2E-01	1.9E-01	6.6E+02	4.0E-06	8.0E-05	3.7E-02	4.5E-02	1.4E+03	7.8E-03	3.1E-07	5.9E-01	6.4
10	Combined HDS B Influent	351.7	2.1E-02	1.5E+02	3.4E-01	2.0E-02	1.9E+03	7.5E-02	4.8E+01	6.3E+00	8.4E-02	2.9E+01	4.7E+00	2.4E+02	1.2E+03	1.9E+01	6.8E+02	8.8E+01	1.4E-01	7.5E-01	1.3E-01	9.5E+03	8.1E-03	9.9E-02	8.0E+00	6.2
11	Sulfate B Influent	351.7	3.3E-03	1.5E+02	3.1E-06	9.6E-03	5.1E+02	8.3E-04	4.7E+01	6.1E-04	5.8E-02	3.8E-03	4.6E+00	9.3E-04	6.5E+02	1.9E-01	6.6E+02	3.9E-03	7.9E-05	7.3E-01	8.9E-02	4.3E+03	7.9E-03	3.1E-07	5.8E-01	10.5
12	Sulfate B Effluent	351.7	3.3E-03	1.5E-01	3.1E-06	9.6E-03	1.3E+03	8.3E-04	4.7E+01	9.4E-08	5.8E-02	3.8E-03	1.7E+00	9.3E-04	3.2E-01	1.9E-01	6.6E+02	4.0E-06	7.9E-05	3.7E-02	4.5E-02	1.4E+03	7.8E-03	3.1E-07	5.8E-01	12.5
13	Calcite B Effluent	351.7	3.3E-03	1.5E-01	3.2E-06	9.6E-03	1.4E+00	8.3E-04	4.7E+01	9.5E-08	5.8E-02	3.8E-03	1.7E+00	9.3E-04	3.2E-01	1.9E-01	6.7E+02	4.0E-06	8.0E-05	3.7E-02	4.5E-02	1.4E+03	7.9E-03	3.1E-07	5.9E-01	10.8
14	Calcite B Effluent to Final Effluent	140.7	3.3E-03	1.5E-01	3.2E-06	9.6E-03	1.4E+00	8.3E-04	4.7E+01	9.5E-08	5.8E-02	3.8E-03	1.7E+00	9.3E-04	3.2E-01	1.9E-01	6.6E+02	4.0E-06	8.0E-05	3.7E-02	4.5E-02	1.4E+03	7.8E-03	3.1E-07	5.9E-01	6.4
15	Calcite B Effluent to VSEP B	211.0	3.3E-03	1.5E-01	3.2E-06	9.6E-03	1.4E+00	8.3E-04	4.7E+01	9.5E-08	5.8E-02	3.8E-03	1.7E+00	9.3E-04	3.2E-01	1.9E-01	6.6E+02	4.0E-06	8.0E-05	3.7E-02	4.5E-02	1.4E+03	7.8E-03	3.1E-07	5.9E-01	6.4
16	VSEP B Permeate to Final Effluent	287.0	1.3E-04	9.2E-04	1.9E-06	7.7E-03	1.4E-01	2.2E-05	4.6E+01	5.8E-09	6.2E-03	1.6E-04	1.0E+00	3.7E-05	4.7E-02	4.8E-02	2.9E+02	6.3E-07	1.8E-06	2.0E-03	2.7E-03	1.2E+02	4.2E-04	4.1E-08	3.7E-02	6.3
17	VSEP B Concentrate	71.8	1.6E-02	7.4E-01	8.1E-06	1.7E-02	6.4E+00	4.1E-03	5.2E+01	4.6E-07	2.7E-01	1.9E-02	4.5E+00	4.5E-03	1.4E+00	7.7E-01	2.2E+03	1.8E-05	4.0E-04	1.8E-01	2.1E-01	6.8E+03	3.8E-02	1.4E-06	2.8E+00	6.7
18	VSEP B Concentrate to HDS B	35.9	1.6E-02	7.4E-01	8.1E-06	1.7E-02	6.4E+00	4.1E-03	5.2E+01	4.6E-07	2.7E-01	1.9E-02	4.5E+00	4.5E-03	1.4E+00	7.7E-01	2.2E+03	1.8E-05	4.0E-04	1.8E-01	2.1E-01	6.8E+03	3.8E-02	1.4E-06	2.8E+00	6.7
19	VSEP B Concentrate to HDS A	35.9	1.6E-02	7.4E-01	8.1E-06	1.7E-02	6.4E+00	4.1E-03	5.2E+01	4.6E-07	2.7E-01	1.9E-02	4.5E+00	4.5E-03	1.4E+00	7.7E-01	2.2E+03	1.8E-05	4.0E-04	1.8E-01	2.1E-01	6.8E+03	3.8E-02	1.4E-06	2.8E+00	6.7
20	Low Conc EQ Effluent	2391.8	1.9E-04	1.7E-03	6.3E-02	3.9E-04	2.5E+02	5.5E-03	3.4E+01	2.1E-01	4.1E-03	1.7E+00	7.8E-01	1.9E-01	1.1E+02	3.7E-01	9.2E+01	3.1E+00	6.4E-03	3.1E-02	9.7E-03	6.6E+02	1.8E-04	9.9E-03	5.6E-01	7.0
21	GSF Backwash	119.6	1.9E-04	1.7E-03	1.0E+00	3.9E-04	2.5E+02	1.0E-01	3.4E+01	4.2E+00	4.1E-03	3.3E+01	7.7E-01	3.7E+00	1.1E+02	7.2E+00	9.2E+01	5.6E+01	1.2E-01	3.1E-02	9.7E-03	6.5E+02	1.8E-04	9.8E-03	1.1E+01	7.0
22	GSF Backwash Solids	59.8	1.9E-04	1.7E-03	1.7E+00	3.9E-04	2.5E+02	1.9E-01	3.4E+01	8.1E+00	4.1E-03	6.3E+01	7.7E-01	7.2E+00	1.1E+02	1.4E+01	9.2E+01	1.0E+02	2.2E-01	3.1E-02	9.7E-03	6.5E+02	1.8E-04	9.8E-03	2.1E+01	7.0
23	GSF Backwash Decant	59.8	1.9E-04	1.7E-03	3.2E-01	3.9E-04	2.5E+02	1.5E-02	3.4E+01	2.7E-01	4.1E-03	3.6E+00	7.7E-01	2.2E-01	1.1E+02	7.2E-01	9.2E+01	1.0E+01	1.8E-02	3.1E-02	9.7E-03	6.5E+02	1.8E-04	9.8E-03	8.0E-01	7.0
24	GSF Permeate/NF Feed	2272.2	1.9E-04	1.7E-03	1.9E-02	3.9E-04	2.5E+02	6.1E-04	3.4E+01	3.4E-03	4.1E-03	1.1E-01	7.8E-01	2.0E-03	1.1E+02	2.0E-02	9.2E+01	4.4E-01	7.1E-04	3.1E-02	9.7E-03	6.6E+02	1.8E-04	9.9E-03	1.3E-02	7.0
25	NF Permeate	1817.8	1.4E-04	1.2E-04	2.4E-04	2.8E-05	3.0E+01	4.3E-05	3.8E+01	1.2E-04	2.9E-04	8.4E-03	6.1E-01	0.0E+00	7.2E+00	3.0E-03	5.9E+01	1.6E-02	2.8E-05	2.2E-03	3.9E-04	2.7E+01	1.3E-05	7.0E-04	2.6E-04	6.0
26	NF Concentrate to VSEP A	454.4	3.8E-04	8.1E-03	9.5E-02	1.9E-03	1.1E+03	2.9E-03	1.6E+01	1.7E-02	2.0E-02	5.1E-01	1.5E+00	9.9E-03	5.1E+02	8.9E-02	2.3E+02	2.2E+00	3.5E-03	1.5E-01	4.7E-02	3.2E+03	8.7E-04	4.7E-02	6.5E-02	9.1
27	VSEP A Permeate to Final Effluent	363.6	1.5E-05	5.0E-05	5.8E-02	1.5E-03	1.0E+02	7.5E-05	1.6E+01	1.0E-03	2.1E-03	2.2E-02	8.7E-01	4.0E-04	7.5E+01	2.3E-02	1.0E+02	3.4E-01	7.8E-05	8.0E-03	2.9E-03	2.7E+02	4.6E-05	6.2E-03	4.1E-03	5.7
28	VSEP A Concentrate	90.9	1.9E-03	4.2E-02	2.5E-01	3.5E-03	5.4E+03	1.5E-02	1.8E+01	8.1E-02	9.3E-02	2.5E+00	3.9E+00	5.0E-02	2.3E+03	3.7E-01	7.5E+02	9.8E+00	1.8E-02	7.4E-01	2.3E-01	1.5E+04	4.3E-03	2.2E-01	3.2E-01	9.8
29	VSEP A Concentrate to HDS B	45.4	1.9E-03	4.2E-02	2.5E-01	3.5E-03	5.4E+03	1.5E-02	1.8E+01	8.1E-02	9.3E-02	2.5E+00	3.9E+00	5.0E-02	2.3E+03	3.7E-01	7.5E+02	9.8E+00	1.8E-02	7.4E-01	2.3E-01	1.5E+04	4.3E-03	2.2E-01	3.2E-01	9.8
30	VSEP A Concentrate to HDS A	45.4	1.9E-03	4.2E-02	2.5E-01	3.5E-03	5.4E+03	1.5E-02	1.8E+01	8.1E-02	9.3E-02	2.5E+00	3.9E+00	5.0E-02	2.3E+03	3.7E-01	7.5E+02	9.8E+00	1.8E-02	7.4E-01	2.3E-01	1.5E+04	4.3E-03	2.2E-01	3.2E-01	9.8
31	HDS A Underflow Sludge	20.1	3.1E-01	0.0E+00	5.8E+00	1.8E-01	8.3E+04	1.3E+00	0.0E+00	1.1E+02	4.2E-01	5.0E+02	0.0E+00	4.1E+03	8.8E+03	3.3E+02	0.0E+00	1.5E+03	2.5E+00	0.0E+00	6.7E-01	8.9E+04	0.0E+00	1.7E+00	1.3E+02	10.5
32	Sulfate A Underflow Sludge	33.3	2.1E-08	1.5E+03	0.0E+00	0.0E+00	3.6E+04	1.9E-08	3.2E-01	6.5E-03	0.0E+00	5.7E-05	3.1E+01	0.0E+00	6.8E+03	0.0E+00	0.0E+00	4.1E-02	0.0E+00	7.4E+00	4.7E-01	3.0E+04	0.0E+00	0.0E+00	0.0E+00	12.5
33	Calcite A Underflow Sludge	11.9	2.9E-08	0.0E+00	0.0E+00	0.0E+00	3.8E+04	2.3E-08	0.0E+00	0.0E+00	0.0E+00	8.6E-05	0.0E+00	0.0E+00	1.8E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.8
34	HDS B Underflow Sludge	20.1	3.1E-01	0.0E+00	5.8E+00	1.8E-01	8.3E+04	1.3E+00	0.0E+00	1.1E+02	4.2E-01	5.0E+02	0.0E+00	4.1E+03	8.8E+03	3.3E+02	0.0E+00	1.5E+03	2.5E+00	0.0E+00	6.7E-01	8.9E+04	0.0E+00	1.7E+00	1.3E+02	10.5
35	Sulfate B Underflow Sludge	33.3	2.1E-08	1.5E+03	0.0E+00	0.0E+00	3.6E+04	1.9E-08	3.2E-01	6.5E-03	0.0E+00	5.7E-05	3.1E+01	0.0E+00	6.8E+03	0.0E+00	0.0E+00	4.1E-02	0.0E+00	7.4E+00	4.7E-01	3.0E+04	0.0E+00	0.0E+00	0.0E+00	12.5
36	Calcite B Underflow Sludge	11.9	2.9E-08	0.0E+00	0.0E+00	0.0E+00	3.8E+04	2.3E-08	0.0E+00	0.0E+00	0.0E+00	8.6E-05	0.0E+00	0.0E+00	1.8E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.8
37	Plant Site VSEP Concentrate	158.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
38	Plant Site Concentrate to HDS A	79.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
39	Plant Site Concentrate to HDS B	79.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
40	Final Effluent to CPS	2813.0	5.1E-04	1.8E-02	7.6E-03	2.2E-03	3.3E+01	1.4E-04	3.7E+01	2.1E-04	8.2E-03	9.0E-03	8.2E-01	1.7E-04	1.4E+01	3.3E-02	1.6E+02	5.4E-02	3.8E-05	7.2E-03	6.4E-03	2.4E+02	1.0E-03	1.3E-03	7.6E-02	5.9

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	351.7	NA	NA	NA	379.0	9.9	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	47.4	27.27	20.1	NA	NA	NA	NA	NA	NA	25	1.18	3.50	1.49	2.01
5	Sulfate A Influent	351.7	NA	NA	NA	390.8	8.3	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	72.3	39.08	33.3	NA	NA	NA	NA	NA	NA	10	1.05	1.83	0.80	1.03
6	Sulfate A Effluent	351.7	NA	NA	256.7	608.4	NA	NA	3.1	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	11.9	0.00	11.9	NA	NA	NA	NA	NA	NA	10	1.06	0.29	0.29	0.00
7	Calcite A Effluent	351.7	NA	NA	91.7	443.4	NA	NA	1.1	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	351.7	NA	NA	NA	379.0	9.9	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	47.4	27.27	20.1	NA	NA	NA	NA	NA	NA	25	1.18	3.50	1.49	2.01
11	Sulfate B Influent	351.7	NA	NA		390.8	8.3	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	72.3	39.08	33.3	NA	NA	NA	NA	NA	NA	10	1.05	1.83	0.80	1.03
12	Sulfate B Effluent	351.7	NA	NA	256.7	608.4	NA	NA	3.1	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	11.9	0.00	11.9	NA	NA	NA	NA	NA	NA	10	1.06	0.29	0.29	0.00
13	Calcite B Effluent	351.7	NA	NA	91.7	351.7	NA	NA	1.1	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	2391.8	NA	NA	NA	NA	NA	NA	NA	47.3	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	454.4	NA	NA	366.7*	NA	NA	NA	4.4	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 9 P90 Summer Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	323.0	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
2	High Conc EQ Effluent to HDS A	161.5	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
3	High Conc EQ Effluent to HDS B	161.5	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
4	Combined HDS A Influent	346.8	2.2E-02	1.5E+02	3.2E-01	2.1E-02	1.8E+03	7.4E-02	4.9E+01	6.2E+00	9.2E-02	2.9E+01	4.8E+00	2.4E+02	1.1E+03	1.9E+01	7.4E+02	8.8E+01	1.4E-01	7.5E-01	1.3E-01	9.5E+03	1.0E-02	9.6E-02	7.8E+00	6.2
5	Sulfate A Influent	346.8	3.3E-03	1.5E+02	3.0E-06	9.8E-03	5.0E+02	8.1E-04	4.8E+01	6.3E-04	6.4E-02	3.8E-03	4.7E+00	9.4E-04	6.4E+02	1.9E-01	7.3E+02	4.1E-03	7.8E-05	7.3E-01	9.0E-02	4.4E+03	1.0E-02	3.0E-07	5.9E-01	10.5
6	Sulfate A Effluent	346.8	3.3E-03	1.5E-01	3.0E-06	9.8E-03	1.2E+03	8.1E-04	4.8E+01	1.0E-07	6.4E-02	3.8E-03	1.7E+00	9.4E-04	3.1E-01	1.9E-01	7.3E+02	4.3E-06	7.8E-05	3.7E-02	4.5E-02	1.5E+03	1.0E-02	3.0E-07	5.9E-01	12.5
7	Calcite A Effluent	346.8	3.4E-03	1.5E-01	3.1E-06	9.9E-03	8.5E-01	8.2E-04	4.8E+01	1.0E-07	6.4E-02	3.9E-03	1.7E+00	9.5E-04	3.2E-01	1.9E-01	7.3E+02	4.3E-06	7.9E-05	3.7E-02	4.5E-02	1.5E+03	1.0E-02	3.0E-07	6.0E-01	11.0
8	Calcite A Effluent to Final Effluent	138.7	3.3E-03	1.5E-01	3.1E-06	9.9E-03	8.4E-01	8.1E-04	4.8E+01	1.0E-07	6.4E-02	3.8E-03	1.7E+00	9.4E-04	3.2E-01	1.9E-01	7.3E+02	4.3E-06	7.9E-05	3.7E-02	4.5E-02	1.5E+03	1.0E-02	3.0E-07	5.9E-01	6.6
9	Calcite A Effluent to VSEP B	208.1	3.3E-03	1.5E-01	3.1E-06	9.9E-03	8.4E-01	8.1E-04	4.8E+01	1.0E-07	6.4E-02	3.8E-03	1.7E+00	9.4E-04	3.2E-01	1.9E-01	7.3E+02	4.3E-06	7.9E-05	3.7E-02	4.5E-02	1.5E+03	1.0E-02	3.0E-07	5.9E-01	6.6
10	Combined HDS B Influent	346.8	2.2E-02	1.5E+02	3.2E-01	2.1E-02	1.8E+03	7.4E-02	4.9E+01	6.2E+00	9.2E-02	2.9E+01	4.8E+00	2.4E+02	1.1E+03	1.9E+01	7.4E+02	8.8E+01	1.4E-01	7.5E-01	1.3E-01	9.5E+03	1.0E-02	9.6E-02	7.8E+00	6.2
11	Sulfate B Influent	346.8	3.3E-03	1.5E+02	3.0E-06	9.8E-03	5.0E+02	8.1E-04	4.8E+01	6.3E-04	6.4E-02	3.8E-03	4.7E+00	9.4E-04	6.4E+02	1.9E-01	7.3E+02	4.1E-03	7.8E-05	7.3E-01	9.0E-02	4.4E+03	1.0E-02	3.0E-07	5.9E-01	10.5
12	Sulfate B Effluent	346.8	3.3E-03	1.5E-01	3.0E-06	9.8E-03	1.2E+03	8.1E-04	4.8E+01	1.0E-07	6.4E-02	3.8E-03	1.7E+00	9.4E-04	3.1E-01	1.9E-01	7.3E+02	4.3E-06	7.8E-05	3.7E-02	4.5E-02	1.5E+03	1.0E-02	3.0E-07	5.9E-01	12.5
13	Calcite B Effluent	346.8	3.4E-03	1.5E-01	3.1E-06	9.9E-03	8.5E-01	8.2E-04	4.8E+01	1.0E-07	6.4E-02	3.9E-03	1.7E+00	9.5E-04	3.2E-01	1.9E-01	7.3E+02	4.3E-06	7.9E-05	3.7E-02	4.5E-02	1.5E+03	1.0E-02	3.0E-07	6.0E-01	11.0
14	Calcite B Effluent to Final Effluent	138.7	3.3E-03	1.5E-01	3.1E-06	9.9E-03	8.4E-01	8.1E-04	4.8E+01	1.0E-07	6.4E-02	3.8E-03	1.7E+00	9.4E-04	3.2E-01	1.9E-01	7.3E+02	4.3E-06	7.9E-05	3.7E-02	4.5E-02	1.5E+03	1.0E-02	3.0E-07	5.9E-01	6.6
15	Calcite B Effluent to VSEP B	208.1	3.3E-03	1.5E-01	3.1E-06	9.9E-03	8.4E-01	8.1E-04	4.8E+01	1.0E-07	6.4E-02	3.8E-03	1.7E+00	9.4E-04	3.2E-01	1.9E-01	7.3E+02	4.3E-06	7.9E-05	3.7E-02	4.5E-02	1.5E+03	1.0E-02	3.0E-07	5.9E-01	6.6
16	VSEP B Permeate to Final Effluent	338.5	1.3E-04	9.3E-04	1.9E-06	7.9E-03	7.5E-02	2.1E-05	4.7E+01	6.2E-09	6.8E-03	1.6E-04	1.0E+00	3.8E-05	4.6E-02	4.9E-02	3.3E+02	6.7E-07	1.8E-06	2.0E-03	2.8E-03	1.3E+02	5.4E-04	4.0E-08	3.8E-02	6.5
17	VSEP B Concentrate	84.6	1.6E-02	7.5E-01	7.8E-06	1.8E-02	4.0E+00	4.0E-03	5.3E+01	4.8E-07	3.0E-01	1.9E-02	4.6E+00	4.6E-03	1.4E+00	7.7E-01	2.4E+03	1.9E-05	3.9E-04	1.8E-01	2.2E-01	7.0E+03	4.9E-02	1.3E-06	2.9E+00	7.2
18	VSEP B Concentrate to HDS B	42.3	1.6E-02	7.5E-01	7.8E-06	1.8E-02	4.0E+00	4.0E-03	5.3E+01	4.8E-07	3.0E-01	1.9E-02	4.6E+00	4.6E-03	1.4E+00	7.7E-01	2.4E+03	1.9E-05	3.9E-04	1.8E-01	2.2E-01	7.0E+03	4.9E-02	1.3E-06	2.9E+00	7.2
19	VSEP B Concentrate to HDS A	42.3	1.6E-02	7.5E-01	7.8E-06	1.8E-02	4.0E+00	4.0E-03	5.3E+01	4.8E-07	3.0E-01	1.9E-02	4.6E+00	4.6E-03	1.4E+00	7.7E-01	2.4E+03	1.9E-05	3.9E-04	1.8E-01	2.2E-01	7.0E+03	4.9E-02	1.3E-06	2.9E+00	7.2
20	Low Conc EQ Effluent	2032.8	1.9E-04	1.7E-03	5.5E-02	3.9E-04	2.2E+02	5.0E-03	2.5E+01	1.9E-01	3.7E-03	1.5E+00	6.0E-01	1.9E-01	9.6E+01	3.5E-01	8.4E+01	2.6E+00	7.1E-03	2.7E-02	7.2E-03	5.5E+02	1.8E-04	9.8E-03	5.2E-01	7.0
21	GSF Backwash	101.6	1.9E-04	1.7E-03	1.0E+00	3.9E-04	2.5E+02	1.0E-01	3.4E+01	4.2E+00	4.1E-03	3.3E+01	7.7E-01	3.7E+00	1.1E+02	7.2E+00	9.2E+01	5.6E+01	1.2E-01	3.1E-02	9.7E-03	6.6E+02	1.8E-04	9.8E-03	1.1E+01	7.0
22	GSF Backwash Solids	50.8	1.9E-04	1.7E-03	1.7E+00	3.9E-04	2.5E+02	1.9E-01	3.4E+01	8.1E+00	4.1E-03	6.3E+01	7.7E-01	7.2E+00	1.1E+02	1.4E+01	9.2E+01	1.0E+02	2.2E-01	3.1E-02	9.7E-03	6.6E+02	1.8E-04	9.8E-03	2.1E+01	7.0
23	GSF Backwash Decant	50.8	1.9E-04	1.7E-03	3.2E-01	3.9E-04	2.5E+02	1.5E-02	3.4E+01	2.7E-01	4.1E-03	3.6E+00	7.7E-01	2.2E-01	1.1E+02	7.2E-01	9.2E+01	1.0E+01	1.8E-02	3.1E-02	9.7E-03	6.6E+02	1.8E-04	9.8E-03	8.0E-01	7.0
24	GSF Permeate/NF Feed	1931.2	1.9E-04	1.7E-03	1.9E-02	3.9E-04	2.5E+02	6.1E-04	3.4E+01	3.4E-03	4.1E-03	1.1E-01	7.8E-01	2.0E-03	1.1E+02	2.0E-02	9.2E+01	4.4E-01	7.1E-04	3.1E-02	9.7E-03	6.6E+02	1.8E-04	9.9E-03	1.3E-02	7.0
25	NF Permeate	1544.9	1.4E-04	1.2E-04	2.4E-04	2.8E-05	3.0E+01	4.3E-05	3.8E+01	1.2E-04	2.9E-04	8.4E-03	6.1E-01	0.0E+00	7.2E+00	3.0E-03	5.9E+01	1.6E-02	2.8E-05	2.2E-03	3.9E-04	2.7E+01	1.3E-05	7.0E-04	2.6E-04	6.0
26	NF Concentrate to VSEP A	386.2	3.8E-04	8.1E-03	9.5E-02	1.9E-03	1.1E+03	2.9E-03	1.6E+01	1.7E-02	2.0E-02	5.1E-01	1.5E+00	9.9E-03	5.1E+02	8.9E-02	2.3E+02	2.2E+00	3.5E-03	1.5E-01	4.7E-02	3.2E+03	8.7E-04	4.7E-02	6.5E-02	9.1
27	VSEP A Permeate to Final Effluent	309.0	1.5E-05	5.0E-05	5.8E-02	1.5E-03	1.0E+02	7.5E-05	1.6E+01	1.0E-03	2.1E-03	2.2E-02	8.7E-01	4.0E-04	7.5E+01	2.3E-02	1.0E+02	3.4E-01	7.8E-05	8.0E-03	2.9E-03	2.7E+02	4.6E-05	6.2E-03	4.1E-03	5.6
28	VSEP A Concentrate	77.2	1.9E-03	4.2E-02	2.5E-01	3.5E-03	5.4E+03	1.5E-02	1.8E+01	8.1E-02	9.3E-02	2.6E+00	3.9E+00	5.0E-02	2.3E+03	3.7E-01	7.5E+02	9.8E+00	1.8E-02	7.4E-01	2.3E-01	1.5E+04	4.3E-03	2.2E-01	3.2E-01	9.4
29	VSEP A Concentrate to HDS B	38.6	1.9E-03	4.2E-02	2.5E-01	3.5E-03	5.4E+03	1.5E-02	1.8E+01	8.1E-02	9.3E-02	2.6E+00	3.9E+00	5.0E-02	2.3E+03	3.7E-01	7.5E+02	9.8E+00	1.8E-02	7.4E-01	2.3E-01	1.5E+04	4.3E-03	2.2E-01	3.2E-01	9.4
30	VSEP A Concentrate to HDS A	38.6	1.9E-03	4.2E-02	2.5E-01	3.5E-03	5.4E+03	1.5E-02	1.8E+01	8.1E-02	9.3E-02	2.6E+00	3.9E+00	5.0E-02	2.3E+03	3.7E-01	7.5E+02	9.8E+00	1.8E-02	7.4E-01	2.3E-01	1.5E+04	4.3E-03	2.2E-01	3.2E-01	9.4
31	HDS A Underflow Sludge	19.7	3.2E-01	0.0E+00	5.5E+00	1.9E-01	8.3E+04	1.3E+00	5.5E-01	1.1E+02	4.7E-01	5.0E+02	1.9E-02	4.2E+03	8.5E+03	3.3E+02	0.0E+00	1.5E+03	2.5E+00	3.4E-06	6.8E-01	8.7E+04	0.0E+00	1.7E+00	1.2E+02	10.5
32	Sulfate A Underflow Sludge	33.1	8.8E-08	1.6E+03	0.0E+00	0.0E+00	3.6E+04	0.0E+00	3.3E-01	6.6E-03	5.0E-07	5.7E-05	3.1E+01	0.0E+00	6.7E+03	2.4E-06	0.0E+00	4.3E-02	0.0E+00	7.3E+00	4.7E-01	3.0E+04	0.0E+00	0.0E+00	0.0E+00	12.5
33	Calcite A Underflow Sludge	11.7	0.0E+00	1.1E-09	0.0E+00	0.0E+00	3.7E+04	2.0E-09	8.2E-10	2.6E-11	0.0E+00	8.7E-05	2.3E-05	0.0E+00	0.0E+00	2.2E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.1E-02	0.0E+00	0.0E+00	0.0E+00	11.0
34	HDS B Underflow Sludge	19.7	3.2E-01	0.0E+00	5.5E+00	1.9E-01	8.3E+04	1.3E+00	5.5E-01	1.1E+02	4.7E-01	5.0E+02	1.9E-02	4.2E+03	8.5E+03	3.3E+02	0.0E+00	1.5E+03	2.5E+00	3.4E-06	6.8E-01	8.7E+04	0.0E+00	1.7E+00	1.2E+02	10.5
35	Sulfate B Underflow Sludge	33.1	8.8E-08	1.6E+03	0.0E+00	0.0E+00	3.6E+04	0.0E+00	3.3E-01	6.6E-03	5.0E-07	5.7E-05	3.1E+01	0.0E+00	6.7E+03	2.4E-06	0.0E+00	4.3E-02	0.0E+00	7.3E+00	4.7E-01	3.0E+04	0.0E+00	0.0E+00	0.0E+00	12.5
36	Calcite B Underflow Sludge	11.7	0.0E+00	1.1E-09	0.0E+00	0.0E+00	3.7E+04	2.0E-09	8.2E-10	2.6E-11	0.0E+00	8.7E-05	2.3E-05	0.0E+00	0.0E+00	2.2E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.1E-02	0.0E+00	0.0E+00	0.0E+00	11.0
37	Plant Site VSEP Concentrate	158.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
38	Plant Site Concentrate to HDS A	79.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
39	Plant Site Concentrate to HDS B	79.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
40	Final Effluent to CPS	2463.0	4.8E-04	1.7E-02	7.4E-03	2.4E-03	3.2E+01	1.3E-04	3.8E+01	2.0E-04	8.4E-03	8.0E-03	8.2E-01	1.6E-04	1.4E+01	3.2E-02	1.7E+02	5.2E-02	3.6E-05	6.7E-03	6.0E-03	2.3E+02	1.2E-03	1.2E-03	7.1E-02	6.0

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	346.8	NA	NA	NA	372.8	9.9	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	45.6	25.94	19.7	NA	NA	NA	NA	NA	NA	25	1.18	3.37	1.46	1.92
5	Sulfate A Influent	346.8	NA	NA	NA	385.4	8.3	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	71.7	38.54	33.1	NA	NA	NA	NA	NA	NA	10	1.05	1.81	0.79	1.02
6	Sulfate A Effluent	346.8	NA	NA	256.7	603.5	NA	NA	3.1	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	11.7	0.00	11.7	NA	NA	NA	NA	NA	NA	10	1.06	0.28	0.28	0.00
7	Calcite A Effluent	346.8	NA	NA	96.3	443.1	NA	NA	1.2	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	346.8	NA	NA	NA	372.8	9.9	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	45.6	25.94	19.7	NA	NA	NA	NA	NA	NA	25	1.18	3.37	1.46	1.92
11	Sulfate B Influent	346.8	NA	NA		385.4	8.3	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	71.7	38.54	33.1	NA	NA	NA	NA	NA	NA	10	1.05	1.81	0.79	1.02
12	Sulfate B Effluent	346.8	NA	NA	256.7	603.5	NA	NA	3.1	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	11.7	0.00	11.7	NA	NA	NA	NA	NA	NA	10	1.06	0.28	0.28	0.00
13	Calcite B Effluent	346.8	NA	NA	96.3	346.8	NA	NA	1.2	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	2032.8	NA	NA	NA	NA	NA	NA	NA	40.2	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	386.2	NA	NA	366.7*	NA	NA	NA	4.4	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 9 P90 Winter Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	79.0	4.0E-02	3.2E+02	3.4E-01	3.5E-02	1.6E+03	1.1E-01	5.4E+01	1.2E+01	2.7E-02	5.1E+01	1.8E+00	5.2E+02	8.6E+02	3.8E+01	2.3E+02	1.7E+02	2.2E-01	1.3E+00	1.4E-01	1.1E+04	6.1E-03	6.1E-02	1.2E+01	5.0
2	High Conc EQ Effluent to HDS A	39.5	4.0E-02	3.2E+02	3.4E-01	3.5E-02	1.6E+03	1.1E-01	5.4E+01	1.2E+01	2.7E-02	5.1E+01	1.8E+00	5.2E+02	8.6E+02	3.8E+01	2.3E+02	1.7E+02	2.2E-01	1.3E+00	1.4E-01	1.1E+04	6.1E-03	6.1E-02	1.2E+01	5.0
3	High Conc EQ Effluent to HDS B	39.5	4.0E-02	3.2E+02	3.4E-01	3.5E-02	1.6E+03	1.1E-01	5.4E+01	1.2E+01	2.7E-02	5.1E+01	1.8E+00	5.2E+02	8.6E+02	3.8E+01	2.3E+02	1.7E+02	2.2E-01	1.3E+00	1.4E-01	1.1E+04	6.1E-03	6.1E-02	1.2E+01	5.0
4	Combined HDS A Influent	215.7	1.2E-02	5.9E+01	1.8E-01	1.1E-02	1.1E+03	3.7E-02	3.7E+01	2.6E+00	1.6E-01	1.3E+01	4.4E+00	9.6E+01	7.7E+02	8.3E+00	9.8E+02	3.7E+01	7.0E-02	3.5E-01	8.1E-02	6.5E+03	4.1E-02	6.7E-02	4.0E+00	6.2
5	Sulfate A Influent	215.7	4.0E-03	5.8E+01	7.0E-06	5.9E-03	4.8E+02	9.7E-04	3.6E+01	6.2E-04	1.2E-01	4.1E-03	4.4E+00	1.1E-03	5.5E+02	8.1E-02	9.7E+02	4.2E-03	5.3E-05	3.4E-01	5.6E-02	4.8E+03	4.1E-02	8.2E-07	6.5E-01	10.6
6	Sulfate A Effluent	215.7	4.0E-03	5.8E-02	7.0E-06	5.9E-03	1.0E+03	9.7E-04	3.6E+01	1.2E-07	1.2E-01	4.1E-03	1.9E+00	1.1E-03	3.1E-01	8.1E-02	9.7E+02	5.3E-06	5.3E-05	1.7E-02	2.8E-02	1.8E+03	4.0E-02	8.2E-07	6.5E-01	12.5
7	Calcite A Effluent	215.7	4.0E-03	5.9E-02	7.1E-06	6.0E-03	1.2E+00	9.8E-04	3.6E+01	1.2E-07	1.2E-01	4.1E-03	2.0E+00	1.1E-03	3.1E-01	8.2E-02	9.8E+02	5.3E-06	5.3E-05	1.7E-02	2.8E-02	1.8E+03	4.1E-02	8.3E-07	6.6E-01	10.4
8	Calcite A Effluent to Final Effluent	86.3	4.0E-03	5.9E-02	7.1E-06	5.9E-03	1.2E+00	9.8E-04	3.6E+01	1.2E-07	1.2E-01	4.1E-03	1.9E+00	1.1E-03	3.1E-01	8.2E-02	9.7E+02	5.3E-06	5.3E-05	1.7E-02	2.8E-02	1.8E+03	4.1E-02	8.2E-07	6.6E-01	6.6
9	Calcite A Effluent to VSEP B	129.4	4.0E-03	5.9E-02	7.1E-06	5.9E-03	1.2E+00	9.8E-04	3.6E+01	1.2E-07	1.2E-01	4.1E-03	1.9E+00	1.1E-03	3.1E-01	8.2E-02	9.7E+02	5.3E-06	5.3E-05	1.7E-02	2.8E-02	1.8E+03	4.1E-02	8.2E-07	6.6E-01	6.6
10	Combined HDS B Influent	215.7	1.2E-02	5.9E+01	1.8E-01	1.1E-02	1.1E+03	3.7E-02	3.7E+01	2.6E+00	1.6E-01	1.3E+01	4.4E+00	9.6E+01	7.7E+02	8.3E+00	9.8E+02	3.7E+01	7.0E-02	3.5E-01	8.1E-02	6.5E+03	4.1E-02	6.7E-02	4.0E+00	6.2
11	Sulfate B Influent	215.7	4.0E-03	5.8E+01	7.0E-06	5.9E-03	4.8E+02	9.7E-04	3.6E+01	6.2E-04	1.2E-01	4.1E-03	4.4E+00	1.1E-03	5.5E+02	8.1E-02	9.7E+02	4.2E-03	5.3E-05	3.4E-01	5.6E-02	4.8E+03	4.1E-02	8.2E-07	6.5E-01	10.6
12	Sulfate B Effluent	215.7	4.0E-03	5.8E-02	7.0E-06	5.9E-03	1.0E+03	9.7E-04	3.6E+01	1.2E-07	1.2E-01	4.1E-03	1.9E+00	1.1E-03	3.1E-01	8.1E-02	9.7E+02	5.3E-06	5.3E-05	1.7E-02	2.8E-02	1.8E+03	4.0E-02	8.2E-07	6.5E-01	12.5
13	Calcite B Effluent	215.7	4.0E-03	5.9E-02	7.1E-06	6.0E-03	1.2E+00	9.8E-04	3.6E+01	1.2E-07	1.2E-01	4.1E-03	2.0E+00	1.1E-03	3.1E-01	8.2E-02	9.8E+02	5.3E-06	5.3E-05	1.7E-02	2.8E-02	1.8E+03	4.1E-02	8.3E-07	6.6E-01	10.4
14	Calcite B Effluent to Final Effluent	86.3	4.0E-03	5.9E-02	7.1E-06	5.9E-03	1.2E+00	9.8E-04	3.6E+01	1.2E-07	1.2E-01	4.1E-03	1.9E+00	1.1E-03	3.1E-01	8.2E-02	9.7E+02	5.3E-06	5.3E-05	1.7E-02	2.8E-02	1.8E+03	4.1E-02	8.2E-07	6.6E-01	6.6
15	Calcite B Effluent to VSEP B	129.4	4.0E-03	5.9E-02	7.1E-06	5.9E-03	1.2E+00	9.8E-04	3.6E+01	1.2E-07	1.2E-01	4.1E-03	1.9E+00	1.1E-03	3.1E-01	8.2E-02	9.7E+02	5.3E-06	5.3E-05	1.7E-02	2.8E-02	1.8E+03	4.1E-02	8.2E-07	6.6E-01	6.6
16	VSEP B Permeate to Final Effluent	345.1	1.6E-04	3.7E-04	4.4E-06	4.7E-03	1.1E-01	2.6E-05	3.5E+01	7.1E-09	1.3E-02	1.7E-04	1.2E+00	4.2E-05	4.6E-02	2.1E-02	4.3E+02	8.3E-07	1.2E-06	9.2E-04	1.7E-03	1.5E+02	2.2E-03	1.1E-07	4.2E-02	6.5
17	VSEP B Concentrate	86.3	2.0E-02	3.0E-01	1.8E-05	1.1E-02	5.6E+00	4.9E-03	4.0E+01	5.6E-07	5.7E-01	2.0E-02	5.1E+00	5.2E-03	1.4E+00	3.3E-01	3.2E+03	2.3E-05	2.6E-04	8.3E-02	1.4E-01	8.4E+03	2.0E-01	3.7E-06	3.1E+00	7.2
18	VSEP B Concentrate to HDS B	43.1	2.0E-02	3.0E-01	1.8E-05	1.1E-02	5.6E+00	4.9E-03	4.0E+01	5.6E-07	5.7E-01	2.0E-02	5.1E+00	5.2E-03	1.4E+00	3.3E-01	3.2E+03	2.3E-05	2.6E-04	8.3E-02	1.4E-01	8.4E+03	2.0E-01	3.7E-06	3.1E+00	7.2
19	VSEP B Concentrate to HDS A	43.1	2.0E-02	3.0E-01	1.8E-05	1.1E-02	5.6E+00	4.9E-03	4.0E+01	5.6E-07	5.7E-01	2.0E-02	5.1E+00	5.2E-03	1.4E+00	3.3E-01	3.2E+03	2.3E-05	2.6E-04	8.3E-02	1.4E-01	8.4E+03	2.0E-01	3.7E-06	3.1E+00	7.2
20	Low Conc EQ Effluent	842.1	1.9E-04	1.7E-03	6.3E-02	3.9E-04	2.5E+02	5.5E-03	3.4E+01	2.1E-01	4.1E-03	1.7E+00	7.8E-01	1.9E-01	1.1E+02	3.7E-01	9.2E+01	3.1E+00	6.4E-03	3.1E-02	9.7E-03	6.6E+02	1.8E-04	9.9E-03	5.6E-01	7.0
21	GSF Backwash	42.2	1.9E-04	1.7E-03	1.0E+00	3.9E-04	2.5E+02	1.0E-01	3.4E+01	4.2E+00	4.1E-03	3.3E+01	7.7E-01	3.7E+00	1.1E+02	7.2E+00	9.2E+01	5.6E+01	1.2E-01	3.1E-02	9.7E-03	6.5E+02	1.8E-04	9.8E-03	1.1E+01	7.0
22	GSF Backwash Solids	21.1	1.9E-04	1.7E-03	1.7E+00	3.9E-04	2.5E+02	1.9E-01	3.4E+01	8.1E+00	4.1E-03	6.3E+01	7.7E-01	7.2E+00	1.1E+02	1.4E+01	9.2E+01	1.0E+02	2.2E-01	3.1E-02	9.7E-03	6.5E+02	1.8E-04	9.8E-03	2.1E+01	7.0
23	GSF Backwash Decant	21.1	1.9E-04	1.7E-03	3.2E-01	3.9E-04	2.5E+02	1.5E-02	3.4E+01	2.7E-01	4.1E-03	3.6E+00	7.7E-01	2.2E-01	1.1E+02	7.2E-01	9.2E+01	1.0E+01	1.8E-02	3.1E-02	9.7E-03	6.5E+02	1.8E-04	9.8E-03	8.0E-01	7.0
24	GSF Permeate/NF Feed	799.9	1.9E-04	1.7E-03	1.9E-02	3.9E-04	2.5E+02	6.1E-04	3.4E+01	3.4E-03	4.1E-03	1.1E-01	7.8E-01	2.0E-03	1.1E+02	2.0E-02	9.2E+01	4.4E-01	7.1E-04	3.1E-02	9.7E-03	6.6E+02	1.8E-04	9.9E-03	1.3E-02	7.0
25	NF Permeate	640.0	1.4E-04	1.2E-04	2.4E-04	2.8E-05	3.0E+01	4.3E-05	3.8E+01	1.2E-04	2.9E-04	8.4E-03	6.1E-01	0.0E+00	7.2E+00	3.0E-03	5.9E+01	1.6E-02	2.8E-05	2.2E-03	3.9E-04	2.7E+01	1.3E-05	7.0E-04	2.6E-04	6.2
26	NF Concentrate to VSEP A	160.0	3.8E-04	8.1E-03	9.5E-02	1.9E-03	1.1E+03	2.9E-03	1.6E+01	1.7E-02	2.0E-02	5.1E-01	1.5E+00	9.9E-03	5.1E+02	8.9E-02	2.3E+02	2.2E+00	3.5E-03	1.5E-01	4.7E-02	3.2E+03	8.7E-04	4.7E-02	6.5E-02	9.0
27	VSEP A Permeate to Final Effluent	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	VSEP A Concentrate	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29	VSEP A Concentrate to HDS B	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30	VSEP A Concentrate to HDS A	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	7.3	2.4E-01	0.0E+00	5.4E+00	1.4E-01	9.1E+04	1.1E+00	6.9E-01	7.6E+01	8.8E-01	3.7E+02	3.0E-02	2.8E+03	6.1E+03	2.4E+02	1.1E-02	1.1E+03	2.0E+00	1.1E-05	7.1E-01	4.8E+04	0.0E+00	1.9E+00	9.7E+01	10.6
32	Sulfate A Underflow Sludge	17.0	2.2E-08	7.4E+02	0.0E+00	0.0E+00	3.1E+04	0.0E+00	2.9E-01	7.9E-03	0.0E+00	7.4E-05	3.1E+01	1.8E-08	6.9E+03	0.0E+00	8.2E-08	5.3E-02	2.7E-10	4.1E+00	3.5E-01	3.8E+04	0.0E+00	0.0E+00	0.0E+00	12.5
33	Calcite A Underflow Sludge	6.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.7E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.4
34	HDS B Underflow Sludge	7.3	2.4E-01	0.0E+00	5.4E+00	1.4E-01	9.1E+04	1.1E+00	6.9E-01	7.6E+01	8.8E-01	3.7E+02	3.0E-02	2.8E+03	6.1E+03	2.4E+02	1.1E-02	1.1E+03	2.0E+00	1.1E-05	7.1E-01	4.8E+04	0.0E+00	1.9E+00	9.7E+01	10.6
35	Sulfate B Underflow Sludge	17.0	2.2E-08	7.4E+02	0.0E+00	0.0E+00	3.1E+04	0.0E+00	2.9E-01	7.9E-03	0.0E+00	7.4E-05	3.1E+01	1.8E-08	6.9E+03	0.0E+00	8.2E-08	5.3E-02	2.7E-10	4.1E+00	3.5E-01	3.8E+04	0.0E+00	0.0E+00	0.0E+00	12.5
36	Calcite B Underflow Sludge	6.0	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.7E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.1E-04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.7E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.4
37	Plant Site VSEP Concentrate	85.1	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
38	Plant Site Concentrate to HDS A	42.6	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
39	Plant Site Concentrate to HDS B	42.6	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
40	Final Effluent to CPS	985.1	1.5E-04	2.1E-04	1.6E-04	1.7E-03	2.0E+01	3.7E-05	3.7E+01	8.0E-05	4.8E-03	6.0E-03	8.0E-01	1.5E-05	4.7E+00	9.2E-03	1.9E+02	1.0E-02	1.9E-05	1.8E-03	8.5E-04	7.1E+01	7.7E-04	4.6E-04	1.5E-02	6.3

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	215.7	NA	NA	NA	256.2	4.4	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	47.8	40.50	7.3	NA	NA	NA	NA	NA	NA	25	1.18	3.54	0.54	3.00
5	Sulfate A Influent	215.7	NA	NA	NA	239.7	3.3	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	41.0	23.97	17.0	NA	NA	NA	NA	NA	NA	10	1.05	1.04	0.41	0.63
6	Sulfate A Effluent	215.7	NA	NA	132.9	348.6	NA	NA	1.6	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	6.0	0.00	6.0	NA	NA	NA	NA	NA	NA	10	1.06	0.15	0.15	0.00
7	Calcite A Effluent	215.7	NA	NA	55.0	270.7	NA	NA	0.7	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	215.7	NA	NA	NA	256.2	4.4	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	47.8	40.50	7.3	NA	NA	NA	NA	NA	NA	25	1.18	3.54	0.54	3.00
11	Sulfate B Influent	215.7	NA	NA		239.7	3.3	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	41.0	23.97	17.0	NA	NA	NA	NA	NA	NA	10	1.05	1.04	0.41	0.63
12	Sulfate B Effluent	215.7	NA	NA	132.9	348.6	NA	NA	1.6	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	6.0	0.00	6.0	NA	NA	NA	NA	NA	NA	10	1.06	0.15	0.15	0.00
13	Calcite B Effluent	215.7	NA	NA	55.0	215.7	NA	NA	0.7	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	842.1	NA	NA	NA	NA	NA	NA	NA	16.7	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	160.0	NA	NA	0*	NA	NA	NA	0.0	NA	NA	NA	NA	NA	NA

Mine Water Treatment Trains Flow and Load Detail
Year 10 P90 Annual Average Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	211.0	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
2	High Conc EQ Effluent to HDS A	105.5	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
3	High Conc EQ Effluent to HDS B	105.5	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
4	Combined HDS A Influent	275.4	2.1E-02	1.5E+02	2.6E-01	1.9E-02	1.7E+03	7.0E-02	4.5E+01	6.2E+00	1.2E-01	2.8E+01	5.5E+00	2.1E+02	1.2E+03	1.8E+01	9.8E+02	9.5E+01	1.5E-01	7.2E-01	1.2E-01	9.5E+03	2.0E-02	1.0E-01	7.4E+00	6.1
5	Sulfate A Influent	275.4	3.5E-03	1.4E+02	3.1E-06	8.1E-03	4.9E+02	7.8E-04	4.4E+01	6.9E-04	8.2E-02	3.8E-03	5.4E+00	9.1E-04	7.0E+02	1.8E-01	9.6E+02	4.7E-03	6.9E-05	7.1E-01	8.4E-02	4.8E+03	1.9E-02	3.8E-07	5.9E-01	10.5
6	Sulfate A Effluent	275.4	3.5E-03	1.4E-01	3.1E-06	8.1E-03	8.9E+02	7.8E-04	4.4E+01	7.5E-08	8.2E-02	3.8E-03	2.0E+00	9.1E-04	6.4E-01	1.8E-01	9.6E+02	2.6E-06	6.9E-05	3.5E-02	4.2E-02	1.8E+03	1.9E-02	3.8E-07	5.9E-01	12.2
7	Calcite A Effluent	275.4	3.6E-03	1.4E-01	3.2E-06	8.2E-03	4.0E+00	7.8E-04	4.4E+01	7.6E-08	8.3E-02	3.8E-03	2.0E+00	9.2E-04	6.5E-01	1.8E-01	9.7E+02	2.6E-06	7.0E-05	3.6E-02	4.2E-02	1.8E+03	1.9E-02	3.8E-07	5.9E-01	11.0
8	Calcite A Effluent to Final Effluent	110.2	3.6E-03	1.4E-01	3.2E-06	8.2E-03	4.0E+00	7.8E-04	4.4E+01	7.6E-08	8.3E-02	3.8E-03	2.0E+00	9.2E-04	6.5E-01	1.8E-01	9.7E+02	2.6E-06	7.0E-05	3.5E-02	4.2E-02	1.8E+03	1.9E-02	3.8E-07	5.9E-01	6.8
9	Calcite A Effluent to VSEP B	165.2	3.6E-03	1.4E-01	3.2E-06	8.2E-03	4.0E+00	7.8E-04	4.4E+01	7.6E-08	8.3E-02	3.8E-03	2.0E+00	9.2E-04	6.5E-01	1.8E-01	9.7E+02	2.6E-06	7.0E-05	3.5E-02	4.2E-02	1.8E+03	1.9E-02	3.8E-07	5.9E-01	6.8
10	Combined HDS B Influent	275.4	2.1E-02	1.5E+02	2.6E-01	1.9E-02	1.7E+03	7.0E-02	4.5E+01	6.2E+00	1.2E-01	2.8E+01	5.5E+00	2.1E+02	1.2E+03	1.8E+01	9.8E+02	9.5E+01	1.5E-01	7.2E-01	1.2E-01	9.5E+03	2.0E-02	1.0E-01	7.4E+00	6.1
11	Sulfate B Influent	275.4	3.5E-03	1.4E+02	3.1E-06	8.1E-03	4.9E+02	7.8E-04	4.4E+01	6.9E-04	8.2E-02	3.8E-03	5.4E+00	9.1E-04	7.0E+02	1.8E-01	9.6E+02	4.7E-03	6.9E-05	7.1E-01	8.4E-02	4.8E+03	1.9E-02	3.8E-07	5.9E-01	10.5
12	Sulfate B Effluent	275.4	3.5E-03	1.4E-01	3.1E-06	8.1E-03	8.9E+02	7.8E-04	4.4E+01	7.5E-08	8.2E-02	3.8E-03	2.0E+00	9.1E-04	6.4E-01	1.8E-01	9.6E+02	2.6E-06	6.9E-05	3.5E-02	4.2E-02	1.8E+03	1.9E-02	3.8E-07	5.9E-01	12.2
13	Calcite B Effluent	275.4	3.6E-03	1.4E-01	3.2E-06	8.2E-03	4.0E+00	7.8E-04	4.4E+01	7.6E-08	8.3E-02	3.8E-03	2.0E+00	9.2E-04	6.5E-01	1.8E-01	9.7E+02	2.6E-06	7.0E-05	3.6E-02	4.2E-02	1.8E+03	1.9E-02	3.8E-07	5.9E-01	11.0
14	Calcite B Effluent to Final Effluent	110.2	3.6E-03	1.4E-01	3.2E-06	8.2E-03	4.0E+00	7.8E-04	4.4E+01	7.6E-08	8.3E-02	3.8E-03	2.0E+00	9.2E-04	6.5E-01	1.8E-01	9.7E+02	2.6E-06	7.0E-05	3.5E-02	4.2E-02	1.8E+03	1.9E-02	3.8E-07	5.9E-01	6.8
15	Calcite B Effluent to VSEP B	165.2	3.6E-03	1.4E-01	3.2E-06	8.2E-03	4.0E+00	7.8E-04	4.4E+01	7.6E-08	8.3E-02	3.8E-03	2.0E+00	9.2E-04	6.5E-01	1.8E-01	9.7E+02	2.6E-06	7.0E-05	3.5E-02	4.2E-02	1.8E+03	1.9E-02	3.8E-07	5.9E-01	6.8
16	VSEP B Permeate to Final Effluent	352.5	1.4E-04	9.0E-04	2.0E-06	6.5E-03	3.5E-01	2.0E-05	4.3E+01	4.6E-09	8.8E-03	1.6E-04	1.2E+00	3.7E-05	9.5E-02	4.6E-02	4.3E+02	4.0E-07	1.6E-06	1.9E-03	2.6E-03	1.6E+02	1.0E-03	5.1E-08	3.8E-02	8.1
17	VSEP B Concentrate	88.1	1.7E-02	7.2E-01	8.1E-06	1.5E-02	1.9E+01	3.9E-03	4.9E+01	3.6E-07	3.8E-01	1.9E-02	5.2E+00	4.5E-03	2.9E+00	7.3E-01	3.1E+03	1.1E-05	3.5E-04	1.7E-01	2.0E-01	8.5E+03	9.3E-02	1.7E-06	2.8E+00	5.8
18	VSEP B Concentrate to HDS B	44.1	1.7E-02	7.2E-01	8.1E-06	1.5E-02	1.9E+01	3.9E-03	4.9E+01	3.6E-07	3.8E-01	1.9E-02	5.2E+00	4.5E-03	2.9E+00	7.3E-01	3.1E+03	1.1E-05	3.5E-04	1.7E-01	2.0E-01	8.5E+03	9.3E-02	1.7E-06	2.8E+00	5.8
19	VSEP B Concentrate to HDS A	44.1	1.7E-02	7.2E-01	8.1E-06	1.5E-02	1.9E+01	3.9E-03	4.9E+01	3.6E-07	3.8E-01	1.9E-02	5.2E+00	4.5E-03	2.9E+00	7.3E-01	3.1E+03	1.1E-05	3.5E-04	1.7E-01	2.0E-01	8.5E+03	9.3E-02	1.7E-06	2.8E+00	5.8
20	Low Conc EQ Effluent	1549.7	1.9E-04	1.7E-03	5.5E-02	3.9E-04	2.2E+02	5.0E-03	2.5E+01	1.9E-01	3.7E-03	1.5E+00	6.0E-01	1.9E-01	9.6E+01	3.5E-01	8.4E+01	2.6E+00	7.1E-03	2.7E-02	7.7E-03	5.5E+02	1.8E-04	9.8E-03	5.2E-01	7.0
21	GSF Backwash	77.5	1.9E-04	1.7E-03	9.0E-01	3.9E-04	2.2E+02	9.3E-02	2.5E+01	3.7E+00	3.7E-03	3.0E+01	6.0E-01	3.8E+00	9.6E+01	6.8E+00	8.3E+01	4.8E+01	1.3E-01	2.7E-02	7.7E-03	5.5E+02	1.8E-04	9.8E-03	1.0E+01	7.0
22	GSF Backwash Solids	38.7	1.9E-04	1.7E-03	1.5E+00	3.9E-04	2.2E+02	1.7E-01	2.5E+01	7.1E+00	3.7E-03	5.6E+01	6.0E-01	7.3E+00	9.6E+01	1.3E+01	8.3E+01	8.8E+01	2.5E-01	2.7E-02	7.7E-03	5.5E+02	1.8E-04	9.8E-03	2.0E+01	7.0
23	GSF Backwash Decant	38.7	1.9E-04	1.7E-03	2.8E-01	3.9E-04	2.2E+02	1.4E-02	2.5E+01	2.4E-01	3.7E-03	3.2E+00	6.0E-01	2.3E-01	9.6E+01	6.8E-01	8.3E+01	8.7E+00	2.0E-02	2.7E-02	7.7E-03	5.5E+02	1.8E-04	9.8E-03	7.4E-01	7.0
24	GSF Permeate/NF Feed	1472.3	1.9E-04	1.7E-03	1.7E-02	3.9E-04	2.2E+02	5.5E-04	2.5E+01	3.0E-03	3.7E-03	9.6E-02	6.0E-01	2.0E-03	9.6E+01	1.9E-02	8.4E+01	3.8E-01	7.8E-04	2.7E-02	7.7E-03	5.5E+02	1.8E-04	9.8E-03	1.2E-02	7.0
25	NF Permeate	1177.8	1.4E-04	1.2E-04	2.1E-04	2.8E-05	2.7E+01	3.9E-05	2.8E+01	1.1E-04	2.6E-04	7.4E-03	4.7E-01	0.0E+00	6.5E+00	2.8E-03	5.4E+01	1.4E-02	3.1E-05	1.9E-03	3.1E-04	2.3E+01	1.3E-05	7.0E-04	2.4E-04	6.2
26	NF Concentrate to VSEP A	294.5	3.8E-04	7.9E-03	8.3E-02	1.9E-03	1.0E+03	2.6E-03	1.2E+01	1.4E-02	1.8E-02	4.5E-01	1.1E+00	1.0E-02	4.6E+02	8.4E-02	2.0E+02	1.9E+00	3.8E-03	1.3E-01	3.8E-02	2.7E+03	8.6E-04	4.7E-02	6.0E-02	9.0
27	VSEP A Permeate to Final Effluent	235.6	1.5E-05	5.0E-05	5.1E-02	1.5E-03	9.0E+01	6.8E-05	1.1E+01	8.9E-04	1.9E-03	1.9E-02	6.7E-01	4.0E-04	6.7E+01	2.1E-02	9.1E+01	2.9E-01	8.6E-05	6.9E-03	2.3E-03	2.3E+02	4.6E-05	6.2E-03	3.8E-03	5.4
28	VSEP A Concentrate	58.9	1.9E-03	4.1E-02	2.2E-01	3.5E-03	4.9E+03	1.3E-02	1.3E+01	7.1E-02	8.3E-02	2.3E+00	3.0E+00	5.1E-02	2.1E+03	3.5E-01	6.8E+02	8.4E+00	1.9E-02	6.3E-01	1.8E-01	1.3E+04	4.2E-03	2.2E-01	3.0E-01	9.0
29	VSEP A Concentrate to HDS B	29.4	1.9E-03	4.1E-02	2.2E-01	3.5E-03	4.9E+03	1.3E-02	1.3E+01	7.1E-02	8.3E-02	2.3E+00	3.0E+00	5.1E-02	2.1E+03	3.5E-01	6.8E+02	8.4E+00	1.9E-02	6.3E-01	1.8E-01	1.3E+04	4.2E-03	2.2E-01	3.0E-01	9.0
30	VSEP A Concentrate to HDS A	29.4	1.9E-03	4.1E-02	2.2E-01	3.5E-03	4.9E+03	1.3E-02	1.3E+01	7.1E-02	8.3E-02	2.3E+00	3.0E+00	5.1E-02	2.1E+03	3.5E-01	6.8E+02	8.4E+00	1.9E-02	6.3E-01	1.8E-01	1.3E+04	4.2E-03	2.2E-01	3.0E-01	9.0
31	HDS A Underflow Sludge	16.1	2.9E-01	3.3E-03	4.4E+00	1.8E-01	8.5E+04	1.2E+00	4.9E-01	1.0E+02	6.3E-01	4.7E+02	2.1E-02	3.4E+03	7.5E+03	3.0E+02	1.0E-02	1.6E+03	2.4E+00	3.1E-06	6.2E-01	7.6E+04	0.0E+00	1.7E+00	1.1E+02	10.5
32	Sulfate A Underflow Sludge	26.8	0.0E+00	1.5E+03	3.7E-11	0.0E+00	3.9E+04	1.5E-09	2.9E-01	7.1E-03	0.0E+00	5.6E-05	3.5E+01	0.0E+00	7.2E+03	0.0E+00	4.5E-08	4.9E-02	0.0E+00	6.9E+00	4.3E-01	3.1E+04	0.0E+00	0.0E+00	0.0E+00	12.2
33	Calcite A Underflow Sludge	10.4	0.0E+00	0.0E+00	1.5E-13	0.0E+00	2.4E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.8E-05	0.0E+00	0.0E+00	1.1E-05	0.0E+00	1.1E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	11.0
34	HDS B Underflow Sludge	16.1	2.9E-01	3.3E-03	4.4E+00	1.8E-01	8.5E+04	1.2E+00	4.9E-01	1.0E+02	6.3E-01	4.7E+02	2.1E-02	3.4E+03	7.5E+03	3.0E+02	1.0E-02	1.6E+03	2.4E+00	3.1E-06	6.2E-01	7.6E+04	0.0E+00	1.7E+00	1.1E+02	10.5
35	Sulfate B Underflow Sludge	26.8	0.0E+00	1.5E+03	3.7E-11	0.0E+00	3.9E+04	1.5E-09	2.9E-01	7.1E-03	0.0E+00	5.6E-05	3.5E+01	0.0E+00	7.2E+03	0.0E+00	4.5E-08	4.9E-02	0.0E+00	6.9E+00	4.3E-01	3.1E+04	0.0E+00	0.0E+00	0.0E+00	12.2
36	Calcite B Underflow Sludge	10.4	0.0E+00	0.0E+00	1.5E-13	0.0E+00	2.4E+04	0.0E+00	0.0E+00	0.0E+00	0.0E+00	7.8E-05	0.0E+00	0.0E+00	1.1E-05	0.0E+00	1.1E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	11.0
37	Plant Site VSEP Concentrate	154.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
38	Plant Site Concentrate to HDS A	77.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
39	Plant Site Concentrate to HDS B	77.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
40	Final Effluent to CPS	1876.0	3.3E-04	8.7E-03	6.5E-03	1.9E-03	2.9E+01	8.2E-05	3.0E+01	1.8E-04	6.9E-03	7.0E-03	7.2E-01	1.1E-04	1.3E+01	2.4E-02	1.8E+02	4.5E-02	3.5E-05	4.5E-03	3.4E-03	1.8E+02	1.3E-03	1.2E-03	4.2E-02	6.0

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	275.4	NA	NA	NA	304.8	8.8	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	45.6	29.45	16.1	NA	NA	NA	NA	NA	NA	25	1.18	3.37	1.19	2.18
5	Sulfate A Influent	275.4	NA	NA	NA	306.0	3.9	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	57.4	30.60	26.8	NA	NA	NA	NA	NA	NA	10	1.05	1.45	0.64	0.81
6	Sulfate A Effluent	275.4	NA	NA	137.5	412.9	NA	NA	1.7	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	10.4	0.00	10.4	NA	NA	NA	NA	NA	NA	10	1.06	0.25	0.25	0.00
7	Calcite A Effluent	275.4	NA	NA	64.2	339.5	NA	NA	0.8	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	275.4	NA	NA	NA	304.8	8.8	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	45.6	29.45	16.1	NA	NA	NA	NA	NA	NA	25	1.18	3.37	1.19	2.18
11	Sulfate B Influent	275.4	NA	NA		306.0	3.9	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	57.4	30.60	26.8	NA	NA	NA	NA	NA	NA	10	1.05	1.45	0.64	0.81
12	Sulfate B Effluent	275.4	NA	NA	137.5	412.9	NA	NA	1.7	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	10.4	0.00	10.4	NA	NA	NA	NA	NA	NA	10	1.06	0.25	0.25	0.00
13	Calcite B Effluent	275.4	NA	NA	64.2	275.4	NA	NA	0.8	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1549.7	NA	NA	NA	NA	NA	NA	NA	30.7	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	294.5	NA	NA	366.7*	NA	NA	NA	4.4	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 10 P90 Peak Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	368.0	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
2	High Conc EQ Effluent to HDS A	184.0	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
3	High Conc EQ Effluent to HDS B	184.0	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
4	Combined HDS A Influent	379.1	2.4E-02	1.8E+02	3.3E-01	2.1E-02	1.9E+03	8.3E-02	4.3E+01	7.8E+00	7.4E-02	3.6E+01	4.4E+00	2.6E+02	1.2E+03	2.3E+01	6.1E+02	1.2E+02	1.7E-01	8.7E-01	1.2E-01	9.6E+03	8.9E-03	1.0E-01	8.9E+00	6.1
5	Sulfate A Influent	379.1	3.1E-03	1.8E+02	2.2E-06	8.8E-03	5.0E+02	1.3E-03	4.2E+01	1.3E-03	4.8E-02	3.5E-03	4.3E+00	7.9E-04	8.5E+02	2.2E-01	6.0E+02	8.3E-03	8.4E-05	8.5E-01	8.4E-02	4.8E+03	8.7E-03	2.1E-07	5.3E-01	10.4
6	Sulfate A Effluent	379.1	3.1E-03	1.8E-01	2.2E-06	8.8E-03	1.3E+03	1.3E-03	4.2E+01	1.5E-07	4.8E-02	3.5E-03	1.6E+00	7.9E-04	3.3E-01	2.2E-01	6.0E+02	6.2E-06	8.4E-05	4.2E-02	4.2E-02	1.4E+03	8.7E-03	2.1E-07	5.3E-01	12.4
7	Calcite A Effluent	379.1	3.2E-03	1.8E-01	2.2E-06	8.9E-03	9.5E-01	1.4E-03	4.2E+01	1.5E-07	4.9E-02	3.6E-03	1.7E+00	8.0E-04	3.3E-01	2.2E-01	6.0E+02	6.3E-06	8.5E-05	4.3E-02	4.2E-02	1.4E+03	8.8E-03	2.1E-07	5.3E-01	10.2
8	Calcite A Effluent to Final Effluent	151.6	3.1E-03	1.8E-01	2.2E-06	8.9E-03	9.4E-01	1.3E-03	4.2E+01	1.5E-07	4.9E-02	3.5E-03	1.7E+00	7.9E-04	3.3E-01	2.2E-01	6.0E+02	6.3E-06	8.4E-05	4.3E-02	4.2E-02	1.4E+03	8.8E-03	2.1E-07	5.3E-01	6.6
9	Calcite A Effluent to VSEP B	227.5	3.1E-03	1.8E-01	2.2E-06	8.9E-03	9.4E-01	1.3E-03	4.2E+01	1.5E-07	4.9E-02	3.5E-03	1.7E+00	7.9E-04	3.3E-01	2.2E-01	6.0E+02	6.3E-06	8.4E-05	4.3E-02	4.2E-02	1.4E+03	8.8E-03	2.1E-07	5.3E-01	6.6
10	Combined HDS B Influent	379.1	2.4E-02	1.8E+02	3.3E-01	2.1E-02	1.9E+03	8.3E-02	4.3E+01	7.8E+00	7.4E-02	3.6E+01	4.4E+00	2.6E+02	1.2E+03	2.3E+01	6.1E+02	1.2E+02	1.7E-01	8.7E-01	1.2E-01	9.6E+03	8.9E-03	1.0E-01	8.9E+00	6.1
11	Sulfate B Influent	379.1	3.1E-03	1.8E+02	2.2E-06	8.8E-03	5.0E+02	1.3E-03	4.2E+01	1.3E-03	4.8E-02	3.5E-03	4.3E+00	7.9E-04	8.5E+02	2.2E-01	6.0E+02	8.3E-03	8.4E-05	8.5E-01	8.4E-02	4.8E+03	8.7E-03	2.1E-07	5.3E-01	10.4
12	Sulfate B Effluent	379.1	3.1E-03	1.8E-01	2.2E-06	8.8E-03	1.3E+03	1.3E-03	4.2E+01	1.5E-07	4.8E-02	3.5E-03	1.6E+00	7.9E-04	3.3E-01	2.2E-01	6.0E+02	6.2E-06	8.4E-05	4.2E-02	4.2E-02	1.4E+03	8.7E-03	2.1E-07	5.3E-01	12.4
13	Calcite B Effluent	379.1	3.2E-03	1.8E-01	2.2E-06	8.9E-03	9.5E-01	1.4E-03	4.2E+01	1.5E-07	4.9E-02	3.6E-03	1.7E+00	8.0E-04	3.3E-01	2.2E-01	6.0E+02	6.3E-06	8.5E-05	4.3E-02	4.2E-02	1.4E+03	8.8E-03	2.1E-07	5.3E-01	10.2
14	Calcite B Effluent to Final Effluent	151.6	3.1E-03	1.8E-01	2.2E-06	8.9E-03	9.4E-01	1.3E-03	4.2E+01	1.5E-07	4.9E-02	3.5E-03	1.7E+00	7.9E-04	3.3E-01	2.2E-01	6.0E+02	6.3E-06	8.4E-05	4.3E-02	4.2E-02	1.4E+03	8.8E-03	2.1E-07	5.3E-01	6.6
15	Calcite B Effluent to VSEP B	227.5	3.1E-03	1.8E-01	2.2E-06	8.9E-03	9.4E-01	1.3E-03	4.2E+01	1.5E-07	4.9E-02	3.5E-03	1.7E+00	7.9E-04	3.3E-01	2.2E-01	6.0E+02	6.3E-06	8.4E-05	4.3E-02	4.2E-02	1.4E+03	8.8E-03	2.1E-07	5.3E-01	6.6
16	VSEP B Permeate to Final Effluent	266.9	1.3E-04	1.1E-03	1.4E-06	7.1E-03	8.4E-02	3.5E-05	4.1E+01	9.0E-09	5.2E-03	1.5E-04	9.9E-01	3.2E-05	4.9E-02	5.6E-02	2.7E+02	9.8E-07	1.9E-06	2.3E-03	2.6E-03	1.2E+02	4.7E-04	2.8E-08	3.4E-02	7.5
17	VSEP B Concentrate	66.7	1.5E-02	9.1E-01	5.6E-06	1.6E-02	4.4E+00	6.6E-03	4.6E+01	7.0E-07	2.2E-01	1.7E-02	4.3E+00	3.9E-03	1.5E+00	9.0E-01	1.9E+03	2.8E-05	4.2E-04	2.1E-01	2.0E-01	6.4E+03	4.2E-02	9.3E-07	2.5E+00	5.3
18	VSEP B Concentrate to HDS B	33.4	1.5E-02	9.1E-01	5.6E-06	1.6E-02	4.4E+00	6.6E-03	4.6E+01	7.0E-07	2.2E-01	1.7E-02	4.3E+00	3.9E-03	1.5E+00	9.0E-01	1.9E+03	2.8E-05	4.2E-04	2.1E-01	2.0E-01	6.4E+03	4.2E-02	9.3E-07	2.5E+00	5.3
19	VSEP B Concentrate to HDS A	33.4	1.5E-02	9.1E-01	5.6E-06	1.6E-02	4.4E+00	6.6E-03	4.6E+01	7.0E-07	2.2E-01	1.7E-02	4.3E+00	3.9E-03	1.5E+00	9.0E-01	1.9E+03	2.8E-05	4.2E-04	2.1E-01	2.0E-01	6.4E+03	4.2E-02	9.3E-07	2.5E+00	5.3
20	Low Conc EQ Effluent	2626.7	1.9E-04	1.7E-03	5.5E-02	3.9E-04	2.2E+02	5.0E-03	2.5E+01	1.9E-01	3.7E-03	1.5E+00	6.0E-01	1.9E-01	9.6E+01	3.5E-01	8.4E+01	2.6E+00	7.1E-03	2.7E-02	7.2E-03	5.5E+02	1.8E-04	9.8E-03	5.2E-01	7.0
21	GSF Backwash	131.3	1.9E-04	1.7E-03	9.0E-01	3.9E-04	2.2E+02	9.3E-02	2.5E+01	3.7E+00	3.7E-03	3.0E+01	6.0E-01	3.8E+00	9.6E+01	6.8E+00	8.3E+01	4.8E+01	1.3E-01	2.7E-02	7.2E-03	5.5E+02	1.8E-04	9.8E-03	1.0E+01	7.0
22	GSF Backwash Solids	65.7	1.9E-04	1.7E-03	1.5E+00	3.9E-04	2.2E+02	1.7E-01	2.5E+01	7.1E+00	3.7E-03	5.6E+01	6.0E-01	7.3E+00	9.6E+01	1.3E+01	8.3E+01	8.8E+01	2.5E-01	2.7E-02	7.2E-03	5.5E+02	1.8E-04	9.8E-03	2.0E+01	7.0
23	GSF Backwash Decant	65.7	1.9E-04	1.7E-03	2.8E-01	3.9E-04	2.2E+02	1.4E-02	2.5E+01	2.4E-01	3.7E-03	3.2E+00	6.0E-01	2.3E-01	9.6E+01	6.8E-01	8.3E+01	8.7E+00	2.0E-02	2.7E-02	7.2E-03	5.5E+02	1.8E-04	9.8E-03	7.4E-01	7.0
24	GSF Permeate/NF Feed	2495.3	1.9E-04	1.7E-03	1.7E-02	3.9E-04	2.2E+02	5.5E-04	2.5E+01	3.0E-03	3.7E-03	9.6E-02	6.0E-01	2.0E-03	9.6E+01	1.9E-02	8.4E+01	3.8E-01	7.8E-04	2.7E-02	7.2E-03	5.5E+02	1.8E-04	9.8E-03	1.2E-02	7.0
25	NF Permeate	1996.3	1.4E-04	1.2E-04	2.1E-04	2.8E-05	2.7E+01	3.9E-05	2.8E+01	1.1E-04	2.6E-04	7.4E-03	4.7E-01	2.8E-20	6.5E+00	2.8E-03	5.4E+01	1.4E-02	3.1E-05	1.9E-03	2.9E-04	2.3E+01	1.3E-05	7.0E-04	2.4E-04	6.2
26	NF Concentrate to VSEP A	499.1	3.8E-04	7.9E-03	8.3E-02	1.9E-03	1.0E+03	2.6E-03	1.2E+01	1.4E-02	1.8E-02	4.5E-01	1.1E+00	1.0E-02	4.6E+02	8.4E-02	2.0E+02	1.9E+00	3.8E-03	1.3E-01	3.5E-02	2.7E+03	8.6E-04	4.7E-02	6.0E-02	9.0
27	VSEP A Permeate to Final Effluent	399.3	1.5E-05	5.0E-05	5.1E-02	1.5E-03	9.0E+01	6.8E-05	1.1E+01	8.8E-04	1.9E-03	1.9E-02	6.7E-01	4.0E-04	6.7E+01	2.1E-02	9.1E+01	2.9E-01	8.6E-05	6.9E-03	2.1E-03	2.3E+02	4.6E-05	6.2E-03	3.8E-03	5.6
28	VSEP A Concentrate	99.8	1.9E-03	4.1E-02	2.2E-01	3.4E-03	4.9E+03	1.3E-02	1.3E+01	7.1E-02	8.3E-02	2.3E+00	3.0E+00	5.1E-02	2.1E+03	3.5E-01	6.8E+02	8.4E+00	1.9E-02	6.3E-01	1.7E-01	1.3E+04	4.2E-03	2.1E-01	2.9E-01	9.3
29	VSEP A Concentrate to HDS B	49.9	1.9E-03	4.1E-02	2.2E-01	3.4E-03	4.9E+03	1.3E-02	1.3E+01	7.1E-02	8.3E-02	2.3E+00	3.0E+00	5.1E-02	2.1E+03	3.5E-01	6.8E+02	8.4E+00	1.9E-02	6.3E-01	1.7E-01	1.3E+04	4.2E-03	2.1E-01	2.9E-01	9.3
30	VSEP A Concentrate to HDS A	49.9	1.9E-03	4.1E-02	2.2E-01	3.4E-03	4.9E+03	1.3E-02	1.3E+01	7.1E-02	8.3E-02	2.3E+00	3.0E+00	5.1E-02	2.1E+03	3.5E-01	6.8E+02	8.4E+00	1.9E-02	6.3E-01	1.7E-01	1.3E+04	4.2E-03	2.1E-01	2.9E-01	9.3
31	HDS A Underflow Sludge	19.8	3.9E-01	6.4E-03	6.2E+00	2.3E-01	8.5E+04	1.5E+00	5.2E-01	1.5E+02	4.7E-01	6.7E+02	1.9E-02	4.9E+03	5.6E+03	4.2E+02	0.0E+00	2.2E+03	3.2E+00	1.8E-05	6.9E-01	8.8E+04	0.0E+00	1.9E+00	1.6E+02	10.4
32	Sulfate A Underflow Sludge	38.9	0.0E+00	1.8E+03	0.0E+00	1.1E-07	3.0E+04	6.9E-08	2.7E-01	1.2E-02	0.0E+00	4.9E-05	2.6E+01	5.9E-09	8.3E+03	0.0E+00	0.0E+00	8.1E-02	6.8E-10	7.9E+00	4.1E-01	3.3E+04	0.0E+00	0.0E+00	0.0E+00	12.4
33	Calcite A Underflow Sludge	22.5	0.0E+00	0.0E+00	0.0E+00	1.2E-08	2.3E+04	5.9E-08	0.0E+00	0.0E+00	0.0E+00	4.6E-05	4.7E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.9E-11	0.0E+00	0.0E+00	4.5E-11	5.4E-02	0.0E+00	0.0E+00	0.0E+00	10.2
34	HDS B Underflow Sludge	19.8	3.9E-01	6.4E-03	6.2E+00	2.3E-01	8.5E+04	1.5E+00	5.2E-01	1.5E+02	4.7E-01	6.7E+02	1.9E-02	4.9E+03	5.6E+03	4.2E+02	0.0E+00	2.2E+03	3.2E+00	1.8E-05	6.9E-01	8.8E+04	0.0E+00	1.9E+00	1.6E+02	10.4
35	Sulfate B Underflow Sludge	38.9	0.0E+00	1.8E+03	0.0E+00	1.1E-07	3.0E+04	6.9E-08	2.7E-01	1.2E-02	0.0E+00	4.9E-05	2.6E+01	5.9E-09	8.3E+03	0.0E+00	0.0E+00	8.1E-02	6.8E-10	7.9E+00	4.1E-01	3.3E+04	0.0E+00	0.0E+00	0.0E+00	12.4
36	Calcite B Underflow Sludge	22.5	0.0E+00	0.0E+00	0.0E+00	1.2E-08	2.3E+04	5.9E-08	0.0E+00	0.0E+00	0.0E+00	4.6E-05	4.7E-06	0.0E+00	0.0E+00	0.0E+00	0.0E+00	8.9E-11	0.0E+00	0.0E+00	4.5E-11	5.4E-02	0.0E+00	0.0E+00	0.0E+00	10.2
37	Plant Site VSEP Concentrate	158.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
38	Plant Site Concentrate to HDS A	79.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
39	Plant Site Concentrate to HDS B	79.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
40	Final Effluent to CPS	3087.0	5.4E-04	2.5E-02	6.7E-03	2.0E-03	2.9E+01	2.2E-04	2.9E+01	1.8E-04	7.5E-03	8.0E-03	7.0E-01	1.6E-04	1.3E+01	4.0E-02	1.5E+02	4.6E-02	4.3E-05	8.2E-03	6.5E-03	2.4E+02	1.3E-03	1.3E-03	7.6E-02	6.0

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	379.1	NA	NA	NA	401.5	9.9	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	42.3	22.42	19.8	NA	NA	NA	NA	NA	NA	25	1.18	3.12	1.47	1.66
5	Sulfate A Influent	379.1	NA	NA	NA	421.2	8.3	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	81.0	42.12	38.9	NA	NA	NA	NA	NA	NA	10	1.05	2.04	0.93	1.11
6	Sulfate A Effluent	379.1	NA	NA	302.5	681.6	NA	NA	3.6	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	22.5	0.00	22.5	NA	NA	NA	NA	NA	NA	10	1.06	0.54	0.54	0.00
7	Calcite A Effluent	379.1	NA	NA	68.8	447.9	NA	NA	0.8	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	379.1	NA	NA	NA	401.5	9.9	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	42.3	22.42	19.8	NA	NA	NA	NA	NA	NA	25	1.18	3.12	1.47	1.66
11	Sulfate B Influent	379.1	NA	NA		421.2	8.3	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	81.0	42.12	38.9	NA	NA	NA	NA	NA	NA	10	1.05	2.04	0.93	1.11
12	Sulfate B Effluent	379.1	NA	NA	302.5	681.6	NA	NA	3.6	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	22.5	0.00	22.5	NA	NA	NA	NA	NA	NA	10	1.06	0.54	0.54	0.00
13	Calcite B Effluent	379.1	NA	NA	68.8	379.1	NA	NA	0.8	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	2626.7	NA	NA	NA	NA	NA	NA	NA	52.0	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	499.1	NA	NA	458.3*	NA	NA	NA	5.5	NA	NA	NA	NA	NA	NA

*CO_2 carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 10 P90 Summer Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	368.0	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
2	High Conc EQ Effluent to HDS A	184.0	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
3	High Conc EQ Effluent to HDS B	184.0	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
4	Combined HDS A Influent	374.9	2.4E-02	1.9E+02	3.1E-01	2.2E-02	1.8E+03	8.2E-02	4.4E+01	7.8E+00	7.9E-02	3.5E+01	4.4E+00	2.6E+02	1.1E+03	2.3E+01	6.5E+02	1.2E+02	1.7E-01	8.7E-01	1.2E-01	9.6E+03	1.0E-02	9.7E-02	8.8E+00	6.1
5	Sulfate A Influent	374.9	3.2E-03	1.8E+02	2.1E-06	8.9E-03	5.0E+02	1.5E-03	4.3E+01	1.4E-03	5.2E-02	3.5E-03	4.4E+00	7.9E-04	8.6E+02	2.2E-01	6.4E+02	9.2E-03	8.2E-05	8.5E-01	8.6E-02	4.9E+03	1.0E-02	1.9E-07	5.3E-01	10.4
6	Sulfate A Effluent	374.9	3.2E-03	1.8E-01	2.1E-06	8.9E-03	1.3E+03	1.5E-03	4.3E+01	1.6E-07	5.2E-02	3.5E-03	1.7E+00	7.9E-04	3.3E-01	2.2E-01	6.4E+02	6.9E-06	8.2E-05	4.3E-02	4.3E-02	1.4E+03	1.0E-02	1.9E-07	5.3E-01	12.5
7	Calcite A Effluent	374.9	3.3E-03	1.8E-01	2.1E-06	8.9E-03	8.2E-01	1.5E-03	4.3E+01	1.6E-07	5.2E-02	3.6E-03	1.7E+00	7.9E-04	3.3E-01	2.2E-01	6.4E+02	6.9E-06	8.3E-05	4.3E-02	4.3E-02	1.4E+03	1.0E-02	2.0E-07	5.3E-01	10.9
8	Calcite A Effluent to Final Effluent	150.0	3.3E-03	1.8E-01	2.1E-06	8.9E-03	8.2E-01	1.5E-03	4.3E+01	1.6E-07	5.2E-02	3.5E-03	1.7E+00	7.9E-04	3.3E-01	2.2E-01	6.4E+02	6.9E-06	8.2E-05	4.3E-02	4.3E-02	1.4E+03	1.0E-02	2.0E-07	5.3E-01	6.6
9	Calcite A Effluent to VSEP B	224.9	3.3E-03	1.8E-01	2.1E-06	8.9E-03	8.2E-01	1.5E-03	4.3E+01	1.6E-07	5.2E-02	3.5E-03	1.7E+00	7.9E-04	3.3E-01	2.2E-01	6.4E+02	6.9E-06	8.2E-05	4.3E-02	4.3E-02	1.4E+03	1.0E-02	2.0E-07	5.3E-01	6.6
10	Combined HDS B Influent	374.9	2.4E-02	1.9E+02	3.1E-01	2.2E-02	1.8E+03	8.2E-02	4.4E+01	7.8E+00	7.9E-02	3.5E+01	4.4E+00	2.6E+02	1.1E+03	2.3E+01	6.5E+02	1.2E+02	1.7E-01	8.7E-01	1.2E-01	9.6E+03	1.0E-02	9.7E-02	8.8E+00	6.1
11	Sulfate B Influent	374.9	3.2E-03	1.8E+02	2.1E-06	8.9E-03	5.0E+02	1.5E-03	4.3E+01	1.4E-03	5.2E-02	3.5E-03	4.4E+00	7.9E-04	8.6E+02	2.2E-01	6.4E+02	9.2E-03	8.2E-05	8.5E-01	8.6E-02	4.9E+03	1.0E-02	1.9E-07	5.3E-01	10.4
12	Sulfate B Effluent	374.9	3.2E-03	1.8E-01	2.1E-06	8.9E-03	1.3E+03	1.5E-03	4.3E+01	1.6E-07	5.2E-02	3.5E-03	1.7E+00	7.9E-04	3.3E-01	2.2E-01	6.4E+02	6.9E-06	8.2E-05	4.3E-02	4.3E-02	1.4E+03	1.0E-02	1.9E-07	5.3E-01	12.5
13	Calcite B Effluent	374.9	3.3E-03	1.8E-01	2.1E-06	8.9E-03	8.2E-01	1.5E-03	4.3E+01	1.6E-07	5.2E-02	3.6E-03	1.7E+00	7.9E-04	3.3E-01	2.2E-01	6.4E+02	6.9E-06	8.3E-05	4.3E-02	4.3E-02	1.4E+03	1.0E-02	2.0E-07	5.3E-01	10.9
14	Calcite B Effluent to Final Effluent	150.0	3.3E-03	1.8E-01	2.1E-06	8.9E-03	8.2E-01	1.5E-03	4.3E+01	1.6E-07	5.2E-02	3.5E-03	1.7E+00	7.9E-04	3.3E-01	2.2E-01	6.4E+02	6.9E-06	8.2E-05	4.3E-02	4.3E-02	1.4E+03	1.0E-02	2.0E-07	5.3E-01	6.6
15	Calcite B Effluent to VSEP B	224.9	3.3E-03	1.8E-01	2.1E-06	8.9E-03	8.2E-01	1.5E-03	4.3E+01	1.6E-07	5.2E-02	3.5E-03	1.7E+00	7.9E-04	3.3E-01	2.2E-01	6.4E+02	6.9E-06	8.2E-05	4.3E-02	4.3E-02	1.4E+03	1.0E-02	2.0E-07	5.3E-01	6.6
16	VSEP B Permeate to Final Effluent	317.9	1.3E-04	1.1E-03	1.3E-06	7.1E-03	7.3E-02	3.9E-05	4.2E+01	9.8E-09	5.5E-03	1.5E-04	1.0E+00	3.2E-05	4.9E-02	5.7E-02	2.9E+02	1.1E-06	1.9E-06	2.3E-03	2.6E-03	1.2E+02	5.5E-04	2.6E-08	3.4E-02	7.3
17	VSEP B Concentrate	79.5	1.6E-02	9.2E-01	5.4E-06	1.6E-02	3.8E+00	7.3E-03	4.7E+01	7.7E-07	2.4E-01	1.7E-02	4.4E+00	3.9E-03	1.5E+00	9.0E-01	2.1E+03	3.0E-05	4.1E-04	2.1E-01	2.1E-01	6.5E+03	5.0E-02	8.8E-07	2.5E+00	5.3
18	VSEP B Concentrate to HDS B	39.7	1.6E-02	9.2E-01	5.4E-06	1.6E-02	3.8E+00	7.3E-03	4.7E+01	7.7E-07	2.4E-01	1.7E-02	4.4E+00	3.9E-03	1.5E+00	9.0E-01	2.1E+03	3.0E-05	4.1E-04	2.1E-01	2.1E-01	6.5E+03	5.0E-02	8.8E-07	2.5E+00	5.3
19	VSEP B Concentrate to HDS A	39.7	1.6E-02	9.2E-01	5.4E-06	1.6E-02	3.8E+00	7.3E-03	4.7E+01	7.7E-07	2.4E-01	1.7E-02	4.4E+00	3.9E-03	1.5E+00	9.0E-01	2.1E+03	3.0E-05	4.1E-04	2.1E-01	2.1E-01	6.5E+03	5.0E-02	8.8E-07	2.5E+00	5.3
20	Low Conc EQ Effluent	2290.3	1.9E-04	1.7E-03	5.5E-02	3.9E-04	2.2E+02	5.0E-03	2.5E+01	1.9E-01	3.7E-03	1.5E+00	6.0E-01	1.9E-01	9.6E+01	3.5E-01	8.4E+01	2.6E+00	7.1E-03	2.7E-02	7.2E-03	5.5E+02	1.8E-04	9.8E-03	5.2E-01	7.0
21	GSF Backwash	114.5	1.9E-04	1.7E-03	9.0E-01	3.9E-04	2.2E+02	9.3E-02	2.5E+01	3.7E+00	3.7E-03	3.0E+01	6.0E-01	3.8E+00	9.6E+01	6.8E+00	8.3E+01	4.8E+01	1.3E-01	2.7E-02	7.2E-03	5.5E+02	1.8E-04	9.8E-03	1.0E+01	7.0
22	GSF Backwash Solids	57.3	1.9E-04	1.7E-03	1.5E+00	3.9E-04	2.2E+02	1.7E-01	2.5E+01	7.1E+00	3.7E-03	5.6E+01	6.0E-01	7.3E+00	9.6E+01	1.3E+01	8.3E+01	8.8E+01	2.5E-01	2.7E-02	7.2E-03	5.5E+02	1.8E-04	9.8E-03	2.0E+01	7.0
23	GSF Backwash Decant	57.3	1.9E-04	1.7E-03	2.8E-01	3.9E-04	2.2E+02	1.4E-02	2.5E+01	2.4E-01	3.7E-03	3.2E+00	6.0E-01	2.3E-01	9.6E+01	6.8E-01	8.3E+01	8.7E+00	2.0E-02	2.7E-02	7.2E-03	5.5E+02	1.8E-04	9.8E-03	7.4E-01	7.0
24	GSF Permeate/NF Feed	2175.7	1.9E-04	1.7E-03	1.7E-02	3.9E-04	2.2E+02	5.5E-04	2.5E+01	3.0E-03	3.7E-03	9.6E-02	6.0E-01	2.0E-03	9.6E+01	1.9E-02	8.4E+01	3.8E-01	7.8E-04	2.7E-02	7.2E-03	5.5E+02	1.8E-04	9.8E-03	1.2E-02	7.0
25	NF Permeate	1740.6	1.4E-04	1.2E-04	2.1E-04	2.8E-05	2.7E+01	3.9E-05	2.8E+01	1.1E-04	2.6E-04	7.4E-03	4.7E-01	0.0E+00	6.5E+00	2.8E-03	5.4E+01	1.4E-02	3.1E-05	1.9E-03	2.9E-04	2.3E+01	1.3E-05	7.0E-04	2.4E-04	6.2
26	NF Concentrate to VSEP A	435.1	3.8E-04	7.9E-03	8.3E-02	1.9E-03	1.0E+03	2.6E-03	1.2E+01	1.4E-02	1.8E-02	4.5E-01	1.1E+00	1.0E-02	4.6E+02	8.4E-02	2.0E+02	1.9E+00	3.8E-03	1.3E-01	3.5E-02	2.7E+03	8.6E-04	4.7E-02	6.0E-02	9.0
27	VSEP A Permeate to Final Effluent	348.1	1.5E-05	5.0E-05	5.1E-02	1.5E-03	9.0E+01	6.8E-05	1.1E+01	8.9E-04	1.9E-03	1.9E-02	6.7E-01	4.0E-04	6.7E+01	2.1E-02	9.1E+01	2.9E-01	8.6E-05	6.9E-03	2.1E-03	2.3E+02	4.6E-05	6.2E-03	3.8E-03	5.5
28	VSEP A Concentrate	87.0	1.9E-03	4.1E-02	2.2E-01	3.4E-03	4.9E+03	1.3E-02	1.3E+01	7.1E-02	8.3E-02	2.3E+00	3.0E+00	5.1E-02	2.1E+03	3.5E-01	6.8E+02	8.4E+00	1.9E-02	6.3E-01	1.7E-01	1.3E+04	4.2E-03	2.1E-01	3.0E-01	9.1
29	VSEP A Concentrate to HDS B	43.5	1.9E-03	4.1E-02	2.2E-01	3.4E-03	4.9E+03	1.3E-02	1.3E+01	7.1E-02	8.3E-02	2.3E+00	3.0E+00	5.1E-02	2.1E+03	3.5E-01	6.8E+02	8.4E+00	1.9E-02	6.3E-01	1.7E-01	1.3E+04	4.2E-03	2.1E-01	3.0E-01	9.1
30	VSEP A Concentrate to HDS A	43.5	1.9E-03	4.1E-02	2.2E-01	3.4E-03	4.9E+03	1.3E-02	1.3E+01	7.1E-02	8.3E-02	2.3E+00	3.0E+00	5.1E-02	2.1E+03	3.5E-01	6.8E+02	8.4E+00	1.9E-02	6.3E-01	1.7E-01	1.3E+04	4.2E-03	2.1E-01	3.0E-01	9.1
31	HDS A Underflow Sludge	19.4	4.0E-01	7.3E-10	5.9E+00	2.4E-01	8.5E+04	1.5E+00	5.4E-01	1.5E+02	5.0E-01	6.7E+02	1.9E-02	5.0E+03	5.1E+03	4.3E+02	0.0E+00	2.3E+03	3.2E+00	4.2E-06	7.1E-01	8.7E+04	3.9E-08	1.8E+00	1.6E+02	10.4
32	Sulfate A Underflow Sludge	39.0	0.0E+00	1.8E+03	8.0E-22	5.8E-08	3.0E+04	0.0E+00	2.7E-01	1.3E-02	5.6E-17	4.8E-05	2.6E+01	6.7E-10	8.2E+03	2.4E-13	6.7E-13	8.8E-02	0.0E+00	7.8E+00	4.1E-01	3.3E+04	1.5E-14	2.6E-12	2.1E-06	12.5
33	Calcite A Underflow Sludge	21.8	1.1E-18	6.7E-16	0.0E+00	0.0E+00	2.3E+04	1.5E-19	0.0E+00	9.2E-24	0.0E+00	4.7E-05	7.9E-15	5.6E-20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-16	7.9E-14	0.0E+00	1.1E-21	4.8E-17	10.9
34	HDS B Underflow Sludge	19.4	4.0E-01	7.3E-10	5.9E+00	2.4E-01	8.5E+04	1.5E+00	5.4E-01	1.5E+02	5.0E-01	6.7E+02	1.9E-02	5.0E+03	5.1E+03	4.3E+02	0.0E+00	2.3E+03	3.2E+00	4.2E-06	7.1E-01	8.7E+04	3.9E-08	1.8E+00	1.6E+02	10.4
35	Sulfate B Underflow Sludge	39.0	0.0E+00	1.8E+03	8.0E-22	5.8E-08	3.0E+04	0.0E+00	2.7E-01	1.3E-02	5.6E-17	4.8E-05	2.6E+01	6.7E-10	8.2E+03	2.4E-13	6.7E-13	8.8E-02	0.0E+00	7.8E+00	4.1E-01	3.3E+04	1.5E-14	2.6E-12	2.1E-06	12.5
36	Calcite B Underflow Sludge	21.8	1.1E-18	6.7E-16	0.0E+00	0.0E+00	2.3E+04	1.5E-19	0.0E+00	9.2E-24	0.0E+00	4.7E-05	7.9E-15	5.6E-20	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.4E-16	7.9E-14	0.0E+00	1.1E-21	4.8E-17	10.9
37	Plant Site VSEP Concentrate	158.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
38	Plant Site Concentrate to HDS A	79.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
39	Plant Site Concentrate to HDS B	79.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
40	Final Effluent to CPS	2759.0	5.2E-04	2.4E-02	6.5E-03	2.2E-03	2.9E+01	2.3E-04	2.9E+01	1.8E-04	7.7E-03	8.0E-03	7.1E-01	1.6E-04	1.3E+01	4.0E-02	1.6E+02	4.5E-02	4.1E-05	7.8E-03	6.2E-03	2.3E+02	1.4E-03	1.2E-03	7.2E-02	6.0

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO$_2$ Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO$_2$ [ton/d]	NaMnO$_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	374.9	NA	NA	NA	396.3	9.9	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	40.9	21.44	19.4	NA	NA	NA	NA	NA	NA	25	1.18	3.02	1.44	1.58
5	Sulfate A Influent	374.9	NA	NA	NA	416.5	8.3	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	80.7	41.65	39.0	NA	NA	NA	NA	NA	NA	10	1.05	2.04	0.94	1.10
6	Sulfate A Effluent	374.9	NA	NA	293.3	668.2	NA	NA	3.5	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	21.8	0.00	21.8	NA	NA	NA	NA	NA	NA	10	1.06	0.53	0.53	0.00
7	Calcite A Effluent	374.9	NA	NA	96.3	471.1	NA	NA	1.2	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	374.9	NA	NA	NA	396.3	9.9	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	40.9	21.44	19.4	NA	NA	NA	NA	NA	NA	25	1.18	3.02	1.44	1.58
11	Sulfate B Influent	374.9	NA	NA		416.5	8.3	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	80.7	41.65	39.0	NA	NA	NA	NA	NA	NA	10	1.05	2.04	0.94	1.10
12	Sulfate B Effluent	374.9	NA	NA	293.3	668.2	NA	NA	3.5	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	21.8	0.00	21.8	NA	NA	NA	NA	NA	NA	10	1.06	0.53	0.53	0.00
13	Calcite B Effluent	374.9	NA	NA	96.3	374.9	NA	NA	1.2	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	2290.3	NA	NA	NA	NA	NA	NA	NA	45.3	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	435.1	NA	NA	458.3*	NA	NA	NA	5.5	NA	NA	NA	NA	NA	NA

*CO$_2$ carrier water adds flow to feed tank, not to VSEP units

Mine Water Treatment Trains Flow and Load Detail
Year 10 P90 Winter Flow

Flow and Load Details

Item	Description	Flow [gpm]	[Ag] [mg/L]	[Al] [mg/L]	[As] [mg/L]	[Be] [mg/L]	[Ca] [mg/L]	[Cd] [mg/L]	[Cl] [mg/L]	[Co] [mg/L]	[Cr] [mg/L]	[Cu] [mg/L]	[F] [mg/L]	[Fe] [mg/L]	[Mg] [mg/L]	[Mn] [mg/L]	[Na] [mg/L]	[Ni] [mg/L]	[Pb] [mg/L]	[Sb] [mg/L]	[Se] [mg/L]	[SO4] [mg/L]	[Tl] [mg/L]	[V] [mg/L]	[Zn] [mg/L]	pH [std units]
1	High Conc EQ Effluent	83.0	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
2	High Conc EQ Effluent to HDS A	41.5	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
3	High Conc EQ Effluent to HDS B	41.5	4.4E-02	3.8E+02	3.4E-01	3.7E-02	1.6E+03	1.2E-01	4.7E+01	1.5E+01	2.7E-02	6.2E+01	1.8E+00	5.3E+02	9.3E+02	4.3E+01	2.2E+02	2.3E+02	2.6E-01	1.5E+00	1.5E-01	1.1E+04	7.6E-03	6.4E-02	1.4E+01	5.0
4	Combined HDS A Influent	296.7	1.2E-02	5.3E+01	1.5E-01	9.8E-03	1.2E+03	3.6E-02	3.4E+01	2.4E+00	2.0E-01	1.2E+01	4.9E+00	7.5E+01	8.3E+02	7.4E+00	1.1E+03	3.7E+01	7.2E-02	3.2E-01	7.0E-02	6.3E+03	4.1E-02	7.5E-02	3.6E+00	6.2
5	Sulfate A Influent	296.7	4.8E-03	5.2E+01	7.0E-06	5.8E-03	4.9E+02	1.6E-03	3.3E+01	7.2E-04	1.7E-01	3.9E-03	4.8E+00	9.6E-04	6.5E+02	7.3E-02	1.1E+03	5.1E-03	6.9E-05	3.1E-01	4.8E-02	4.9E+03	4.0E-02	1.1E-06	6.1E-01	10.5
6	Sulfate A Effluent	296.7	4.8E-03	5.2E-02	7.0E-06	5.8E-03	1.2E+03	1.6E-03	3.3E+01	1.2E-07	1.7E-01	3.9E-03	1.8E+00	9.6E-04	3.0E-01	7.3E-02	1.1E+03	5.6E-06	6.9E-05	1.6E-02	2.4E-02	1.7E+03	4.0E-02	1.1E-06	6.1E-01	12.5
7	Calcite A Effluent	296.7	4.9E-03	5.3E-02	7.0E-06	5.8E-03	5.0E+01	1.6E-03	3.3E+01	1.2E-07	1.7E-01	3.9E-03	1.9E+00	9.7E-04	3.0E-01	7.4E-02	1.1E+03	5.7E-06	6.9E-05	1.6E-02	2.4E-02	1.7E+03	4.1E-02	1.1E-06	6.2E-01	10.9
8	Calcite A Effluent to Final Effluent	118.7	4.9E-03	5.3E-02	7.0E-06	5.8E-03	5.0E+01	1.6E-03	3.3E+01	1.2E-07	1.7E-01	3.9E-03	1.8E+00	9.7E-04	3.0E-01	7.3E-02	1.1E+03	5.7E-06	6.9E-05	1.6E-02	2.4E-02	1.7E+03	4.0E-02	1.1E-06	6.1E-01	6.8
9	Calcite A Effluent to VSEP B	178.0	4.9E-03	5.3E-02	7.0E-06	5.8E-03	5.0E+01	1.6E-03	3.3E+01	1.2E-07	1.7E-01	3.9E-03	1.8E+00	9.7E-04	3.0E-01	7.3E-02	1.1E+03	5.7E-06	6.9E-05	1.6E-02	2.4E-02	1.7E+03	4.0E-02	1.1E-06	6.1E-01	6.8
10	Combined HDS B Influent	296.7	1.2E-02	5.3E+01	1.5E-01	9.8E-03	1.2E+03	3.6E-02	3.4E+01	2.4E+00	2.0E-01	1.2E+01	4.9E+00	7.5E+01	8.3E+02	7.4E+00	1.1E+03	3.7E+01	7.2E-02	3.2E-01	7.0E-02	6.3E+03	4.1E-02	7.5E-02	3.6E+00	6.2
11	Sulfate B Influent	296.7	4.8E-03	5.2E+01	7.0E-06	5.8E-03	4.9E+02	1.6E-03	3.3E+01	7.2E-04	1.7E-01	3.9E-03	4.8E+00	9.6E-04	6.5E+02	7.3E-02	1.1E+03	5.1E-03	6.9E-05	3.1E-01	4.8E-02	4.9E+03	4.0E-02	1.1E-06	6.1E-01	10.5
12	Sulfate B Effluent	296.7	4.8E-03	5.2E-02	7.0E-06	5.8E-03	1.2E+03	1.6E-03	3.3E+01	1.2E-07	1.7E-01	3.9E-03	1.8E+00	9.6E-04	3.0E-01	7.3E-02	1.1E+03	5.6E-06	6.9E-05	1.6E-02	2.4E-02	1.7E+03	4.0E-02	1.1E-06	6.1E-01	12.5
13	Calcite B Effluent	296.7	4.9E-03	5.3E-02	7.0E-06	5.8E-03	5.0E+01	1.6E-03	3.3E+01	1.2E-07	1.7E-01	3.9E-03	1.9E+00	9.7E-04	3.0E-01	7.4E-02	1.1E+03	5.7E-06	6.9E-05	1.6E-02	2.4E-02	1.7E+03	4.1E-02	1.1E-06	6.2E-01	10.9
14	Calcite B Effluent to Final Effluent	118.7	4.9E-03	5.3E-02	7.0E-06	5.8E-03	5.0E+01	1.6E-03	3.3E+01	1.2E-07	1.7E-01	3.9E-03	1.8E+00	9.7E-04	3.0E-01	7.3E-02	1.1E+03	5.7E-06	6.9E-05	1.6E-02	2.4E-02	1.7E+03	4.0E-02	1.1E-06	6.1E-01	6.8
15	Calcite B Effluent to VSEP B	178.0	4.9E-03	5.3E-02	7.0E-06	5.8E-03	5.0E+01	1.6E-03	3.3E+01	1.2E-07	1.7E-01	3.9E-03	1.8E+00	9.7E-04	3.0E-01	7.3E-02	1.1E+03	5.7E-06	6.9E-05	1.6E-02	2.4E-02	1.7E+03	4.0E-02	1.1E-06	6.1E-01	6.8
16	VSEP B Permeate to Final Effluent	474.7	1.9E-04	3.3E-04	4.3E-06	4.6E-03	4.5E+00	4.2E-05	3.2E+01	7.2E-09	1.8E-02	1.7E-04	1.1E+00	3.9E-05	4.4E-02	1.9E-02	4.8E+02	8.8E-07	1.6E-06	8.5E-04	1.5E-03	1.4E+02	2.2E-03	1.5E-07	3.9E-02	6.4
17	VSEP B Concentrate	118.7	2.4E-02	2.6E-01	1.8E-05	1.1E-02	2.4E+02	7.9E-03	3.7E+01	5.6E-07	7.8E-01	1.9E-02	4.9E+00	4.7E-03	1.3E+00	3.0E-01	3.5E+03	2.5E-05	3.4E-04	7.7E-02	1.2E-01	7.8E+03	2.0E-01	5.0E-06	3.0E+00	8.8
18	VSEP B Concentrate to HDS B	59.3	2.4E-02	2.6E-01	1.8E-05	1.1E-02	2.4E+02	7.9E-03	3.7E+01	5.6E-07	7.8E-01	1.9E-02	4.9E+00	4.7E-03	1.3E+00	3.0E-01	3.5E+03	2.5E-05	3.4E-04	7.7E-02	1.2E-01	7.8E+03	2.0E-01	5.0E-06	3.0E+00	8.8
19	VSEP B Concentrate to HDS A	59.3	2.4E-02	2.6E-01	1.8E-05	1.1E-02	2.4E+02	7.9E-03	3.7E+01	5.6E-07	7.8E-01	1.9E-02	4.9E+00	4.7E-03	1.3E+00	3.0E-01	3.5E+03	2.5E-05	3.4E-04	7.7E-02	1.2E-01	7.8E+03	2.0E-01	5.0E-06	3.0E+00	8.8
20	Low Conc EQ Effluent	1124.1	1.9E-04	1.7E-03	5.5E-02	3.9E-04	2.2E+02	5.0E-03	2.5E+01	1.9E-01	3.7E-03	1.5E+00	6.0E-01	1.9E-01	9.6E+01	3.5E-01	8.4E+01	2.6E+00	7.1E-03	2.7E-02	7.7E-03	5.5E+02	1.8E-04	9.8E-03	5.2E-01	7.0
21	GSF Backwash	56.2	1.9E-04	1.7E-03	9.0E-01	3.9E-04	2.2E+02	9.3E-02	2.5E+01	3.7E+00	3.7E-03	3.0E+01	6.0E-01	3.8E+00	9.6E+01	6.8E+00	8.3E+01	4.8E+01	1.3E-01	2.7E-02	7.7E-03	5.5E+02	1.8E-04	9.8E-03	1.0E+01	7.0
22	GSF Backwash Solids	28.1	1.9E-04	1.7E-03	1.5E+00	3.9E-04	2.2E+02	1.7E-01	2.5E+01	7.1E+00	3.7E-03	5.6E+01	6.0E-01	7.3E+00	9.6E+01	1.3E+01	8.3E+01	8.8E+01	2.5E-01	2.7E-02	7.7E-03	5.5E+02	1.8E-04	9.8E-03	2.0E+01	7.0
23	GSF Backwash Decant	28.1	1.9E-04	1.7E-03	2.8E-01	3.9E-04	2.2E+02	1.4E-02	2.5E+01	2.4E-01	3.7E-03	3.2E+00	6.0E-01	2.3E-01	9.6E+01	6.8E-01	8.3E+01	8.7E+00	2.0E-02	2.7E-02	7.7E-03	5.5E+02	1.8E-04	9.8E-03	7.4E-01	7.0
24	GSF Permeate/NF Feed	1067.9	1.9E-04	1.7E-03	1.7E-02	3.9E-04	2.2E+02	5.5E-04	2.5E+01	3.0E-03	3.7E-03	9.6E-02	6.0E-01	2.0E-03	9.6E+01	1.9E-02	8.4E+01	3.8E-01	7.8E-04	2.7E-02	7.7E-03	5.5E+02	1.8E-04	9.8E-03	1.2E-02	7.0
25	NF Permeate	854.3	1.4E-04	1.2E-04	2.1E-04	2.8E-05	2.7E+01	3.9E-05	2.8E+01	1.1E-04	2.6E-04	7.4E-03	4.7E-01	0.0E+00	6.5E+00	2.8E-03	5.4E+01	1.4E-02	3.1E-05	1.9E-03	3.1E-04	2.3E+01	1.3E-05	7.0E-04	2.4E-04	6.0
26	NF Concentrate to VSEP A	213.6	3.8E-04	7.9E-03	8.3E-02	1.9E-03	1.0E+03	2.6E-03	1.2E+01	1.4E-02	1.8E-02	4.5E-01	1.1E+00	1.0E-02	4.6E+02	8.4E-02	2.0E+02	1.9E+00	3.8E-03	1.3E-01	3.8E-02	2.7E+03	8.6E-04	4.7E-02	6.0E-02	9.2
27	VSEP A Permeate to Final Effluent	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
28	VSEP A Concentrate	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
29	VSEP A Concentrate to HDS B	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
30	VSEP A Concentrate to HDS A	0.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	10.4	2.0E-01	0.0E+00	4.2E+00	1.1E-01	9.4E+04	9.5E-01	6.1E-01	6.7E+01	9.1E-01	3.3E+02	3.1E-02	2.1E+03	4.6E+03	2.1E+02	0.0E+00	1.0E+03	2.0E+00	3.1E-06	5.9E-01	3.5E+04	0.0E+00	2.1E+00	8.2E+01	10.5
32	Sulfate A Underflow Sludge	26.2	2.1E-07	5.9E+02	0.0E+00	0.0E+00	3.0E+04	9.5E-08	2.4E-01	8.2E-03	0.0E+00	6.3E-05	3.4E+01	0.0E+00	7.4E+03	2.8E-06	0.0E+00	5.7E-02	2.7E-09	3.4E+00	2.7E-01	3.7E+04	0.0E+00	0.0E+00	0.0E+00	12.5
33	Calcite A Underflow Sludge	13.9	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.4E+04	0.0E+00	3.3E-09	0.0E+00	0.0E+00	6.4E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.9
34	HDS B Underflow Sludge	10.4	2.0E-01	0.0E+00	4.2E+00	1.1E-01	9.4E+04	9.5E-01	6.1E-01	6.7E+01	9.1E-01	3.3E+02	3.1E-02	2.1E+03	4.6E+03	2.1E+02	0.0E+00	1.0E+03	2.0E+00	3.1E-06	5.9E-01	3.5E+04	0.0E+00	2.1E+00	8.2E+01	10.5
35	Sulfate B Underflow Sludge	26.2	2.1E-07	5.9E+02	0.0E+00	0.0E+00	3.0E+04	9.5E-08	2.4E-01	8.2E-03	0.0E+00	6.3E-05	3.4E+01	0.0E+00	7.4E+03	2.8E-06	0.0E+00	5.7E-02	2.7E-09	3.4E+00	2.7E-01	3.7E+04	0.0E+00	0.0E+00	0.0E+00	12.5
36	Calcite B Underflow Sludge	13.9	0.0E+00	0.0E+00	0.0E+00	0.0E+00	2.4E+04	0.0E+00	3.3E-09	0.0E+00	0.0E+00	6.4E-05	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	10.9
37	Plant Site VSEP Concentrate	150.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
38	Plant Site Concentrate to HDS A	75.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
39	Plant Site Concentrate to HDS B	75.0	4.2E-03	2.5E-01	4.4E-03	7.3E-03	2.1E+03	3.1E-02	5.7E+01	9.4E-03	1.5E-01	6.0E-01	1.3E+01	6.7E-01	2.1E+03	3.0E+00	1.1E+03	1.2E+00	8.7E-02	2.0E-01	5.0E-02	8.4E+03	4.3E-03	1.9E-01	5.0E-02	5.9
40	Final Effluent to CPS	1329.0	1.6E-04	1.9E-04	1.4E-04	1.7E-03	1.9E+01	4.0E-05	3.0E+01	6.9E-05	6.6E-03	5.0E-03	7.0E-01	1.4E-05	4.2E+00	8.4E-03	2.1E+02	9.0E-03	2.1E-05	1.5E-03	7.3E-04	6.5E+01	7.8E-04	4.5E-04	1.4E-02	6.1

Chemical Addition, Flow Recycle, and Sludge Detail

		Flows					Chemical Additions				Solids Balance				
Item	Description	Flow [gpm]	Sludge Recycle Flow to Clarifier [gpm]	Sludge Waste Flow [gpm]	CO_2 Carrier Water Flow [gpm]	Flow with Recycle, Carrier Water [gpm]	Lime [ton/d]	HCl [ton/d]	CO_2 [ton/d]	$NaMnO_4$ [lb/d]	Sludge Solids Content [%]	Specific Gravity []	Total Solids to Clarifier [ton/hr]	Solids to Press [ton/hr]	Solids Recycled to Clarifier [ton/hr]
4	Combined HDS A Influent	296.7	NA	NA	NA	379.9	6.6	NA	NA	NA	NA	NA	NA	NA	NA
31	HDS A Underflow Sludge	93.7	83.21	10.4	NA	NA	NA	NA	NA	NA	25	1.18	6.94	0.77	6.17
5	Sulfate A Influent	296.7	NA	NA	NA	329.6	5.5	0.0	NA	NA	NA	NA	NA	NA	NA
32	Sulfate A Underflow Sludge	59.1	32.96	26.2	NA	NA	NA	NA	NA	NA	10	1.05	1.50	0.63	0.87
6	Sulfate A Effluent	296.7	NA	NA	183.3	480.0	NA	NA	2.2	NA	NA	NA	NA	NA	NA
33	Calcite A Underflow Sludge	13.9	0.00	13.9	NA	NA	NA	NA	NA	NA	10	1.06	0.33	0.33	0.00
7	Calcite A Effluent	296.7	NA	NA	68.8	365.4	NA	NA	0.8	NA	NA	NA	NA	NA	NA
10	Combined HDS B Influent	296.7	NA	NA	NA	379.9	6.6	NA	NA	NA	NA	NA	NA	NA	NA
34	HDS B Underflow Sludge	93.7	83.21	10.4	NA	NA	NA	NA	NA	NA	25	1.18	6.94	0.77	6.17
11	Sulfate B Influent	296.7	NA	NA		329.6	5.5	0.0	NA	NA	NA	NA	NA	NA	NA
35	Sulfate B Underflow Sludge	59.1	32.96	26.2	NA	NA	NA	NA	NA	NA	10	1.05	1.50	0.63	0.87
12	Sulfate B Effluent	296.7	NA	NA	183.3	480.0	NA	NA	2.2	NA	NA	NA	NA	NA	NA
36	Calcite B Underflow Sludge	13.9	0.00	13.9	NA	NA	NA	NA	NA	NA	10	1.06	0.33	0.33	0.00
13	Calcite B Effluent	296.7	NA	NA	68.8	296.7	NA	NA	0.8	NA	NA	NA	NA	NA	NA
20	Low Conc EQ Effluent	1124.1	NA	NA	NA	NA	NA	NA	NA	22.2	NA	NA	NA	NA	NA
26	NF Concentrate to VSEP A	213.6	NA	NA	0*	NA	NA	NA	0.0	NA	NA	NA	NA	NA	NA

Attachment L

Mine Water Treatment Trains Design Criteria

Design Standard Checklist

Mine Water Treatment Trains of Waste Water Treatment System
NorthMet Project
Poly Met Mining, Inc.

			Standard			PolyMet WWTS Information			
Process	**Equipment**	**Design Requirement**	**10 State Standards(1)**	**Minnesota Pollution Control Agency(2)**	**Pilot/Bench Testing**	**NPDES Permit Design Basis**	**Standards Met?**	**Rationale for Design Basis if Inconsistent with Ten State and MPCA Standards**	**WWTS Design and Operation Report Section**
Headworks	High Concentration Equalization Basin	Size	Sized to effectively reduce expected flow and load variations to the extent deemed economically feasible			Sized to provide storage of spring snowmelt event in Mine Year 10	Yes		4.3.6.1
	Low Concentration Equalization Basins	Size	Sized to effectively reduce expected flow and load variations to the extent deemed economically feasible			Sized to provide storage of spring snowmelt event in Mine Year 10, LCEQ Basin 2 sized to equalize flow from Category 1 stockpile	Yes		4.3.7.1
	Lift Station	Redundancy	Yes, each with capacity to pump peak hourly flow.			Three pumps per pipeline, each with capacity equal to 50% of design flow	Yes		4.3.6.1, 4.3.5
	Intake Structure/bar screen	Screen Opening Size	1.75-inch Maximum			Mechanical screens with <1/2" openings	Yes		
	Flow Splitter Box	Weir Type	Use of upflow division boxes equipped with adjustable sharp-crested weirs is recommended. Valves for flow splitting not accepted.			Will be addressed in final design			
High-Density Metals Precipitation	Rapid Mix Tanks	Detention Time	Detention period should not be more than 30 seconds in municipal coagulation systems		45 minute mixing time used in chemical precipitation bench tests	Min HRT = 5 mins under peak loading conditions	Yes	Mixing time selected to incorporate high chemical doses and recycled sludge	4.3.6.2
		Metal Scavanger			Include for increased cation removal	Scavenger on standby	Yes		
	Sludge Reactors				Reactor time of 60 minutes	Min HRT = 60 mins	Yes		
	Clarifiers	Redundancy	Yes, if flow >1MGD			Yes, two treatment trains	Yes		
		Overflow Rate	<1,500 - 2,000 gpd/sqft. for peak hourly flow for municipal secondary sludge		Use overflow rate of 500 gpd/sq. ft.	500 gpd/sqft average, 750 gpd/sqft peak	Yes	530-1,000 gpd/sqft for tertiary clarification of iron/alum particles (1)	
		Radius		< 5 times sidewater depth		19 ft	Yes		
		Sidewater Depth	>10 feet			10 ft	Yes		
		Inlet/Outlet Distance	>10 feet	>10 feet		Will be met in final design	Yes		
		Weir Trough Velocity		>1 ft/sec @ 50% peak hourly flow		Will be met in final design	Yes		
		Slope of Submerged Surfaces		>1.4:1 vertical to horizontal on top, >1:1 vertical to horizontal on undersides		Will be met in final design	Yes		
		Covers		provided when influent temperature near freezing		Clarifiers will be indoors	Yes		
		Safety Features		machinery covers, life lines, stairways, 12 inches freeboard		Will be met in final design	Yes		
	Lime	Secondary Containment	Yes	Yes		Yes	Yes		5.1.2 and 5.1.3
	Ferric Sulfate	Injection	Feed directly into rapid mix	Mechanical mixing if needed	Maintain iron oxyhydroxide slude at approximately 1%	Mechanical mixing	Yes		
	Polymer Coagulant	Velocity		fluid velocities into settling basins shoud not exceed 1.5 f/s to minimize floc		Will be met in final design	Yes		
	Metal Scavenger				Scaverger improves metals removal by 50% at high pH	On standby			

Design Standard Checklist

Mine Water Treatment Trains of Waste Water Treatment System
NorthMet Project
Poly Met Mining, Inc.

			Standard			PolyMet WWTS Information			
Process	**Equipment**	**Design Requirement**	**10 State Standards(1)**	**Minnesota Pollution Control Agency(2)**	**Pilot/Bench Testing**	**NPDES Permit Design Basis**	**Standards Met?**	**Rationale for Design Basis if Inconsistent with Ten State and MPCA Standards**	**WWTS Design and Operation Report Section**
Gypsum Precipitation	Rapid Mix Tanks	Detention Time	Detention period should not be more than 30 seconds			Min HRT = 5mins under peak loading conditions	Yes		4.3.6.2
	Sludge Reactors				Reactor time of 60 minutes	Min HRT = 60 mins	Yes		
	Clarifiers	Redundancy	Yes, if flow >1MGD			Yes, two treatment trains	Yes		
		Overflow Rate	<1,500 - 2,000 gpd/sqft. for peak hourly flow for municipal secondary sludge		Use overflow rate of 500 gpd/sq. ft.	500 gpd/sq. ft. average, 750 gpd/sq. ft. peak	Yes	1,200-1,800 gpd/sqft for tertiary lime clarifiers (1)	
		Radius		< 5 times sidewater depth		19 ft	Yes		
		Sidewater Depth	>10 feet			10 ft	Yes		
		Inlet/Outlet Distance	>10 feet	>10 feet		Will be met in final design	Yes		
		Weir Trough Velocity		>1 ft/sec @ 50% peak hourly flow		Will be met in final design	Yes		
		Slope of Submerged Surfaces		>1.4:1 vertical to horizontal on top, >1:1 vertical to horizontal on undersides		Will be met in final design	Yes		
		Covers		provided when influent temperature near freezing		Clarifiers will be indoors	Yes		
		Safety Features		machinery covers, life lines, stairways, 12 inches freeboard		Will be met in final design	Yes		
	Lime	Secondary Containment	Yes	Yes		Yes			5.1.2 and 5.1.3
	Ferric Chloride	Injection	Feed directly into rapid mix	Mechanical mixing if needed		None			
	Polymer Coagulant	Velocity		fluid velocities into settling basins shoud not exceed 1.5 f/s to minimize floc disruption		None			
Recarbonation/Calcite Precipitation System	Rapid Mix Tanks	Detention Time	Detention period should not be more than 30 seconds			Will be met in final design	Yes		4.3.6.2
	Clarifiers	Redundancy	Yes, if flow >1MGD			Yes, two treatment trains	Yes		
		Overflow Rate	<1,500 - 2,000 gpd/sqft. for peak hourly flow for municipal secondary sludge			750 gpd/sqft average, 1,000 gpd/sqft peak	Yes	1,200-1,800 gpd/sqft for tertiary lime clarifiers (3)	
		Radius		< 5 times sidewater depth		16 ft	Yes		
		Sidewater Depth	>10 feet			10 ft	Yes		
		Inlet/Outlet Distance	>10 feet	>10 feet		Will be met in final design	Yes		
		Weir Trough Velocity		>1 ft/sec @ 50% peak hourly flow		Will be met in final design	Yes		
		Slope of Submerged Surfaces		>1.4:1 vertical to horizontal on top, >1:1 vertical to horizontal on undersides		Will be met in final design	Yes		
		Covers		provided when influent temperature near freezing		Clarifiers will be indoors	Yes		
		Safety Features		machinery covers, life lines, stairways, 12 inches freeboard		Will be met in final design	Yes		
Effluent Neutralization	Carbon Dioxide	Storage	Stored in corrosion-resistant containers			Stored in Corrosion-Resistant Containers	Yes		
		Injection Point	Pumped in undiluted form from original containers to point of treatment or day tank			Pumped in undiluted form from original containers to point of treatment or day tank	Yes		5.1.2 and 5.1.3
	Carbon Dioxide Injection	Detention Time	20 minutes			30 minutes	Yes		

Design Standard Checklist

Mine Water Treatment Trains of Waste Water Treatment System
NorthMet Project
Poly Met Mining, Inc.

			Standard			PolyMet WWTS Information			
Process	**Equipment**	**Design Requirement**	**10 State Standards$^{(1)}$**	**Minnesota Pollution Control Agency$^{(2)}$**	**Pilot/Bench Testing**	**NPDES Permit Design Basis**	**Standards Met?**	**Rationale for Design Basis if Inconsistent with Ten State and MPCA Standards**	**WWTS Design and Operation Report Section**
		Tank Location	Locate tanks outside or sealed and vented			Tanks located outside of building.	Yes		
Sludge Handling	Sludge Pumping	Redundancy	Yes						4.3.6.3
	Sludge Piping	Size	6-inch diameter minimum for pump suction	6-inch diameter minimum for pump suction		6 inch diameter carbon steel	Yes		
		Velocity		> 3.0 ft/sec		Will be met in final design	Yes		
		Cleaning		provisions for rodding or backlfushing		Will be met in final design	Yes		
		Misc.		method for viewing, sampling, and controling rate of sludge withdrawl		Will be met in final design	Yes		
	Sludge Storage Tanks	Storage requirements	4 days	4 days or standby wet sludge facilities		2 days total sludge production	No	Wastewater generation can be slowed or stopped if sludge production exceeds storage capacity	
	Filter Press	Capacity	Number of mechanical units such that they have capacity to adequately dewaters ludge with largest unit out of service	Number of mechanical units such that they have capacity to adequately dewaters ludge with largest unit out of service		Sufficient to press one day of sludge in one 8-hour shift, will be addressed in final design	No	Wastewater generation can be slowed or stopped if sludge production exceeds storage capacity	
		Ventiliation	Adequate ventilation; condition exhaust air to avoid odor nuisance	Adequate ventilation; condition exhaust air to avoid odor nuisance		Will be met in final design	Yes		
		Discharge		Drainage returned to appropriate treatment process point		Drainage returned to splitter box at plant influent	Yes		
Mine Water Media Filtration	Greensand Filter	Pretreatment	Required			None	No	Filter to be followed by membrane filtration	4.3.7.2
		Rate	Typically 2-4 gpm/sq. ft., must be justified by design engineer to satisfaction of reviewing authority	Maximum allowable flow is 5 gpm/sq. ft. of filter area	3.5-4.9 gpm/sq. ft. sucussfully pilot tested	3.7 gpm/sq. ft. at design flow with all cells in service, 4.9 gpm/sq. ft. with one cell in backwash	Yes	Meets MPCA requirement, filter to be followed by membrane filtration, higher loading rate piloted	
		Backwash Cycle Time	At least 15 minutes			15-25 minutes	Yes		
		Backwash Rate	minimum rate of 15 gpm/sqft, 10 gpm/sqft acceptable for full depth filters			12-15 gpm/sqft	Yes	Greensand filtration media requires lower backwash rate to avoid washout	
	Sodium Permanganate		Iron and manganese can be oxidized with sodium permanganate		Tested 1.65 mg/L to 4.3 mg/L	Use 1.65 mg/L to 4.3 mg/L for optimum removal and dose efficiency	Yes	Pilot testing used for basis	

Design Standard Checklist

Mine Water Treatment Trains of Waste Water Treatment System
NorthMet Project
Poly Met Mining, Inc.

			Standard			**PolyMet WWTS Information**			
Process	**Equipment**	**Design Requirement**	**10 State Standards**$^{(1)}$	**Minnesota Pollution Control Agency**$^{(2)}$	**Pilot/Bench Testing**	**NPDES Permit Design Basis**	**Standards Met?**	**Rationale for Design Basis if Inconsistent with Ten State and MPCA Standards**	**WWTS Design and Operation Report Section**
Mine Water Primary Membranes	Pretreatment	Necessary	Yes			Pretreatment will consist of filtration, pH adjustment, and antiscalant addition	Yes		4.3.7.3
	NF Membranes	Redundancy	Yes, of critical components	Yes, of critical components		Yes	Yes		
		Flux			16 gal/sq ft per day	16 gal/sq ft per day			
		Type			Tested GE HL4040FM (4" element)	Use GE Muni-NF-400 (8" element)	Yes	Equivalent membrane with same flat sheet	
		Recovery			80%	80%	Yes		
	Anti-Scalant				GE Hypersperse MDC700	GE Hypersperse MDC150 or MDC700 at 2.2 ppm		Recommended by manufacturer	
	Sodium Bisulfite	Dose				1 ppm			
	Cleaning	Required, with acid/detergents			Use MC1 and MC4 products from GE	Yes			
Mine Water Secondary VSEP		Redundancy		Yes, of critical components		Yes	Yes		4.3.7.4
		Flux			60 gpd/sq. ft. successfully pilot tested	60 gpd/sq. ft.		Pilot testing used for basis	
		Type			Use Dow NF-270	Use Dow NF-270	Yes		
		Recovery			80%	80%	Yes		
		Cleaning	Required, with acid/detergents		Clean membranes at 50 C	NLR 505 and 404	Yes		
	Anti-Scalant	Chemical and Dose			Use phosphonic acid salt antiscalant at 10 ppm	NLR 759 at 10 ppm	Yes		
	Carbon Dioxide	pH Setpoint				Adjust pH to <6.2			

(1) Ten State 2012 Recommended Standards for Water Works or Ten State 2014 Recommended Standards from Wastewater Facilities
(2) MPCA Waste and Wastewater Treatment Checklists
(3) Water Environment Federation, 2005. *Clarifier Design,* 2nd Ed. Manual of Practices FD-8.

From MPCA's "Reliability for Mechanical Wastewater Treatment Plants," General Information: 1) where duplicate units are not provided, unit bypass structures must be provided so that each unit operation of the plant can be independently removed from service, 2) where duplicate units are provided, each unit operation must be designed such that, with the largest unit out of serive, the hydraulic capacity of the interconnecting piping will be sufficient to transport the peak instantaneous wet weather flow throug the remaining units. 3) duplication of all primary clarifiers, aeration basins, and final clarifiers must be provided in accordane with the following: there must be sufficient number of units of a size such that, with the largest unit out of service, the remaining units will have a design load capacity of at least 50 percent of the total design loading to that unit operation.

Attachment M

WWTS Relocations

resourceful. naturally.
engineering and environmental consultants

Technical Memorandum

To: Ann Foss, Minnesota Pollution Control Agency; Jess Richards, Minnesota Department of Natural Resources; Kenton Spading, U.S. Army Corps of Engineers
Prepared for: Poly Met Mining, Inc.
From: Don E. Richard, PhD, P.E.
Subject: Proposed Waste Water Treatment System (WWTS) Relocations (Version 3)
Date: April 11, 2017
c: Jennifer Saran, Christie Kearney, PolyMet

1.0 Introduction

Poly Met Mining, Inc. (PolyMet) is proposing to modify the footprint of the waste water treatment system (WWTS) for its NorthMet Project (Project), by combining the Mine Site Waste Water Treatment Facility (WWTF) and the Plant Site Waste Water Treatment Plant (WWTP) into a single building located at the Plant Site, at the location of the former WWTP. The WWTS building would be approximately 33% larger than the former WWTP (81,000 square feet instead of 61,000 square feet), and it would contain all the treatment processes formerly housed in the two separate buildings. These changes would have environmental effects that are either the same as those evaluated in the Final Environmental Impact Statement (FEIS) (Reference (1)) or result in some relatively small, but nonetheless important, reductions in environmental effects.

The location for the WWTS, at the location of the former WWTP, is shown on Large Figure 1. At the Mine Site, the WWTF would be eliminated and the equalization basins would be relocated to the south of Dunka Road as shown on Large Figure 2. To transport mine water to the Plant Site for treatment, the single Treated Water Pipeline would be replaced by a three pipeline system. The three Mine to Plant Pipelines would deliver three types of mine water (high concentration mine water, low concentration mine water, and construction mine water) to their respective destinations at the Plant Site (additional details below). Piping relocations necessary to accommodate these changes are shown on Large Figure 1, Large Figure 2, and Large Figure 3. These changes will not increase the proposed corridor width along the Transportation and Utility Corridor or the wetland impacts along the Transportation and Utility Corridor.

There would be a number of benefits from these relocations. PolyMet planned to transport WWTS byproducts and waste streams back and forth between the Plant Site and the Mine Site. With all WWTS operations under one roof, this transport would no longer be necessary. This increased efficiency would require less energy and truck traffic, and eliminate the need to haul WWTS-related material via trains. The one-roof configuration would also allow more efficient use of the treatment units and reduce capital outlays for the Project. The water quality and rate of the treated discharge to the environment and to the FTB Pond would be the same as were evaluated for the FEIS. In addition, the removal of the WWTF and relocation of the Equalization Basin Area will result in 7.9 fewer acres of wetland impacts, including 7.8 acres of direct impact and 0.1 acres of indirect impact (fragmentation).

The following sections describe the proposed WWTS relocations (Section 2), compare the environmental effects of the proposed WWTS relocations with those evaluated in the FEIS (Section 3), and summarize potential ripple effects across the various permitting efforts that are in progress (Section 4).

2.0 WWTS Relocations

The WWTS relocations would modify the physical location and structure of the treatment buildings and collection ponds. Overall, the WWTS would still have the same treatment units and would continue to meet the stated treatment objectives for the system as described in the FEIS, the NPDES/SDS permit application and the Permit to Mine application, while increasing treatment efficiency and reducing environmental effects.

The WWTS evaluated in the FEIS (as described in the WWTS Design and Operation Report (Reference (2)) was developed as an integrated system for managing the quality of water discharged from the Project to the surrounding environment. The design to house waste water treatment in separate facilities housed at both the Mine Site and the Plant Site was based primarily on the iterative nature of the Project development. Waste water treatment for the Project was originally proposed just at the Mine Site, as described in the Draft Environment Impact Statement, to treat mine water prior to sending it to the Tailings Basin. As the Project evaluation progressed, a separate Waste Water Treatment Plant (WWTP) was added to treat water at the Plant Site prior to the discharge, which was needed to supplement streamflow downstream of the Tailings Basin, as described in the Supplemental Draft Environmental Impact Statement. The modifications to the WWTS proposed in this memorandum would integrate the two operations into a single building at the Plant Site (at the location of the WWTP).

2.1 Physical Modifications

The WWTS relocations would consist of the following physical modifications:

- All of the same treatment processes described in the Design and Operation Report (Reference (2)) would be combined into a single treatment building, which would be located at the Plant Site in the same location that was proposed for the WWTP. Large Figure 4 and Large Figure 5 show the general arrangement of the "under-one-roof" WWTS.
- The Waste Water Treatment Facility (WWTF) would be eliminated from the Mine Site and the Central Pumping Station and the mine water equalization basins would be relocated to a new location south of Dunka Road. Large Figure 2 shows the location of the Equalization Basin Area, and Large Figure 3 shows the proposed layout of the equalization basins. The Low and High Concentration Equalization Basins would have the same storage capacity and have the same liner design as the previous design provided in the Waste Water Treatment System: Design and

Operation Report (Reference (2)), therefore leakage rates from the equalization basins would be the same. The Construction Mine Water Basin is smaller than originally proposed, in order to fit in the available Equalization Basin Area footprint, however it will still provide the necessary volume required to manage this water between the construction areas and the FTB by optimizing the pump sizing associated with the construction mine water.[1]

- The pumps and equipment in the former Splitter Structure Building would be integrated into an expanded Central Pumping Station (CPS) near the relocated equalization basins.
- The Treated Water Pipeline would be replaced with three separate pipelines to convey water between the Mine Site and the Plant Site within the same pipeline corridor. The two pipelines carrying mine water from the Mine Site equalization basins would be extended to the Plant Site WWTS building, and the pipeline carrying construction mine water would be routed to the FTB, consistent with what was presented in the FEIS. These pipelines would have flow meters at both ends of each pipe for leak detection. A cross-section of the proposed Mine to Plant Pipelines is included on Large Figure 3.
    - When treated water is needed during operations to manage water levels in the East Pit, it would be pumped from the WWTS via the Construction Mine Water Pipeline. When East Pit backfill begins in Mine Year 11, runoff from the Overburden and Laydown Area (OSLA), which reports to the Construction Mine Water Basin, would be routed directly to the East Pit, making the Construction Mine Water Pipeline available to transport treated water from the WWTS to the Mine Site. These two operating scenarios will not occur simultaneously. No construction mine water will need to be managed after Mine Year 11 as all of the mine feature construction will be completed. East Pit water level management will need to start in Mine Year 12, after the Category 4 waste rock is disposed of in the pit. At that time, the Construction Mine Water Pipeline would be available to use for sending water from the WWTS to the East Pit because no more construction mine water will be generated. For the FEIS evaluation, the water used to manage water levels in the East Pit included both OSLA runoff and treated water from the WWTF, so this operation remains consistent with that analysis. The Construction Mine Water Pipeline would be sized to accommodate flows of treated water needed to manage East Pit water levels as well as construction mine water, recognizing that these would be two separate operating scenarios for this pipeline. In addition, the Construction Mine Water Pipeline would be extended to the WWTS prior to Mine Year 12 to deliver treated

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[1] The previous Construction Mine Water Basin was designed based on the size of the available area and the construction phase of the Project rather than the design requirements during operations. The basin has been designed to manage groundwater inflows to construction areas (the largest source of water that will be sent to the pond) plus 4.8 inches per month of stormwater runoff during the operations phase. Construction mine water during the construction phase will be managed through a combination of this pond and the equalization basins..

    water back to the Mine Site in Mine Year 12. This extension would follow the same route as the other two proposed Mine to Plant Pipelines.

  - Likewise, during reclamation and closure (during West Pit flooding and East Pit flushing), the Construction Mine Water Pipeline would be used to return treated water from the WWTS to the East Pit, and the Construction Mine Water Pipeline would be sized to also accommodate flows of treated water needed for East Pit flushing during this period.
  - This piping configuration and water management in connection with the WWTS will not change quantities or rates of treated water being conveyed to the Mine Site relative to the conveyances reviewed in the FEIS.
- The rail spur needed for WWTP concentrate management at the Mine Site would be eliminated.

The modifications would necessitate limited changes in terminology with regard to the components of the WWTS, as summarized in Table 1.

Table 1 WWTS Terminology Changes

Current name	Proposed name	Notes
Waste Water Treatment Plant (WWTP) and Waste Water Treatment Facility (WWTF)	Waste Water Treatment System (WWTS)	The two sets of treatment trains that were previously at two locations would now be housed under one roof at the Plant Site.
Treated Water Pipeline	As a whole: • Mine to Plant Pipelines (MPP) Three individual pipes: • Construction Mine Water Pipeline • Low Concentration Mine Water Pipeline • High Concentration Mine Water Pipeline	These pipelines would also be used to pump water from the Plant Site to the Mine Site for East Pit filling and to flood the West Pit.
Construction Mine Water Basin	Construction Mine Water Basin	
West Equalization Basin	High Concentration Equalization Basin (HCEQ Basin)	
East Equalization Basin 1	Low Concentration Equalization Basin 1 (LCEQ Basin 1)	
East Equalization Basin 2	Low Concentration Equalization Basin 2 (LCEQ Basin 2)	
WWTP effluent (discharged to receiving waters)	WWTS discharge	
WWTF effluent (sent to the FTB via the CPS)	Treated mine water (WWTS stream pumped to the FTB)	Formerly "treated mine water", which included WWTF effluent, OSLA runoff, and construction mine water. With reconfiguration, that mixture no longer exists, and the "treated mine water" would consist of effluent from the chemical precipitation and membrane filtration portion of the WWTS.
Treated mine water	Treated mine water	"Treated mine water" formerly included WWTF effluent, OSLA runoff, and construction mine water. With reconfiguration, that mixture no longer exists, but these flows still report to the FTB.
Central Pumping Station	Central Pumping Station	The Central Pumping Station would be combined with the Splitter Structure.
--	Equalization Basin Area	New term describing pond area south of Dunka Road
Splitter Structure	--	This structure would be integrated into the Central Pumping Station.
CPS Pond		This pond no longer exists.

2.2 Internal Treatment Plant Flow and Process Modifications

The new operation within the single WWTS building would contain all of the same treatment units and the same operating configuration as proposed in the previous two-building system. Large Figure 4 and Large Figure 5 show the general layout for the combined WWTS building, and Large Figure 6 shows the process flow diagram for the WWTS. The primary membrane operations within the single WWTS building would remain independent for the treatment of mine water and the treatment of FTB seepage capture systems water, as was the case with the two-building system. Treated mine water would continue to be routed to the FTB Pond for further removal of mercury. Treated FTB seepage would be discharged to the environment in the same quantity and quality and from the same locations. The secondary membrane operations would treat the same volume of water, and the secondary membrane concentrate would continue to be routed to the chemical precipitation treatment train.

Because the WWTS treatment process would be the same, and in particular the quantity and quality of treated water discharged to the environment would not change, the modeling included in the existing NPDES/SDS and Permit to Mine applications is not affected. Accordingly, the model results remain valid and need not be revised in connection with the WWTS relocations.

2.3 Comparison of FEIS and WWTS Relocations

Large Figure 7 through Large Figure 10 compare the flows evaluated for the FEIS with the flows for the WWTS during operations, reclamation, closure, and postclosure maintenance.

During operations (Large Figure 7 and Large Figure 8), mine water would be sent to the Plant Site via the Mine to Plant Pipelines located within the Transportation and Utility Corridor, along the alignment planned for the Treated Water Pipeline. The construction mine water would go to the FTB Pond, as it previously had in the FEIS (i.e., previously combined with the treated mine water at the CPS Pond, which was then routed through the Treated Water Pipeline to the FTB Pond). The high concentration mine water would report to chemical precipitation treatment units at the WWTS, and the low concentration mine water would report to membrane filtration treatment units at the WWTS, as was the case in the FEIS configuration of the WWTF. Treated mine water from the membrane separation and chemical precipitation treatment units at the WWTS would be routed to the FTB Pond. When East Pit backfilling begins in approximately Mine Year 11, treated mine water would be routed back to the Mine Site through the Construction Mine Water Pipeline. Treated mine water and OSLA runoff would both be used in water level management during East Pit backfill, with that operation proceeding at the same rate of backfill and water level management as evaluated for the FEIS and with the same type of water as was evaluated for the FEIS. Accordingly, the WWTS relocations would result in no change in management of water from the FTB seepage capture systems as compared to the prior configuration: some water would be returned to the FTB Pond, and some water would be sent to the WWTS for treatment and then discharged under the terms of an NPDES/SDS Permit and the Water Appropriation permits. The quantity, quality, and location of discharge to the environment would be unchanged from what was evaluated in the FEIS and NPDES/SDS permit application, Water Appropriation permit application, and the Permit to Mine application.

During reclamation and closure (Large Figure 9), mine water would be sent to the WWTS for treatment and treated water would be returned to the Mine Site to flush the East Pit and to accelerate flooding of the West Pit, at the same rate as evaluated for the FEIS. As during operations, the WWTS relocations would result in no change from the prior configuration in the management of water from the FTB seepage capture systems during reclamation and closure, and the quantity, quality, and location of discharge to the environment would be unchanged from what was evaluated in the FEIS and Permit to Mine applications. At the beginning of the reclamation phase three of the four EQ basins and one of the Mine to Plant pipelines would be reclaimed. One EQ basin and two Mine to Plant pipelines would remain in use. The basin and one pipeline would be used to send mine water from the East Pit and the Category 1 Waste Rock Stockpile to the WWTS. The second pipeline would be used to send treated water back to the Mine Site for flushing the East Pit and flooding the West Pit.

During postclosure maintenance (Large Figure 10), while mechanical water treatment continues, mine water would be sent to the WWTS for treatment and returned to the Mine Site for discharge to the environment at the same rates and quantities as evaluated for the FEIS. One EQ basin and two Mine to Plant pipelines would remain in use during this phase. The basin and one pipeline would be used to send mine water from the West Pit and the Category 1 Waste Rock Stockpile to the WWTS. The second pipeline would be used to send treated water back to the Mine Site for discharge. As with previous phases, the WWTS relocations would result in no change in management of water from the FTB seepage capture systems and the quantity, quality, and location of discharge to the environment would be unchanged from what was evaluated in the FEIS and Permit to Mine application.

The WWTS relocations would result in no changes to the planned transition to non-mechanical (passive) treatment, which will need to be demonstrated prior to implementation, as described in the FEIS and Permit to Mine application.

Safety inspections and emergency response procedures for the relocated Equalization Basin Area would be the same as those laid out in the WWTS Design and Operation Report (Section 4.4.1 of Reference (2)). As planned for in the previous location, the equalization basins will have water level control systems to automatically shut off incoming flow before the basins reach full capacity. In addition, a high-water-level alarm will alert the operators so that overfilling does not occur. The control room at the WWTS will have water level monitoring of the equalization basins, and the Equalization Basin Area will be visually inspected at least once per shift.

2.4 Operating Efficiencies

The WWTS relocations would result in the following operating efficiencies:

- Waste water treatment plant concentrate would not need to be shipped via trains between the two treatment buildings, reducing the total railcar usage and associated emissions and safety concerns for the Project, and eliminating the need for a rail spur at the Mine Site.
- Chemicals used in the precipitation process would not need to be trucked or hauled by rail to the Mine Site.
- The hauling distance of solids generated from the chemical precipitation process to the HRF, once operational, would be significantly reduced, because the chemical precipitation process would be located at the Plant Site instead of the Mine Site.
- Heating requirements and associated utility costs and maintenance needs for a single building would be reduced in comparison to two buildings.
- Infrastructure costs and operations and maintenance requirements at the Mine Site would be reduced by eliminating the WWTF building, integrating the Splitter building into the Central Pumping System (CPS) building, and eliminating the CPS Pond from the Project.
- Staffing, potable water and sewage operations, instrumentation, monitoring, and control systems would be streamlined by being in a single location.

As discussed in Section 3, these operational efficiencies would have environmental effects that are either the same as those evaluated in the FEIS or result in some relatively small, but nonetheless important, reductions in environmental effects.

In addition to these immediate operational efficiencies, having all of the water treatment process equipment at a single location provides additional redundancy between process units and allows the potential for greater operating flexibility and improvement through adaptive management during the operations phase of the Project.

3.0 Environmental Outcomes

PolyMet evaluated whether the WWTS relocations would change the environmental effects that were evaluated in the FEIS and permit applications. The water quality and rate of the treated discharge to the environment would be the same as were evaluated for the FEIS. Air quality impacts would be unchanged, or potentially slightly decreased, due to the improved efficiency of the proposed modifications. Wetland impacts would slightly decrease, and no additional cultural resource impacts would be expected. More detailed results are discussed below.

3.1 Surface Water and Groundwater Quality

WWTS discharge quantity, quality, and location of discharge to the environment would be unchanged during operations, reclamation, closure, and postclosure maintenance, as described in Section 2.2. There would be no change in the type, amount, or rate of water supplied to the Mine Site in the pertinent timeframes to accelerate mine pit flooding, so waste rock in the East Pit would be submerged at the same rate evaluated for the FEIS and the West Pit flooding would also be consistent with the FEIS. There would be no change with regard to compliance with applicable effluent limits and new source performance standards in 40 CFR part 440, as described in Section 5 of Volume III of the NPDES/SDS permit application. Therefore, water quality effects in receiving and downstream waters would be the same as were evaluated for the FEIS and in the Project permit applications. Other potential effects on surface and groundwater quality due to the WWTS relocation could include:

- The addition of two new Mine to Plant pipelines (for a total of three) could theoretically increase the potential for leakage or a pipeline rupture. However, the pipelines will be located along travel corridors for ease of inspection and equipped with a leak detection system through the use of flow meters to monitor the flow into and out of the pipelines. Additionally, these pipelines are designed for local climatic conditions by being covered in a minimum of eight feet of material for protection against frost and protection against direct impact to the pipelines.

- Relocation of the equalization basins would slightly shorten the time for any liner leakage to groundwater to reach the property boundary. This would be a minor effect, because minimal leakage is expected from the highly efficient equalization basin composite liner system. Initial breakthrough of groundwater flow from equalization basin leakage to the Partridge River was estimated for the FEIS to be at approximately Mine Year 85 (Table 5.2.2-22 of Reference (1)). The reduction in flow path length by approximately 10% would proportionally shorten the breakthrough time to approximately Mine Year 76. This change will not result in any estimated non-compliance by the Project with applicable water quality standards. The evaluation of compliance with groundwater quality standards will remain unchanged. In particular, there will be no changes relative to the monitoring well design included in the FEIS with respect to locations of: performance monitoring wells immediately downstream of the basins, indicator wells between the basins and the compliance point, and compliance wells at the groundwater compliance point upgradient of the Partridge River excepted as noted in bullet below; therefore this system continues to allow sufficient time to identify a potential change in groundwater quality and initiate contingency mitigation.

- Relocation of the equalization basins would force abandonment of one existing surficial aquifer monitoring well (MW-5) that was proposed for continued monitoring in the NPDES/SDS permit application. The potential need for a replacement surficial aquifer well in this area would be discussed with the MPCA for NPDES/SDS permitting. No other changes to monitoring locations would be needed.

- The impervious surface area at the Mine Site would be decreased by 11.1 acres, which would reduce the stormwater volumes associated with the Project and thus reduce the amount of watershed reduction from the Partridge River. Runoff from the WWTF was planned to be routed to a stormwater basin within the treatment area footprint, then routed south offsite. Large Figure 2 shows the culverts that will route stormwater offsite under both plans. At the Plant Site the amount of impervious area will slightly increase, from 1.4 acres to 1.9 acres.

3.2 Air Quality

The primary air effects from the WWTS relocations have been evaluated. PolyMet expects an overall reduction in actual air emissions because of the WWTS relocations. The following provides an overview of the primary changes associated with the WWTS relocations that relate to air quality effects:

- The WWTF building would be removed from the air dispersion model configuration.
- The WWTS footprint would be larger than the WWTP footprint (relevant for air dispersion modeling).
- The increased heating demand for the larger footprint of the WWTS is accommodated with the current safety factor that was provided for heating calculations of the previous WWTP building, so there would be no change in the potential air emissions at the Plant Site as a result of heating.
- A lime silo and mix tank would be located at the WWTS at the Plant Site with a maximum daily throughput equal to one-half the rate at the previous WWTF. The throughput rate at the WWTF accounted for both the waste water treatment related lime demand and other lime demands at the Mine Site, but in the modified design these two activities would be split between the Plant Site WWTS and the Mine Site. Total potential Project emissions from lime storage and handling will remain unchanged.
- Reduction in actual truck traffic between the Mine Site and Plant Site – resulting in lower air emissions for the Project.
- The emergency power requirements at the WWTS can be met by the WWTP generator in the current emission inventory, as critical power demand is only indirectly related to building size. Emergency power demand is driven by the size of pumps and other energy intensive equipment that must continue to operate during a power failure.

PolyMet proposes to retain the following sources in the air emissions inventory:

- The lime storage and handling equipment at the WWTF (identified as EU 147, SV 50 and EU 148 in the air permit application) was sized to accommodate the WWTF lime demand along with other neutralization needs at the Mine Site. A lime silo and mix tank would remain in the Mine Site emission inventory, with a maximum daily throughput equal to one-half the previous rate, to account for potential future lime demand if powdered lime would be preferred or required for other Mine Site neutralization needs. The lime storage and handling will be included in the initial air permit for the Project. The date of commencement of construction for this equipment will be dependent on the specific demand that indicates the need for powdered lime at the Mine Site and the Project timeline associated with this demand. All applicable provisions of the air permit and state and federal air quality regulations will be followed when the equipment is installed.

- Truck traffic between the Plant and Mine sites previously associated with waste water treatment would remain unchanged in the emissions inventory, which accounts for variation in operation over the mine life.

The lime storage and handling equipment proposed for relocation to the Plant Site has controlled potential $PM_{2.5}$ emissions of about 0.6 tons per year compared to the current controlled potential $PM_{2.5}$ emissions at the Plant Site of 194.3 tons per year. The WWTS is also located away from the "effective fenceline" (i.e., nearest point to the emission sources where ambient air impacts are evaluated) and is unlikely to influence the stacks located in the Crusher/Concentrator and Hydrometallurgical Plant. Therefore, effects on the Plant Site modeling due to the WWTS changes would be minimal.

Truck traffic associated with hauling of WWTF filtered sludge from the WWTF to the Plant Site for disposal (either offsite, in the HRF once constructed, or into the autoclave for processing once constructed) would be eliminated as a result of this modification. Lime might still be needed at the Mine Site. One option for delivering lime to the Mine Site would be hauling slurry by truck from the Plant Site. The current Plant Site and Mine Site emission inventories have 18, 40-ton trucks per day hauling lime and sludge between the Mine Site and the Plant Site. This number of trips would allow sufficient lime movement to accommodate potential lime needs at the Mine Site and would remain in the emission inventory for future design flexibility over the 20-year mine life.

The relocated ponds at the Mine Site would have minimal effect on air permitting because the new location is within the proposed "effective fenceline" outside of which ambient air impacts are to be evaluated, and there would be no emission-generating activity associated with the ponds. Potential PM_{10} monitoring locations as discussed with MPCA as part of a planned revision to the draft Special Purpose Monitoring Plan would need to be reevaluated considering the location of the ponds, but submittal of an updated plan was already intended based on additional modeling to be completed in connection with the Project's air permit application.

The emissions inventory for the air permit application would need to be updated to reflect the relocation of some sources as described above and changes to the building configurations. WWTS chemical usage with the potential to generate emissions (e.g., dust from handling) would be included in the Plant Site emission inventory. Work on a Class II modeling supplement and AERA verification runs is already underway to address a request from MPCA and an error in a portion of the AERMOD air dispersion modeling system issued by USEPA. The emission inventory, updated to accommodate the WWTS modification discussed in this memo, would be used in the additional modeling to be conducted. The proposed changes are minor in the context of the Class I modeling, so updated Class I modeling is not proposed.

3.3 Wetlands

The WWTS relocations would result in no changes to wetland impacts at the Plant Site, as shown on Large Figure 11 or along the Transportation and Utility Corridors.

With the WWTS relocations at the Mine Site, wetland impacts would decrease by 7.9 acres, including 7.8 acres of direct impact and 0.1 acres of indirect impact (fragmentation)[2]. Wetland impacts would be reduced by 0.3 acres in open bog (Wetland 47; direct impact[3]), by 0.4 acres in coniferous swamp (Wetland 48A; direct impact), and by 7.6 acres (7.5 acres of direct impact and 0.1 acre of indirect (fragment impact)) in coniferous bog (Wetlands 80, 86, 88, and 104). Based on the factors for potential indirect wetland impacts, as identified in the Wetland Data Package (Reference (3)), these wetlands would have a Rating of either 1 or 2 (one or two factors potentially indirectly impacting a wetland). The bog wetlands have a rating of 1 and the coniferous swamp has a rating of 2. Based on these ratings, no changes are planned for the Monitoring Plan for Potential Indirect Wetland Impacts (Reference (4)).

Large Figure 12 compares the wetland area impacts for the WWTS relocations to those that were included in the FEIS, Section 404 permit application, Permit to Mine application, and WCA permit application. The NorthMet Project Wetland Replacement Plan and Wetland Permit Application include the mitigation proposed for the 7.9 acres of wetland impact for the FEIS/permit application location. The wetland impacts planned in the FEIS and permit applications would include open bog, coniferous swamp, and coniferous bog. Mitigation requirements were dependent on the acreage of each type of wetland impacted. This reduction in required mitigation would be accounted for as appropriate under the applicable regulatory processes governing federal and state wetland and water permits.

---

[2] Large Table 2 of the Wetland Replacement Plan v1 (Oct 2016) identifies a total of 758.2 acres of direct impact for the Mine Site. The proposed WWTS relocations would decrease the direct wetland impacts by 7.8 acres. The total direct wetland impact for the Mine Site with the proposed WWTS relocations would be 750.4 acres. Large Table 2 of the Wetland Replacement Plan v1 (Oct 2016) identifies a total of 26.4 acres of indirect (fragmented) wetland impact for the Mine Site. The proposed WWTS relocations would decrease the indirect (fragmented) wetland impacts by 0.1 acres. The total direct wetland impact for the Mine Site with the proposed WWTS relocations would be 26.3 acres.

[3] Wetland 47 is classified as an open bog, which means its hydrology is supported by precipitation and not dependent on the size of the watershed. Therefore, the remaining portion of Wetland 47 would not be considered as fragmented. Factors that may cause potential indirect impacts to Wetland 47 include metals (this factor applies to all wetlands in this revised area, see response to Comment 0019) which would result in a Rating of 1 (one factor potentially indirectly impacting the wetland).

The wetlands that are located within the area of the original WWTF location were considered to be either directly impacted or indirectly impacted (identified as impacted by fragmentation) as part of the wetland impacts analysis for the FEIS and permit applications.

Within the proposed Equalization Basin Area, there are no wetlands[4]. This upland area is forested as is the area of the original location of the WWTF. These areas are approximately the same acreage, so there should not be any modification needed to the Biological Opinion, which required the USACE to consult with the U.S. Fish and Wildlife Service under Section 7 of the Endangered Species Act of 1973, as amended, 16 U.S.C. 1531 *et seq*.

3.4 Cultural Resources

Cultural resources surveys have already been conducted within the Equalization Basin Area. The eastern half of the Equalization Basin Area was surveyed in 1990 for the U.S. Forest Service Stubble Creek Timber Sale. The entire Equalization Basin Area was surveyed as part of a 2004 survey conducted by The 106 Group, which resulted in a "no effect" report (Reference (5)). All but the southern edge of the Equalization Basin Area was surveyed in 2006 and 2008 by Soils Consulting (Reference (6); Reference (7)). Therefore, this area has been surveyed for cultural resources by three different cultural resource teams between 1990 and 2008. Additionally, the Project has completed its NHPA Section 106 review process, resulting in a Memorandum of Agreement to resolve adverse effects on eligible historic properties in the Project area. As a result of these studies and coordination, no additional cultural resources work is needed within this area.

4.0 Permitting Effects

It is envisioned that updates to the air permit application, NPDES/SDS permit application, the consolidated Water Appropriation Permits application, and the Permit to Mine application would need to be provided to the MPCA and the DNR to accurately reflect the WWTS relocations. Based on the environmental effects of the WWTS relocations described in Section 3, descriptions of environmental effects would not need updating. Rather, the changes would principally affect application terminology and descriptions, along with associated supporting information, such as figures and permit application support drawings.

4.1 NPDES/SDS Permit Application Updates

The items that would need to be updated in the NPDES/SDS permit application include:

---

[4] There are wetlands to the south of the proposed WWTS pond relocations. These wetlands have already been identified with a factor rated low to high likelihood of hydrologic impacts (which may be due to changes in watershed). Large Figure 23 in the Wetland Data Package v11 (Apr 2015) identifies these wetlands with Ratings ranging from 1 to 4. There are currently multiple wetland hydrology monitoring wells located in these wetlands; therefore, no changes are planned for the Monitoring Plan for Potential Indirect Wetland Impacts v1 (Feb 2016).

- Descriptions and figures of the WWTS, including a review of the constructability of the ponds at the new location
- Proposed Monitoring Plan (due to the closure of a groundwater well)
- Permit Application Support Drawings for the WWTS (replacing the drawing sets for the WWTF and WWTP)
- Permit application forms (e.g., Municipal and Industrial Pond Attachments)
- Waste water treatment chemical additives information, to reflect that most usage would be at the Plant Site.

4.2 Permit to Mine Application Updates

The portions of the Permit to Mine application that would need to be updated include:

- Description of the WWTS system layout
- Mine Site engineering drawings for mine water piping to the new location of the Construction Mine Water Basin and equalization basins
- Mine Site, Transportation and Utility Corridors, and Plant Site drawings for the Mine to Plant Pipelines from the equalization basins to the WWTS and the Construction Mine Water Basin to the FTB Pond
- Financial assurance calculations, to reflect the proposed WWTS relocations

4.3 Water Appropriation Permits Application Updates

The portions of the consolidated Water Appropriation Permit application that would need to be updated include:

- Dewatering appropriation quantities associated with construction of the WWTS equalization basins and the Construction Mine Water Basin
- Description of the WWTS system layout
- Permit Application Support Drawings for the WWTS (replacing the drawing sets for the WWTF and WWTP)

4.4 Air Quality Permit Application Updates

In addition to the changes described in Section 3.2 to the emission inventory and model inputs, the proposed changes to the WWTS would require updates to the facility description portion of the air permit application, including equipment lists, process flow diagrams, and site layout figures. The PolyMet air permitting team would work with MPCA staff to determine the most efficient way to accomplish the changes. For example, relocated emission units could either be renamed or assigned new ID numbers, whichever was more efficient for data entry into the MPCA's TEMPO system.

4.5 Wetland Permit Updates

The Section 401 water quality certification, the Section 404 permit application, and the Wetland Conservation Act approval would be affected by this Project change. PolyMet will work with these permitting teams to address any needed changes associated with each process.

5.0 References

1. **Minnesota Department of Natural Resources, U.S. Army Corps of Engineers and U.S. Forest Service.** Final Environmental Impact Statement: NorthMet Mining Project and Land Exchange. November 2015.

2. **Barr Engineering Co.** Waste Water Treatment Systems: Design and Operation Report - NorthMet Project v1. July 2016.

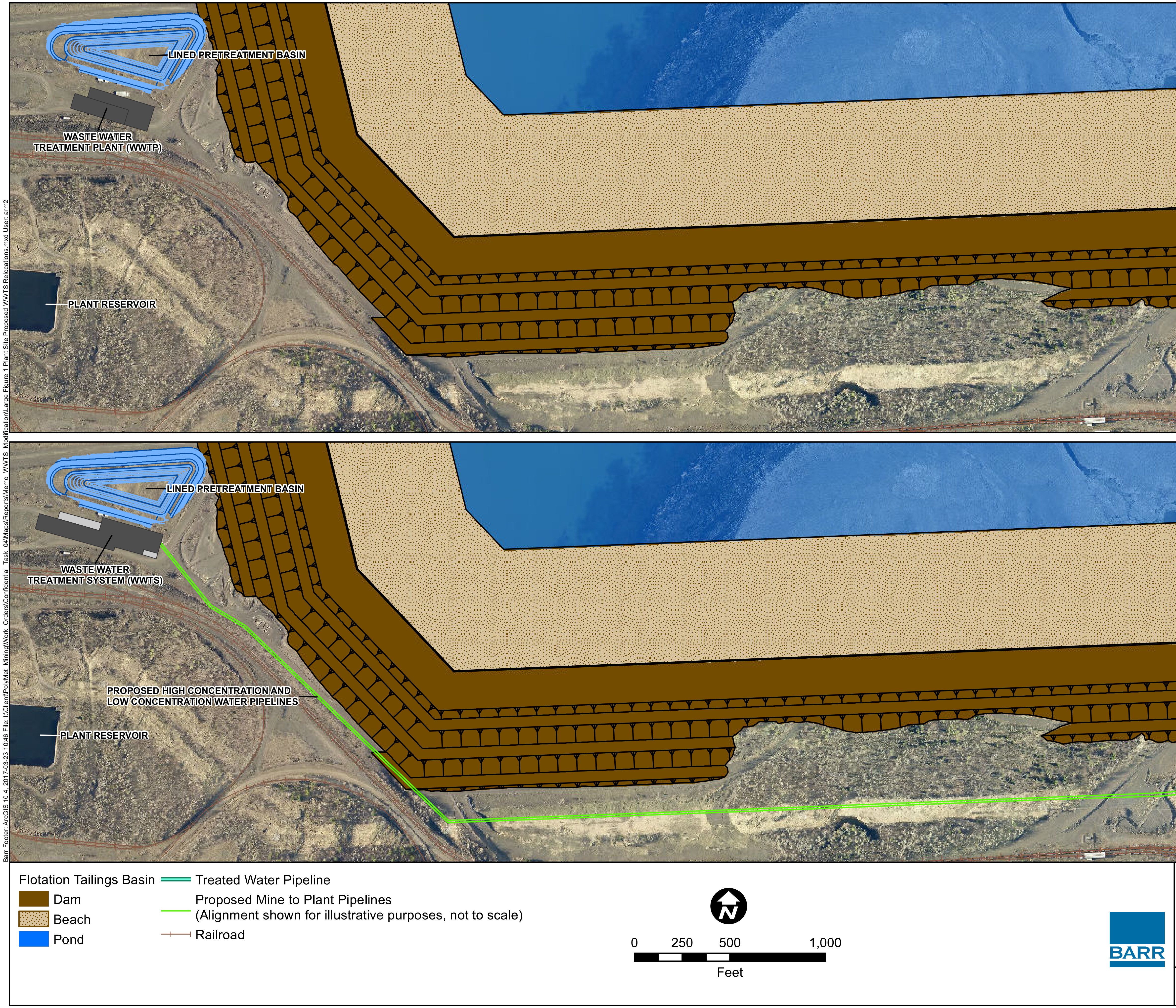
3. **Poly Met Mining Inc.** NorthMet Project Wetland Data Package (v11). April 2015.

4. —. Monitoring Plan for Potential Indirect Wetland Impacts (v1). February 2016.

5. **The 106 Group.** Cultural Resources Assessment for the Environmental Impact Statement Scopiong Document, PolyMet Mining Corporation NorthMet Project, Hoyt Lakes, St. Louis County, Minnesota. Report prepared for Barr Engineering Company. 2004.

6. **Soils Consulting.** Phase I Archaeological Survey, NorthMet Mine Impact Area. 2006.

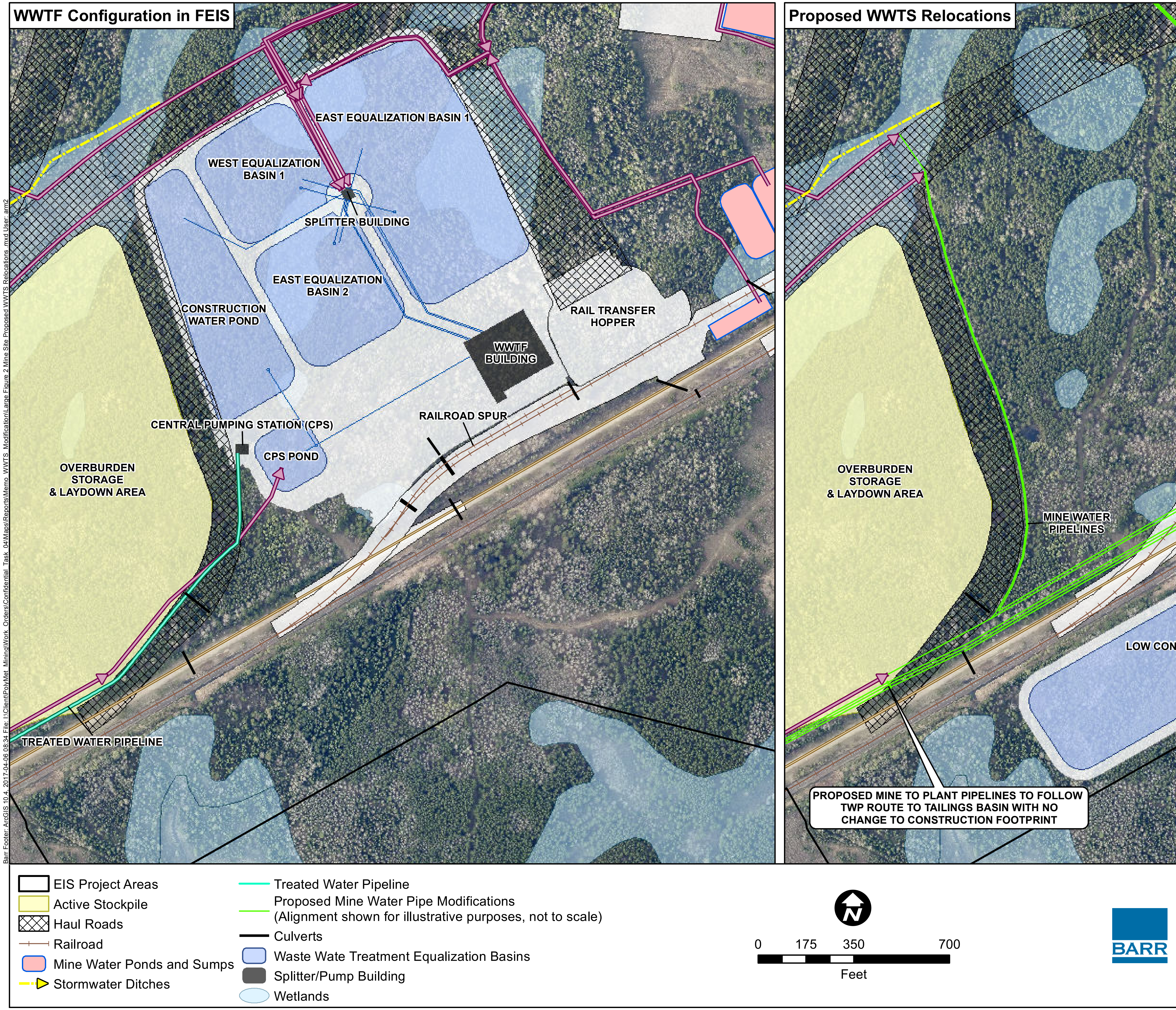
7. —. Phase I Archaeological Survey of Dunka Road Expansion and Substation – and – Phase II Archaeological Evaluation of NorthMet Archaeological Site. 2008.



BARR

PLANT SITE: PROPOSED WWTS RELOCATIONS
NorthMet Project
Poly Met Mining Inc.

Large Figure 1
Proposed Waste Water Treatment System (WWTS) Relocations



BARR

MINE SITE: PROPOSED WWTS RELOCATIONS
NorthMet Project
Poly Met Mining Inc.

Large Figure 2
Proposed Waste Water Treatment System (WWTS) Relocations

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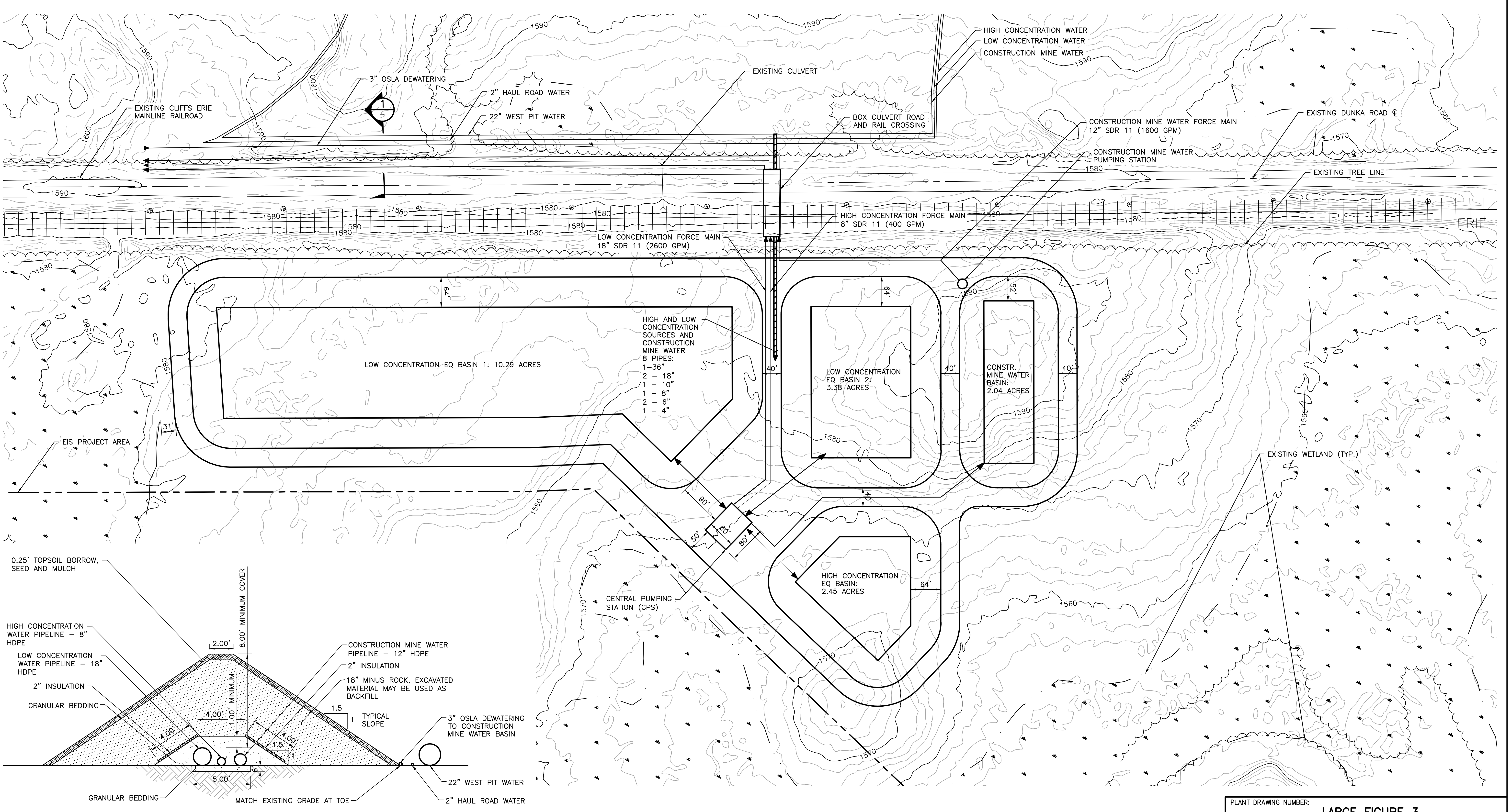

1 – SECTION: TYPICAL PIPELINE CONSTRUCTION

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1 – PLAN: PROPOSED CONDITIONS

N 0 100 200 SCALE IN FEET

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			FOR PERMITTING		
			FOR CONSTRUCTION		

I HEREBY CERTIFY THAT THIS PLAN, SPECIFICATION, OR REPORT WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY LICENSED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

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DATE ____ LICENSE# ____

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BARR PROJECT NO.: 23/69-862.04
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LARGE FIGURE 3

MINE SITE
EQ BASIN/MINE WATER PIPING PLAN

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR

BARR ENGINEERING COMPANY
4300 MARKETPOINTE DRIVE
MINNEAPOLIS, MN.
Ph: 1-800-632-2277

DWG. NO. WWTS-01

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NOTES:

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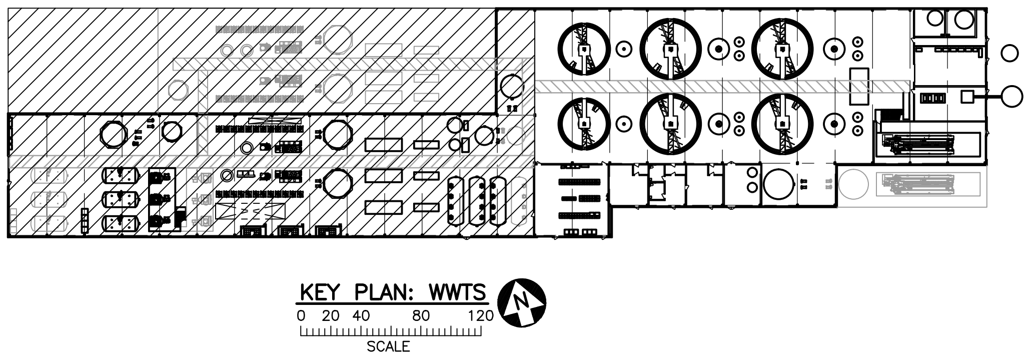
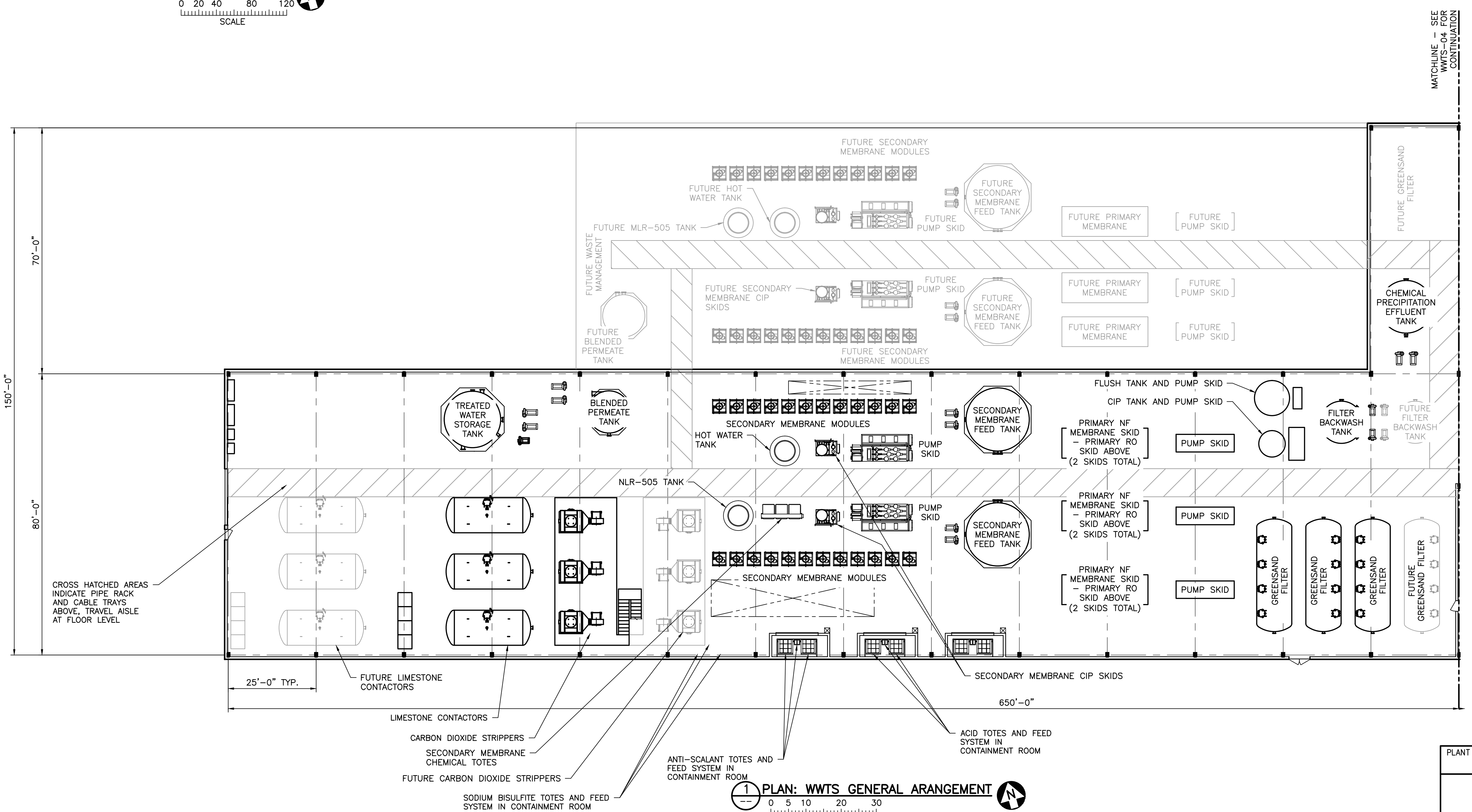


KEY PLAN: WWTS



① PLAN: WWTS GENERAL ARRANGEMENT
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ISSUE STATUS			
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FOR PERMITTING			
FOR CONSTRUCTION			
NOT APPROVED FOR CONSTRUCTION			

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BARR PROJECT NO.: 23/69-0862.04
SCALE: AS SHOWN

PLANT DRAWING NUMBER:

COMBINED WWTS
OVERALL GENERAL ARRANGEMENT
Large Figure 4

POLYMET MINING
POLY MET MINING, INC.
NORTHMET PROJECT
HOYT LAKES, MINNESOTA

BARR
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DWG. NO. WWTS-03
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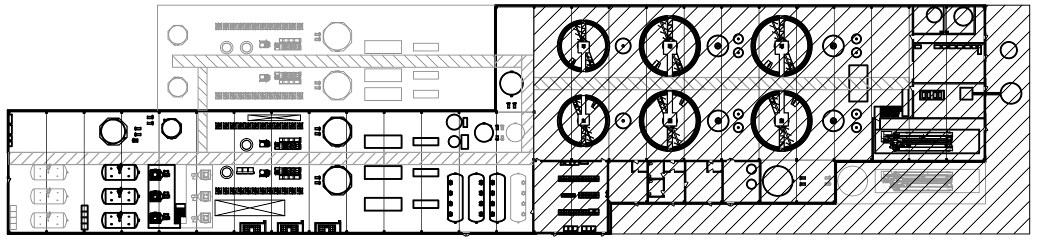
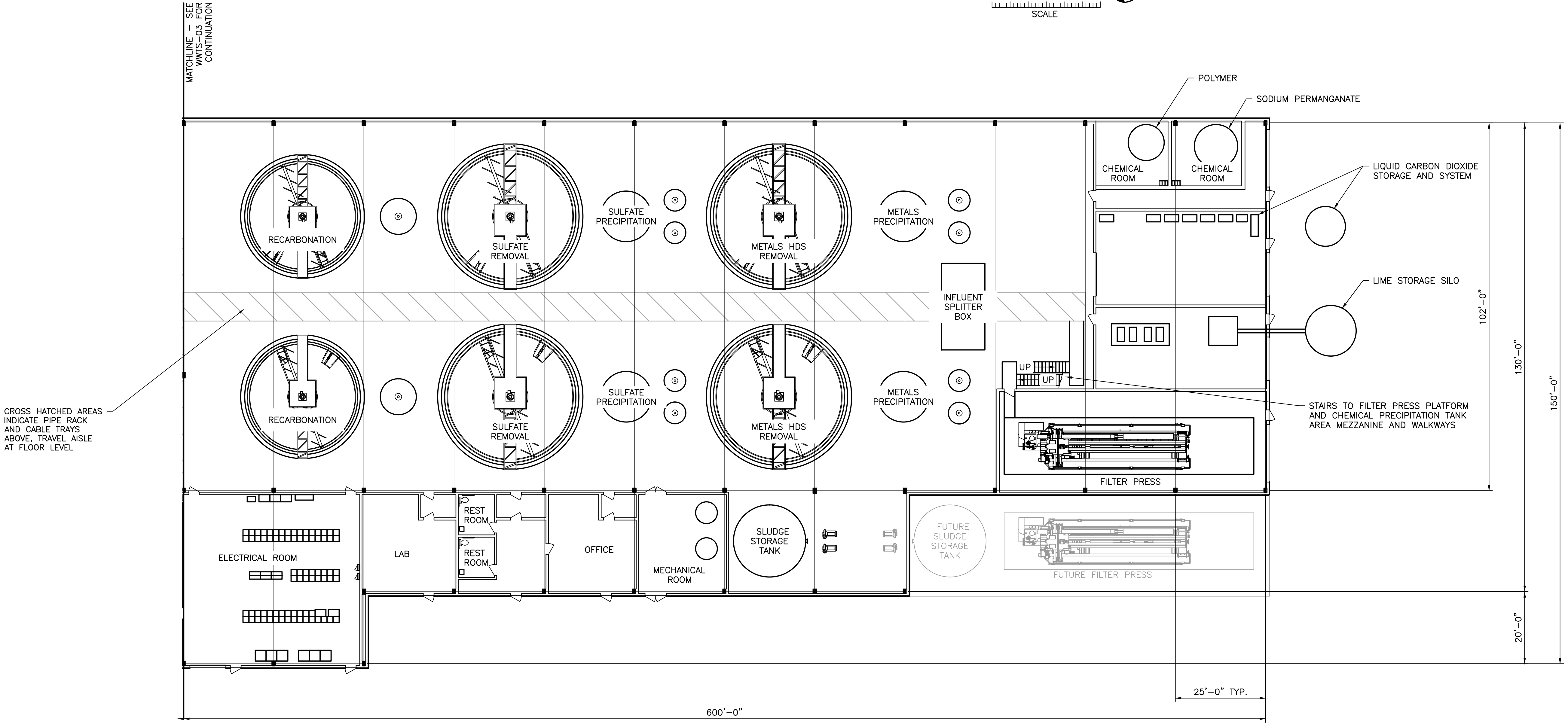


KEY PLAN: WWTS



1 PLAN: WWTS GENERAL ARANGEMENT

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FOR CONSTRUCTION		
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BARR PROJECT NO.: 23/69–0862.04

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PLANT DRAWING NUMBER:

COMBINED WWTS
OVERALL GENERAL ARRANGEMENT
Large Figure 5

POLYMET MINING

POLY MET MINING, INC.
NORTHMET PROJECT
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DWG. NO. WWTS–04

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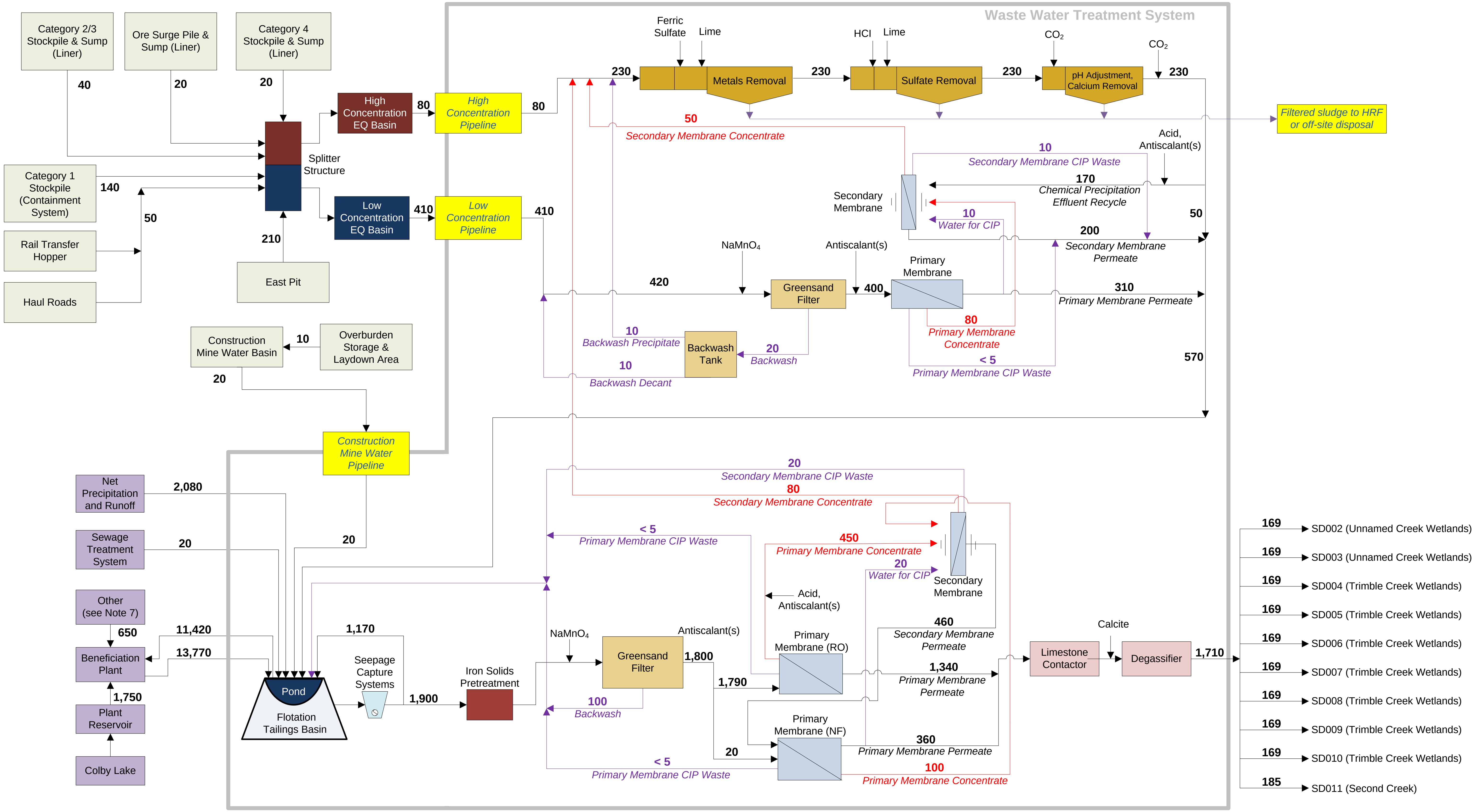


Legend

XX →	P50 Annual average flow (rounded to 10 gpm)
XX →	P50 Annual average membrane concentrate flow (rounded to 10 gpm)
XX →	Intermittent flows for filter cleaning (rounded to 10 gpm)

Notes:

(1) This figure shows the Waste Water Treatment System flow configuration at the beginning of operations. Mine Year 1 is expected to be the year of minimal discharge and minimal loading from the WWTS.

(2) This figure shows average flows from sources of intake water, operations contributing wastewater to the effluent, and treatment units within the WWTS. It does not include flows that do not contribute to the effluent, such as water entrained within tailings and water in sludge from chemical precipitation units. Total flows may not equal the sum of their contributing parts because flows that do not contribute to the effluent are not shown and flows are rounded to the nearest 10 gpm.

(3) Flows are based on the GoldSim water model (Water Modeling Data Package – Mine Site v14 and Water Modeling Data Package – Plant Site v11).

(4) Consistent with the FEIS, average flows outside the WWTS are the annual average of the monthly mean flow rates.

(5) WWTS internal flows were estimated using the FEIS GoldPhreeqc model (Waste Water Treatment System Design and Operation Report v1). For this diagram, the GoldPhreeqc model influent values to the WWTS were the annual average of the monthly median values from the GoldSim model Mine Site and Plant Site flows.

(6) To be consistent with the values reported in the NPDES/SDS permit application on EPA Form 2D, flow rates to the surface water discharge outfalls were not rounded to 10 gpm.

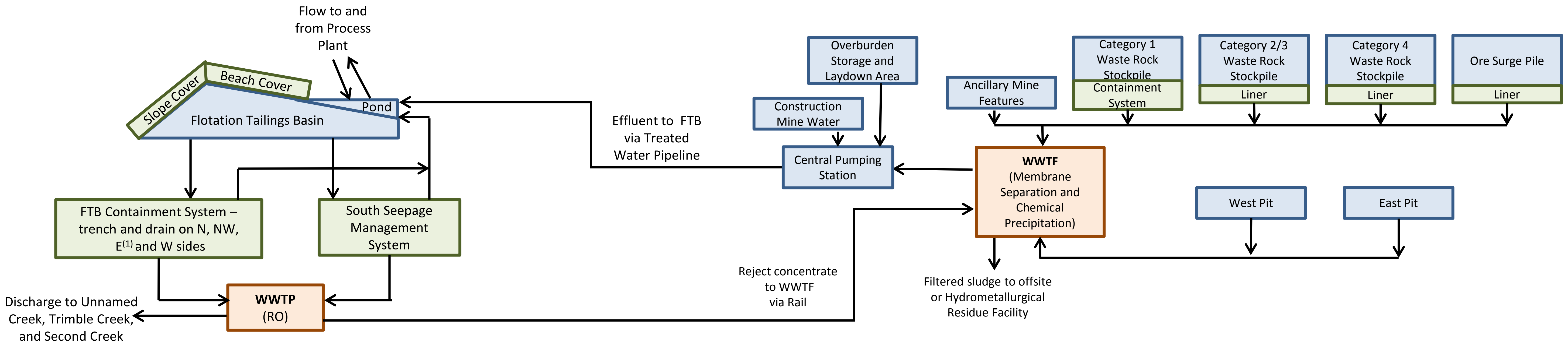
(7) Other inflows to the Beneficiation Plant include water in the raw ore, reagents, and gland seals of slurry pumps.

WATER TREATMENT AVERAGE FLOWS
OVERALL FLOW SHEET – MINE YEAR 1
NorthMet Project
Poly Met Mining Inc.

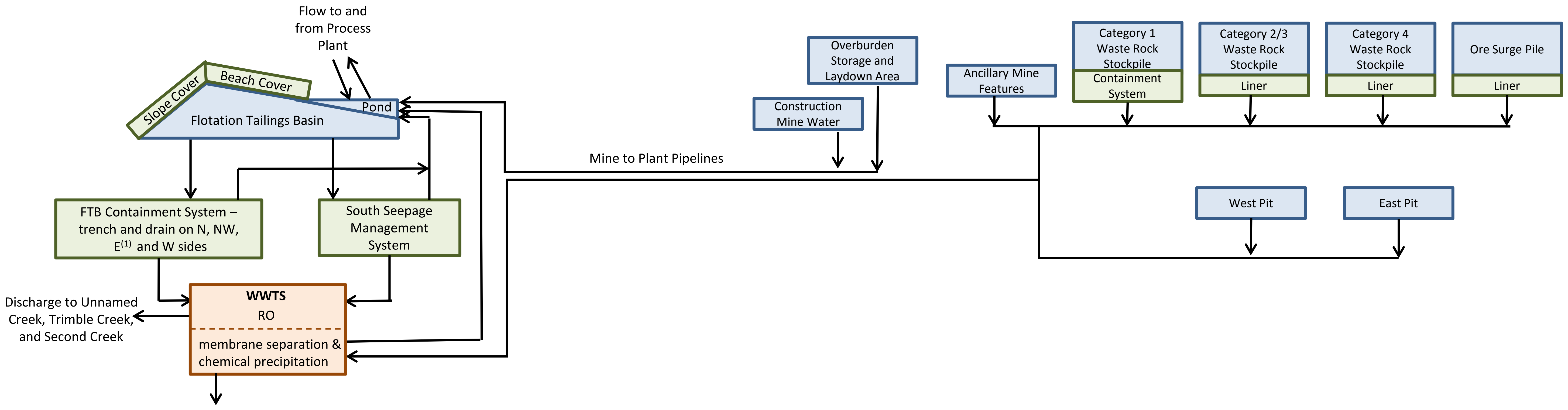
Large FIgure 6
Proposed Waste Water Treatment System
(WWTS) Relocations

Operations: Mine Years 1 to 11

Configuration with WWTP and WWTF Evaluated for FEIS



Proposed WWTS Relocations



Filtered sludge to offsite or Hydrometallurgical Residue Facility

Notes:

(1) Seepage collected by the east segment of the FTB Seepage Containment System will be returned to the FTB Pond

🟦 Project Feature

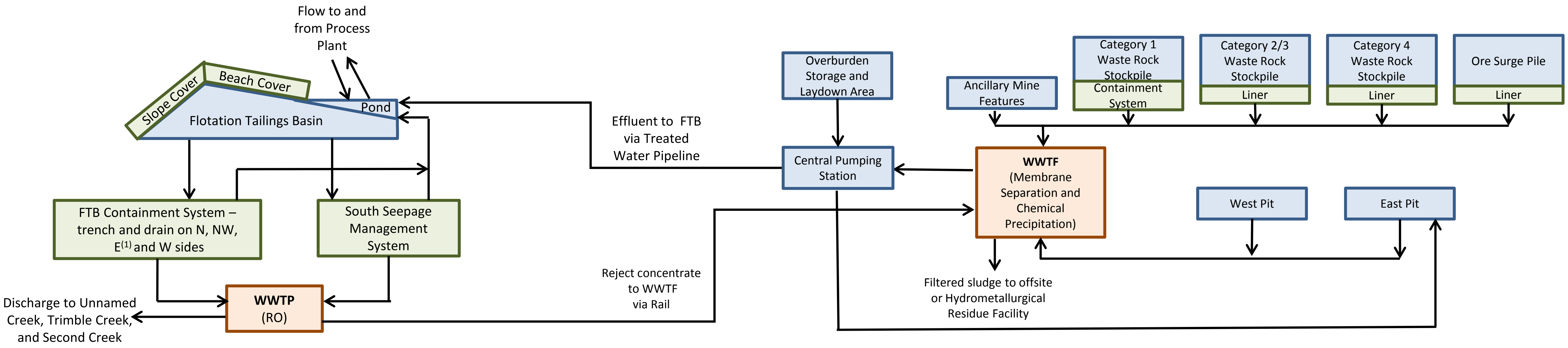
🟩 Fixed Engineering Control

🟧 Adaptive Engineering Control

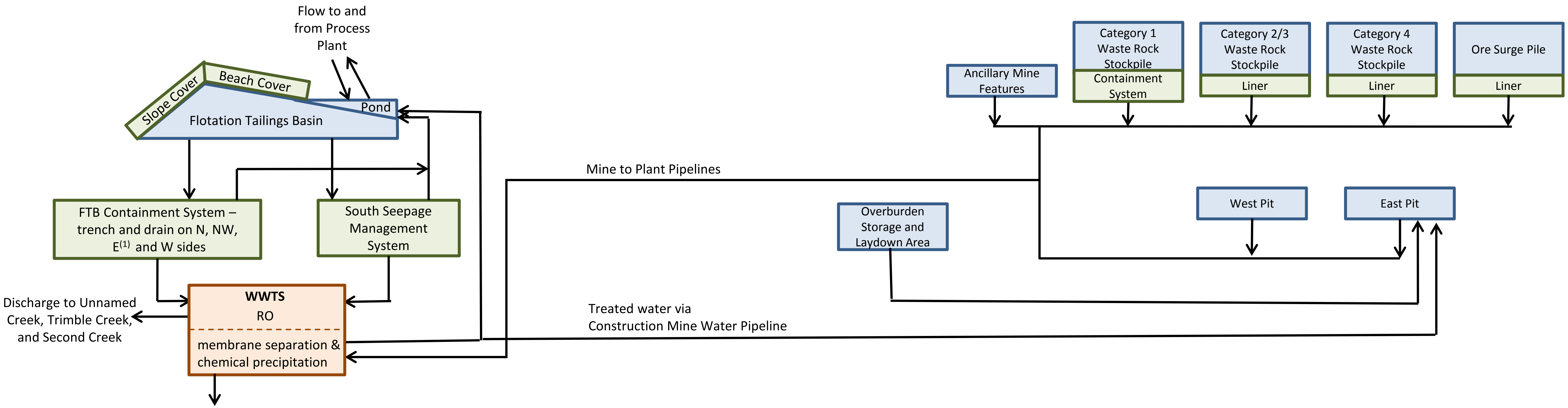
Large Figure 7
Operations Mine Years 1 to 11: Comparison of FEIS Flows and Proposed Flows with WWTS Relocations

Operations: Mine Years 12 to 20 (East Pit Backfilling)

Configuration with WWTP and WWTF Evaluated for FEIS



Proposed WWTS Relocations



Filtered sludge to offsite
or Hydrometallurgical
Residue Facility

Notes:
(1) Seepage collected by the east segment of the FTB Seepage Containment System will be returned to the FTB Pond

🟦 Project Feature

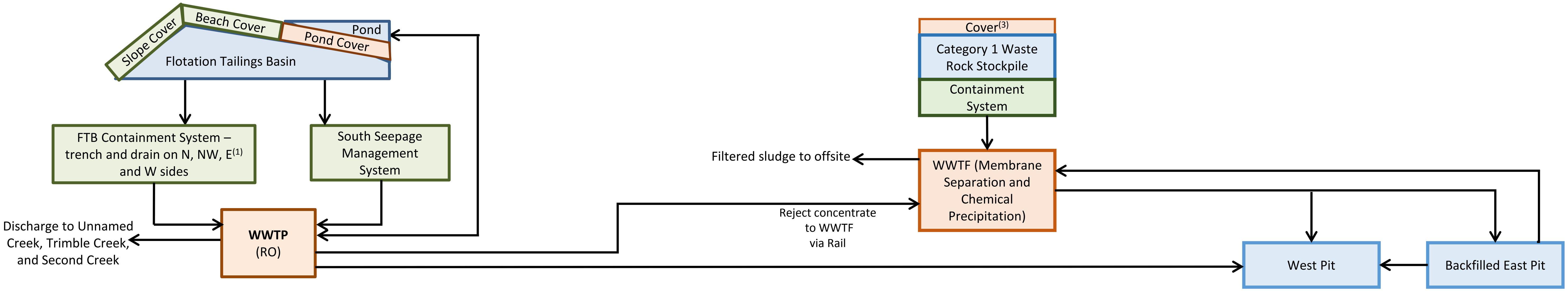
🟩 Fixed Engineering Control

🟧 Adaptive Engineering Control

Large Figure 8
Operations Mine Years 12 to 20: Comparison of FEIS Flows and Proposed Flows with WWTS Relocations

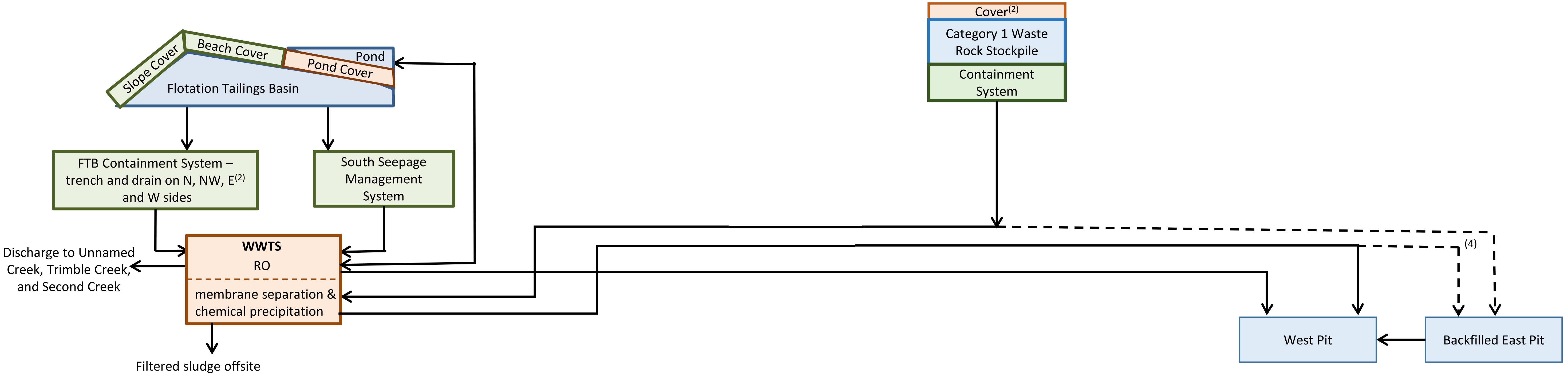
Reclamation(1)

Configuration with WWTP and WWTF Evaluated for FEIS



Reclamation and Closure(1)

Proposed WWTS Relocations

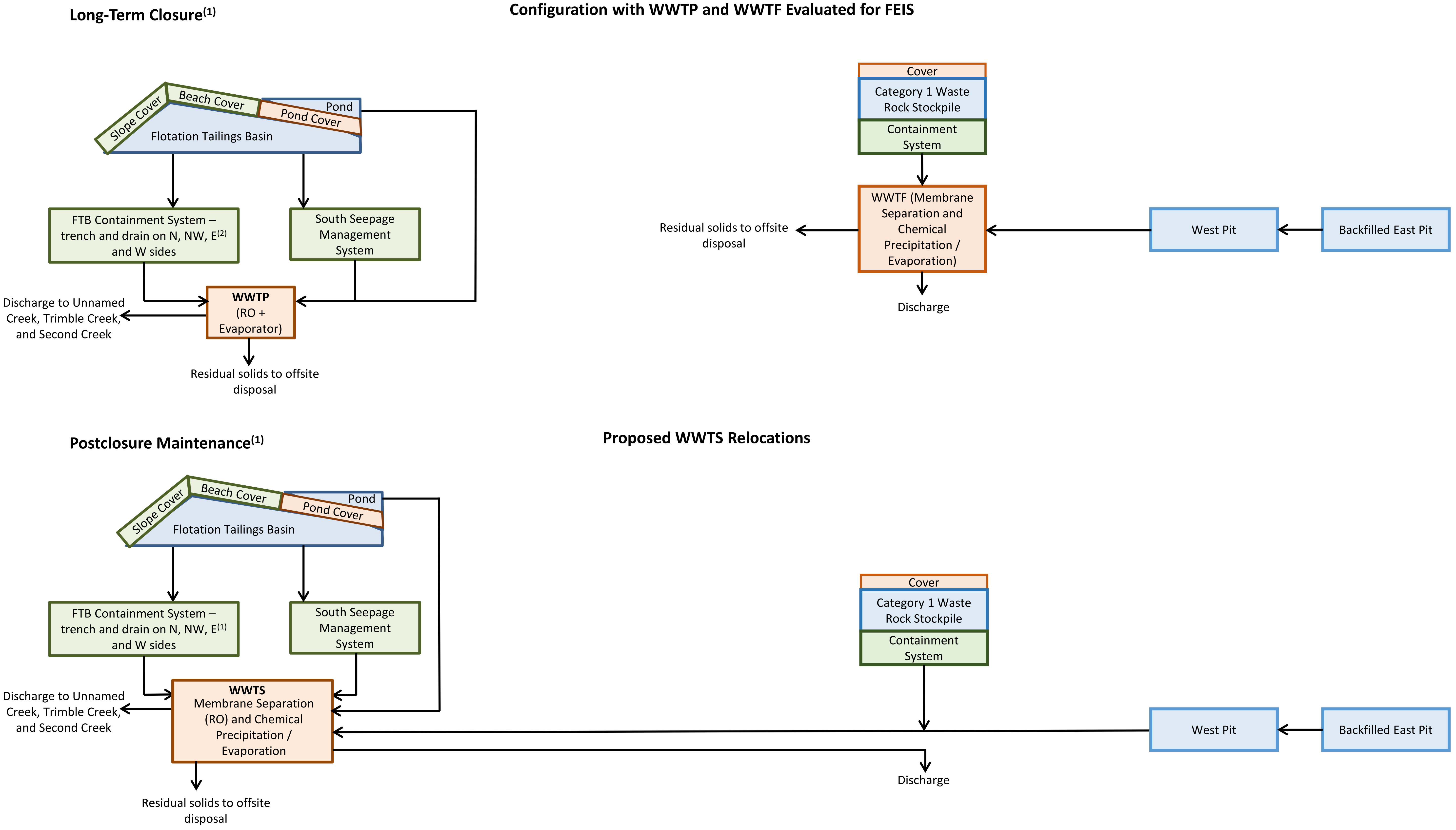


Notes:

(1) The Project phase referred to as “reclamation” in the FEIS encompasses the phases referred to as “reclamation” and “closure” in the Permit to Mine
(2) Seepage collected by the east segment of the FTB Seepage Containment System will be returned to the FTB Pond
(3) Category 1 Waste Rock Stockpile begins in Year 14 and is completed by Year 21
(4) After East Pit flushing is completed (at the end of reclamation) these flows will be discontinued

🟦 Project Feature
🟩 Fixed Engineering Control
🟧 Adaptive Engineering Control

Large Figure 9
Reclamation and Closure: Comparison of FEIS Flows and Proposed Flows with WWTS Relocations



Notes:

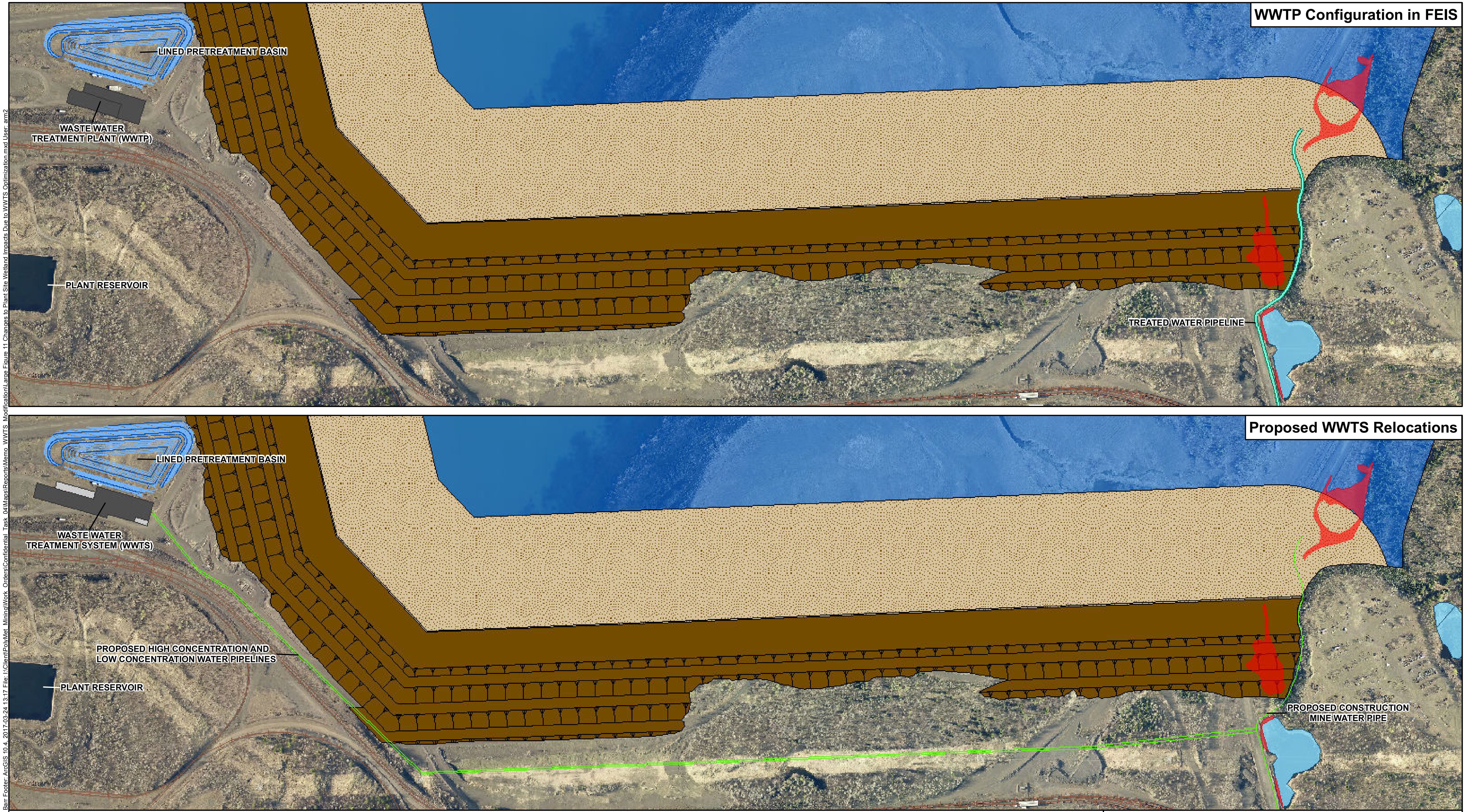
(1) The Project phase referred to as "long-term closure" in the FEIS is referred to as "postclosure maintenance" in the Permit to Mine

(2) Seepage collected by the east segment of the FTB Seepage Containment System will be returned to the FTB Pond

🟦	Project Feature
🟩	Fixed Engineering Control
🟧	Adaptive Engineering Control

Large Figure 10

Postclosure Maintenance: Comparison of FEIS Flows and Proposed Flows with WWTS Relocations



Flotation Tailings Basin

- Dam
- Beach
- Pond

Treated Water Pipeline

Proposed Mine to Plant Pipelines
(Alignment shown for illustrative purposes, not to scale)

Railroad

Potential Direct Wetland Impacts

- Direct Wetland Impacts
- No Direct Impact

N

0 250 500 1,000
Feet

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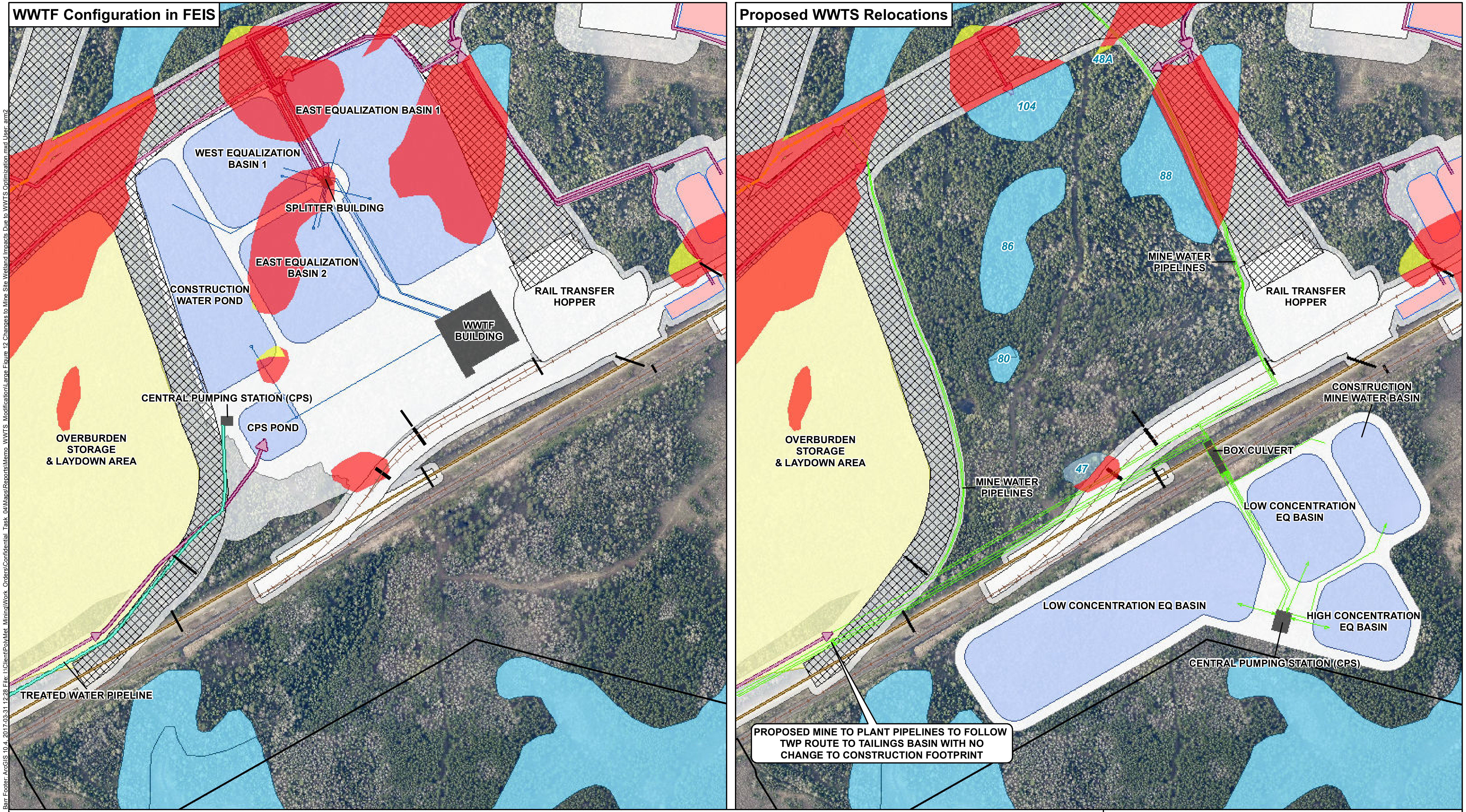
CHANGES TO PLANT SITE WETLAND IMPACTS
DUE TO WWTS RELOCATIONS
NorthMet Project
Poly Met Mining Inc.

Large Figure 11
Proposed Waste Water Treatment System (WWTS) Relocations



- ☐ EIS Project Areas
- ☐ Areas Disturbed by Proposed Project Features
- ▨ Mine Pit
- 🟨 Active Stockpile
- ▨ Haul Roads
- ┼ Railroad
- → Mine Water Pipe
- 🟥 Mine Water Ponds and Sumps
- → Stormwater Ditches
- — Treated Water Pipeline
- — Proposed Mine Water Pipe Modifications (Alignment shown for illustrative purposes, not to scale)
- — Culverts

Potential Direct Wetland Impacts

- 🟥 Direct Impact
- 🟨 Fragmented Wetland
- 🟦 No Direct Impact

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CHANGES TO MINE SITE WETLAND IMPACTS DUE TO WWTS RELOCATIONS

NorthMet Project
Poly Met Mining Inc.

Large Figure 12
Proposed Waste Water Treatment System (WWTS) Relocations

Barr Footer: ArcGIS 10.4, 2017-03-31 12:28 File: I:\Client\PolyMet_Mining\Work_Orders\Confidential_Task_04\Maps\Reports\Memo_WWTS_Modification\Large Figure 12 Changes to Mine Site Wetland Impacts Due to WWTS Optimization.mxd User: arm2