Technical Memorandum

To: Steve Albrecht, City of Burnsville
From: Barr Engineering
Subject: Simulations of Future Kraemer Quarry Pit-Lake Stage and Rise of the Water Table at the Freeway Landfill
Date: April 13, 2015
Project: Freeway Landfill Assistance
c: Freeway Landfill Technical Advisory Committee

Groundwater model simulations were conducted by Barr Engineering to estimate future water table conditions near Freeway Landfill after dewatering ceases at the Kraemer Quarry located directly south of the landfill. The anticipated rise in the water table is compared against the bottom of the waste that was identified in previous MPCA investigations to assess the potential for the waste in the landfill to come into contact with the predicted higher water table. This memorandum is a brief summary of the results. Further documentation and reporting are currently in process.

A refined, local scale, version of the Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3.0 (Metropolitan Council, 2014) was used for the analysis and simulation of future conditions. A telescopic mesh refinement of the regional model was created. Five additional layers were added to better simulate flow conditions within the Prairie du Chien Group, the upper most bedrock at the landfill and the unit currently being quarried. Additional calibration of the model was conducted using data collected in January, 2015 at and near the Freeway Landfill.

After calibration, the model was used to simulate potential future conditions with varying pit-lake stages to estimate the water table elevation within the footprint of the waste at the Freeway Landfill. To address uncertainties in the model simulations, Latin hypercube sampling (Swiler and Wyss, 2004; Watermark Numerical Computing, 2012) was used to generate 1000 unique parameter sets, allowing parameters to vary over expected ranges. Model simulations were then conducted using these parameter sets and the results were compared to the calibration dataset. Parameter combinations that resulted in no more than a 5% increase in the calibration objective function (error of best-fit model to measured data) were deemed acceptable and carried forward for use in simulating potential future conditions. Parameter sets that resulted in more than a 5% increase in the calibration objective function were deemed unacceptable (i.e., poor model fit) and excluded from further analysis. A total of 298 unique parameter combinations, out of 1000 possible, were ultimately used for uncertainty analysis.

For each unique parameter set a series of steady-state simulations were conducted. First, pumping from Kraemer Quarry was reduced to include only pumping for the City of Burnsville supply. The average reported pumping from the quarry for Burnsville from 2010 to 2013 of 3.4 million gallons per day was used; no pumping was included for quarry dewatering operations (8.4 MGD average for 2010-2013) since this scenario was intended to simulate conditions after the Quarry ceases operations. Second, a series of simulations were conducted where pumping rates from the Quarry were adjusted to achieve pit-lake stages between 205 meters and 213 meters (672.6 feet to 698.8 feet) in one meter increments. For each simulation, the simulated water table elevation was compared to the bottom of waste at the Freeway Landfill as measured by Gorman Surveying (2005). The results of these simulations are summarized on Figures 1 to 11 and in Tables 1 and 2. The range of results (minimum, average, and maximum) using all 298 unique parameter sets as defined above are shown. The waste saturation for the various scenarios is estimated as a percentage of the landfill footprint coming into contact with the groundwater (i.e., percentage of area, not percentage of volume).

Table 1. Results of simulations with pumping from Kraemer Quarry for Burnsville supply only, no dewatering for quarry operations.

Pumping for Burnsville Supply (MGD)	Pit-Lake Stage						Percent Waste Saturated by Area		
	Min.		Avg.		Max.				
	m	ft	m	ft	m	ft	Min.	Avg.	Max.
3.4	215.3	706.3	215.8	707.9	216.6	710.5	89	96	98

Table 2. Results of simulations maintaining pit-lake at specified stage.

Pit-Lake Stage		Simulated Pumping Rate to Maintain Stage (MGD)			Percent Waste Saturated by Area		
meters	feet	Min.	Avg.	Max.	Min.	Avg.	Max.
205	672.6	8.1	9.1	10.2	9	11	12
206	675.9	7.7	8.6	9.7	11	13	15
207	679.1	7.2	8.2	9.2	13	16	19
208	682.4	6.8	7.7	8.6	17	21	24
209	685.7	6.3	7.2	8.1	22	28	33
210	689.0	5.9	6.7	7.5	31	37	42
211	692.3	5.4	6.2	7.0	41	48	54
212	695.5	5	5.7	6.4	54	64	71
213	698.8	4.5	5.1	5.8	75	81	85

References

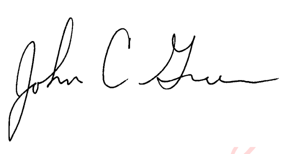
Gorman Surveying, Inc. 2005. Freeway Landfill subsurface exploration results, Job Number 05-032, Sheet 2 of 2.

Metropolitan Council. 2014. Twin Cities Metropolitan Area Regional Groundwater Flow Model, Version 3.0. Prepared by Barr Engineering. Metropolitan Council: Saint Paul, MN.

Swiler, L.P. and Wyss, G.D. 2004. A User's Guide to Sandia's Latin Hypercube Sampling Software: LHS UNIX Library/Standalone Version. Sandia National Laboratories, Report SAND2004-2439.

Watermark Numerical Computing. 2012. PEST Utilities to complement Latin Hypercube Sampling Software developed by Sandia National Laboratories.

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

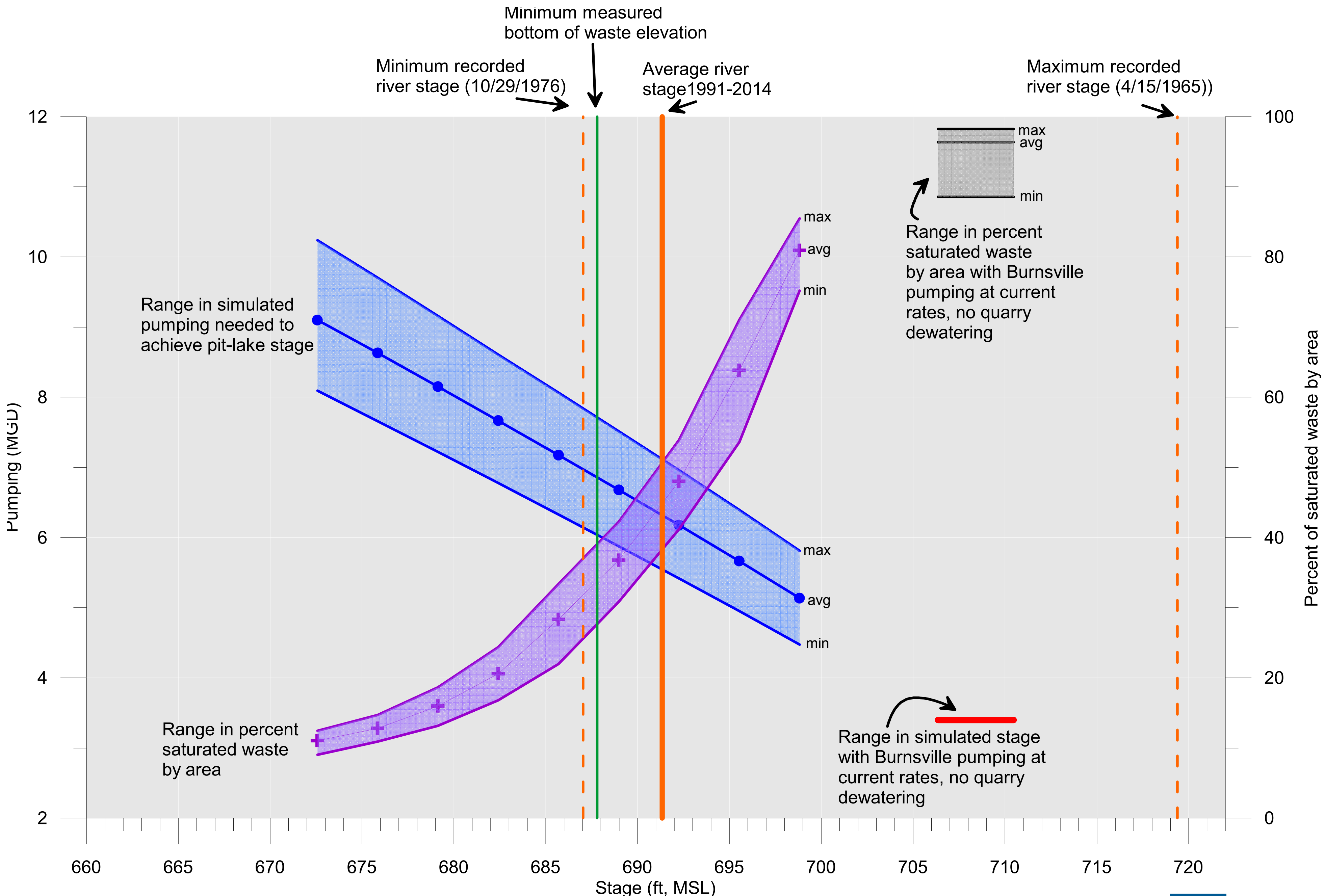


Digitally signed by John C. Greer
DN: cn=John C. Greer, o=Barr Engineering Co., ou, email=jgreer@barr.com, c=US
Date: 2015.04.13 12:28:03 -05'00'

April 13, 2015

John C. Greer
PG #: 30347

Date



Notes:
Blue shaded area indicates the range of simulated pumping rates needed to achieve specified pit-lakes stage
Purple shaded area indicates the range of area of waste where the water table rises above the bottom of waste at specified pit-lake stages
Gray shaded area indicates the range of area of waste where the water table rises above the bottom of waste with pumping only for Burnsville supply
Red horizontal line indicates the range in simulated pit-lake stage with pumping only for Burnsville supply
Vertical orange lines indicate historical minimum, maximum, and average stage for the Minnesota River
Vertical green line indicates the lowest measured elevation for the bottom of waste in the Freeway Landfill

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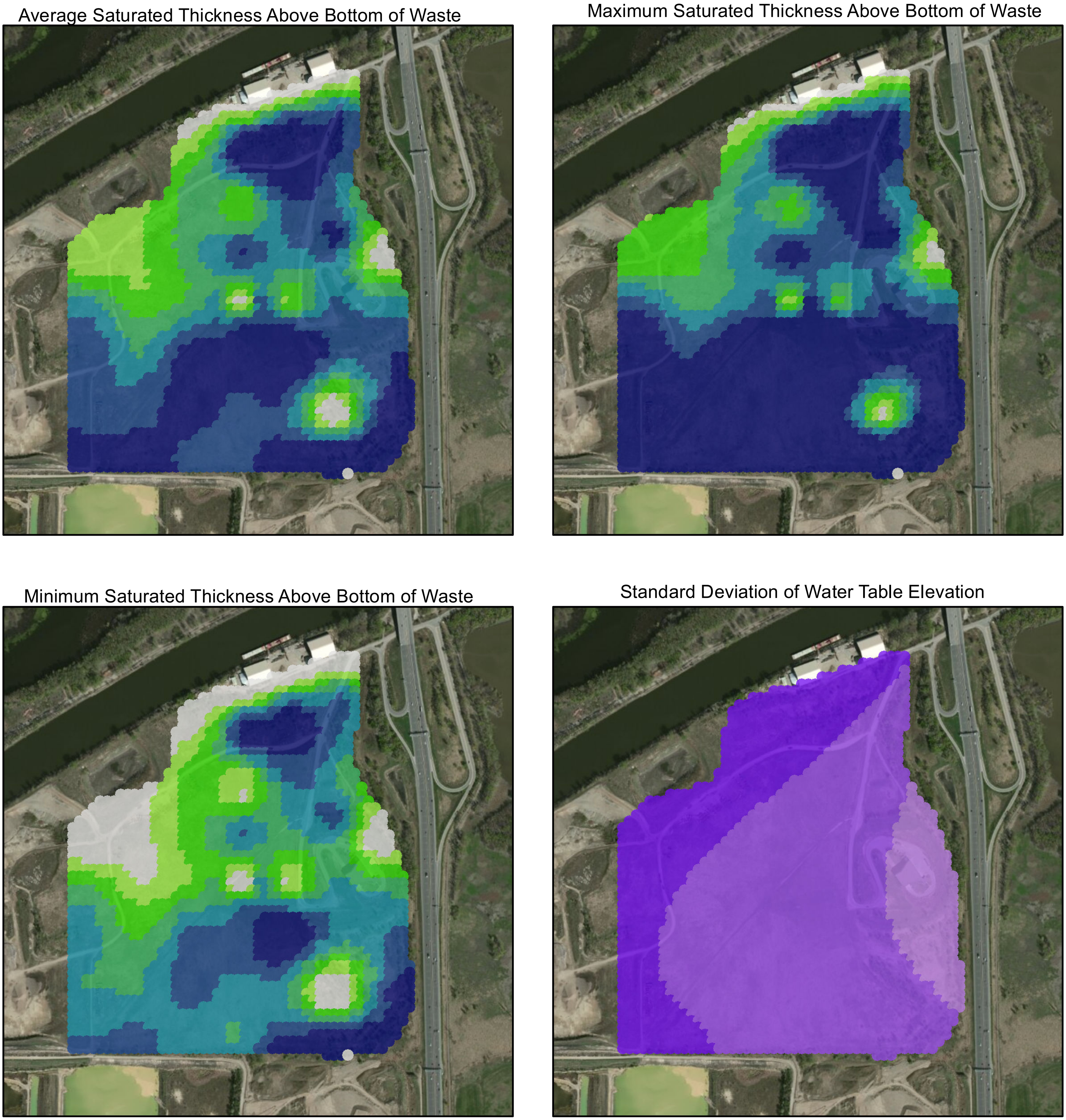
Figure 1

SUMMARY OF SIMULATIONS
OF FUTURE CONDITIONS



Saturated Thickness Above Waste (m)
- Dry
- 0.1 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- > 2.5 m

Standard Deviation of Water Table Elevation (m)
- 0.03 - 0.10
- 0.11 - 0.15
- 0.16 - 0.20
- 0.21 - 0.25

N

Meters
0 200 400

Feet
0 375 750 1,500

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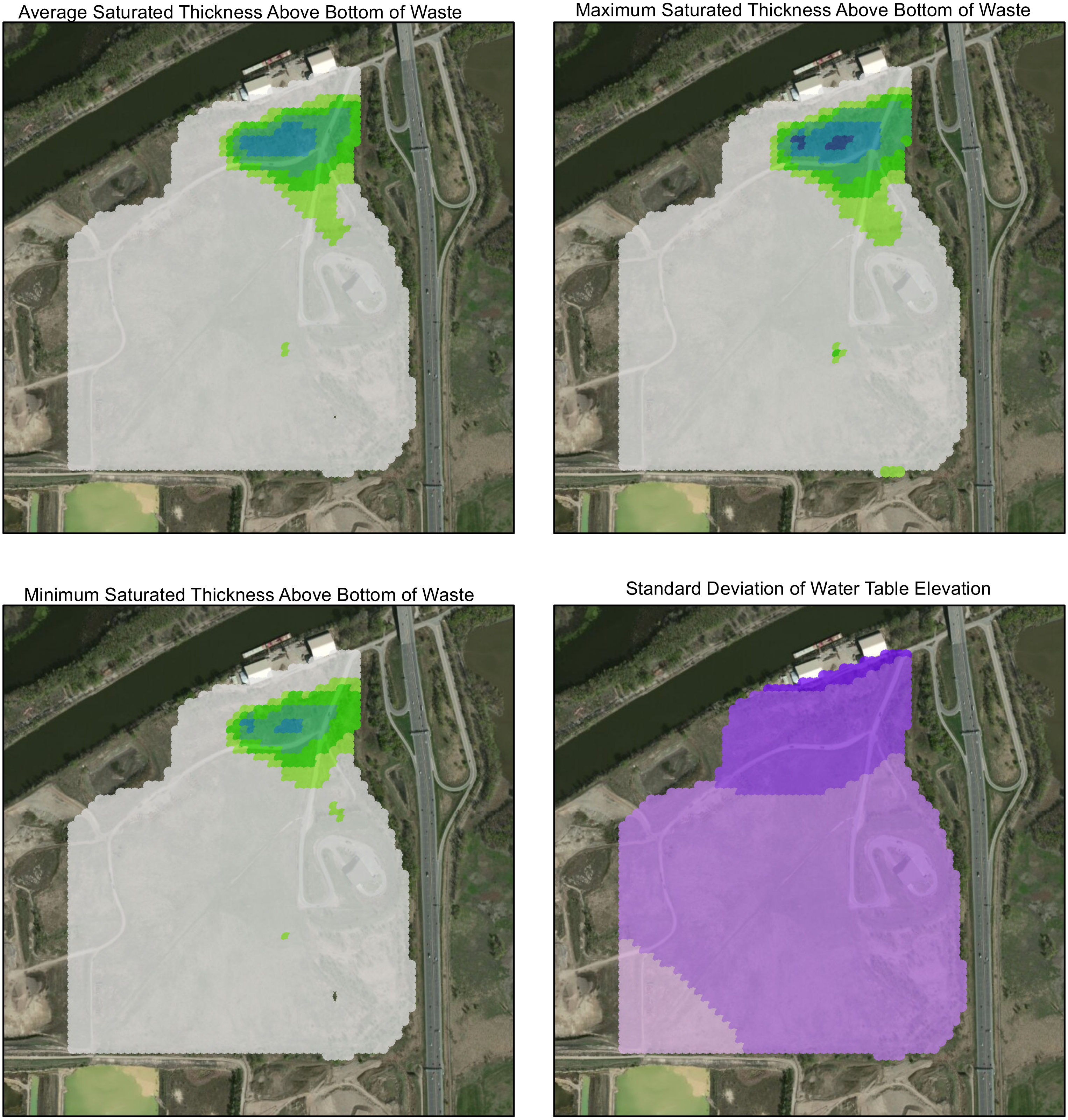
Figure 2

WASTE SATURATION
BURNSVILLE PUMPING ONLY



Saturated Thickness Above Waste (m)

- Dry
- 0.1 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- > 2.5 m

Standard Deviation of Water Table Elevation (m)

- < 0.05
- 0.06 - 0.10
- 0.11 - 0.15
- 0.16 - 0.20

Meters: 0, 200, 400

Feet: 0, 375, 750, 1,500

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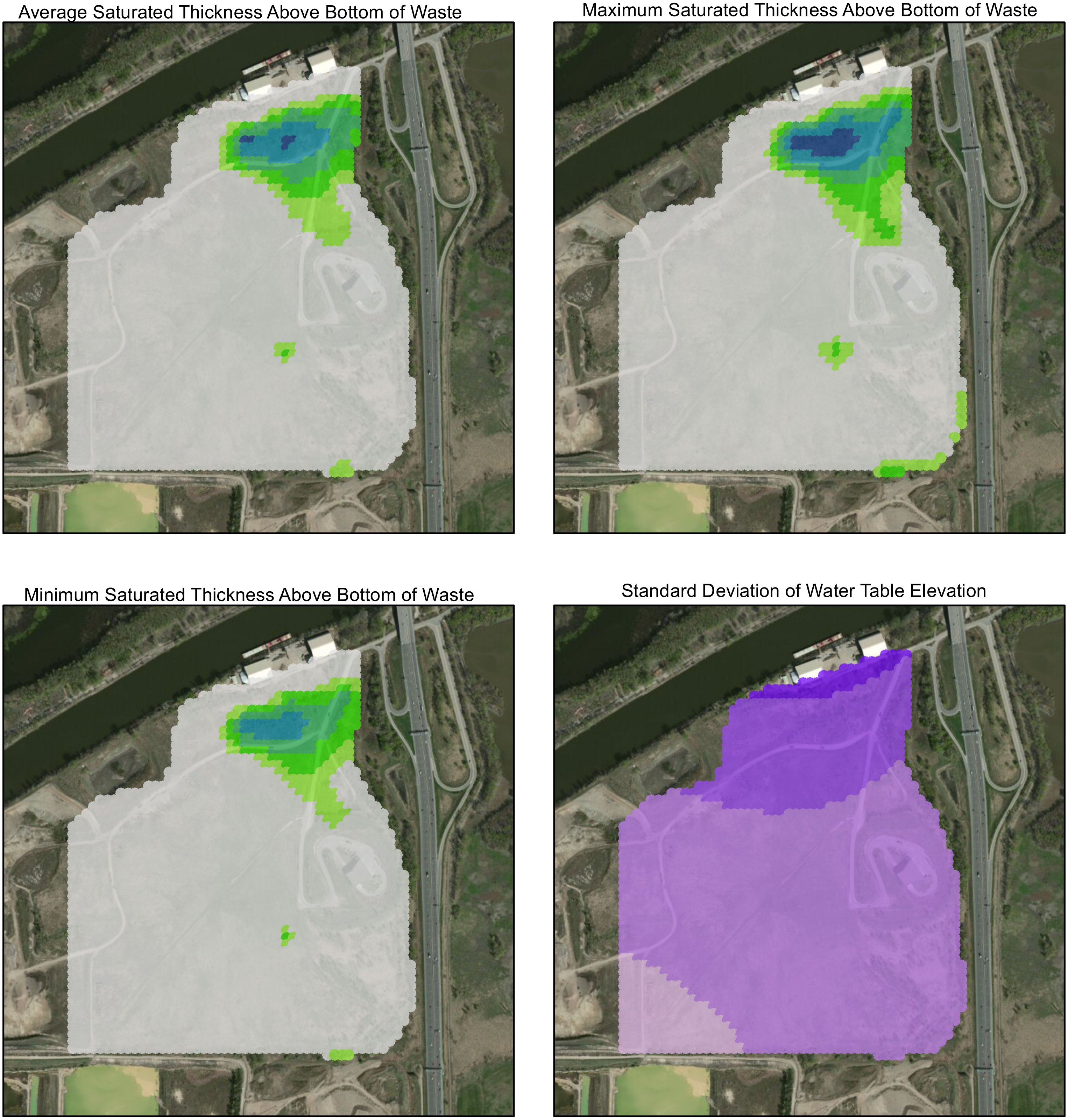
Figure 3

WASTE SATURATION
PIT LAKE AT
205 METERS (672.6 FT)



Saturated Thickness Above Bottom of Waste (m)

- Dry
- 0.1 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- > 2.5 m

Standard Deviation of Water Table Elevation (m)

- < 0.05
- 0.06 - 0.10
- 0.11 - 0.15
- 0.16 - 0.20

N

Meters
0 200 400

Feet
0 375 750 1,500

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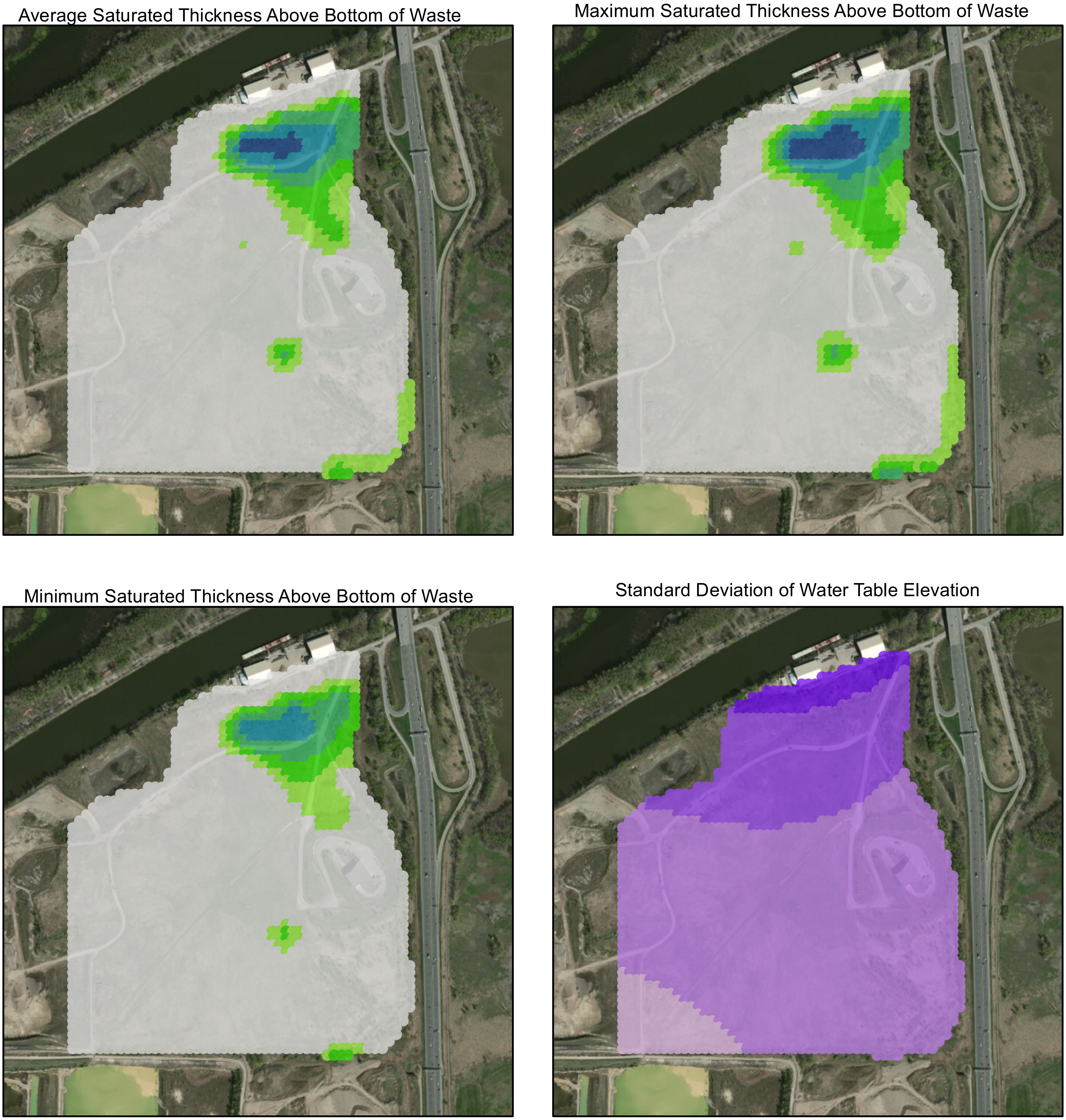
Figure 4

WASTE SATURATION
PIT LAKE AT
206 METERS (675.9 FT)



Saturated Thickness Above Bottom of Waste (m)
- Dry
- 0.1 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- > 2.5 m

Standard Deviation of Water Table Elevation (m)
- < 0.05
- 0.06 - 0.10
- 0.11 - 0.15
- 0.16 - 0.20

N

Meters
0 200 400

Feet
0 375 750 1,500

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Figure 5

WASTE SATURATION
PIT LAKE AT
207 METERS (679.1 FT)

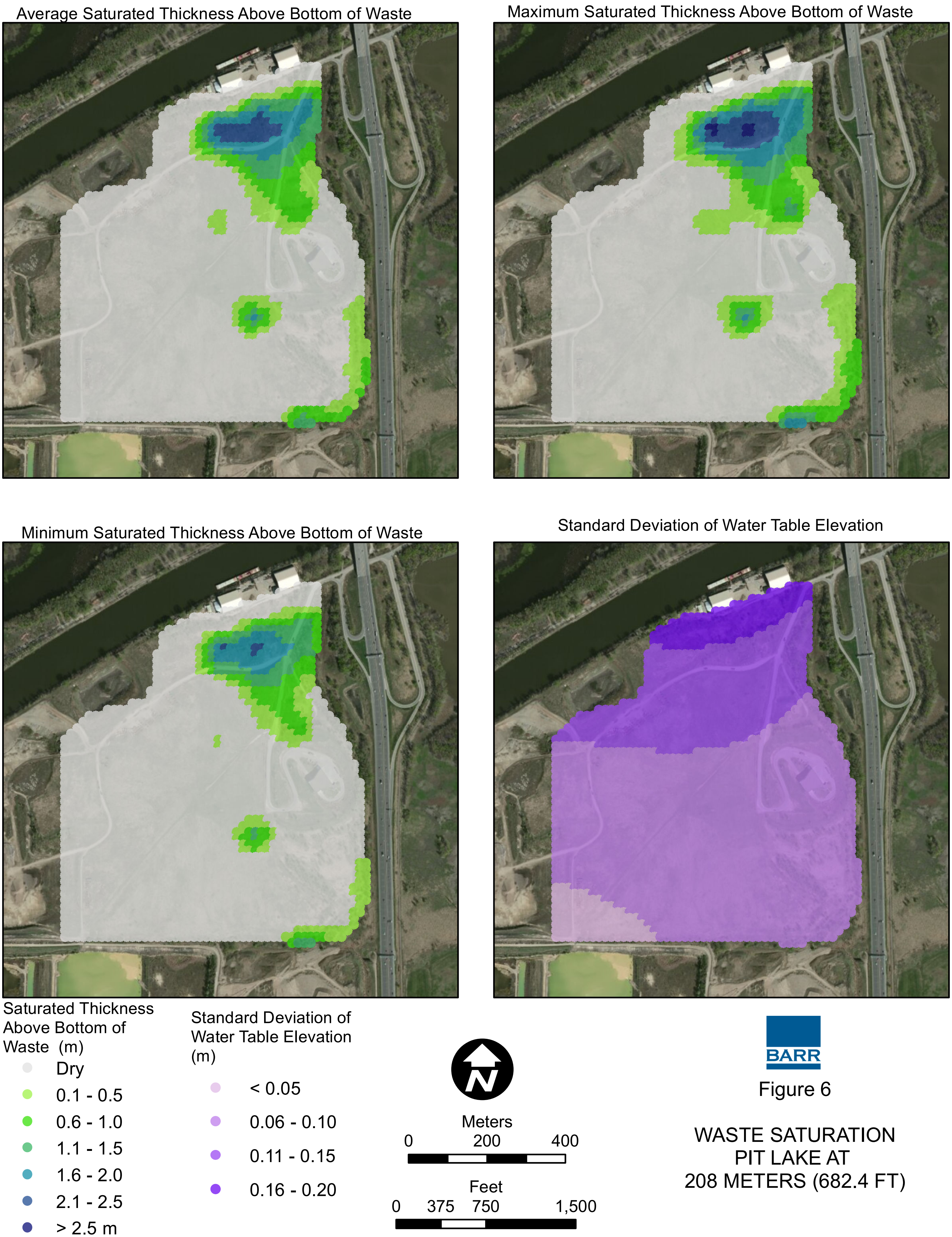

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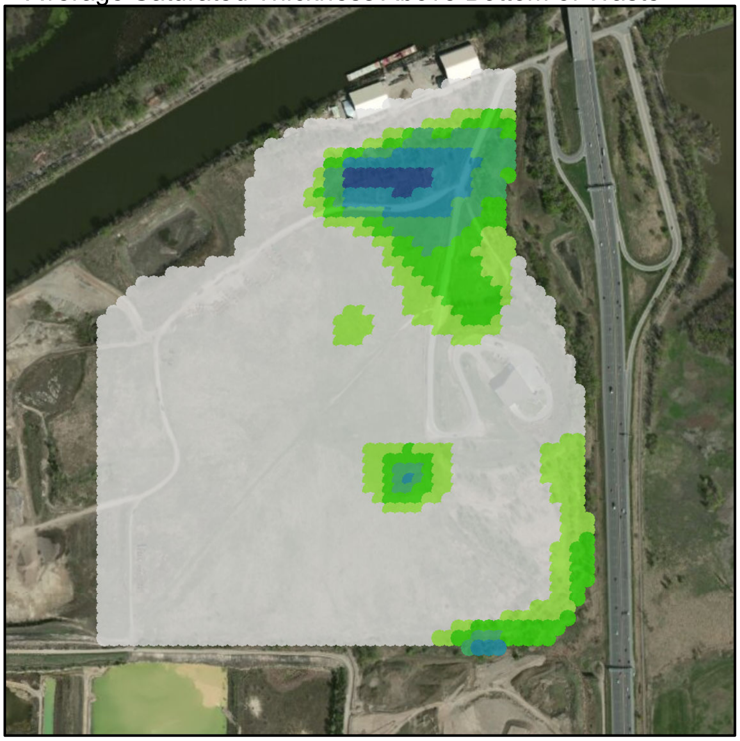
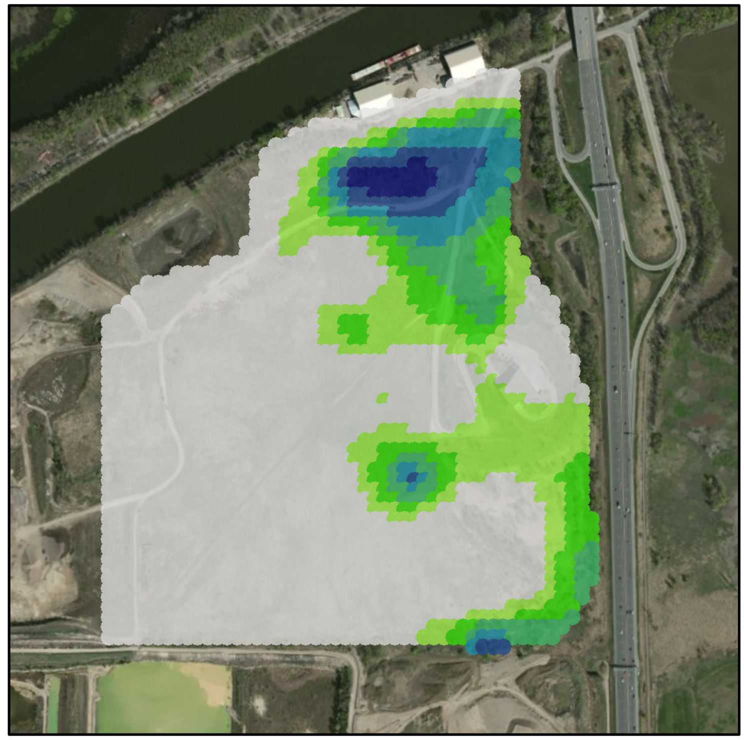
Figure 6

WASTE SATURATION
PIT LAKE AT
208 METERS (682.4 FT)

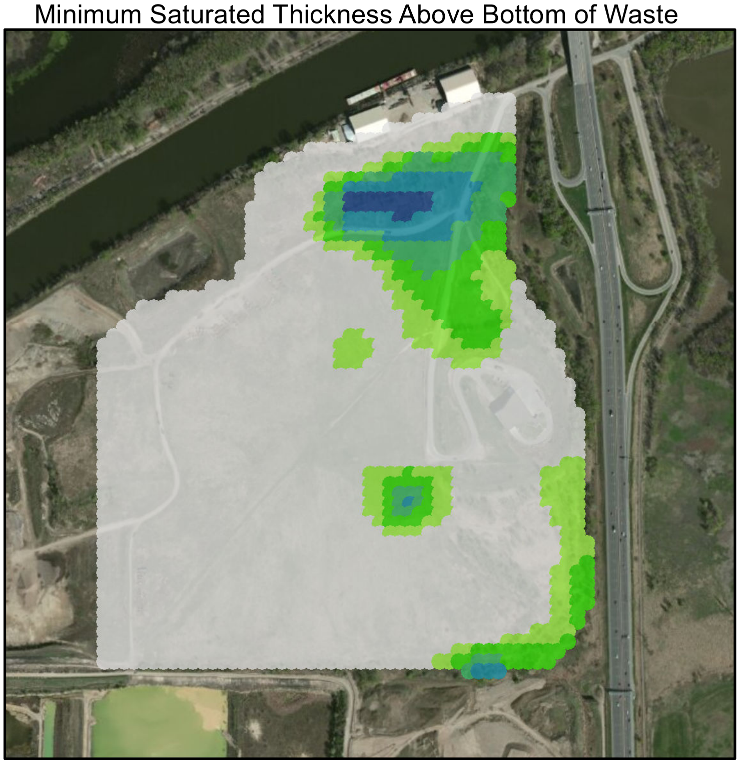
Average Saturated Thickness Above Bottom of Waste



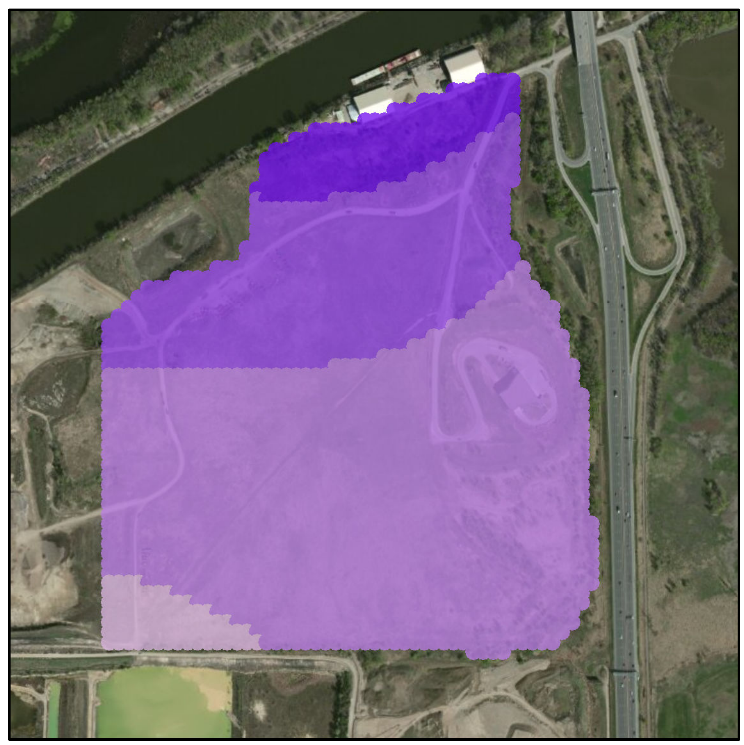
Maximum Saturated Thickness Above Bottom of Waste



Minimum Saturated Thickness Above Bottom of Waste



Standard Deviation of Water Table Elevation



Saturated Thickness Above Bottom of Waste (m)

- Dry
- 0.1 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- > 2.5 m

Standard Deviation of Water Table Elevation (m)

- < 0.05
- 0.06 - 0.10
- 0.11 - 0.15
- 0.16 - 0.20

N

Meters
0 200 400

Feet
0 375 750 1,500

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Figure 7

WASTE SATURATION
PIT LAKE AT
209 METERS (685.7 FT)

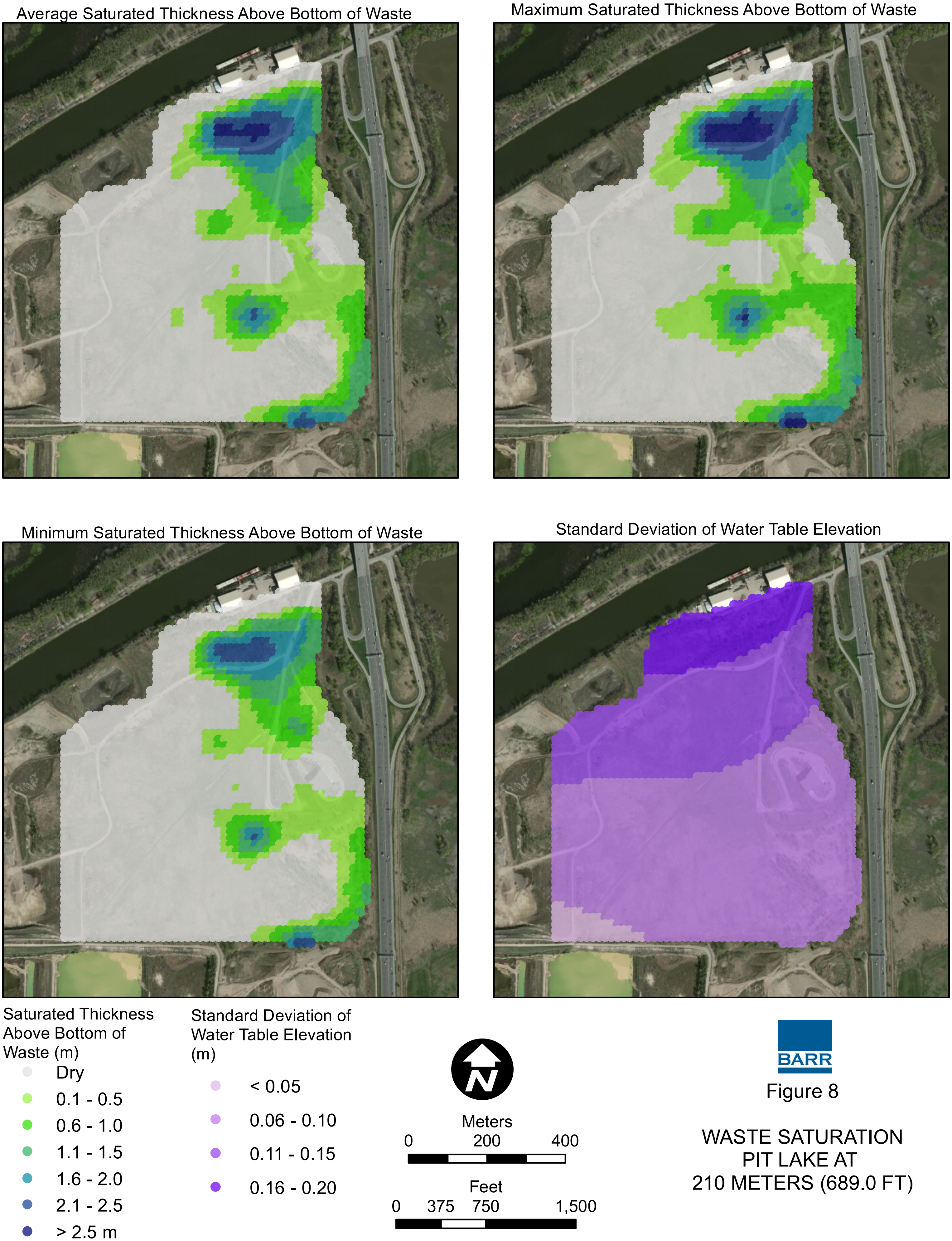
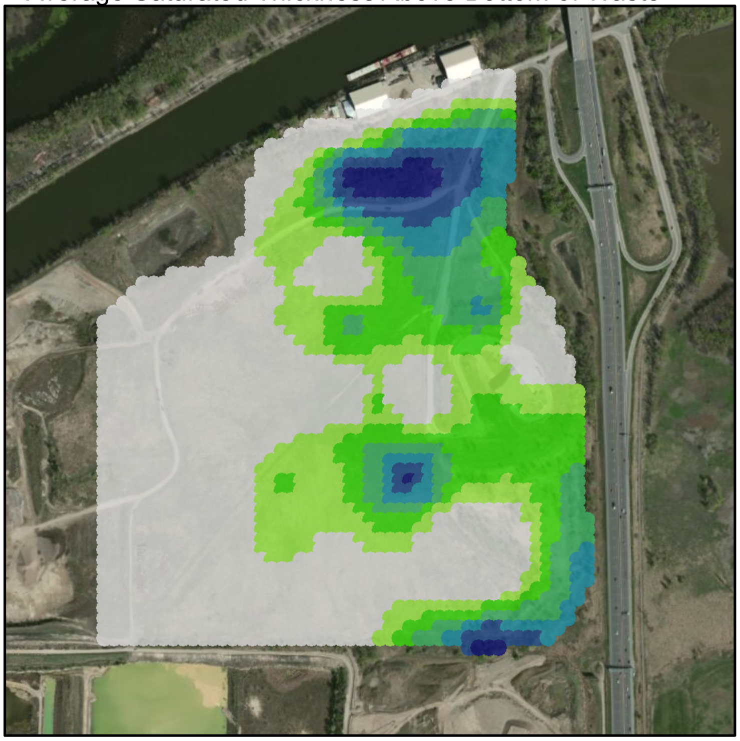


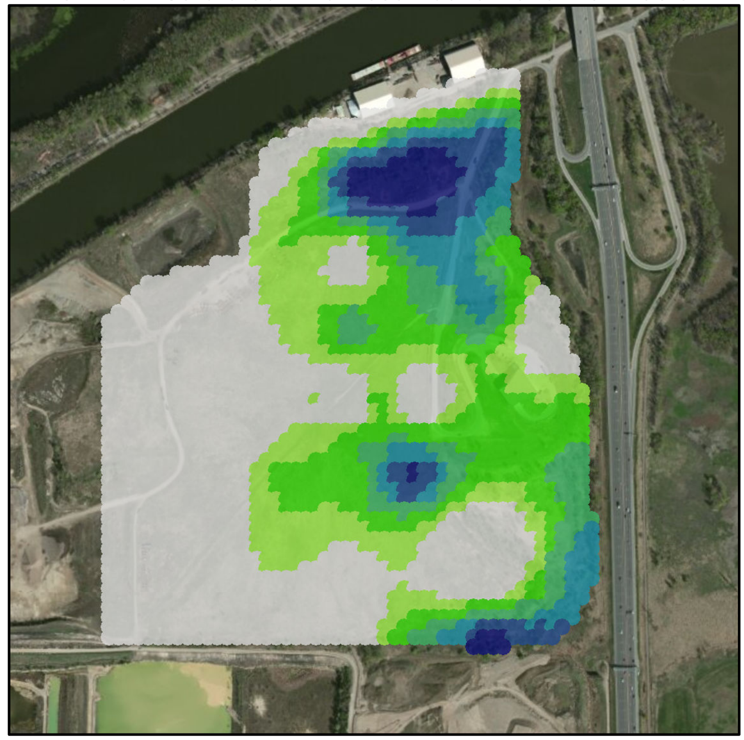
Figure 8

WASTE SATURATION
PIT LAKE AT
210 METERS (689.0 FT)

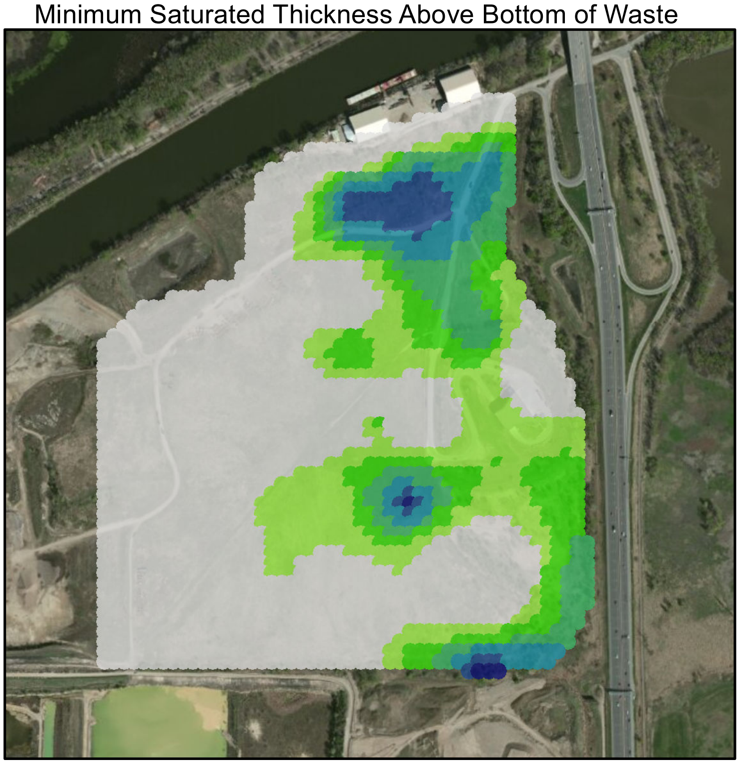
Average Saturated Thickness Above Bottom of Waste



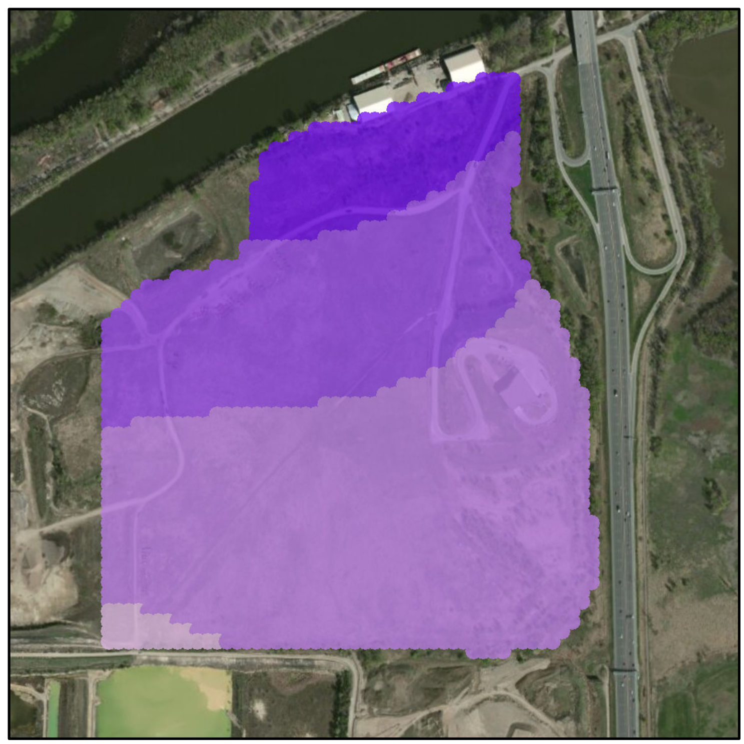
Maximum Saturated Thickness Above Bottom of Waste



Minimum Saturated Thickness Above Bottom of Waste



Standard Deviation of Water Table Elevation



Saturated Thickness Above Bottom of Waste (m)

- Dry
- 0.1 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- > 2.5 m

Standard Deviation of Water Table Elevation (m)

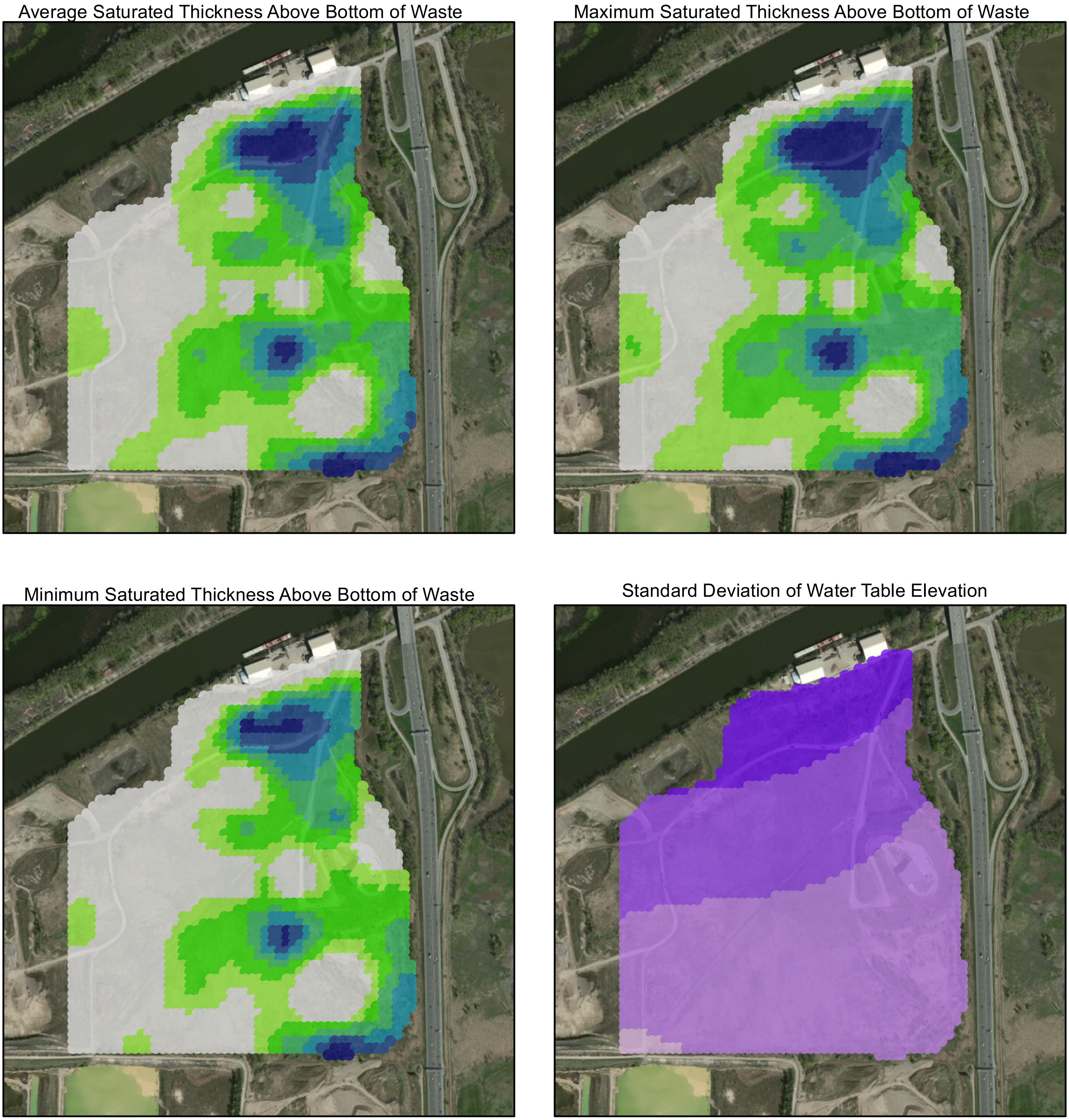
- < 0.05
- 0.06 - 0.10
- 0.11 - 0.15
- 0.16 - 0.20

Meters
0 200 400

Feet
0 375 750 1,500

Figure 9

WASTE SATURATION
PIT LAKE AT
211 METERS (692.3)



Saturated Thickness Above Bottom of Waste (m)

- Dry
- 0.1 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- > 2.5 m

Standard Deviation of Water Table Elevation (m)

- < 0.05
- 0.06 - 0.10
- 0.11 - 0.15
- 0.16 - 0.20

N

Meters
0 200 400

Feet
0 375 750 1,500

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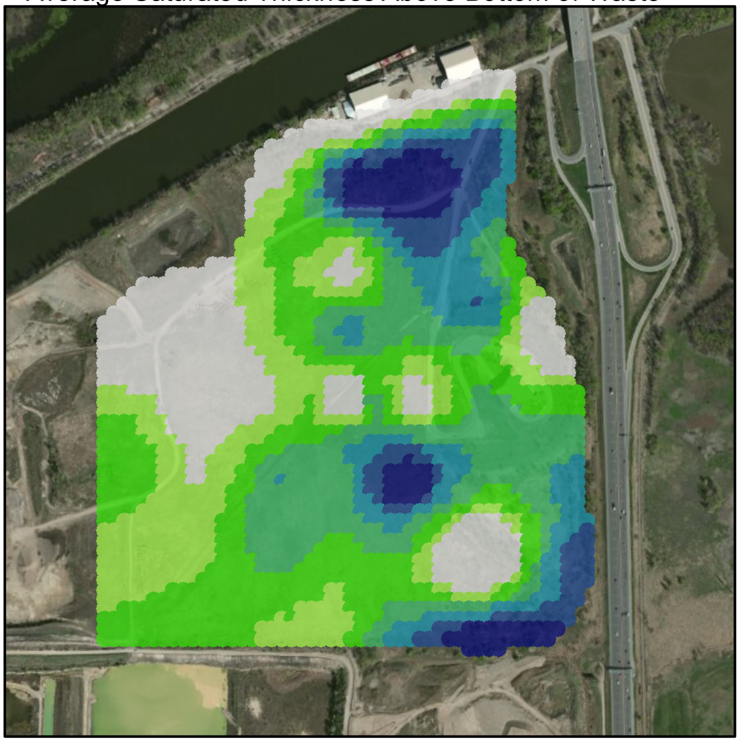
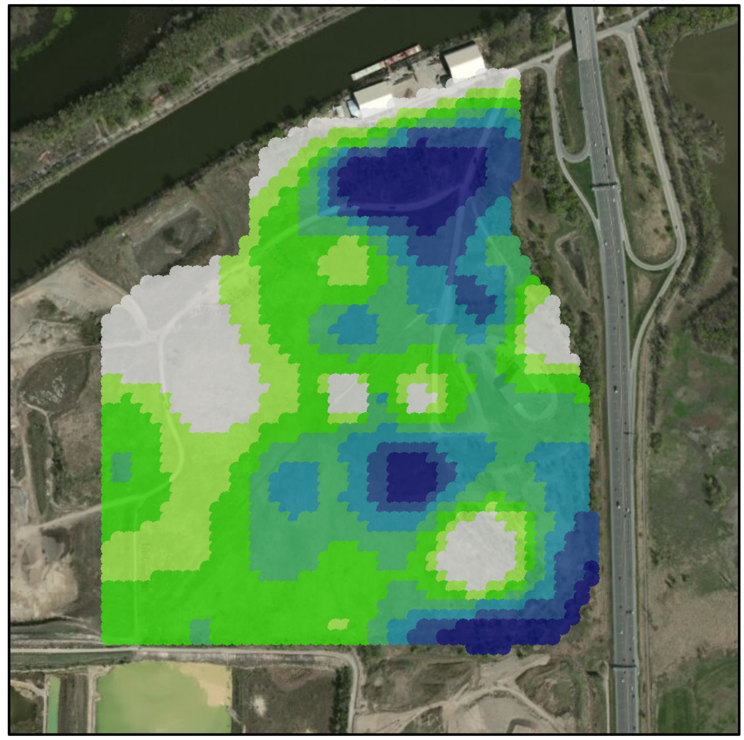
Figure 10

WASTE SATURATION
PIT LAKE AT
212 METERS (695.5)

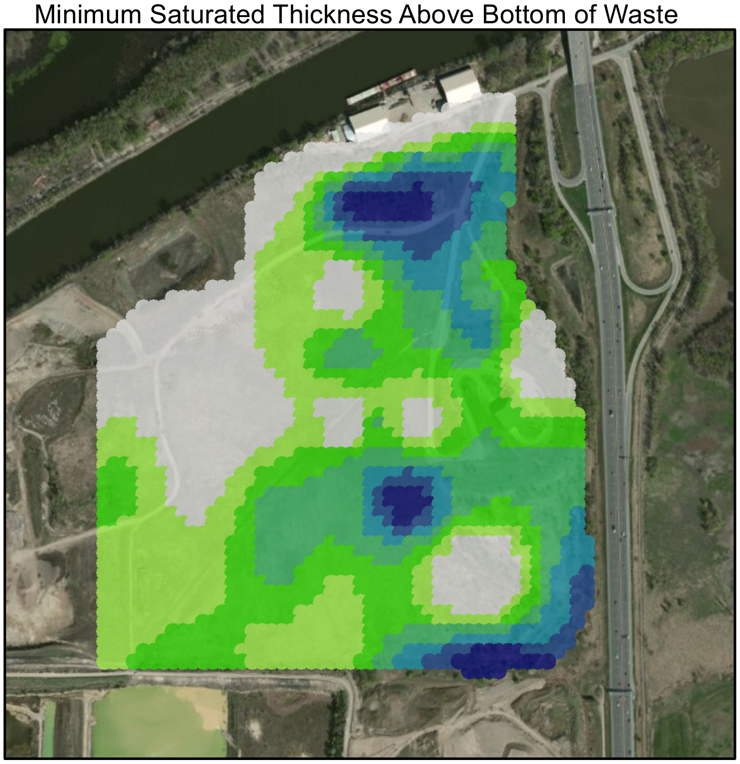
Average Saturated Thickness Above Bottom of Waste



Maximum Saturated Thickness Above Bottom of Waste



Minimum Saturated Thickness Above Bottom of Waste



Standard Deviation of Water Table Elevation

Saturated Thickness Above Bottom of Waste (m)

- Dry
- 0.1 - 0.5
- 0.6 - 1.0
- 1.1 - 1.5
- 1.6 - 2.0
- 2.1 - 2.5
- > 2.5 m

Standard Deviation of Water Table Elevation (m)

- < 0.05
- 0.06 - 0.10
- 0.11 - 0.15
- 0.16 - 0.20

Meters: 0, 200, 400

Feet: 0, 375, 750, 1,500

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Figure 11

WASTE SATURATION
PIT LAKE AT
213 METERS (698.8)