PRELIMINARY EXCAVATION PLAN

West Lake Landfill Superfund Site Operable Unit-1

Prepared For:
The United States Environmental Protection Agency Region VII

Prepared on Behalf of:
The West Lake Landfill OU-1 Respondents

Prepared By:

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UPDATED DRAFT

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List of Acronyms

ACRONYM	Definition
ARAR	Applicable or Relevant and Appropriate Requirements
ASAOC	Administrative Settlement Agreement and Order of Consent
BMP	Best Management Practices
C&D	Construction and Demolition
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
Ci	Curie
DIWP	Design Investigation Work Plan
DOT	U.S. Department of Transportation
DQO	Data Quality Objective
EVS	Earth Volumetric Studio
FAA	Federal Aviation Administration
FFS	Final Feasibility Study
FSP	Field Sampling Plan
HASP	Health and Safety Plan
IBC	International Building Code
IC	International Control
LTODP	Loading, Transportation and Disposal Plan
MDNR	Missouri Department of Natural Resources
MQO	Measurement Quality Objective
MSW	Municipal Solid Waste
NCC	Non-Combustible Cover
NCP	National Oil and Hazardous Substance Pollution Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Agency
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
pCi/g	picoCurie/gram
PEL	Permissible Exposure Limits
PGA	Peak Ground Acceleration
POTW	Publicly Owned Treatment Work
QAPP	Quality Assurance Project Plan
RA	Remedial Action
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
REL	Recommended Exposure Limits
RD	Remedial Design
RDWP	Remedial Design Work Plan
RIM	Radiologically Impacted Material
RODA	Record of Decision Amendment
RSMo	Revised Statutes of Missouri
SMP	Site Management Plan
SOW	Statement of Work
SSP&A	S.S. Papadopolous & Associates
SWMP	Site Wide Monitoring Plan
SWPPP	Stormwater Pollution Prevention Plan
TBC	To Be Considered
UMTRCA	Uranium Mill Tailings Radiation Act
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
UU/UE	Unlimited Use/Unrestricted Exposure
VOC	volatile organic compound
WAC	Waste Acceptance Criteria
WHMP	Wildlife Hazard Mitigation Plan

1.0 Introduction

This Preliminary Excavation Plan has been prepared on behalf of West Lake Landfill OU-1 Respondents Bridgeton Landfill, LLC, Cotter Corporation (N.S.L), and the U.S. Department of Energy (Respondents). The Site is a United States Environmental Protection Agency (USEPA) Superfund Site (ID # MOD079900932). A Record of Decision Amendment (RODA) for Operable Unit 1 (OU-1) of the Site was issued on 27 September 2018 (USEPA 2018). The Respondents entered into a Third Amendment to the Administration Settlement Agreement and Order of Consent (ASAOC) with USEPA (Docket No. VII-93-F-0005) to perform the design of the Amended Remedy selected in the RODA for OU-1 on 6 May 2019 (USEPA 2019). USEPA is the lead agency for the Site and Missouri Department of Natural Resources (MDNR) is the support agency.

The Site is located within the western portion of the St. Louis metropolitan area, east of the Missouri River in northwestern St. Louis County, with a physical address of 13570 St. Charles Rock Road, Bridgeton, Missouri as indicated on **Figures 1 and 2**. The Site consists of an approximately 200-acre parcel of land that includes six inactive waste disposal areas or units as indicated in **Figure 3**. The six units include Radiological Area 1 (Area 1 of OU-1), Radiological Area 2 (Area 2 of OU-1), a closed demolition landfill, an inactive sanitary landfill, the North Quarry, and the South Quarry. Portions of the OU-1 that lie outside the landfill footprint include the Buffer Zone and Lot 2A2. This Preliminary Excavation Plan addresses proposed excavation of landfilled materials in Areas 1 and 2 that will be determined based on a geostatistical model. Excavations in the Buffer Zone and Lot2A2 will be addressed in future deliverables, including the Design Investigation Work Plan (DIWP) and 30% Remedial Design (RD).

The primary purpose for developing the Preliminary Excavation Plan is to provide guidance in identifying boring locations to be executed during the Design Investigation to supplement the existing data set. This Preliminary Excavation Plan has been developed to fulfill the requirements of Section 3.4 of the RD Statement of Work (SOW) attached to the OU-1 Remedial Design ASAOC that describes the RD activities required to implement the RODA (USEPA 2018). The requirements of Section 3.4 of the SOW are:

- An evaluation of location of radiologically impacted material (RIM) greater than 52.9 picoCurie/gram (> 52.9 pCi/g), originally derived from the data and geostatistical model in the December 21, 2017, 3D Extent of RIM Report, or an alternative model as approved by EPA, for the purpose of selecting additional boring locations for the investigation;
- Identification of and evaluation of the optimized excavation locations including:
  - Isolated pockets between 8 and 12 feet below the 2005 topographic ground surface (B2005GS) that, if excavated, would require excavation of large volumes of non-RIM waste as overburden and setback; and
  - Higher concentrations of RIM greater than 12 feet and less than 20 feet B2005GS to be excavated in order to remove the activity represented by RIM greater than 52.9 pCi/g between the 2005 topographic ground surface and 16 feet B2005GS.
- Preliminary estimates of the radioactivity and volume of RIM to be excavated; and
- A preliminary estimate of the volume of all other waste that must be excavated to access the RIM.

2.0 Geostatistical Model

A geostatistical model was developed for the Site by S.S. Papadopolous & Associates, Inc. (SSP&A) for the Final Feasibility Study (FFS) using the software program IK3D, as documented in the "Estimated Three-Dimensional Extent of Radiologically Impacted Material, West Lake Landfill Operable Unit 1, Bridgeton, Missouri" (SSP&A 2017). This geostatistical model was used as the basis for the Selected Remedy in the RODA. Both the RODA and the SOW in the Third Amendment of the ASAOC requires an evaluation of the RIM > 52.9 pCi/g using this geostatistical model or an alternative model approved by USEPA. Parsons has adapted this geostatistical model for use in the remedial design for the Site, as described in **Appendix A**. Parsons is using C-Tech Earth Volumetric Studio (EVS) software (EVS Version 2019.9) to perform the calculations and data presentations. EVS is a well-known and broadly used data analysis and visualization software program in the environmental remediation and resource development industries. It was developed specifically to perform geostatistical modeling and three-dimensional presentation of the data and analyses.

As discussed in **Appendix A**, the following kriging parameters are being used in EVS for performing the geostatistical evaluations:

	EVS	
Parameter	**Area 1**	**Area 2**
Grid Cell Size (x,y) (m^2)	225	225
Layer Thickness (ft)	0.5	0.5
Radium Sill	0.08	0.04
Thorium Sill	0.045	0.17
Range (X,Y,Z)	175	235
Anisotropy	40	55

The geostatistical model estimated the presence of RIM greater than 52.9 pCi/g; the kriging confidence and uncertainty of the model are presented in the attached layered Adobe Acrobat figures for Area 1 (**Figure 4**) and Area 2 (**Figure 5**). The details of the computations are provided in **Appendix A**.

The kriging confidence is based on the standard deviation of the estimated values at each grid location. It is independent of the magnitude of the estimated value. As such, high confidence values are locations where they are near samples that are included in the model estimate, regardless of the concentrations. The confidence layers in the figures only show colors for confidence levels less than 75% (areas colored black have confident levels greater than 75%) to visually highlight areas where the kriging indicates lower sample data and lower confidence in the predicted value.

The uncertainty calculation by EVS factors is the magnitude of the predicted value as well as the confidence in the estimate. A high uncertainty is related to areas of both a low confidence and a high predicted value. This is important to both the remediation and resource fields because the variability of background levels has little relevance, while accurate assessment of significant concentrations of the constituent of interest is a primary objective. The uncertainty graphs show areas with uncertainty greater than 10% (areas colored black have less than 10% uncertainty). Many of the lower confidence locations disappear from the map because the magnitude of the estimated concentrations is significantly lower than the threshold value of interest. The remaining uncertainty locations indicate locations with both significant estimated concentration values and some degree of lower confidence in the estimated value.

The visual color scale bar for these maps is based on all analysis layers for this parameter (e.g., different depths), and therefore not all colors may be visible in any single two-dimensional representation of the three-dimensional analysis. Also, each map is a two-dimensional view of a three-dimensional thickness where the non-visible interior or opposite side may have different values and color representations. Therefore, the full scale of the values in the analysis may not be visible from a specific vantage point. The view from straight above (as shown on map) only shows the value as it exists on the upper outer shell of the three-dimensional object. As discussed above, the limiting ends (highest and lowest values) of the scale may not exist on this map (e.g., confidence on the map is never below 25%) as they may be truncated to focus attention on the zones with more uncertainty or less confidence.

3.0 RIM Activity Calculations

The RODA requires removal of RIM with radioactivity greater than 52.9 pCi/g from the upper 12 feet B2005GS of the landfill except as stated in the RODA and approved by USEPA. USEPA has defined RIM at the Site as any material containing combined Ra-226 plus Ra-228 or combined Th-230 plus Th-232 at levels greater than 7.9 pCi/g, or U-238 plus U-235 plus U-234 at levels greater than 54.5 pCi/g.

The RODA defines a requirement for the total radioactivity to be removed in the Selected Remedy to be equivalent to the total radioactivity represented by the combined radium (Ra) and thorium (Th) greater than 52.9 pCi/g down to 16 feet B2005GS. The RODA Selected Remedy generally requires removal of RIM greater than 52.9 pCi/g to a depth of 12 feet B2005GS, but will include removal of some RIM between 12 and 20 feet below the 2005 surface and allow for isolated pockets of RIM greater than 52.9 pCi/g between 8 feet and 12 feet below the 2005 surface to remain in place. The approach to selecting the locations that will deviate from the general depth of 12 feet below the 2005 surface are discussed in the next paragraph.

Removal of RIM greater than 52.9 pCi/g to 12 feet B2005GS, which is generally required for the RODA Selected Remedy, would result in the removal of less radioactivity than a similar excavation to 16 feet B2005GS described in Alternative 4 of the Proposed Plan. Therefore, the RD excavation design must include additional removal below the 12-foot depth in order to achieve a total radioactivity removal equivalent to Alternative 4 in the Proposed Plan. The RODA proposes that this additional radioactivity will be removed by targeting localized deposits of higher radioactivity materials in the 12- to 20-foot zone, particularly materials with radioactivity greater than 1,000 pCi/g. The RD will consider practical aspects to define the excavation boundaries, including performing deeper excavations in areas where overlying materials are already planned for removal, and leaving local isolated RIM in place where extensive overburden excavation would be required.

The RIM activity calculation methodology to achieve these objectives of the Selected Remedy is provided in **Appendix B**, and is also being performed using C-TECH EVS Studio. The focus of this calculation methodology is to provide a repeatable, consistent analysis estimating the total activity of the total RIM mass and of sub-areas of RIM that may be delineated by elevation or plan area.

The calculated estimate of the total activity in RIM delineated to be greater than 52.9 pCi/g in the zone of 0 to 16 feet B2005GS is 233 Curie (Ci) in Areas 1 and 2. There is an additional 33 Ci in the zone 16 to 20 feet B2005GS which can be used to offset RIM greater than 52.9 pCi/g that may not be excavated in the zone 8 to 16 feet B2005GS.

The computed RIM activities are summarized by area in the table below. This table provides the total computed activity of the 0-16 feet B2005GS zone as well as individual layers of 0 to 8, 8 to 12, 12 to 16, and 16 to 20 feet B2005GS to address the decision-making criteria discussed above.

Total Activity Estimation Summary – Without Excavation				
	Total Activity in RIM >52.9 pCi/g at Stated Depth Intervals (feet B2005GS)	**Area 1 (Ci)**	**Area 2 (Ci)**	**Total Area 1 and 2 (Ci)**
A	**Total Activity 0-16**	**42.1**	**190.4**	**233**
B	Activity in 0 to 8	16.6	147.1	164
C	Activity in 8 to 12	12.1	33.1	45
D	Activity in 12 to 16	13.4	10.2	24
E	Activity in 16 to 20	2.2	30.4	33

4.0 Optimization

The existing contours for the excavation area are show in **Figure 6**. The preliminary excavation plans are shown in **Figures 7** through **9**. Representative cross-section profiles are shown in **Figures 10** and **11**.

The approach to developing these preliminary excavation plans was to identify the areas where RIM greater than 52.9 pCi/g was identified in the geostatistical model within the 0 to 8 feet B2005GS zone. These locations were supplemented by identification of areas where RIM was present from 8 to 12 feet B2005GS, which generally coincided with the 0-8 feet B200GS areas. Deeper RIM greater than 52.9 pCi/g in the 12 to 20-foot zone within these general excavation limits was also targeted in order to achieve a balance of the total activity computed for the 0 to 16 feet B2005GS RIM >52.9pCi/g.

Side slopes of 1.5 horizontal to 1 vertical were assumed for the 0 to 12-feet zone B2005GS as well as overburden that had been placed over this surface. Excavations below 12 feet B2005GS were assumed to have vertical sidewalls.

Figure 12 shows a representation of the excavation limits superimposed on the boundary of all RIM greater than 52.9 pCi/g that the geostatistical model indicates is present between 0 and 20 feet B2005GS.

Figures 13 and **14** highlight locations where RIM will not be excavated at depths of 8 to 16 feet B2005GS because there is little activity in those locations and significant additional excavation area and volume would be required to access it.

The preliminary estimated volumes of RIM and overburden excavation for this preliminary excavation plan, including isolated pocket balancing, are provided in the table below:

	Estimated Excavated Volume for Various Materials	**Area 1 (cubic yards)**	**Area 2 (cubic yards)**	**Total Area 1 and 2 (cubic yards)**
A	**Total Excavation Volume**	**30,200**	**192,800**	**223,000**
B	RIM > 52.9 pCi/g	10,800	71,800	82,600
D	Material < 52.9 pCi/g	19,400	121,000	140,400

These estimated volumes are preliminary based on current existing site information and interpretation of the current geostatistical model. They are neat line, in-place volumes and do not include fluffing during excavation, processing, and loading into containers. They do not include typical minor over-excavation inherent in the excavation process. They are subject to change based on incorporation of additional data into the geostatistical model in the future.

The volumes above are based on the isolated pocket activity balancing processes described in Appendix B. The follow summary demonstrates the activity accounting balance as part of the optimization.

Activity Removal Summary				
	Total Activity Removal >52.9 pCi/g at Stated Depth Intervals (feet B2005GS)	**Area 1 (Ci)**	**Area 2 (Ci)**	**Total Area 1 and 2 (Ci)**
A	**Total Activity Removed 0-17**	**41.6**	**191.4**	**233**
Breakdown by Depth Interval				
B	Activity removal in 0 to 8	16.6	147.1	164
C	Activity removal in 8 to 12	12.1	33.0	45
D	Activity removal in 12 to 16	12.9	9.0	22
E	Activity removal in 16 to 17	0.0	2.2	2

Note: Activity removal shown on line E depicts activity from 16-17 ft, which compensates for all potentially identified isolated pockets

5.0 Data Gaps

The primary purpose for developing the Preliminary Excavation Plan is to provide guidance in identifying boring locations to be executed during the Design Investigation to supplement the existing data set. It is expected that the additional boring locations will be selected using one or more of the following criteria:

- Kriging confidence and uncertainty, which is generally influenced by:
  - Isolated locations identified by little data
  - Gaps between data locations
  - Significant variability of nearby sample results
  - Lack of thorium laboratory confirmation (“hard data”)
- Elevation or plan location data quality

The kriging confidence and uncertainty are presented in the attached layered Adobe Acrobat figures for Area 1 (**Figure 4**) and Area 2 (**Figure 5**). As discussed in **Appendix A**, the confidence is generally lowest and uncertainty highest in areas that have the least exploration and data, but where there are data indicating that RIM may be present at elevated levels. Therefore, the interpretation of confidence and uncertainty is focused on locations where elevated levels are computed by the kriging analysis. As discussed in Section 2.0, the coincidence of low confidence and elevated estimated concentrations results in higher uncertainty which indicates that additional data in these locations will likely improve the accuracy of the model. **Figures 4** and **5** have been developed to focus on these areas. In particular, the figures depicting the uncertainty evaluations will be the most valuable in identifying potential boring locations.

These figures show the portions of the confidence and uncertainty scale where confidence is below 75% or uncertainty is greater than 10%. The geostatistical model develops these values in a three-dimensional shape, with only the upper surface of that shape shown on the layered pdfs, so not all colors in the scale bar can be seen in any given view as discussed previously. **Figures 15** and **16** show a cross-section through the thorium uncertainty shapes (truncated at 5% instead of 10% with white instead of black background) for a different perspective. These figures show that the uncertainty is generally low to moderate. There are only small isolated areas with high uncertainty.

The geostatistical evaluation does not address poor elevation or plan location data quality, except as it is reflected in lower quality correlations between “soft” data and “hard” data. The available data set has a variety of “hard” and “soft” data that was obtained from borings and other methods, such as surface gamma scans. The “hard” laboratory data provides high quality data regarding the concentration of radium and thorium (and other constituents that are tested), but poor recovery in some boreholes may make the elevation of the sample uncertain. The “soft” data of core gamma scans has a similar geometric uncertainty to it. Downhole gamma logging, another “soft” data type, has very good elevation accuracy and precision, but correlating it to core samples with uncertain elevations reduces the potential accuracy of correlations with the downhole gamma logs. The geometric quality of the data will be evaluated separately as part of the DIWP development.

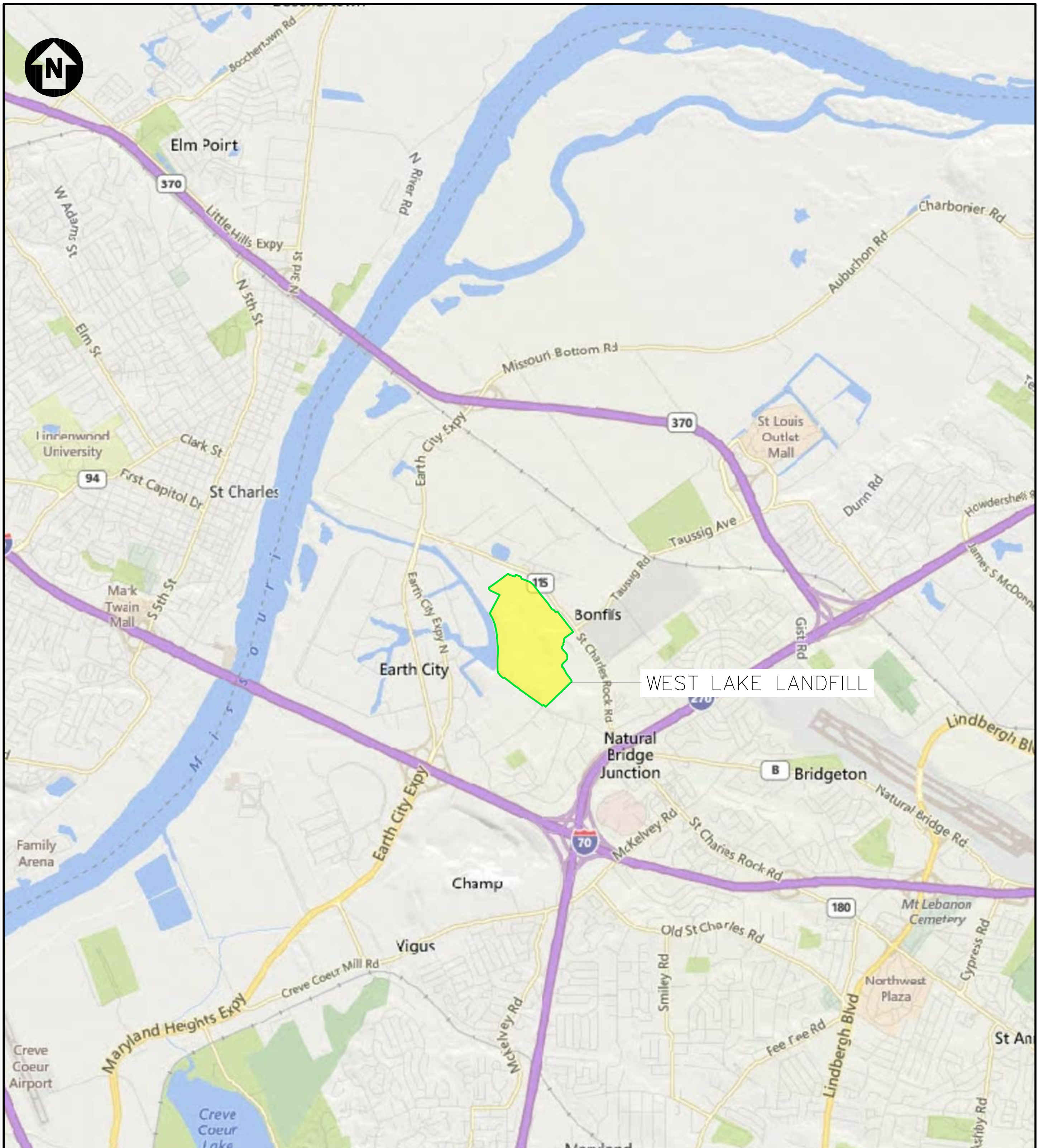
6.0 References

S.S. Papadopolous & Associates. 2017. *Estimated Three-Dimensional Extent of Radiologically Impacted Material, West Lake Landfill Operable Unit 1, Bridgeton, Missouri*. December 2017.

USEPA, 2018. *Record of Decision Amendment, West Lake Landfill Site, Bridgeton, Missouri, Operable Unit 1*, September 2018.

USEPA, 2019. *Third Amendment to Administrative Settlement Agreement and Order on Consent and Statement of Work*, Docket No: VII-93-F-0005, May 2019.

Figures



Missouri

5000 2500 0

SCALE: 1"=5000'

SITE LOCATION MAP

West Lake Landfill OU-1 Respondents
Preliminary Excavation Plan
WEST LAKE LANDFILL OU-1

PARSONS

301 PLAINFIELD ROAD * SUITE 350 * SYRACUSE, NY 13212 * 315-451-9560

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
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Missouri

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SCALE: 1"=5000'

SITE LOCATION MAP
ON AERIAL PHOTO

West Lake Landfill OU-1 Respondents
Preliminary Excavation Plan
WEST LAKE LANDFILL OU-1

PARSONS

301 PLAINFIELD ROAD * SUITE 350 * SYRACUSE, NY 13212 * 315-451-9560

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
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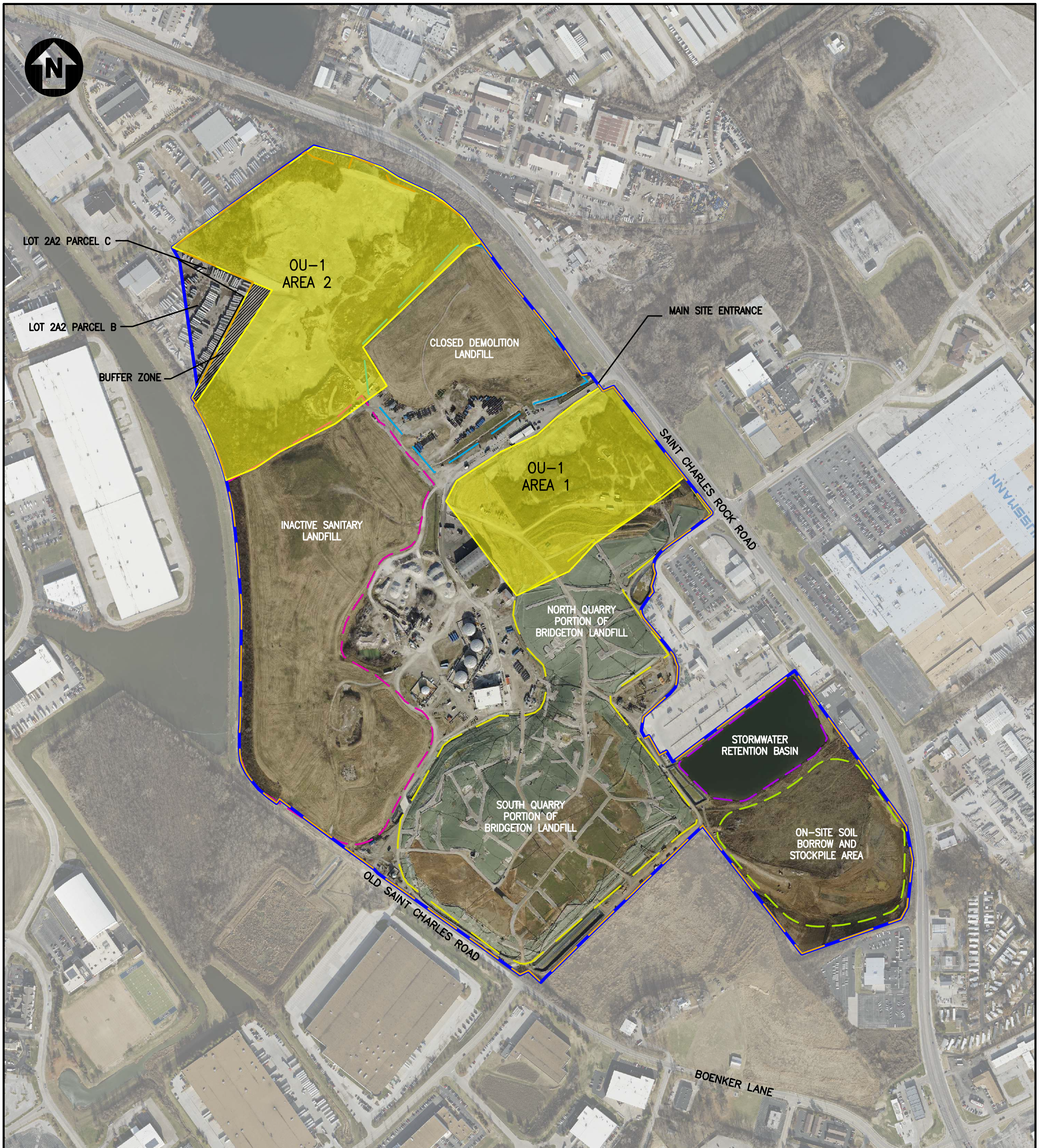

LEGEND:

SUPERFUND SITE
LANDFILL BOUNDARY
BRIDGETON LANDFILL
INACTIVE SANITARY LANDFILL
CLOSED DEMOLITION LANDFILL
STORMWATER RETENTION POND
SOIL BORROW/STOCKPILE AREA

800 400 0

SCALE: 1"=800'

SITE AREAS

West Lake Landfill OU-1 Respondents
Preliminary Excavation Plan
WEST LAKE LANDFILL OU-1

PARSONS

301 PLAINFIELD ROAD * SUITE 350 * SYRACUSE, NY 13212 * 315-451-9560

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
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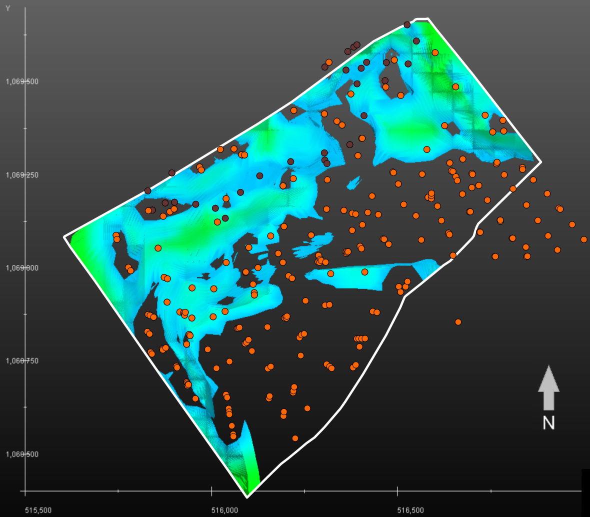
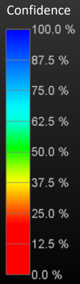
Area 1 - Radium - Confidence - 0-12 - Showing values below 75% of scale

Area 1 Sample Locations

NCC Locations

Boring Locations





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Limiting ends of the scale may not exist on this map (e.g. confidence is never below 25%).

Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

In EVS, uncertainty is high where concentrations are predicted to be relatively high but the confidence in that prediction is low. Therefore it draws attention to areas where additional higher concentrations may exist. Uncertainty values should be considered unitless and their magnitudes cannot directly be used to assess the quality of a site assessment.

PRELIMINARY DRAFT

AREA 1
UNCERTAINTY AND CONFIDENCE
LAYERED PDF MAP

West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	MJB	JWS	4

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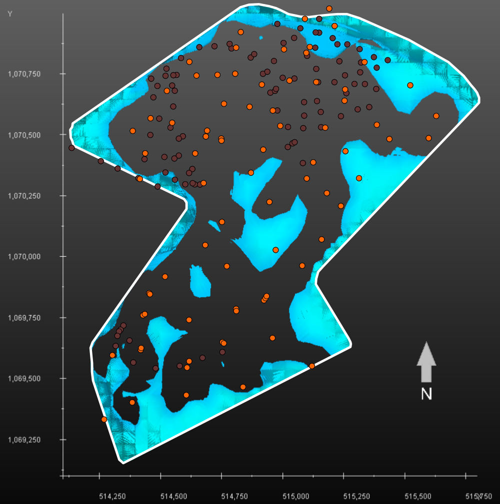
Area 2 - Radium - Confidence - 0-12 - Showing values below 75% of scale



Confidence

100.0 %
87.5 %
75.0 %
62.5 %
50.0 %
37.5 %
25.0 %
12.5 %
0.0 %

The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

Limiting ends of the scale may not exist on this map (e.g. confidence is never below 25%).

- Area 2 Sample Locations
- NCC Locations
- Boring Locations

Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

In EVS, uncertainty is high where concentrations are predicted to be relatively high but the confidence in that prediction is low. Therefore it draws attention to areas where additional higher concentrations may exist. Uncertainty values should be considered unitless and their magnitudes cannot directly be used to assess the quality of a site assessment.

PRELIMINARY DRAFT

AREA 2
UNCERTAINTY AND CONFIDENCE
LAYERED PDF MAP

West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE#
451662.03100	12/27/2019	MJB	JWS	5

PRELIMINARY DRAFT

OVERALL EXISTING CONDITIONS SITE PLAN
AREA 1 AND 2

West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
301 PLAINFIELD ROAD * SUITE 350 * SYRACUSE, NY 13212 * 315-451-9560

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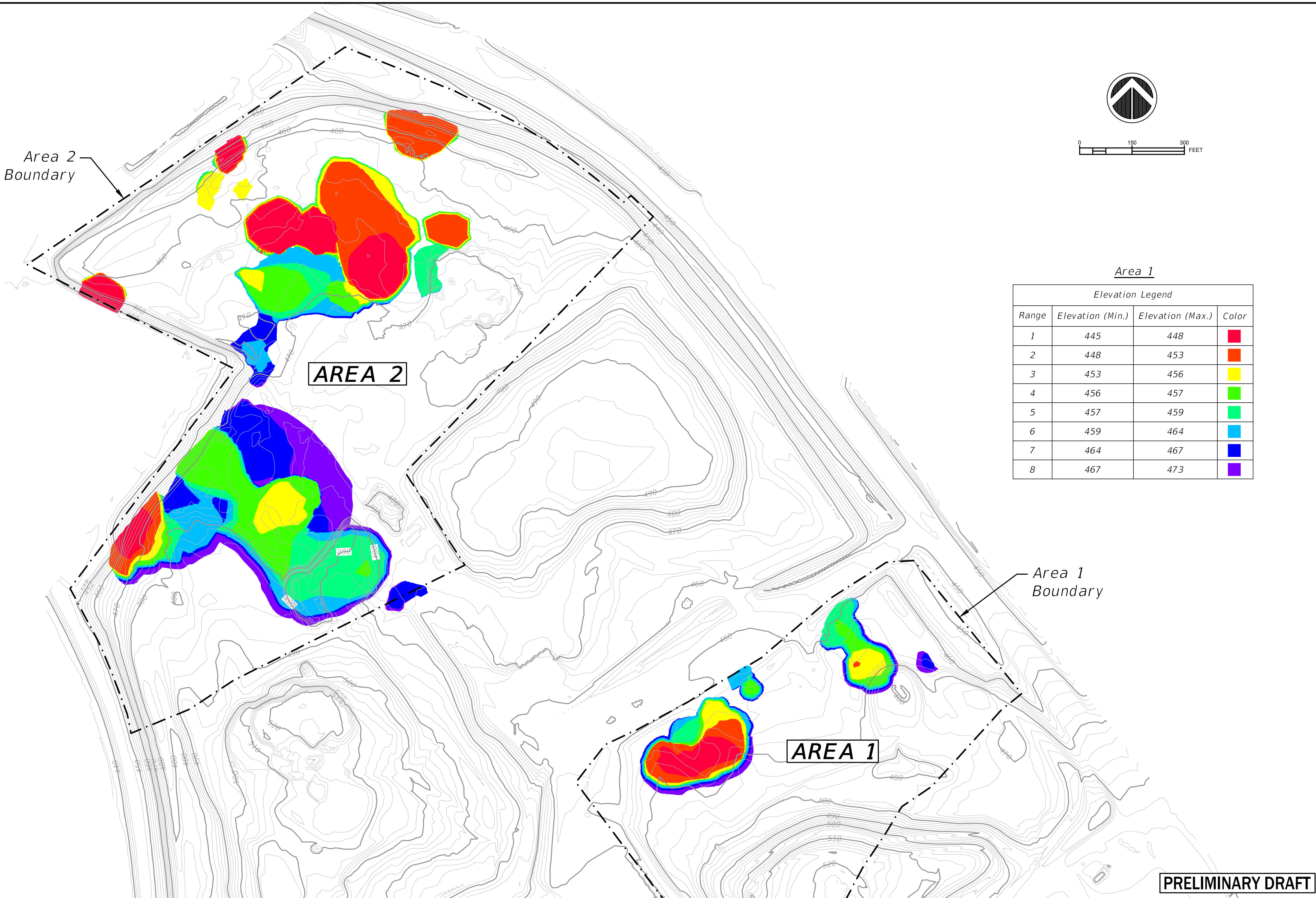

PRELIMINARY DRAFT

Area 2

Elevation Legend			
Range	Elevation (Min.)	Elevation (Max.)	Color
1	443	453	red
2	453	456	orange
3	456	458	yellow
4	458	461	green
5	461	463	light green
6	463	466	light blue
7	466	470	blue
8	470	486	purple

Area 1

Elevation Legend			
Range	Elevation (Min.)	Elevation (Max.)	Color
1	445	448	red
2	448	453	orange
3	453	456	yellow
4	456	457	green
5	457	459	light green
6	459	464	light blue
7	464	467	blue
8	467	473	purple

OVERALL EXCAVATION SITE PLAN
AREA 1 AND 2

West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
301 PLAINFIELD ROAD * SUITE 350 * SYRACUSE, NY 13212 * 315-451-9560

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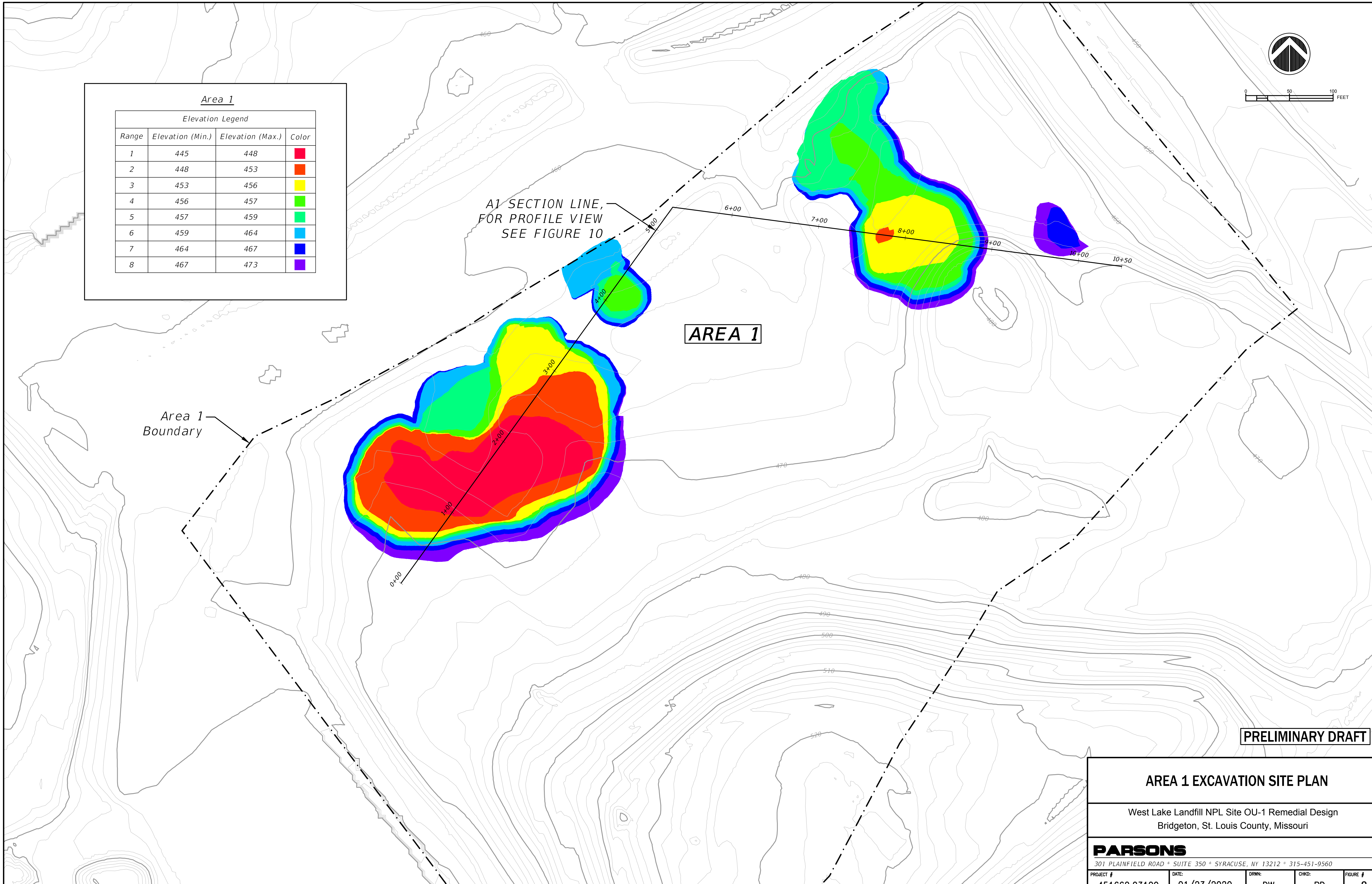

Area 1

Elevation Legend

Range	Elevation (Min.)	Elevation (Max.)	Color
1	445	448	
2	448	453	
3	453	456	
4	456	457	
5	457	459	
6	459	464	
7	464	467	
8	467	473	

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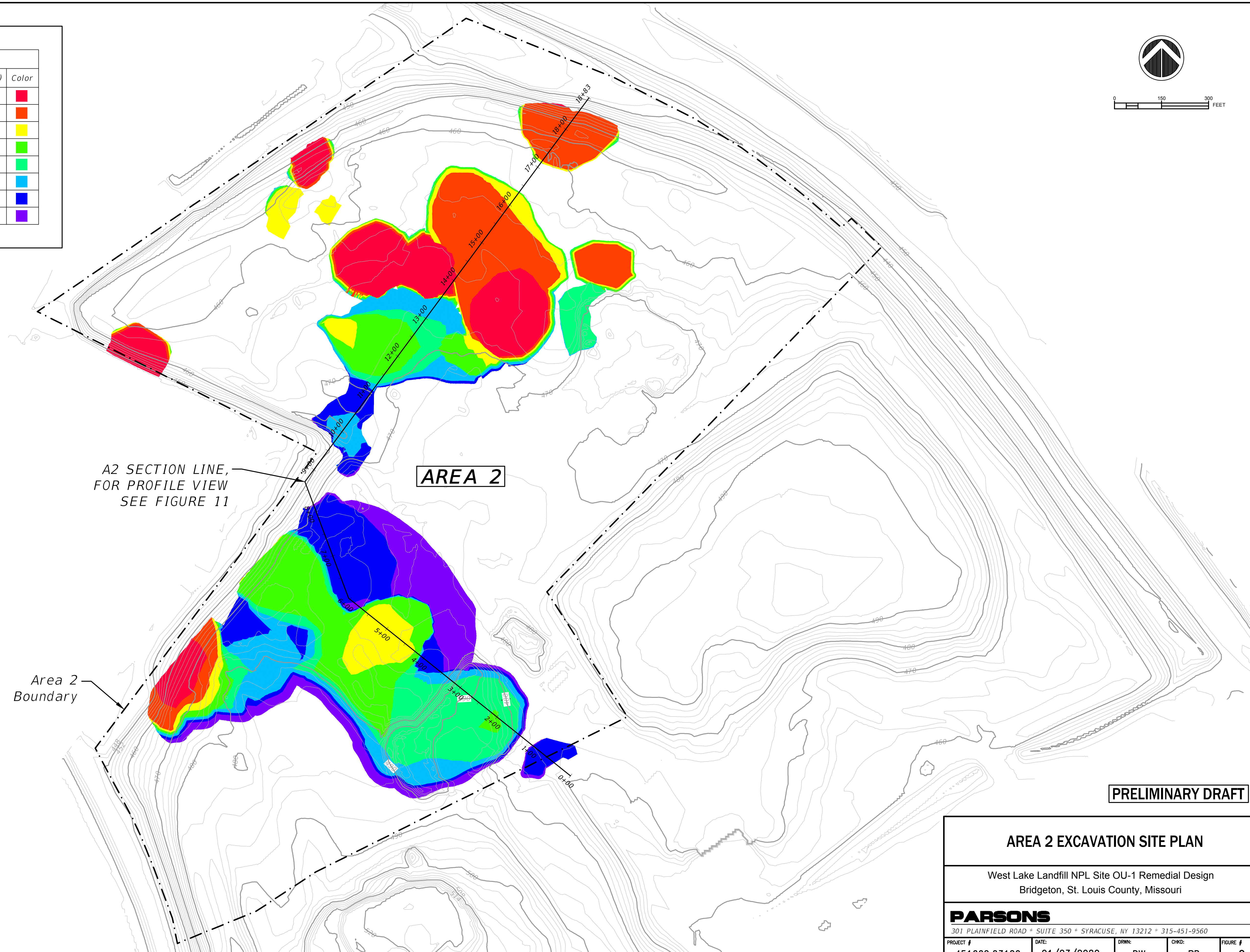
PLOT DATE: 1/23/2020 11:02 AM PLOTTED BY: WEAR, DON

Area 2

Elevation Legend			
Range	Elevation (Min.)	Elevation (Max.)	Color
1	443	453	
2	453	456	
3	456	458	
4	458	461	
5	461	463	
6	463	466	
7	466	470	
8	470	486	



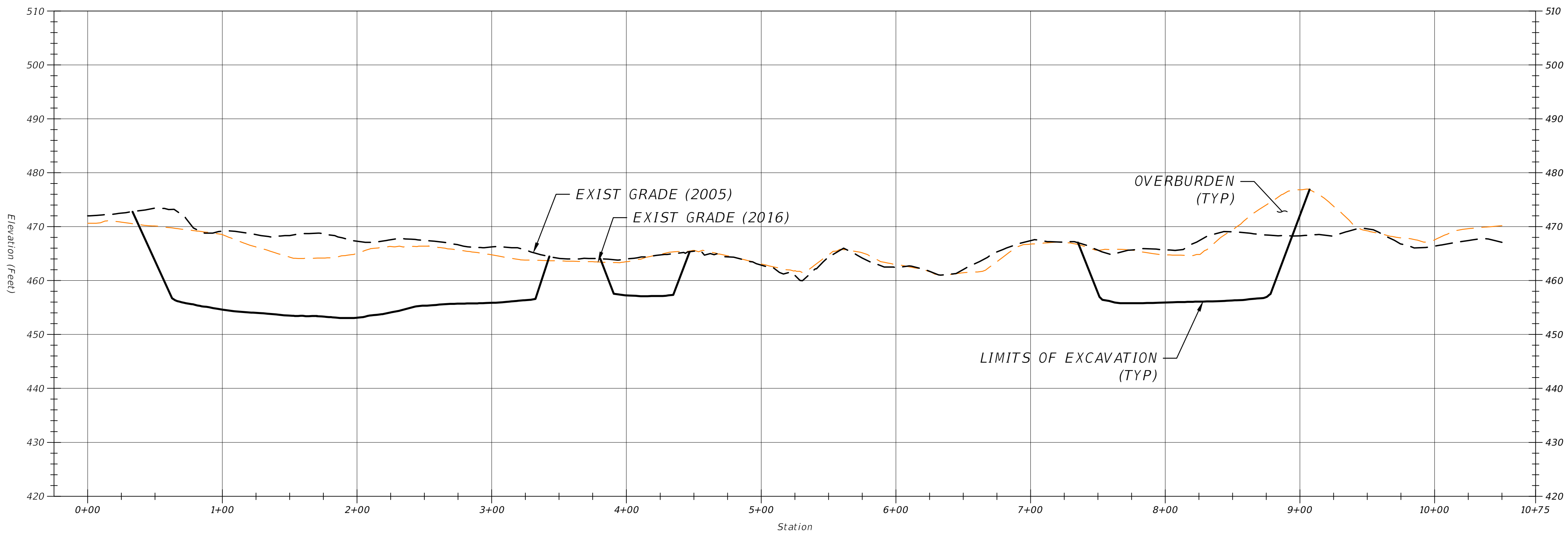
AREA 2 EXCAVATION SITE PLAN

West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
301 PLAINFIELD ROAD * SUITE 350 * SYRACUSE, NY 13212 * 315-451-9560

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
451662.03100	01/23/2020	DW	RD	9

FILE NAME: C:\USERS\P0049601\DESKTOP\NEW YORK OFFICE\WESTLAKE LANDFILL\FIGURES\EXCAVATION PLANS.DWG
PLOT DATE: 1/23/2020 11:02 AM PLOTTED BY: WEAR, DON



PROFILE

HORIZ. SCALE 0 50 100 FEET

VERT. SCALE 0 25 FEET

PRELIMINARY DRAFT

NOTES:

1. THE SLOPE OF EXCAVATION FROM THE EXISTING GRADE (2016) TO 12FT DEPTH SHALL NOT EXCEED 1.5:1.

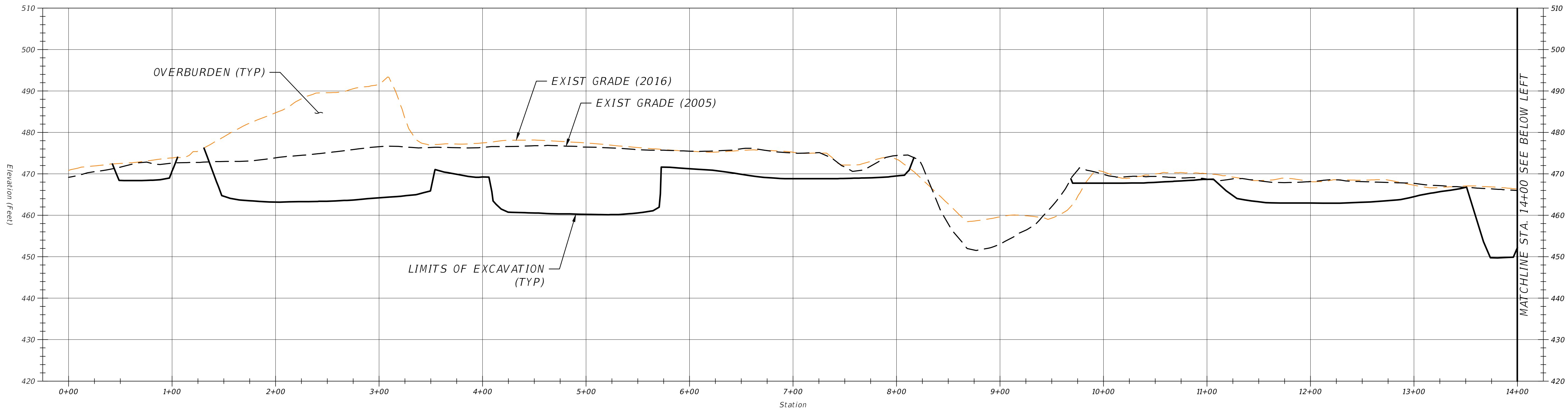
AREA 1 - PROFILE VIEW

West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

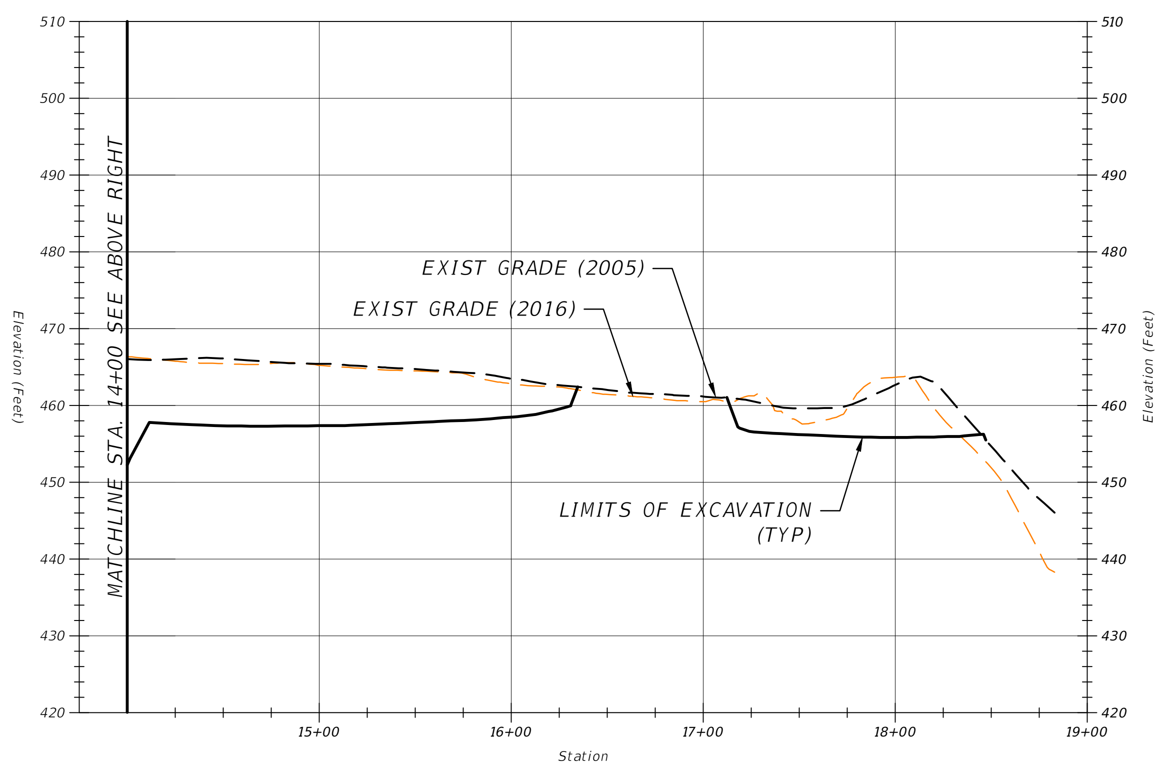
PARSONS
301 PLAINFIELD ROAD * SUITE 350 * SYRACUSE, NY 13212 * 315-451-9560

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
451662.03100	01/23/2020	DW	RD	10

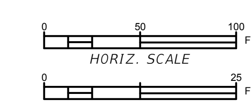
FILE NAME: C:\USERS\P0049601\DESKTOP\NEW YORK OFFICE\WESTLAKE LANDFILL\FIGURES\EXCAVATION PROFILES.DWG
PLOT DATE: 1/23/2020 11:25 AM PLOTTED BY: WEAR, DON



PROFILE



PROFILE



PRELIMINARY DRAFT

NOTES:

1. THE SLOPE OF EXCAVATION FROM THE EXISTING GRADE (2016) TO 12FT DEPTH SHALL NOT EXCEED 1.5:1.

AREA 2 - PROFILE VIEW

West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
301 PLAINFIELD ROAD * SUITE 350 * SYRACUSE, NY 13212 * 315-451-9560

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
451662.03100	01/23/2020	DW	RD	11

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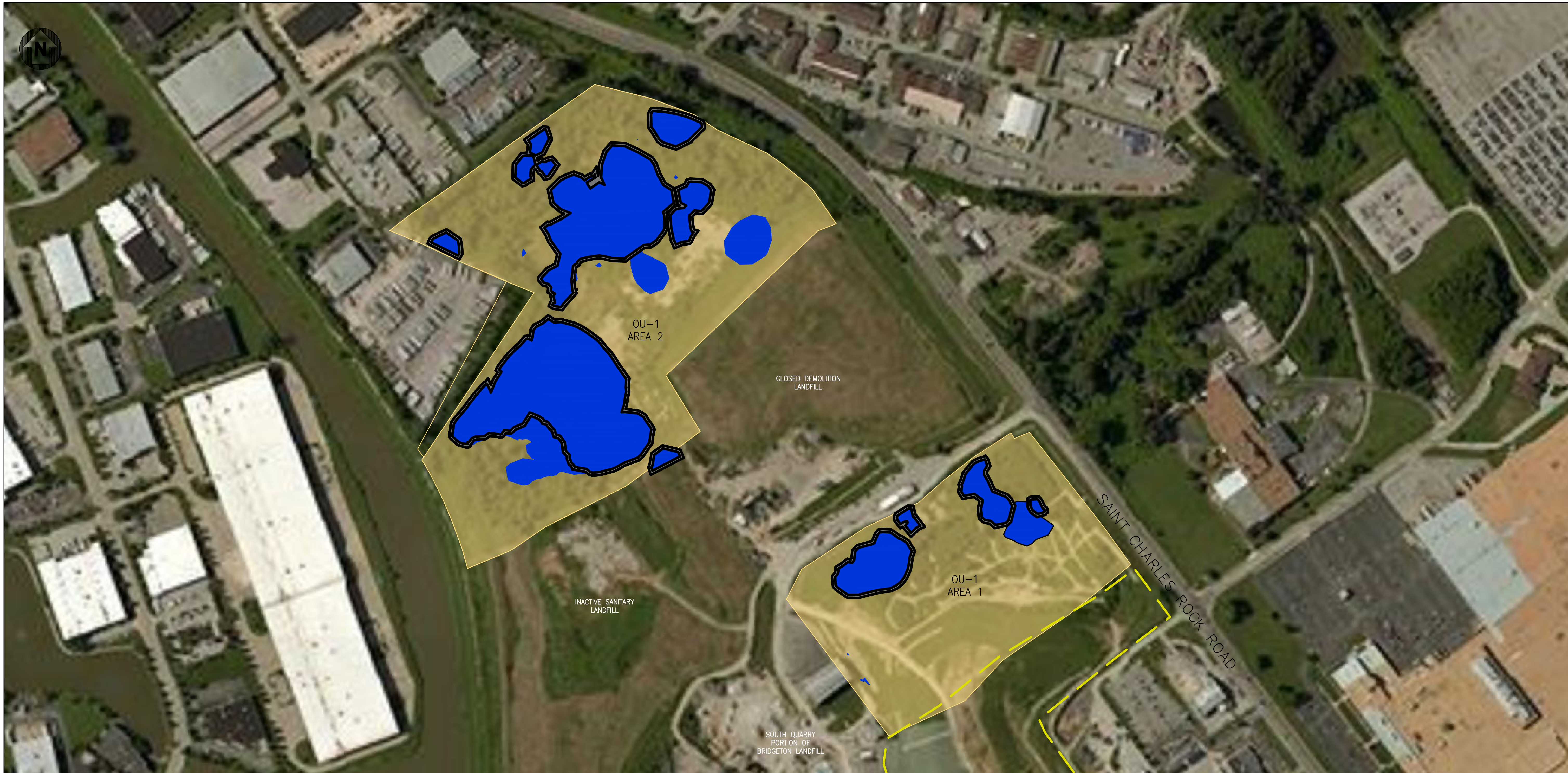


LEGEND:

LANDFILL BOUNDARY
BRIDGETON LANDFILL

RIM > 52.9 pCi/g

EXCAVATION AREAS (SLOPE SHOWN)

NOTE:
SMALL ARTIFACTS OF THE KRIGING ESTIMATE ARE SHOWN IN THIS MAP, HOWEVER THEY ARE NOT TARGETED AS PART OF THE EXCAVATION.

400 200 0 400 800

SCALE: 1"=400'

EXCAVATION BOUNDARY AND RIM >52.9 pCi/g FROM 0-20 FEET B2005GS

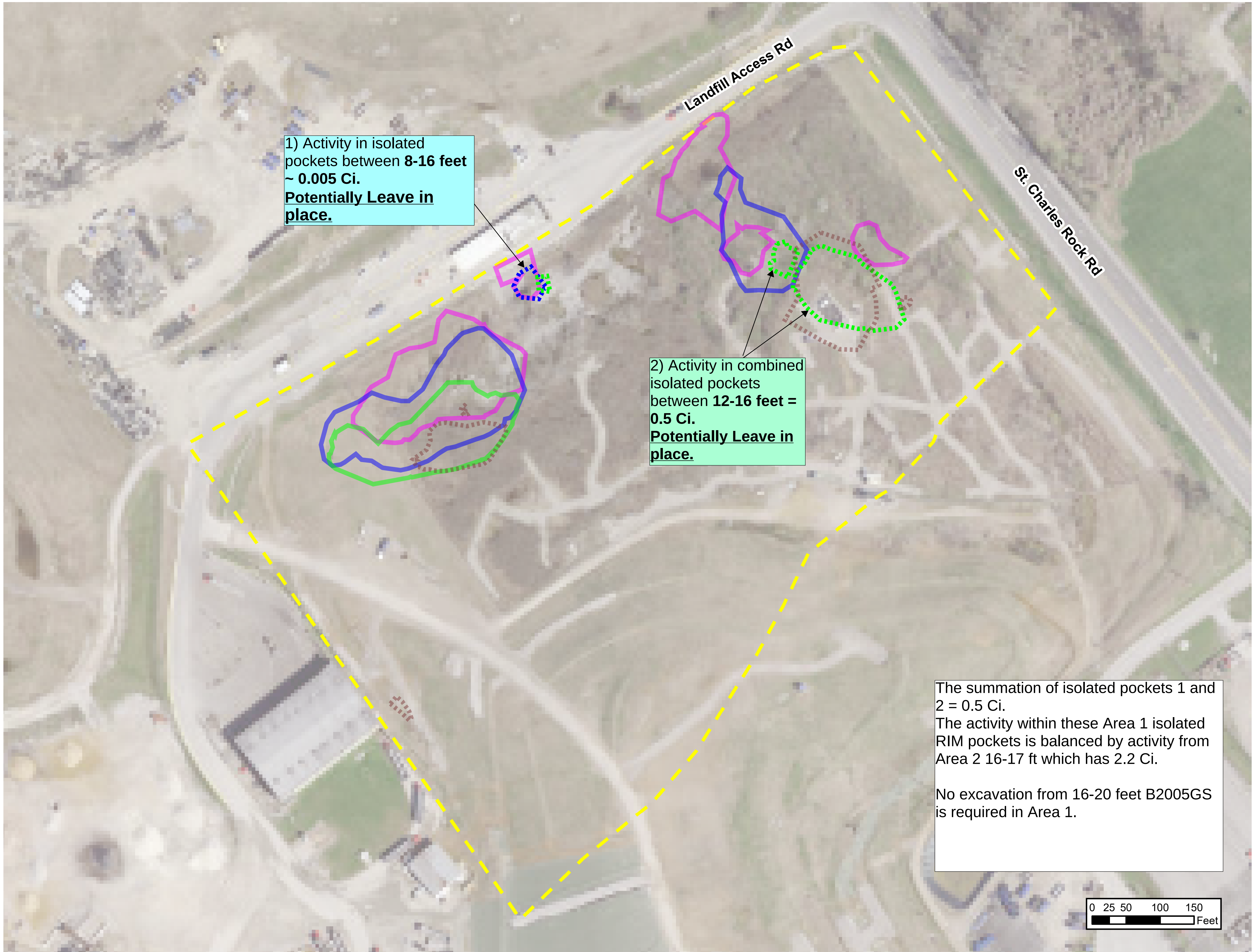
West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS

301 PLAINFIELD ROAD * SUITE 350 * SYRACUSE, NY 13212 * 315-451-9560

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
451662	01/07/20	JR	JS	12

FILE NAME: P:\WEST LAKE\10.0 TECHNICAL CATEGORIES\10.1 CAD\FIGURES\PRELIM_EXC_PLAN\REV-1\PEP-FIG-12-REV-1.DWG
PLOT DATE: 1/22/2020 10:06 AM PLOTTED BY: RUSSO, JILL



Legend

0 - 8 feet B2005GS RIM >52.9 pCi/g

8 - 12 feet B2005GS RIM >52.9 pCi/g

12 - 16 feet B2005GS RIM >52.9 pCi/g

16 - 20 feet B2005GS RIM >52.9 pCi/g

Solid line indicates area is to be excavated.

Dashed line indicates area is to be left in place.

~ identifies RIM < 0.1 and is considered to have less accuracy than higher values.

Area Boundary

N

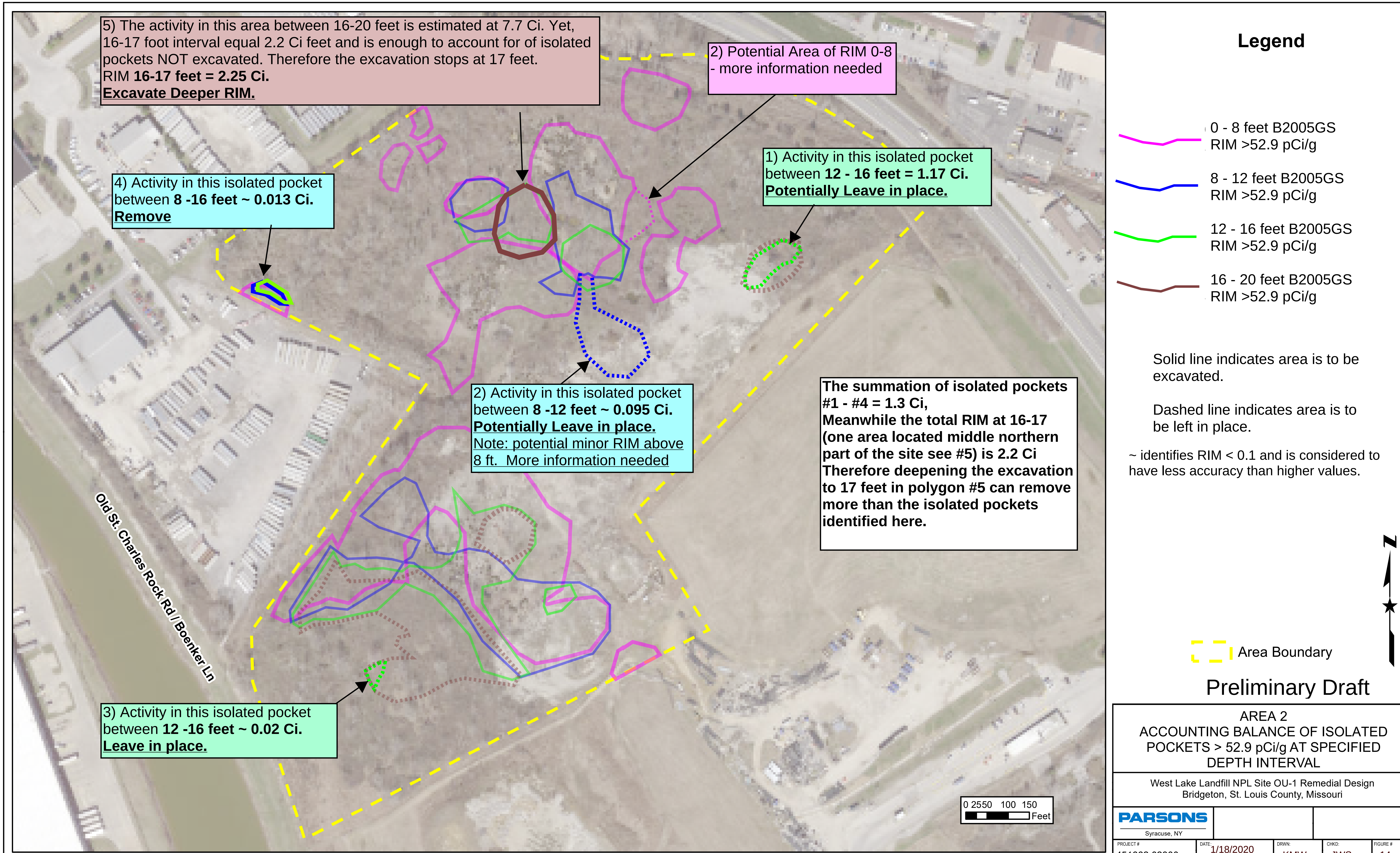
Preliminary Draft

AREA 1
LATERAL EXTENT OF RIM EXCEEDING
52.9 pCi/g AT SPECIFIED DEPTH INTERVAL

West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

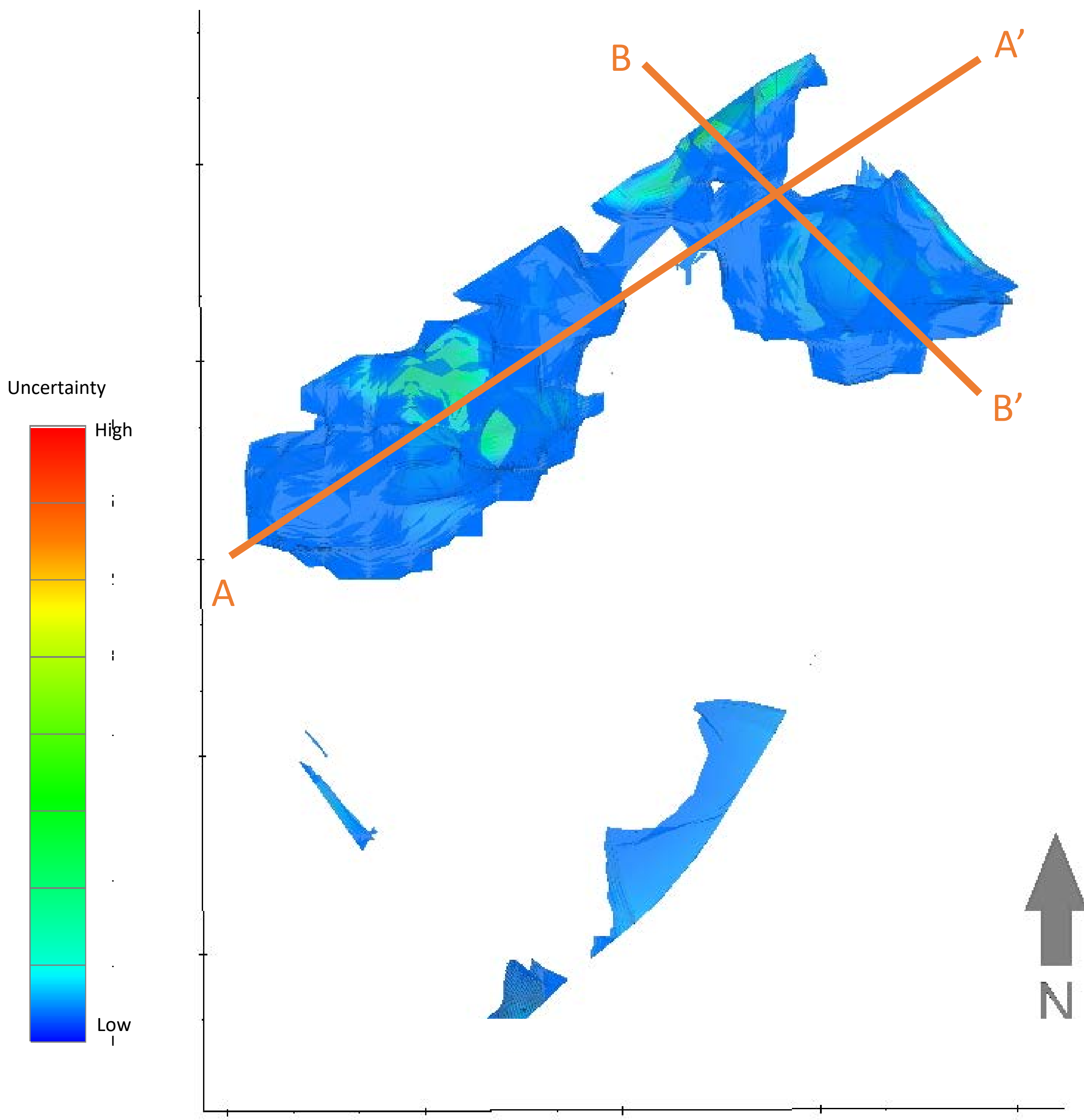
PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
451662.02300	1/18/2020	KMW	JWS	13



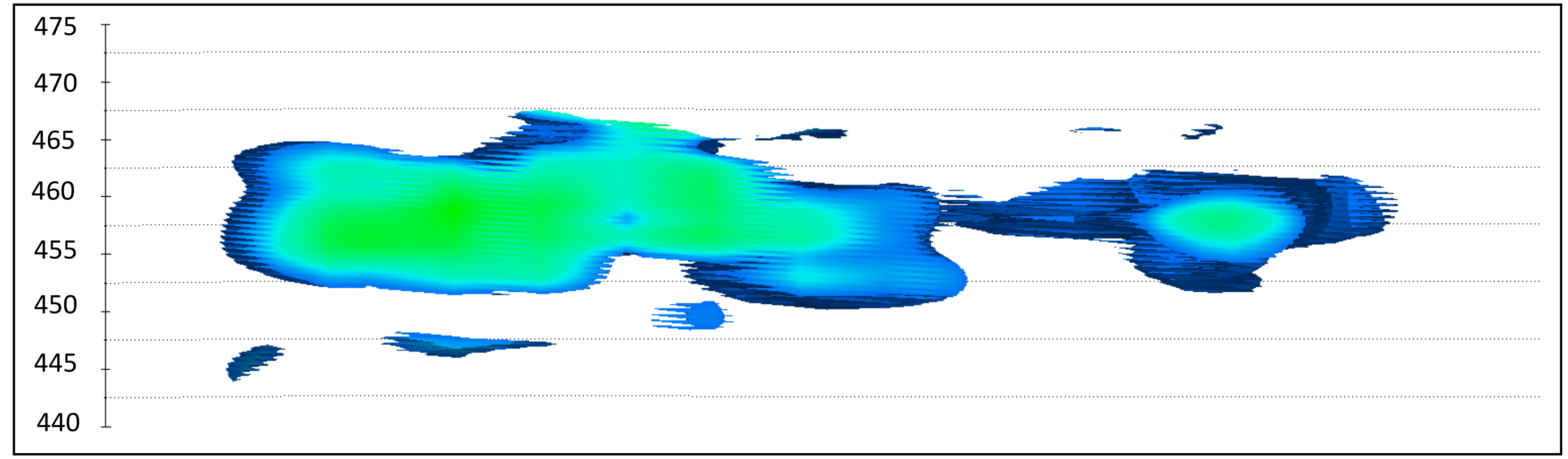
5) The activity in this area between 16-20 feet is estimated at 7.7 Ci. Yet, 16-17 foot interval equal 2.2 Ci feet and is enough to account for of isolated pockets NOT excavated. Therefore the excavation stops at 17 feet.
RIM **16-17 feet = 2.25 Ci.**
Excavate Deeper RIM.
2) Potential Area of RIM 0-8 - more information needed
1) Activity in this isolated pocket between **12 - 16 feet = 1.17 Ci.**
Potentially Leave in place.
4) Activity in this isolated pocket between **8 -16 feet ~ 0.013 Ci.**
Remove
2) Activity in this isolated pocket between **8 -12 feet ~ 0.095 Ci.**
Potentially Leave in place.
Note: potential minor RIM above 8 ft. More information needed
The summation of isolated pockets #1 - #4 = 1.3 Ci, Meanwhile the total RIM at 16-17 (one area located middle northern part of the site see #5) is 2.2 Ci Therefore deepening the excavation to 17 feet in polygon #5 can remove more than the isolated pockets identified here.
Old St. Charles Rock Rd / Boenker Ln
3) Activity in this isolated pocket between **12 -16 feet ~ 0.02 Ci.**
Leave in place.
0 2550 100 150
Feet
Legend
0 - 8 feet B2005GS RIM >52.9 pCi/g
8 - 12 feet B2005GS RIM >52.9 pCi/g
12 - 16 feet B2005GS RIM >52.9 pCi/g
16 - 20 feet B2005GS RIM >52.9 pCi/g
Solid line indicates area is to be excavated.
Dashed line indicates area is to be left in place.
~ identifies RIM < 0.1 and is considered to have less accuracy than higher values.
N
Area Boundary
Preliminary Draft
AREA 2
ACCOUNTING BALANCE OF ISOLATED POCKETS > 52.9 pCi/g AT SPECIFIED DEPTH INTERVAL
West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri
PARSONS
Syracuse, NY
PROJECT #
451662.02300
DATE:
1/18/2020
DRWN:
KMW
CHKD:
JWS
FIGURE #
14

Preliminary Draft

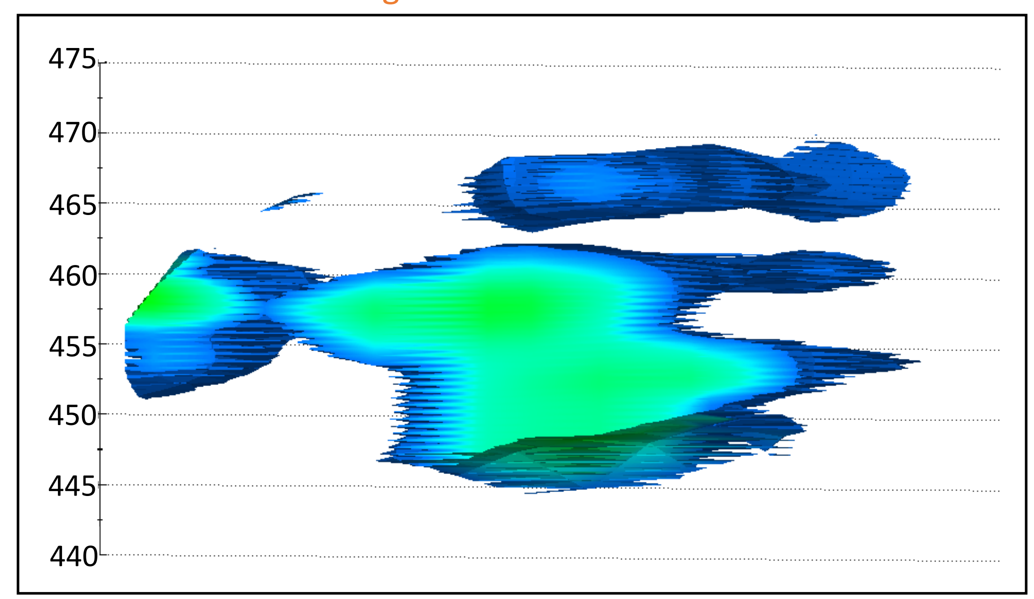
Plan view of uncertainty in of thorium in Area 1



A – A': Slice view looking in the north east direction



B – B': Slice view looking in the north east direction



Notes:

- Figure shows uncertainty of thorium in Area 1 from 0 to 20 feet B2005GS at greater than 5% of uncertainty scale to show more of the plume as compared with map in Attachment A.
- Slices are a vertical exaggeration of 8x, elevations in feet AMSL.
- Slices are through a 3D plume and shows some RIM "behind" the slice.

Area 1
Uncertainty Conceptualization

West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

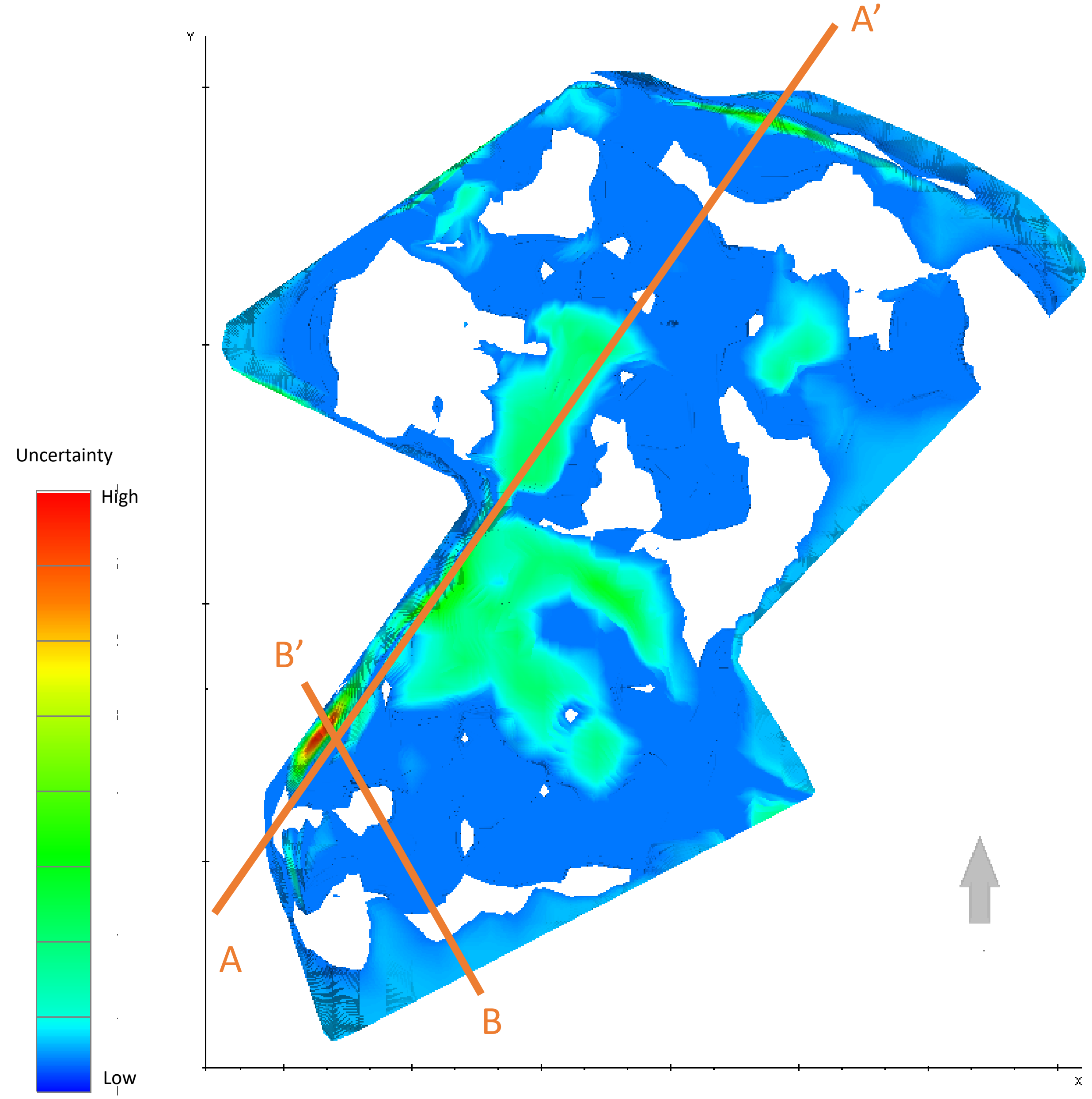
PARSONS
Syracuse, NY

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE:
451662.02300	1/8/2020	JWS	KMW	16

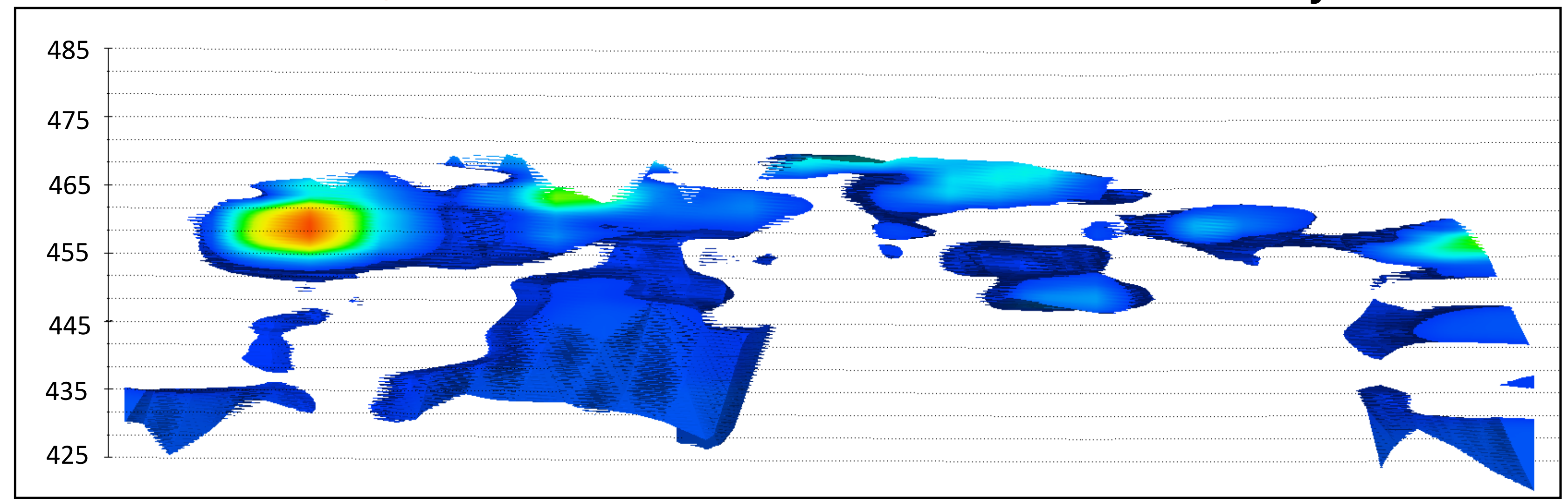
FILE NAME: P:\ WEST LAKE\\PREUM_EXC_PLAN\A1_A2_Th_0-20ft_5%: KMW - JWS

Preliminary Draft

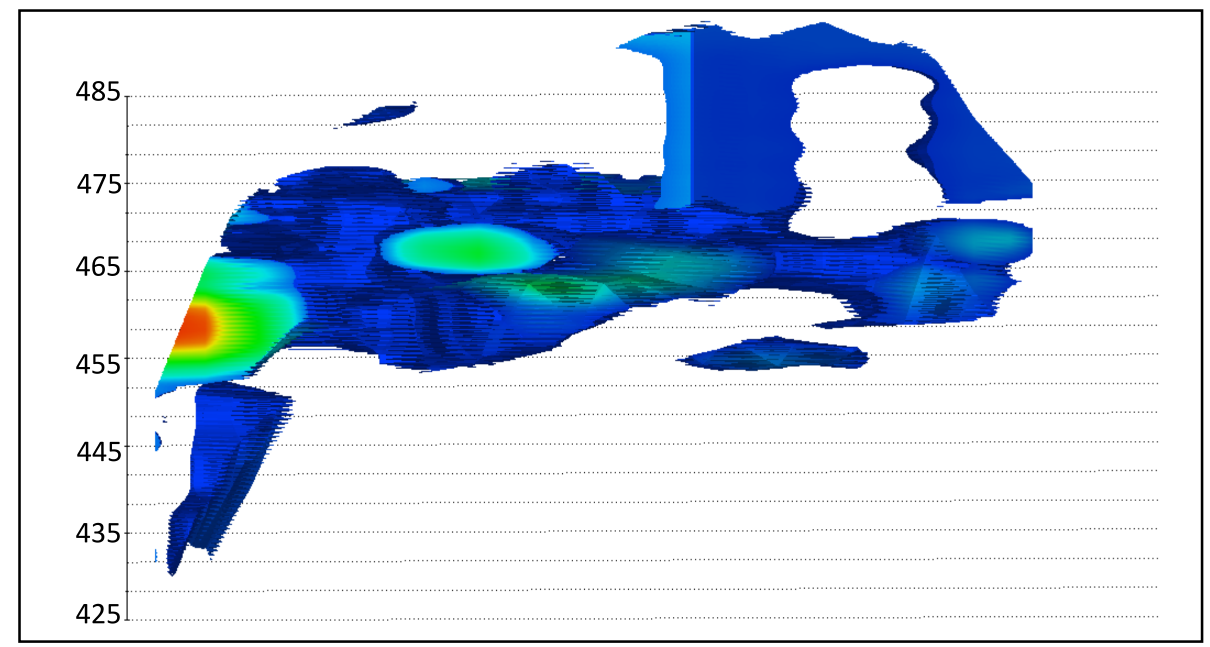
Plan view of uncertainty in of thorium in Area 2



A – A': Slice view looking in the north west direction



B – B': Slice view looking in the northeast direction



Notes:

- Figure shows uncertainty of thorium in Area 1 from 0 to 20 feet B2005GS at greater than 5% of uncertainty scale show more of the plume as compared with map in Attachment A.
- Slices are a vertical exaggeration of 8x, elevations in feet AMSL.
- Slices are through a 3D plume and shows some RIM "behind" the slice.

Area 2
Uncertainty Conceptualization

West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE:
451662.02300	1/8/2020	JWS	KMW	17

FILE NAME: P:\ WEST LAKE\\PREUM_EXC_PLAN\A1_A2_Th_0-20ft_5%: KMW - JWS

Appendix A – Geostatistical Analysis Technical Memorandum

Technical Memorandum

To: West Lake Team Date: 01/08/2020

From: Parsons Geostatistical Team

Subject: West Lake Geostatistical Details Regarding Preliminary Excavation Plan

1.0 Introduction

This Technical Memorandum provides a summary of the geostatistical analyses as related to estimation of three-dimensional (3D) extent of radiologically impacted material (RIM) within Areas 1 and 2 of Operable Unit 1 (OU-1) at West Lake Landfill, Bridgeton, Missouri. The analyses and estimates provided here were developed from the original work completed by S.S. Papadopoulos & Associates, Inc. (SSP&A) for the Final Feasibility Study (FFS) and documented in "Estimated Three-Dimensional Extent of Radiologically Impacted Material, West Lake Landfill Operable Unit 1, Bridgeton, Missouri" (SSP&A, December 2017). This document provides a summary of the expanded geostatistical model, model updates, and transition of the process to remedial design (RD), while relying on the extensive analyses and elaborate documentation from SSP&A (December 2017).

Under the RD phase of the remediation, the purpose of the West Lake geostatistical model is to support the design and construction of the proposed RIM removal through the following three categorical uses:

(1) Identification of areas and depths of RIM within OU-1 Area 1 and Area 2 that have greater than 50 percent (%) probability of being above 52.9 picoCuries per gram (pCi/g) in activity concentration.
(2) Supporting Record of Decision Amendment (RODA) total activity calculations in order to meet the removal requirements as summarized in the Design Criteria Report (Parsons, December 2019):
    a. "The RODA defines a requirement for the total radioactivity to be removed in the selected remedy to be equivalent to the total radioactivity represented

by the combined radium and thorium greater than 52.9 pCi/g down to 16 feet below the 2005 topographic surface." And, that:

b. "the RODA selected remedy generally requires removal of RIM greater than 52.9 pCi/g to a depth of 12 feet below the 2005 topographic surface but will include removal of some RIM between 12 and 20 feet below the 2005 surface and allow for isolated pockets of RIM greater than 52.9 pCi/g between 8 feet and 12 feet below the 2005 surface to remain in place."

(3) Support the Remedial Design Investigation through identification of additional borings with the intent of further delineating areas of RIM >52.9 pCi/g, improving accuracy of geostatistical modeling by improving correlations between hard data and soft data, and better defining RIM concentrations to facilitate meeting total activity removal requirements.

Due to the complexity and direct relationship to excavation design, item number two above (total activity calculations) is discussed in a separate technical memorandum (see Appendix B of the Preliminary Excavation Report).

Based on the three intended uses described above, the geostatistical efforts were set forth with the following objectives:

- Review and evaluate the previously completed geostatistical approach and determine if there are potential intrinsic failures, oversimplifications, or areas for potential improvement;
- Re-analyze the site data with the previous tools (e.g., IK3D software) to verify that the previous work by SSP&A could be re-created using the same tools and analysis;
- Migrate the analysis to software better suited to for the RD phase of work for integration into engineering calculations and designs;
- Conduct sensitivity analyses to determine if small changes in parameter values impact design outcome;
- Identify and document the process for estimating total activity as related to the objectives documented in the Revised Design Criteria Report (Parsons, December 2019); and
- Document the processes for integrating the geostatistical model to support the Remedial Design Investigation, with a focus on how geostatistical analysis can help identify locations for additional borings.

The analyses and processes used for meeting these objectives are described herein, with additional details provided in attachments.

The purpose of this memorandum is to describe the workflow, summarize the processes, and demonstrate future use / execution of the geostatistical application / model in order to meet requirements of the RODA and the Design Criteria Report (Parsons, December 2019). This was not an attempt to re-analyze, redevelop, or re-describe the multitude of tests and discussion that were previously completed and submitted to EPA (SSP&A, December 2017).

2.0 Previous Work

From 2016 to 2018 SSP&A completed geostatistical analyses utilizing various analytical techniques, which are summarized in SSP&A's 3D Extent of RIM report (December 2017):

> *"Estimates of the volume and extent of RIM were previously calculated and reported in 2016 in support of draft Remedial Investigation (RI) Addendum and Final Feasibility Study (FFS) documents, and in 2017 as an addendum to the revised RI Addendum (RIA) (EMSI, 2017a). The extent and volume estimates are used as one basis for the evaluation and costing of various potential excavation remedies. The extent and volume estimates have been updated over time to reflect changes in the underlying dataset, data selection rules, methods for incorporating the effects of landfill subsidence, and other factors. An accounting of the volume estimates provided during 2016 and 2017, and changes that occurred leading to revised volume estimates, is provided in Appendix G to this report."*

The geostatistical 3D model designed by SSP&A, which has been carried through into this Preliminary Excavation Plan, involves a complex history of data analyses, geostatistical routines, and 3D analysis, which is thoroughly documented in SSP&A (December 2017). This model was transitioned into the current platform (C-TECH EVS) while integrating the majority but not the totality of methods used by SSP&A. Aspects of the calculations completed by SSP&A that were not transitioned into the current work consisted of exploratory exercises undertaken during the FFS to evaluate the sensitivity of the RIM volume estimates to various assumptions and inputs, that ultimately were not integrated into the final SSP&A geostatistical model.

From a broad perspective, the geostatistical model can be summarized into the following steps which are provided in **Figure A-1**:

1) Data pre-processing to construct inputs for multiple indicator kriging (MIK):

- Hard data: development of preliminary continuous distribution functions (CDFs) and assignment of hard data to binary indicators above or below a particular activity concentration threshold (e.g. 52.9 pCi/g).
- Soft data: processing for removal of estimated background values followed by normalization of the background-adjusted response.
- Updating of CDFs based on correlation analysis between soft data and hard data.
- Translation of hard data and normalized soft data into indicator values based upon concentration thresholds. In each case, these indicator values are the equivalent of probabilities lying in the range from 0 to 1 (as in 0% to 100%) of the soft or hard data *not* exceeding particular specified activity concentration thresholds:
    - Hard data translate to either a 0 (meaning very likely above the threshold) or a 1 (meaning very likely below threshold).
    - Soft data translate to values on a continuum between 0 and 1 reflecting the fact soft data are indirect, rather than direct, measurements of activity concentration.

2) Geostatistical mapping:
    - Multiple indicator kriging via ordinary kriging of indicators values (i.e., the converted probabilities of non-exceedance of defined activity concentration thresholds):
        - Kriging of combined thorium (Th) and combined radium (Ra) separately
        - Selecting the *lower* interpolated non-exceedance probability (i.e. more likely to be above the activity concentration threshold) at each kriged grid node.
    - 3D mapping of kriged indicators (i.e., non-exceedance probabilities) at values indicating a greater than 50% probability (interpreted as “more-likely-than-not”) of exceeding activity concentration thresholds of interest – in this case, 52.9 pCi/g.

The development of this process over time by SSP&A was iterative, in that the advancement of a particular calculation or statistical test provided feedback on previous estimation processes. As such, revisions to previous assumptions and inputs were tested, and in some cases alternative procedures were implemented to evaluate the need to further revisit or modify inputs or assumptions. Many aspects of these evaluations of inputs, assumptions, and procedures were documented in SSP&A’s *Evaluation of Uncertainty* (Appendix I of SSP&A December 2017) which determined that the estimates of RIM volume and extent were quite stable over reasonable ranges of input values and assumptions. Additional sensitivity testing was completed during the transition from SSP&A’s FFS modeling and Parsons’ RD modeling, as discussed in the applicable sections below.

Beyond the overview workflow described above and provided in **Figure A-1**, additional sub-workflow is provided here to assist in the understanding of CDF development. **Figure A-2** provides an overview of the processes demonstrating that two different methods of CDF development were utilized: (1) Base Case CDF, and (2) continuous CDF (CCDF) Development.

For the base case development (Method 1) the following basic steps were taken (SSP&A, December 2017):

- Step 1 - Estimation of the global CDF based upon available hard sample results.
- Step 2 - Estimation of a CDF based upon the relationship between combined Ra or combined Th, and normalized gamma (both borehole and core, together) as supported by linear regressions.
- Step 3 - Combining of these two CDFs into a single CDF to represent combined information from the global hard sample data CDF and from the local normalized gamma measurements.

SSP&A summarizes the results of these steps as follows:

> *"The resulting final base case CDF was used as the basis for the singular estimates of RIM volume provided in the RIA and FFS documents, using the base case variograms detailed elsewhere in this report. The resulting final base case CDFs produced predictions of RIM extent that corresponded well with independent estimates and that also resulted in a relatively small number of artefactual (i.e., non-locally supported) predictions of RIM beyond or within the 3D convex hull of the hard and soft data, which could not be verified and were deemed undesirable as a basis for the development of approximate, comparative, excavation alternatives and costing within the FFS. The calculations completed using the base case CDFs were, however, subjected to further analysis and comparison with alternate approaches, as detailed in Appendix I "Evaluation of Uncertainty"."*

Development of the CCDF (Method 2) based upon regression analyses was completed for comparison to Base Case CDF (Method 1) and to support various evaluations of uncertainty in terms of RIM volume and extent. The following basic approach was taken in development of the CCDF as described in SSP&A (December 2017). What follows is a summary-level description of the approach that does not include all details and assumptions; see SSP&A (December 2017) for more information:

- Combined Ra and combined Th were separately plotted against normalized gamma responses, and loess lines (a type of locally-weighted regression) were fitted to the resulting scatter.
- Regressions were then undertaken on a subset of the data, placing reduced emphasis on lower values of Ra and Th (less than about 4) as well as two Ra values and 13 Th values for which normalized gamma was equal to zero.
- Error matrices were constructed, and an error analysis undertaken to evaluate and then mitigate any remaining apparent prediction bias (i.e., patterns of false-positive or false-negative predictions of RIM) obtained via the linear regressions.
- Resulting line-fits were mathematically described for predictions of combined Ra and combined Th from normalized gamma while specifying the standard error (SE) of the regression residuals.
- The CCDF was then constructed about the mean value (a standard practice for a CCDF) of the hard data that was predicted using the measured values of the soft data, the adjusted line fits developed on a scatter plot, and the standard error of the regression.

The resulting CCDFs were plotted with the intermediate and the Base Case CDF for graphical comparison. These CCDFs were also used as the basis for evaluating uncertainty as described in SSP&A (December 2017) Appendix I (*Evaluation of Uncertainty*). It should be noted that although the CCDF was developed for comparison and used as an alternative CDF, the final Base Case CDF (described in Method 1, above) was carried forward in the FFS and is used herein as the basis for the Preliminary Excavation Plan phase of the RD. Thus far all sensitivity analyses conducted by SSP&A indicate that the final Base Case CDF is appropriate, and the results are insensitive to small differences in the CDFs when comparing the volumes and extent of RIM >52.9 pCi/g. It is understood that as further data are collected and the geostatistical model is updated, additional CDFs can be evaluated as appropriate.

Figure A-3 provides the Base Base, intermediate, and CCDFs for radium and thorium along with the indicator values derived from the Base Case CDF.

3.0 Transition from IK3D to C-Tech EVS

3.1 IK3D

SSP&A used Fortran source code and executables for IK3D and subsequent post-processing programs to perform the multiple indicator kriging calculations (SSP&A, December 2017), obtain RIM, overburden and setback volume estimates, and complete other FFS calculations.

IK3D is a Fortran-based code developed for kriging 3D data sets available through the Geostatistics Software Library (GSLIB; http://www.gslib.com/ Deutsch and Journel, 1992). IK3D is an open source code for which the practitioner can develop custom programs and applications to fit their specific project needs. The IK3D output must be post processed (using a separate GSLIB-provided Fortran source code or other codes) and then the files must be translated in order to be displayed using a visualization software. IK3D was designed with the purpose of providing computational analysis and geostatistical estimation capabilities; it is not distributed with or accompanied by software designed for purposes of excavation engineering remedy design. A thorough description of kriging computation and the IK3D workflow is provided in SSP&A's technical report (December 2017). Given the transition from model research and development activities in support of the FFS to excavation engineering remedy design for the RD, it was determined that migrating the calculation process to familiar commercial software possessing additional desirable capabilities would facilitate efficient modeling processes and estimates and eliminate the need to further adapt source code. Furthermore, migrating to a very highly-capable commercial software package provides additional visualization and post-processing capabilities to facilitate RD calculations, collaboration and stakeholder engagement. This commercial software package together with its valuable capabilities, is described next.

3.2 C-Tech Earth Volumetric Studio

Parsons migrated the geostatistical model from IK3D to Earth Volumetric Studio (EVS, Version 2019.9) prior to submitting the Preliminary Excavation Plan. EVS is a well-known industry wide software developed by C-Tech Development Corporation (C-Tech), designed for the purposes of 3D modeling and visualization. The software performs kriging calculations using the same fundamentals as IK3D, but allows the user to simultaneously visualize, perform statistics, and export kriged data to engineering 3D design software. Transitioning to EVS involved confirming that the prior IK3D model could be reproduced in EVS under similar settings such as grid size, kriging parameters, etc.

The steps for EVS model development and transition from IK3D are as follows:

- Create input files based on SSP&A data sets, using SSP&A's established indicator thresholds and translation from activity concentration to probability of non-exceedance;
- Account for co-located data by choosing either the hard data point, or the highest RIM probability (lowest indicator value);

- Perform indicator kriging for combined radium and combined thorium separately using the same kriging settings (range, sill, reach, etc.) as IK3D;
- Combine the two (combined radium and combined thorium) data sets by choosing the lower indicator value (the value with the highest probability of RIM);
- Truncate the RIM extent at the 2005 topographical ground surface, and the Area boundary polygon;
- Visually compare the result to the IK3D model to ensure that RIM location and extents are equivalent;
- Compare RIM volume estimates obtained from EVS and IK3D model outputs; and
- Account for small differences in RIM volume by adjusting the kriging range (as discussed in Section 4).

As stated above, Parsons used the same process and parameters outlined by SSP&A, for the 52.9 pCi/g threshold, with minor exceptions of grid size and inconsequential differences in kriging parameters. The determination of these settings was accomplished by starting with SSP&A parameters, and then, where subtle differences were noticed, conducting iterative response testing to provide acceptable matches of: (1) volumes, and (2) spatial extent of RIM >52.9 pCi/g. Additionally, sensitivity analyses were conducted during and after this process to guide the determination of acceptable ranges of parameters that will not substantively change the outcome. Table A-1 (below) provides the list of relevant kriging settings comparing those from IK3D to EVS.

Table A-1. Kriging Parameters for IK3D and EVS

	IK3D		EVS	
Parameter	**Area 1**	**Area 2**	**Area 1**	**Area 2**
Grid Cell Size (x,y) (m^2)	Ranged 100-2000		225	225
Layer Thickness (ft)	0.5	0.5	0.5	0.5
Radium Sill	0.08	0.04	0.08	0.04
Thorium Sill	0.045	0.17	0.045	0.17
Range (X,Y for IK3D)	140	200	175	235
Range (z)	3.5	3.5	NA	NA
Anisotropy	40	57	40	55

NA - Not applicable

IK3D uses a horizontal and a vertical variogram while EVS uses a 3D variogram which includes a setting for anisotropy.

Updated January 23, 2020

IK3D uses a two-dimensional variogram for the horizontal direction and a separate variogram for the vertical direction. EVS uses a slightly different approach resulting in slightly different sill and range values (although the sill does not affect estimation, it only affects kriging confidence and uncertainty). Instead of applying a separate range length for the horizontal direction and the vertical direction, an anisotropy is applied to the range length, which accomplishes the same objective but with different parameter definitions. The range length for the horizontal direction in Area 1 is 140 feet and 3.5 feet in the vertical direction resulting in an anisotropy of 40 (140 feet/3.5 feet). The anisotropy for Area 2 is 55 feet, based on horizontal range of 200 feet and vertical of 3.5 feet. Sensitivity testing, discussed in Section 4, demonstrated that the results of volume and extent of RIM >52.9 pCi/g are insensitive to these parameters based on the applicable ranges over which would potentially vary.

3.3 Summary of Transition from IK3D to C-Tech EVS

Parsons maintained all of the same kriging parameters as SSP&A, except for the slight changes to the range length described above. The range length for both Area 1 and Area 2 are about 20% than used with IK3D (roughly 20%), as a result of the differing variogram types and conventions. These values were selected through iterative response testing with identification of optimal parameters that relate closely to previously SSPA model results. Final RIM volumes estimated using EVS software and parameters were within 0.1 % of the IK3D model for both Areas, indicating that the two models (IK3D and EVS) are in good agreement with each other.

4.0 Sensitivity Analyses

Sensitivity analyses were completed to determine the extent that changes in model parameters may affect the estimates of volume and extent of RIM >52.9 pCi/g. Sensitivity analyses were completed initially by SSP&A using IK3D for the FFS, and subsequently by Parsons using both IK3D and EVS. The analyses focused on a variety of parameters, including variogram parameters used with IK3D, alternative CDFs, grid size, and variogram parameters used with EVS.

4.1 Summary of SSP&A Uncertainty Evaluation (Appendix I Geostatistics Report)

This section summarizes the work done by SSP&A (as detailed in Appendix I of the Geostatistics Report, December 2017) which evaluated the sensitivity of RIM volume and extent estimates and demonstrated that within a reasonable range of variogram setting and CDFs there is no appreciable change in RIM extent or volume.

SSP&A performed an uncertainty analysis on the prediction of RIM extent above three proposed RIM threshold values (7.9, 52.9, and 1,000 pCi/g) plus an intermediate threshold used to span the range between 52.9 and 1000 pCi/g (i.e., 500 pCi/g). The purpose of this analysis was to employ alternate and viable indicator kriging inputs and assumptions to both determine the sensitivity of the model to the CDF, the variograms, and the search strategy, while also confirming that the method chosen is the appropriate choice for estimating RIM extent and volume. The analysis involved performing indicator kriging calculations using the following alternatives: (1) the Base Case CDF and variograms; (2) alternate CDF and Base Case variograms; and (3) both alternate CDF and alternate variograms. The third method (alternate CDF and alternate variograms) also included two variants: (3a) using the base case search strategy; and (3b) using an alternate search strategy.

Method 2 was designed with the purpose of determining the relative effect of the CDF on the estimated RIM volume and extent. An alternate CDF was developed with the same soft data used for the Base Case CDF, but with additional linear regression and error matrix evaluations.

Method 3 was designed with the purpose of determining the relative effect of the variograms on the estimated RIM volume and extent. The Base Case variogram was established around the 52.9 pCi/g threshold, assuming "*all parameters of the horizontal variogram could be reasonably assumed to be equal across all thresholds*" (SSP&A, December 2017). The alternate variogram was "*developed in an attempt to match the noisy empirical data and reflect what might be expected in a more natural setting. For each of the four kriging thresholds (7.9, 52.9, 500, and 1000 pCi/g), for each of the hard data constituents (combined Ra and combined Th), and each of the two Areas, an empirical variogram was calculated from the data and a plausible model fit to the empirical variogram*" (SSP&A, December 2017). These construction of these alternate variograms resulted in different range lengths for each of the thresholds, hard data constituents, and Areas.

Methods 3a and 3b were developed with the intent to explore the effects of the search strategy (the reach) on the results. The search strategy is determined by the practitioner in a spatial model. The search strategy, or reach, is the distance at which the model will continue to search for sample locations for use in an indicator kriging calculation at a certain point in the grid. In other words, the search strategy "*is used to construct a three-dimensional ellipsoid centered on each un-sampled location, from which data will be considered to make the kriging estimate at* *that location*" (SSP&A, December 2017). The base-case search ellipsoids are 280 feet in the horizontal direction and 20 feet in the vertical direction for Area 1; and 400 feet in the horizontal and 20 feet in the vertical for Area 2. The alternate search ellipsoids for Method 3b are double the range for the alternate variograms from Method 3. They are 220 feet in the horizontal direction and 20 feet in the vertical direction for Area 1; and 600 feet in the horizontal direction and 20 feet in the vertical direction for Area 2.

The results of the uncertainty analysis are shown in **Figure A-4** (as presented as Figure I-3 in SSP&A, December 2017). SSP&A describes the figure as representing:

> "*results from indicator kriging for one concertation threshold, for one Area (recall that both combined Ra and combined Th are evaluated together as an "either-or", to calculate volumes from the indicator kriging). In each panel of Figure I-3 the x-axis is the volume (in cubic yards) calculated from the indicator kriging output, and y-axis represents the cumulative non-exceedance probability that was used to post-process the indicator kriging output. As a results each line on the graph represents the volume of RIM calculated above the corresponding threshold (top panels 7.9: middle panels 52.9, bottom panels, 1,000) for each of the Areas (left panels Area 1: right panels Area 2) for 9 cumulative probability deciles of the posterior CCDF (0.1 through 0.9)*" (SSP&A, December 2017).

The 52.9 pCi/g portion of **Figure A-4** demonstrates that, across a range of settings, the indicator kriging produces remarkably similar estimates of the volume and extent of RIM >52.9 pCi/g for each Area, indicating the model is relatively insensitive to the CDF, variograms, and search criteria. This insensitivity is likely the result of the strategic collection of data both horizontally and vertically to delineate and constrain areas of RIM.

4.2 Grid Size Evaluation

Sensitivity testing was conducted on grid size to evaluate the most optimal grid size while considering both computational efficiency and spatial resolution. This analysis focused on the 52.9 pCi/g concentration since this value was established as the removal activity concentration in the RODA.

The previously reported IK3D base model emphasized a grid size of 25 square meters (16.4 by 16.4 feet) with other calculations made using a grid size of 100 square meters (32.8 by 32.8 feet), in each case using a vertical discretization of 0.5 feet. The grid size was suitable for the data density in both Area 1 and Area 2 for initial geostatistical model development; however, it was computationally time consuming and provided higher resolution than will be necessary for the excavation design.

The IK3D model was recreated using the following grid dimensions in each area: 25, 100, 500, 1,000, and 2,000 square meters in order to test the sensitivity of these grid options on the estimated RIM volume and extent. In all cases, the vertical discretization of 0.5 feet was maintained. RIM extent in each grid size scenario was compared both visually, through comparison of maximum RIM extent in plan view (**Figures A-5** and **A-6**), and by comparing the RIM volume (**Figure A-7**). For both Areas, visual inspection shows that the general locations of RIM are maintained, but the shape and extent are altered when using the different grid sizes. This is in part due to the grid size increasing beyond the average or typical data density, resulting in some data points being effectively averaged with other nearby data points. While the spatial extent appears to be visually altered, the estimated volumes stayed within 15% of the original estimate for Area 1, and 10% for Area 2. The largest observable changes in volumes are at grid sizes 1000 square meters and 2000 square meters. As a result, it was determined that 225 square meters (15 by 15 meter grid cells) was the most appropriate for adequately estimating RIM extent and volume while providing realistic design basis calculations.

4.3 Parsons EVS Sensitivity Analysis

During the transition from IK3D to EVS, the sensitivities of the kriging parameters (range and sill) on RIM volume estimates were tested. Estimating the relative sensitivity of the spatial model to the kriging parameters provides a qualitative analysis of uncertainty of the geospatial model's ability to predict RIM extent. Similar to SSP&A's uncertainty analysis, Parsons examined the effects of range length on the RIM volume estimates in EVS.

The analysis was completed by holding all parameters in the kriging estimation process constant except for the sill and the range. The range was altered while holding the sill constant, and the sill was altered while holding the range constant.

To minimize differences between radium and thorium kriging estimation methods, the range and the sill were altered equally for both radium and thorium prior to combining the data sets (i.e., thorium range was adjusted by the same amount as radium range as opposed to having two different ranges for the two data sets). The anisotropy remained constant for the analysis since the range length in the horizontal and vertical directions are related by the anisotropy (i.e., adjusting the range length in horizontal direction, the range length in the vertical direction is proportionately adjusted by the value of the anisotropy). The formal sensitivity analysis focused on Area 2, while recognizing that, during initial parameter adjustment in Area 1, testing provided comparable RIM volumes to the IK3D model, and the results proved similar volumes to that of Area 2.

Figure A-8 provides the results of the sensitivity runs and parameters plotted against the RIM >52.9 pCi/g volume in cubic yards. In general, adjusting the range beyond 200 feet (SSP&A's range length) had a minimal effect on the RIM volume, changing it less than 7%. A range length of 100 feet produced the largest change in RIM volume, dropping it by 78%. A range length below 100 and above 500 feet is not reasonable given the data density and variograms, which is confirmed by the testing.

As anticipated (because of how kriging mathematics is applied), the RIM volume and extent are completely insensitive to the sill. However, the sill directly relates to the variance, which directly affects the kriging estimation or prediction errors (see Section 5 of this memorandum for discussion of kriging results for locating additional borings). While the general patterns of uncertainty and confidence do not change by adjusting the sill, the relative confidence and uncertainty values are affected. This is also discussed further in Section 5 of this memorandum.

In summary, the estimates of RIM volume and extent are generally robust (insensitive) over reasonable values of the range length; and as anticipated, the volume and extent are insensitive to the value of the sill, although the absolute magnitude of the kriging prediction error variances change with changing sill value. Based on these results, all kriging input parameter values are maintained between IK3D and C-Tech EVS with the exception of the range length, which is adjusted moderately to produce an equivalent RIM volume (Table A-1).

5.0 Geostatistical Model for Supporting Preliminary Design and Additional Boring Locations

The geostatistical 3D and visualization model provides a method for quantitative identification of potential additional boring locations to support the Remedial Design Investigation. There are three main objectives for identification of potential additional boring locations which the geostatistical model will support:

- Further delineating areas of RIM >52.9 pCi/g;
- Further evaluating and improving upon previously determined correlations between soft data and hard data; and

- Further defining activity concentration estimates in support of meeting total activity requirements.

The geostatistical model assists in locating additional borings by first providing visual 3D demonstration of where RIM is >52.9 pCi/g compared with existing borings and samples through a traditional type of exercise, where maps of RIM are compared with locations and depth. This standard investigation technique involves professional judgement and (usually) a team of professionals reaching shared agreement on where to obtain additional samples. This qualitative approach can be enhanced through parameters defined in the kriging process and with EVS. Spatial parameters, “confidence” and “uncertainty”, can be mapped similar to RIM, providing a statistically-derived depiction of the relation between data distribution, density and potential data gaps.

Within any kriging algorithm the solution of the kriging system of equations provides additional information beyond the estimated value - such as the kriging prediction error variance (or standard deviation) - at every grid cell or node, in order to determine the weight which is then applied to the estimated value (see SSP&A [December 2017] for a detailed discussion of kriging and example calculation). As explained in the C-Tech manual (C-Tech EVS 2019): “*Inherent in the kriging process is the determination of the expected error or Standard Deviation at each estimated point. As we approach the location of our samples, the standard deviation will approach zero (0.0) since there should be no error or deviation at the measured locations.*” From the standard deviation EVS estimates the “confidence” associated with the prediction made using the kriging model. While the use of confidence is related to standard deviation and thereby a component of the kriging, it also provides a spatial parameter which can be mapped and used as a tool for locating additional borings. Mapping confidence is then a semi-quantification of data density and, conversely, indicates where additional sample collection might be needed. In other words, where kriging confidence is low, additional borings can be considered. Given that confidence is calculated without considering the concentration value, and that most boring programs are purposely biased toward areas of higher concentrations, it is usually the case that uncertainty is highest around the outside of a site area where there are fewer sample locations and each kriging estimate is usually supported by a smaller number of sample values than within the interior of the data domain. This is further explained in the C-Tech manual (C-Tech EVS 2019):

> “*At first glance, confidence seems to be a reasonable measure of site assessment quality. If the confidence is high (and we are asking the right question), we can be assured of the*

reasonableness of the predicted values. You might be tempted to collect samples everywhere that the confidence was low…But, there is a better, more cost-effective way. Instead of focusing on every place where confidence was low, we could focus on only those locations where there was low confidence and where the predicted concentration was reasonably high. We make that easy by providing the Uncertainty.

In EVS, uncertainty is high where concentrations are predicted to be relatively high…but the confidence in that prediction is low. If the goal is to find the contamination, using uncertainty allows for more rapid, cost effective site assessment"

"NOTICE: Uncertainty values should be considered unitless and their magnitudes cannot directly be used to assess the quality of a site assessment. Please observe the following precautions:

- *Use Uncertainty as it was intended, as a guide to locations needing additional characterization.*
- *Do not use Uncertainty values directly to assess the quality of a site assessment*
- *A 50% reduction in Uncertainty magnitude cannot be construed as a 50% improvement in site assessment"*.

Figures A-9 through **A-30** provide a mapped representation of radium and thorium in Areas 1 and 2. From each of these maps the reader can gain appreciation for areas of high versus low "confidence" and high versus low "uncertainty". Furthermore, these maps are included in a layered PDF, provided as **Figures 4** and **5** of the Preliminary Excavation Plan, of which this geostatistical memorandum is an appendix. The layered PDFs give the reader the ability to turn layers "on" and "off" thereby graphically helping the reader identify spatial relationships. Through graphical representation of previous boring locations, RIM > 52.9 pCi/g, kriging confidence and kriging uncertainty, analysts can identify potential locations for additional borings and sample depths during the Remedial Design Investigation Phase.

The scale bar for the confidence and uncertainty maps represents the parameter (i.e. uncertainty or confidence) scaled across different depth intervals. Therefore, not all colors may be visible on one particular map or view. The map is a 2D view of a 3D thickness, and due to this third dimensionality the scale range is not always represented on the map. The view from straight above (as shown on map) only shows the value as they exist on upper limits of the three-dimensional object, therefore, all of the color scale may not be represented on one map. In some cases, the lowest confidence and highest uncertainty may exist inside the shell or within a different depth interval (on a different map). Cross-section views were also developed through the Area 1 and 2 plumes to help demonstrate this concept (see additional **Figures A-29** and **A-30** for an example). During the Design Investigation Work Plan development, additional maps will be provided to further support this concept.

The maps are truncated at a particular scale to help focus the reader on areas where confidence is relatively low and uncertainty relatively high. For example, the black areas (no color shading) on the confidence maps represent areas where confidence is greater than 75% (areas where RIM >52.9 pCi/g is delineated relatively well) and the black areas on the uncertainty maps represent areas where uncertainty is less than 10% (again, areas where RIM >52.9 pCi/g is delineated relatively well). In both cases it can be observed that the non-color shaded areas are where there are a relatively higher number of sample locations. The sample locations dictate confidence, while confidence and concentration dictate uncertainty.

6.0 Calculations for Meeting Total Activity Removal Requirements

As part of the geostatistical modeling, calculations of RIM activity can be completed in order to support removal requirements as summarized in the Design Criteria Report (Parsons, December 2019): "*The RODA defines a requirement for the total radioactivity to be removed in the selected remedy to be equivalent to the total radioactivity represented by the combined radium and thorium greater than 52.9 pCi/g down to 16 feet below the 2005 topographic surface.*" With the additional conditions that: "*the RODA selected remedy generally requires removal of RIM greater than 52.9 pCi/g to a depth of 12 feet below the 2005 topographic surface (B2005GS) but will include removal of some RIM between 12 and 20 feet B2005GS and allow for isolated pockets of RIM greater than 52.9 pCi/g between 8 feet and 12 feet B2005GS to remain in place.*"

An overview of this process is provided here, with the details provided in *West Lake Activity Calculations for Preliminary Excavation Plan Technical Memorandum* (Appendix B of the Preliminary Excavation Plan).

Figure A-29 gives a general overview processes for total activity calculations, which includes three components:

(1) Estimating the 3D extent of RIM;
(2) Estimating the activity concentrations within the RIM extent (from component 1, above); and
(3) Combining the volume and activity concentration results to estimate the total activity.

Total activity values for Areas 1 and 2 will be achieved by utilizing 3D kriging methods on activity concentrations for combined radium and thorium (see the separate memorandum regarding these calculations for more detail).

At this time, the overall process is provided to enable a preliminary understanding/ estimate of relative levels of activity with depth, as well as examples of how net total activity can be estimated (and eventually achieved) while leaving some isolated pockets of RIM >52.9 pCi/g between 8 and 16 feet B2005GS in place through the removal of "make-up" RIM between 16 and 20 feet B2005GS. This is an exercise of accounting for and balancing of the RIM >52.9 pCi/g and therefore the calculations are of a relative nature. Therefore, this relative calculation is a comparison of activities between different depths (and areas) using the same mathematical process. Because the same mathematical process is applied to each depth interval and / or spatial extent, the relative estimated comparison is valid for the purposes of meeting the RODA requirements.

7.0 References

C-Tech Development Corporation (C-Tech), 2019. Earth Volumetric Studio Help System, Ver. 2019.7. https://www.ctech.com/studio_help/Default.htm. Accessed December 10, 2019.

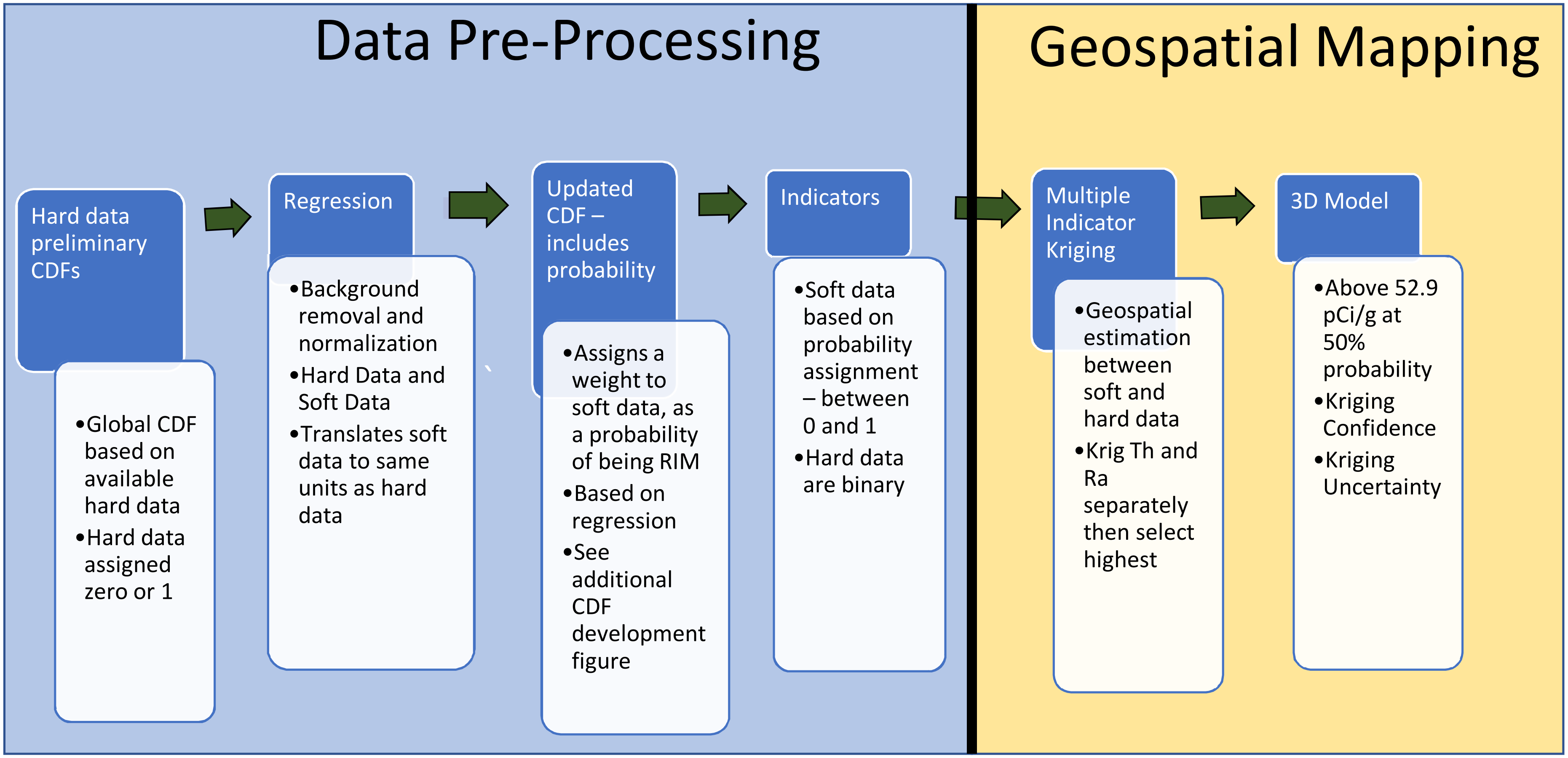
Deutsch, C., and Journel, A. 1992. GSLIB: Geostatistical Software Library and User's Guide. Oxford University Press. 340 pp.

Parsons, 2019. Design Criteria Report, West Lake Landfill Superfund Site Operable Unit 1. December.

S.S. Papadopulos & Associates, Inc. (SSP&A), 2017, Estimated Three-Dimensional Extent of Radiologically Impacted Material, West Lake Landfill Operable Unit-1, Bridgeton, Missouri, December 22.

USEPA, 2018. Record of Decision Amendment West Lake Landfill Site, Bridgeton, Missouri Operable Unit 1. September.

FIGURES



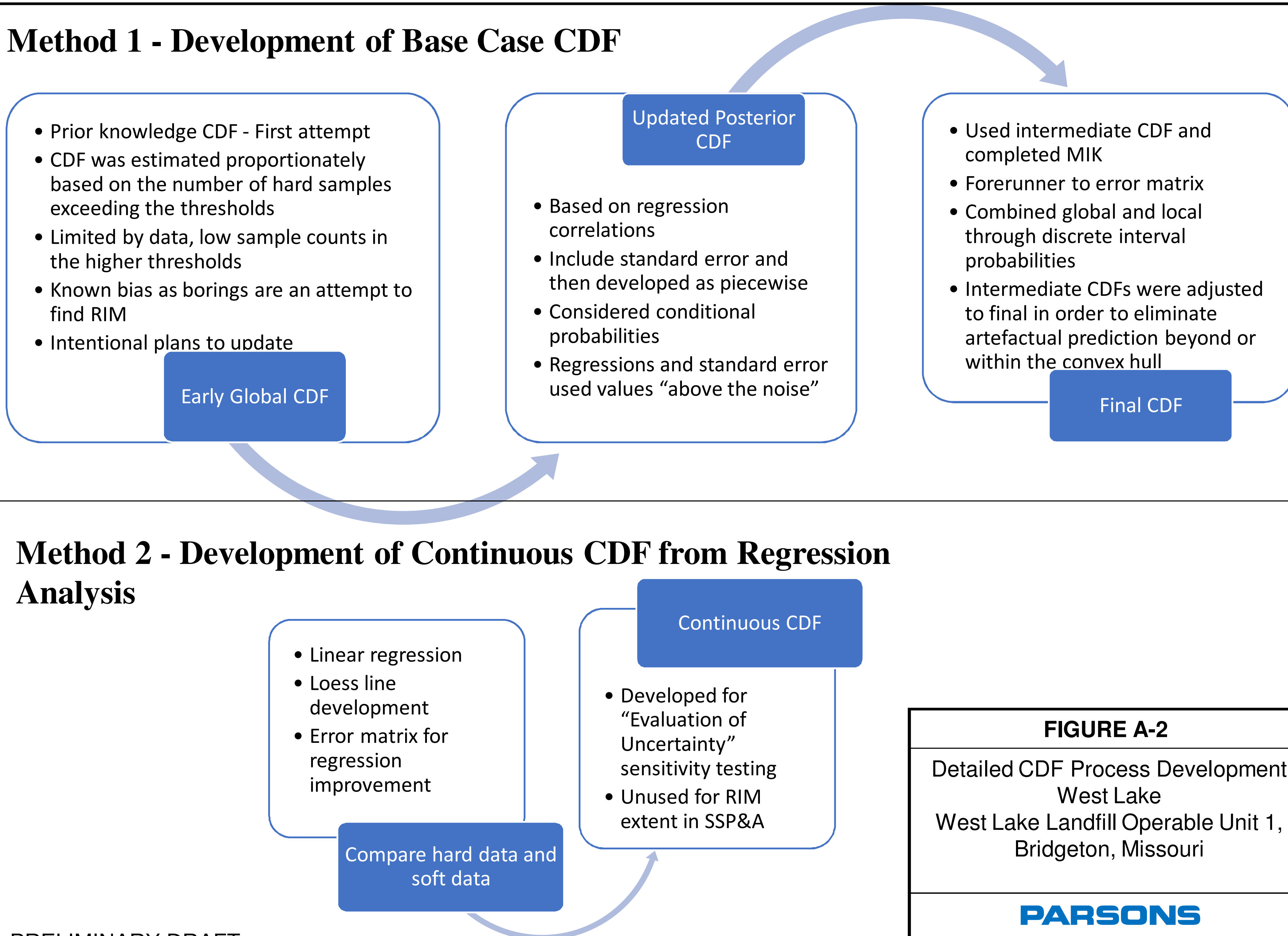
PRELIMINARY DRAFT

FIGURE A-1

Data Processing Workflow
West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY



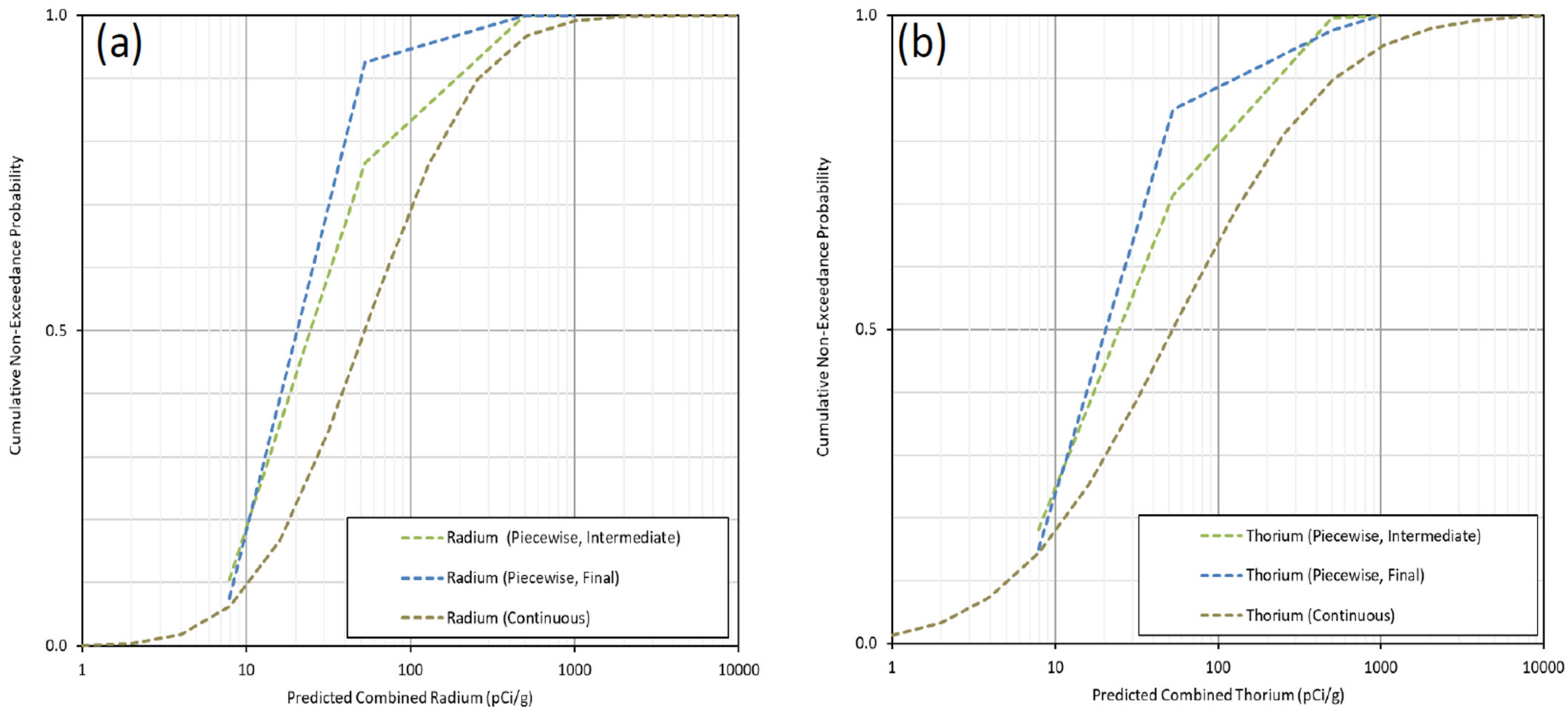
PRELIMINARY DRAFT

FIGURE A-2

Detailed CDF Process Development
West Lake
West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY



PRELIMINARY DRAFT

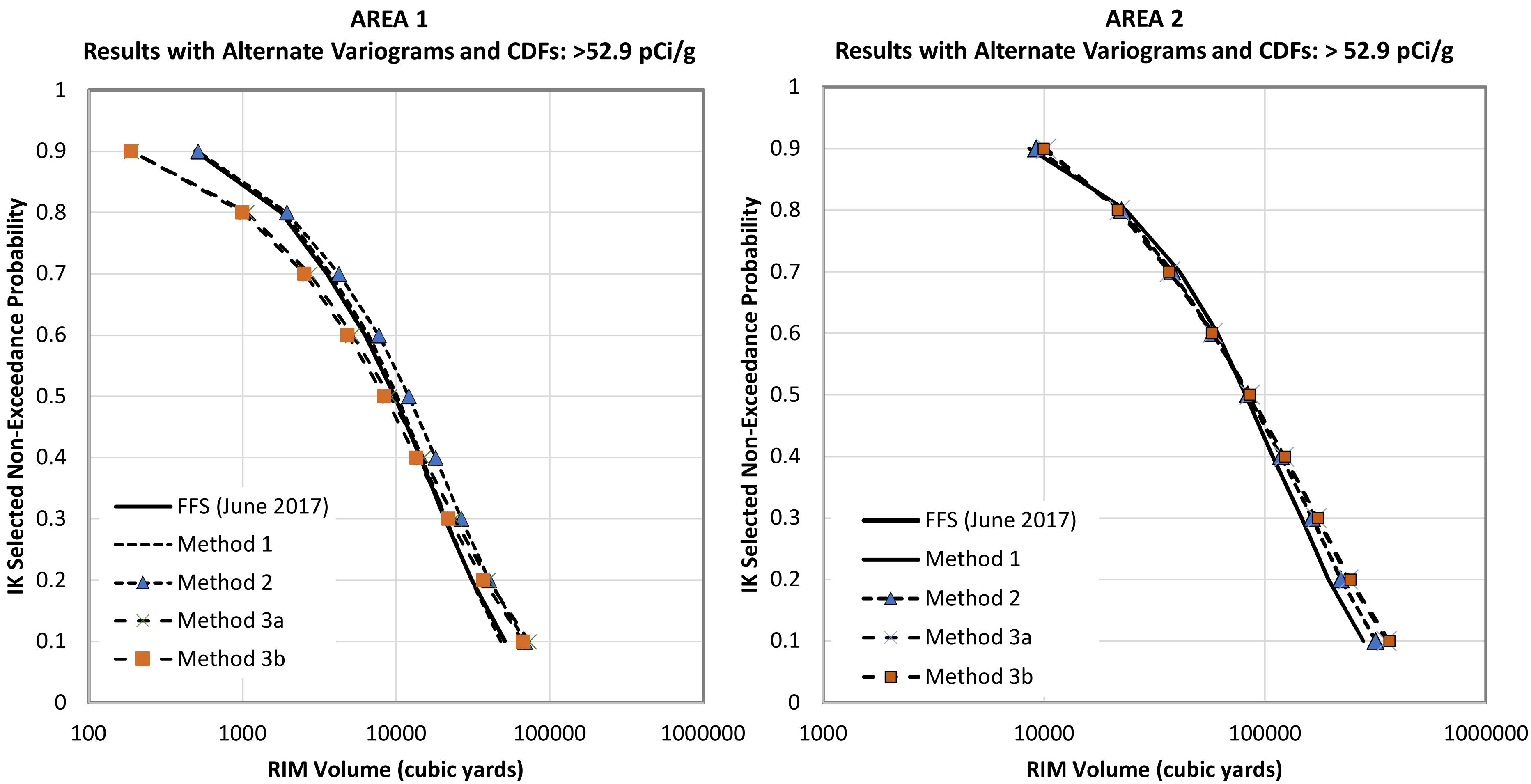
Soft Data Indicators for 52.9 pCi/g RIM		
Range (pCi/g)	**Indicator Threshold Probability of Non-Exceedance**	
	Thorium	Radium
< 7.9	0.975	1.00
7.9 < X <52.9	0.850	0.925
52.9 < X < 500	0.150	0.075
500 < X < 1000	0.025	0.00
> 1000	0.00	0.00

FIGURE A-3

CDF from SSP&A with Associated Indicator Threshold for Soft Data
West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY



PRELIMINARY DRAFT

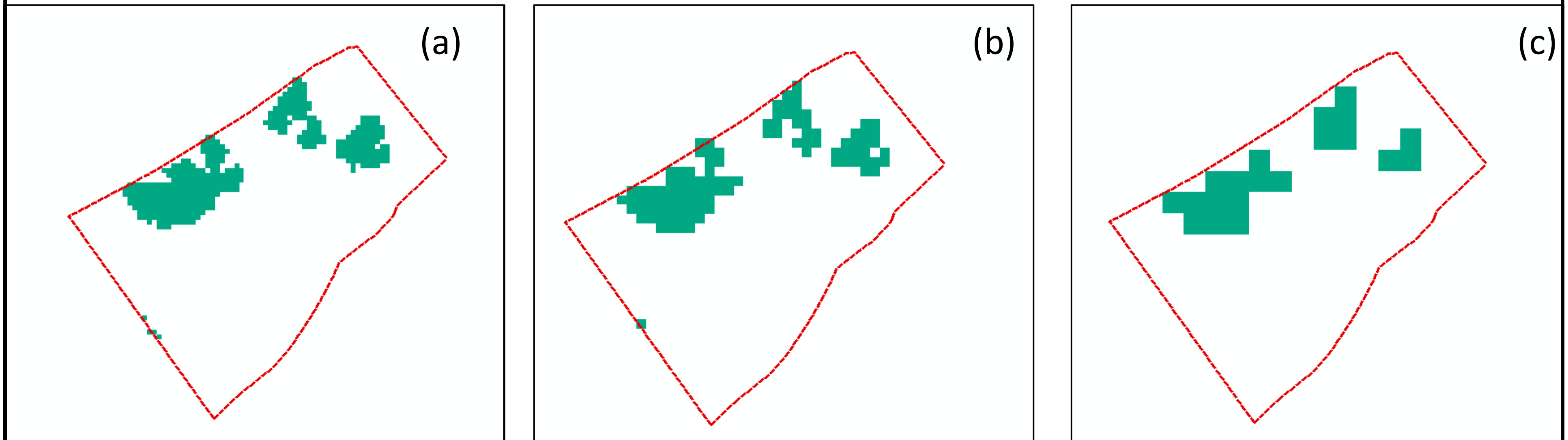
FIGURE A-4

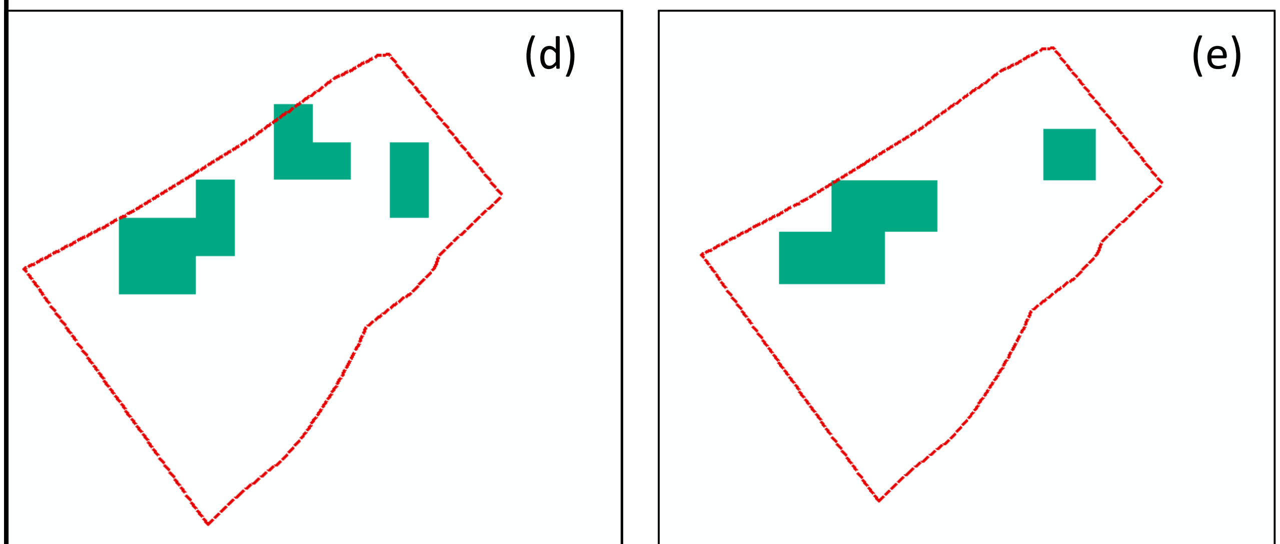
SSP&A Uncertainty Analysis

West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY





Grid Sizes:

(a) 25 square meters
(b) 100 square meters
(c) 500 square meters
(d) 1000 square meters
(e) 2000 square meters

Notes: Polygons represent maximum RIM extent in plan view

PRELIMINARY DRAFT

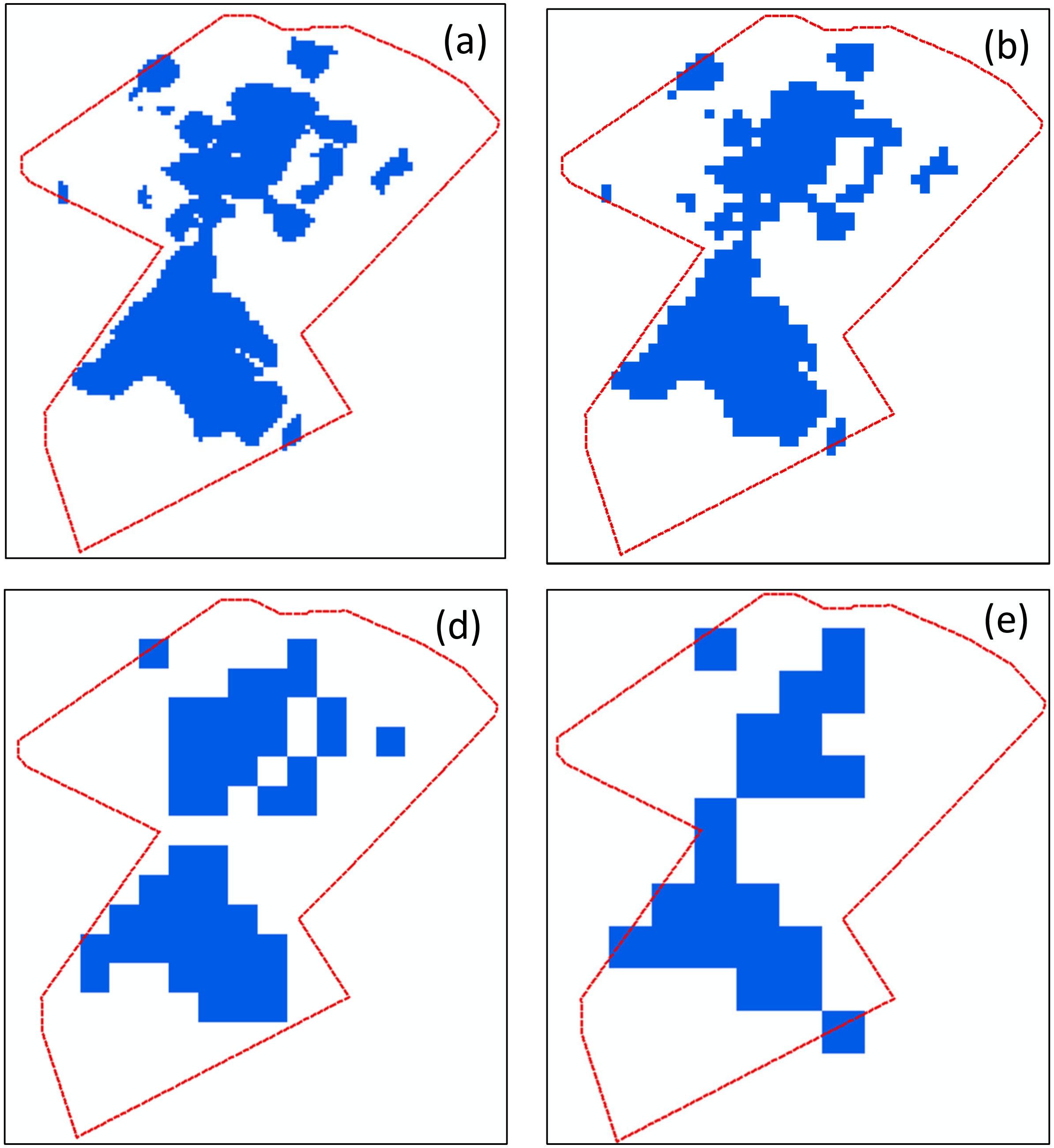
FIGURE A-5

IK3D Grid Size Assessment – Area 1

West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY



Grid Sizes:
(a) 25 square meters
(b) 100 square meters
(c) 500 square meters
(d) 1000 square meters
(e) 2000 square meters

Notes: Polygons represent maximum RIM extent in plan view

PRELIMINARY DRAFT

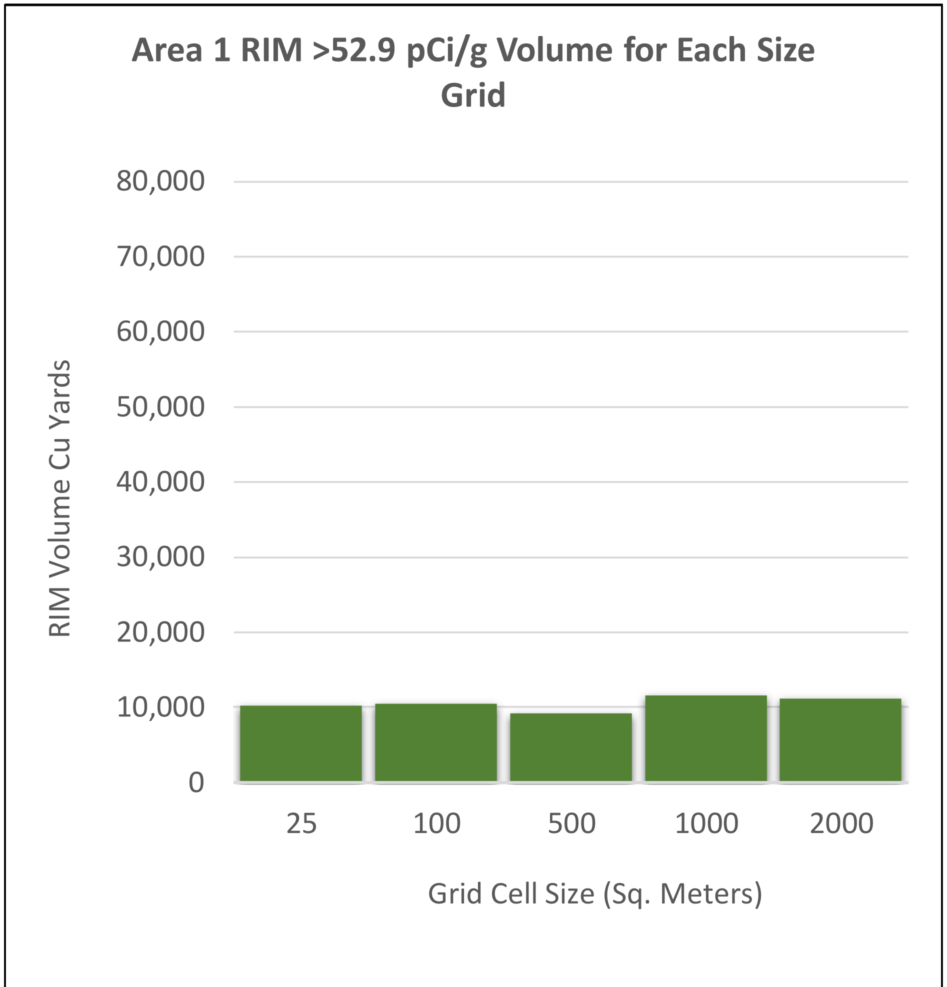
FIGURE A-6

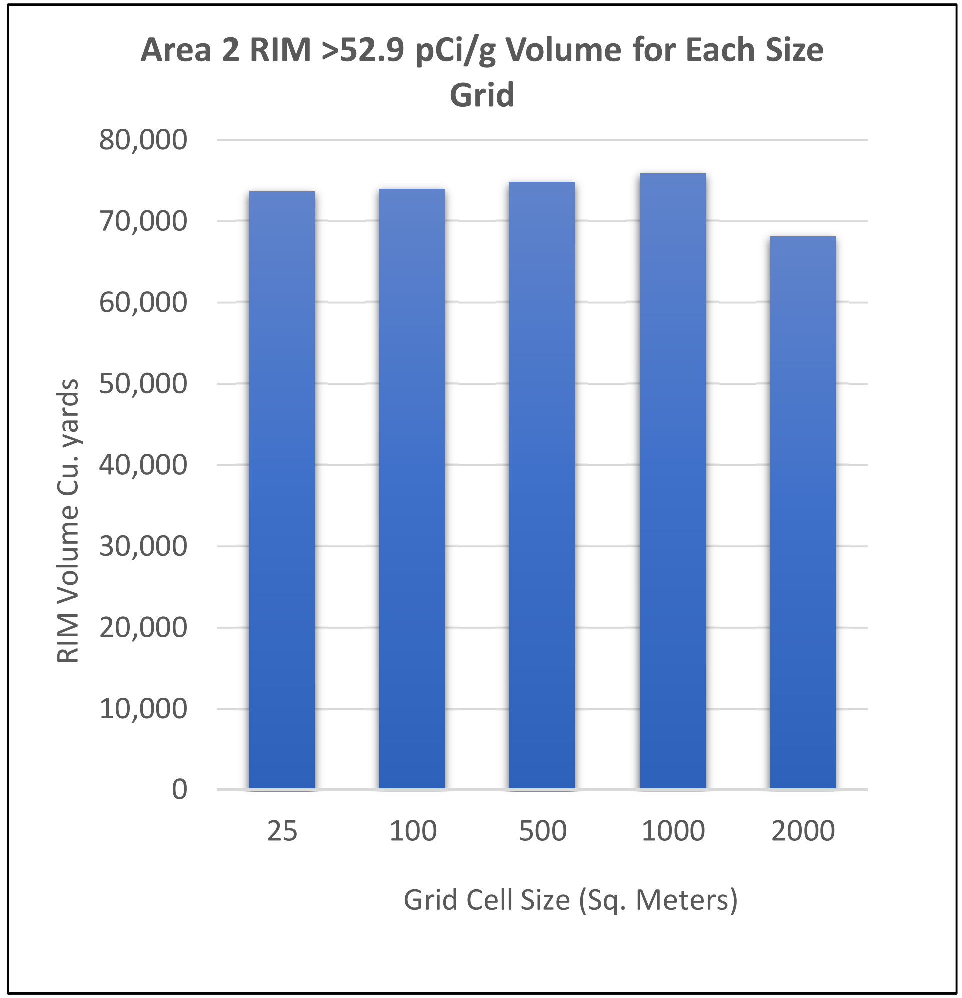
IK3D Grid Size Assessment – Area 1

West Lake Landfill Operable Unit 1, Bridgeton, Missouri

PARSONS

Syracuse, NY





PRELIMINARY DRAFT

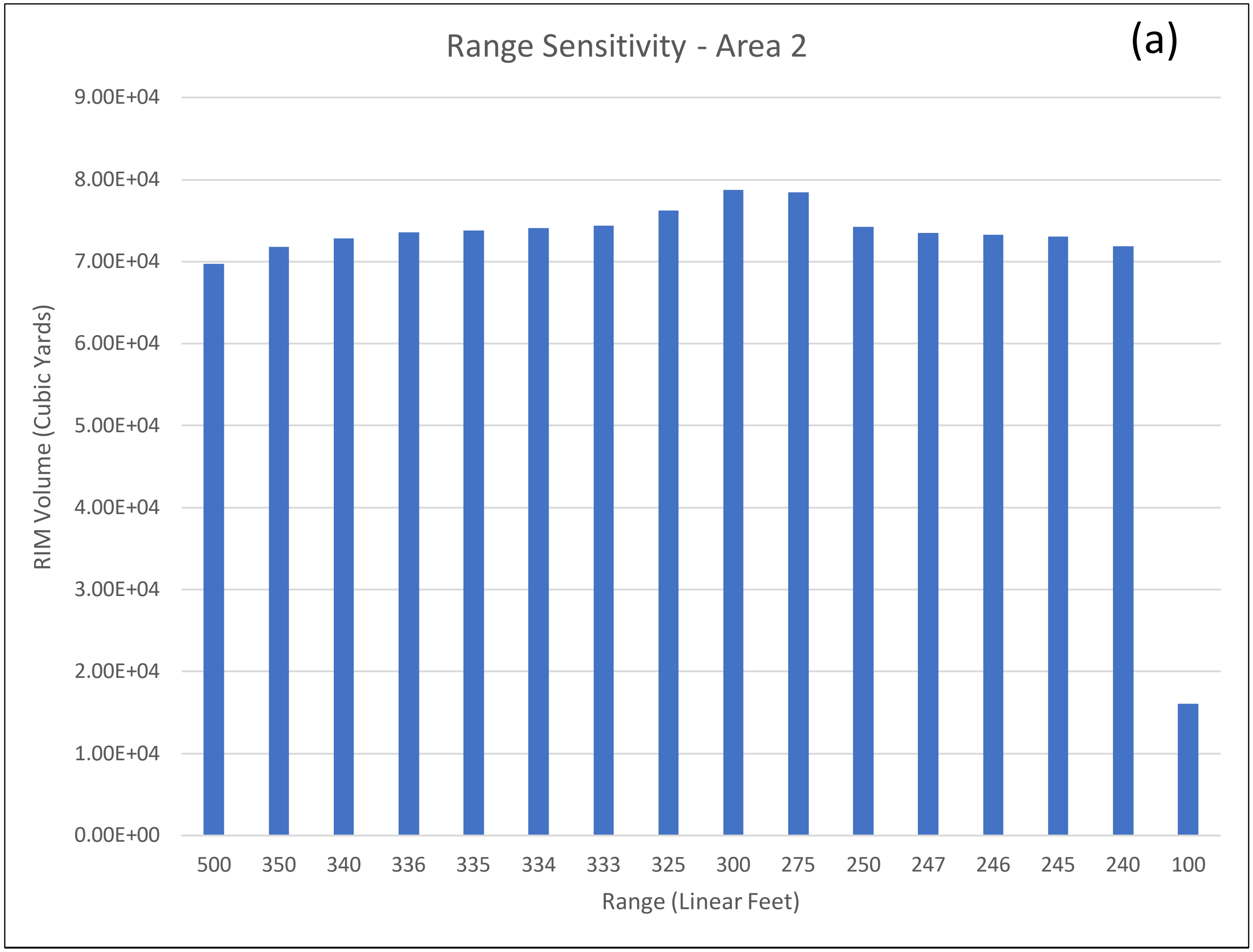
FIGURE A-7

IK3D Grid Size Assessment – Area 1
52.9 RIM Volume Comparisons

West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY



Area 2

(a) Range sensitivities, SSP&A sill applied

PRELIMINARY DRAFT

FIGURE A-8

Range and Sill Sensitivity Testing
Area 1

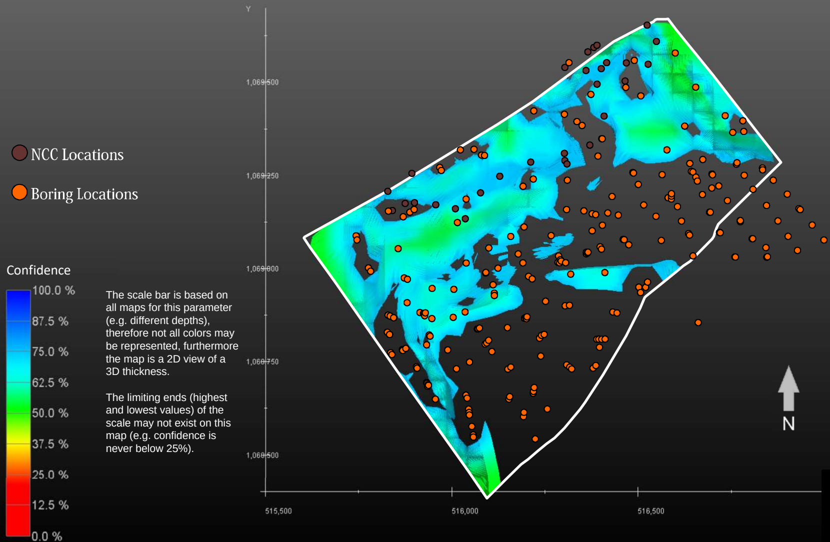
West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

PARSONS

Syracuse, NY

PRELIMINARY DRAFT

Area 1 - Radium - Confidence - 0-12 - Showing values below 75% of scale



The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

AREA 1 RADIUM CONFIDENCE – 0-12' B2005GS SHOWING VALUES BELOW 75% OF SCALE				
West Lake Landfill NPL Site OU-1 Remedial Design Bridgeton, St. Louis County, Missouri				
PARSONS Syracuse, NY				
PROJECT # 451662.02300	DATE: 12/27/2019	DRWN: –	CHKD: –	FIGURE # A-9

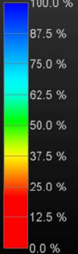
PRELIMINARY DRAFT

Area 1 - Radium - Confidence - 12-16 - Showing values below 75% of scale

NCC Locations

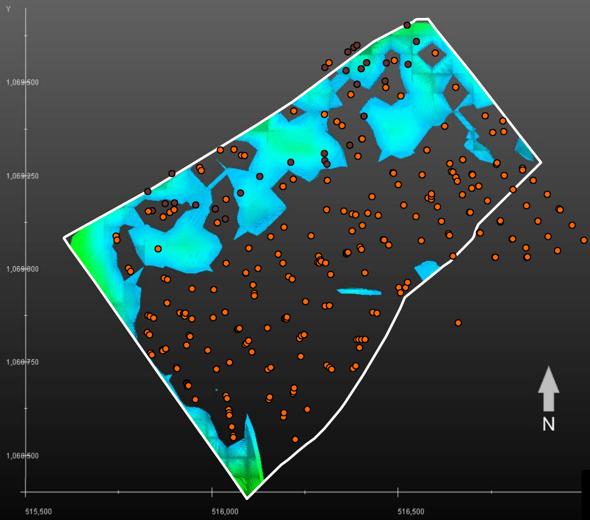
Boring Locations

Confidence



The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).



Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

AREA 1
RADIUM CONFIDENCE – 12-16' B2005GS
SHOWING VALUES BELOW 75% OF SCALE

West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE	DRWN:	CHK'D:	FIGURE #
451662.02300	12/27/2019	–	–	A-10

PRELIMINARY DRAFT

Area 1 - Radium - Uncertainty - 0-12 - Showing values above 10% of scale

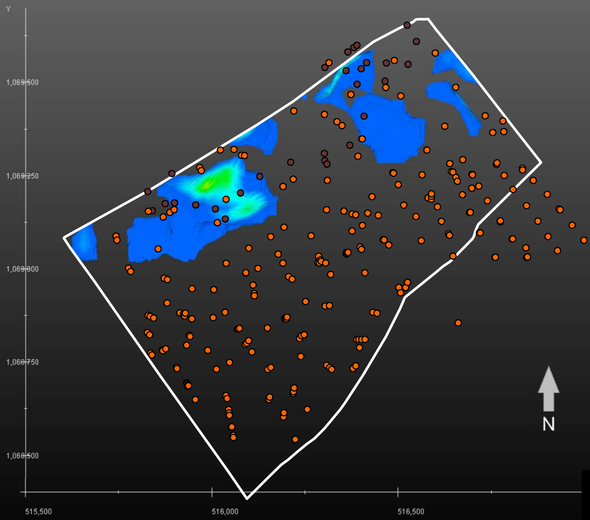
NCC Locations

Boring Locations

Uncertainty

The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).



Notes:

In EVS, uncertainty is high where concentrations are predicted to be relatively high, but the confidence prediction is low. Therefore, it draws attention to areas where additional higher concentrations may exist. Uncertainty values should be considered unitless and their magnitudes cannot directly be used to assess the quality of a site assessment.

AREA 1 RADIUM UNCERTAINTY – 0-12' B2005GS SHOWING VALUES ABOVE 10% OF SCALE				
West Lake Landfill NPL Site OU-1 Remedial Design Bridgeton, St. Louis County, Missouri				
PARSONS Syracuse, NY				
PROJECT # 451662.02300	DATE: 12/27/2019	DRWN: –	CHK'D: –	FIGURE # A-11

PRELIMINARY DRAFT

Area 1 - Radium - Uncertainty - 12-16 - Showing values above 10% of scale

NCC Locations

Boring Locations

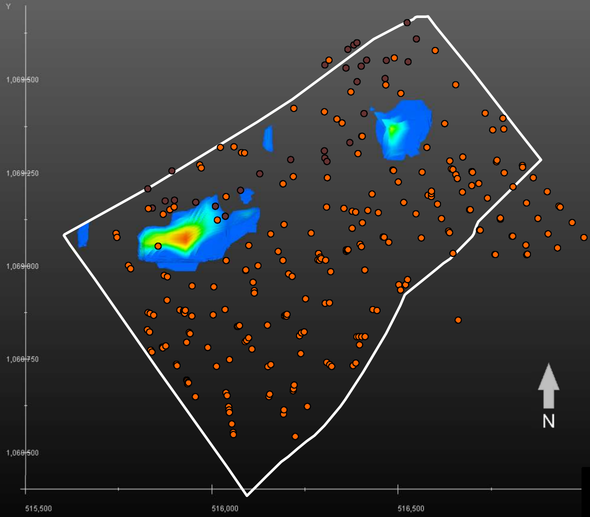
Uncertainty

High

Low

The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).



Notes:

In EVS, uncertainty is high where concentrations are predicted to be relatively high, but the confidence prediction is low. Therefore, it draws attention to areas where additional higher concentrations may exist. Uncertainty values should be considered unitless and their magnitudes cannot directly be used to assess the quality of a site assessment.

AREA 1
RADIUM UNCERTAINTY – 12-16' B2005GS
SHOWING VALUES ABOVE 10% OF SCALE

West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE:	DRWN:	CHK'D:	FIGURE #
451662.02300	12/27/2019	–	–	A-12

PRELIMINARY DRAFT

Area 1 - Thorium - Confidence - 0-12 - Showing values below 75% of scale

NCC Locations

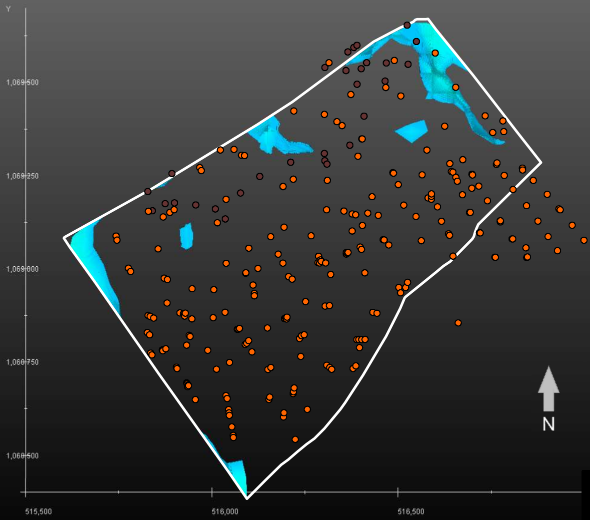
Boring Locations

Confidence

100.0 %
87.5 %
75.0 %
62.5 %
50.0 %
37.5 %
25.0 %
12.5 %
0.0 %

The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).



Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

AREA 1
THORIUM CONFIDENCE – 0-12' B2005GS
SHOWING VALUES BELOW 75% OF SCALE

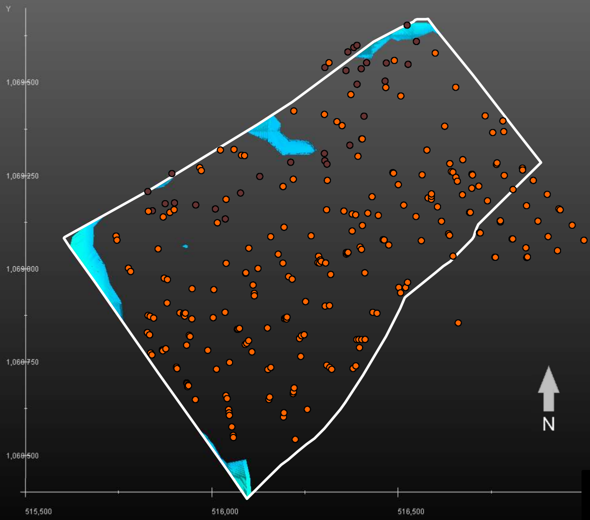
West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	–	–	A-13

PRELIMINARY DRAFT

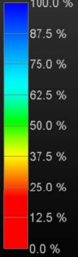
Area 1 - Thorium - Confidence - 12-16 - Showing values below 75% of scale



NCC Locations

Boring Locations

Confidence



The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

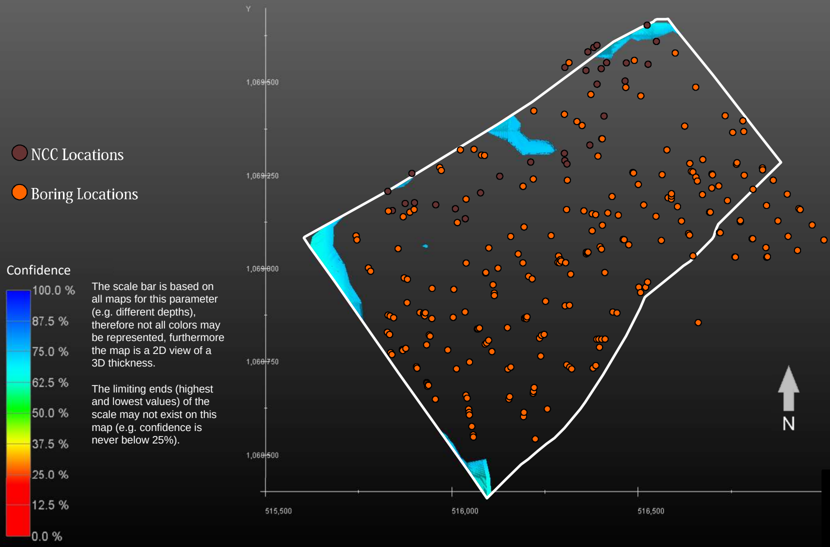
Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

AREA 1 THORIUM CONFIDENCE – 12-16' B2005GS SHOWING VALUES BELOW 75% OF SCALE				
West Lake Landfill NPL Site OU-1 Remedial Design Bridgeton, St. Louis County, Missouri				
PARSONS Syracuse, NY				
PROJECT # 451662.02300	DATE: 12/27/2019	DRWN: –	CHKD: –	FIGURE # A-14

PRELIMINARY DRAFT

Area 1 - Thorium - Confidence - 16-20 - Showing values below 75% of scale



The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

Confidence and uncertainty from 16-20 feet B2005GS are provided for thorium but not radium, as radium has insignificant distribution at depth.

AREA 1 THORIUM CONFIDENCE – 16-20' B2005GS SHOWING VALUES BELOW 75% OF SCALE				
West Lake Landfill NPL Site OU-1 Remedial Design Bridgeton, St. Louis County, Missouri				
PARSONS Syracuse, NY				
PROJECT # 451662.02300	DATE: 12/27/2019	DRWN: –	CHKD: –	FIGURE # A-15

PRELIMINARY DRAFT

Area 1 -Thorium - Uncertainty - 0-12 - Showing values above 10% of scale

NCC Locations

Boring Locations

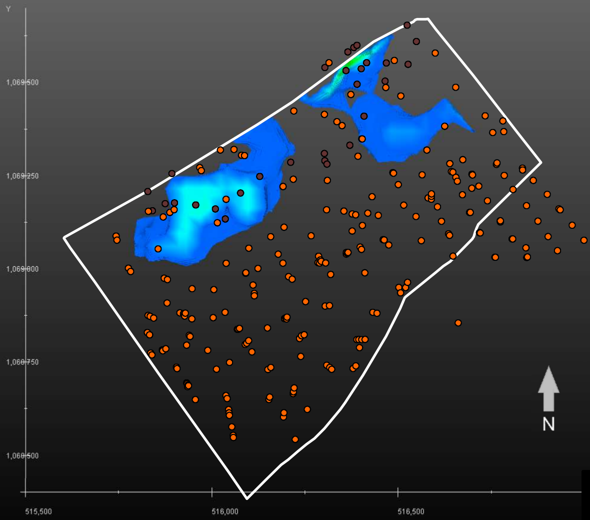
Uncertainty

High

Low

The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).



Notes:

In EVS, uncertainty is high where concentrations are predicted to be relatively high, but the confidence prediction is low. Therefore, it draws attention to areas where additional higher concentrations may exist. Uncertainty values should be considered unitless and their magnitudes cannot directly be used to assess the quality of a site assessment.

AREA 1
THORIUM UNCERTAINTY – 0-12' B2005GS
SHOWING VALUES ABOVE 10% OF SCALE

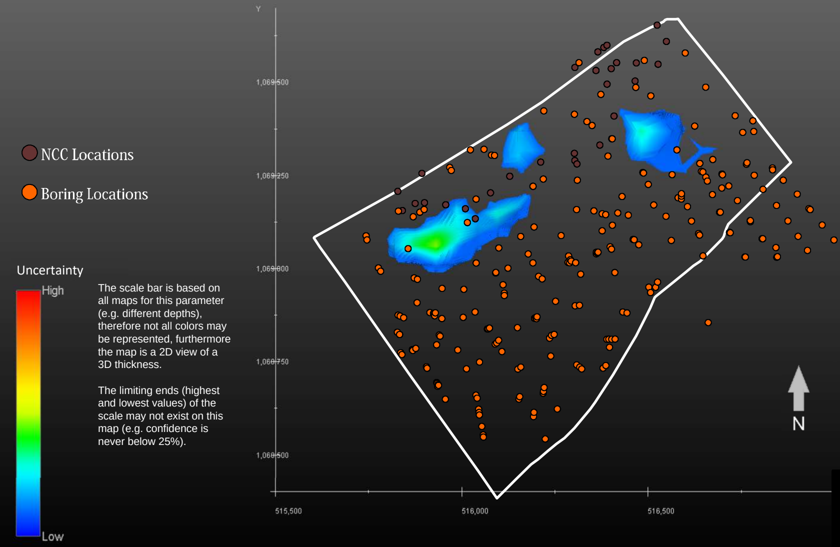
West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	–	–	A-16

PRELIMINARY DRAFT

Area 1 -Thorium - Uncertainty - 12-16 - Showing values above 10% of scale



The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

Notes:

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AREA 1
THORIUM UNCERTAINTY – 12-16' B2005GS
SHOWING VALUES ABOVE 10% OF SCALE

West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

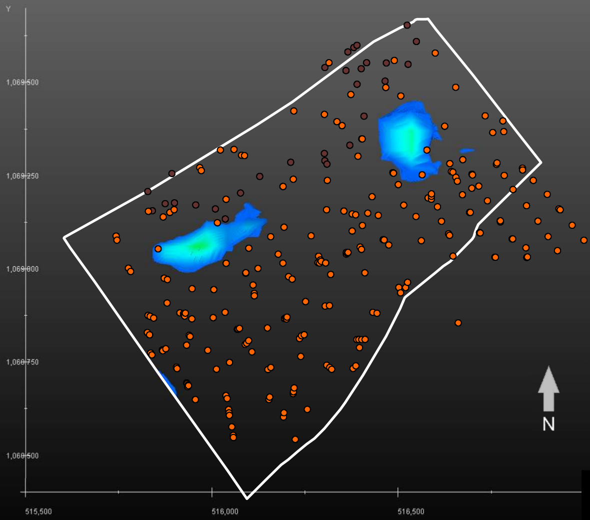
PROJECT #	DATE	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	–	–	A-17

PRELIMINARY DRAFT

Area 1 -Thorium - Uncertainty - 16-20 - Showing values above 10% of scale

NCC Locations

Boring Locations



Uncertainty

High

Low

The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

Notes:

In EVS, uncertainty is high where concentrations are predicted to be relatively high, but the confidence prediction is low. Therefore, it draws attention to areas where additional higher concentrations may exist. Uncertainty values should be considered unitless and their magnitudes cannot directly be used to assess the quality of a site assessment.

Confidence and uncertainty from 16-20 feet B2005GS are provided for thorium but not radium, as radium has insignificant distribution at depth.

AREA 1
THORIUM UNCERTAINTY – 16-20' B2005GS
SHOWING VALUES ABOVE 10% OF SCALE

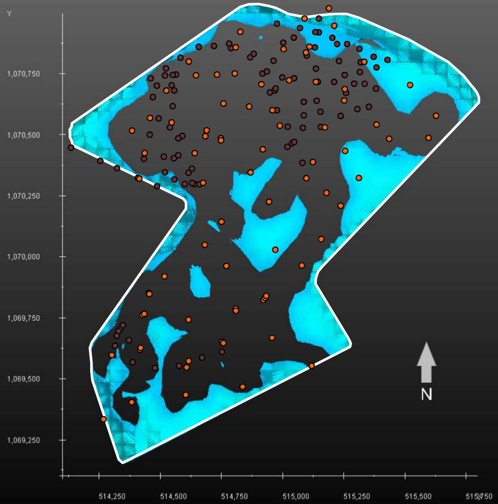
West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

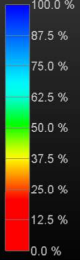
PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	–	–	A-18

PRELIMINARY DRAFT

Area 2 - Radium - Confidence - 0-12 - Showing values below 75% of scale



Confidence



NCC Locations

Boring Locations

The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

AREA 2
RADIUM CONFIDENCE – 0-12' B2005GS
SHOWING VALUES BELOW 75% OF SCALE

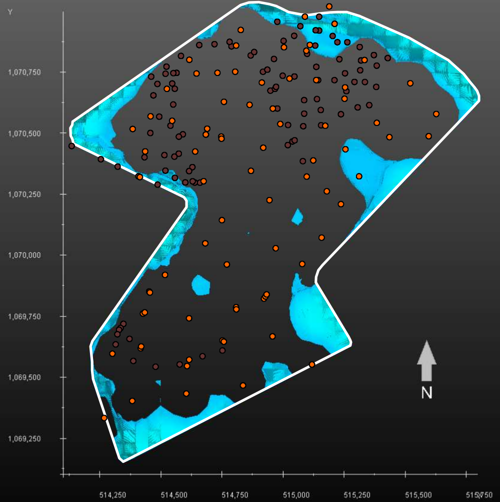
West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	–	–	A-19

PRELIMINARY DRAFT

Area 2 - Radium - Confidence - 12-16 - Showing values below 75% of scale



The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

Confidence

100.0 %
87.5 %
75.0 %
62.5 %
50.0 %
37.5 %
25.0 %
12.5 %
0.0 %

NCC Locations

Boring Locations

Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

AREA 2
RADIUM CONFIDENCE – 12-16' B2005GS
SHOWING VALUES BELOW 75% OF SCALE

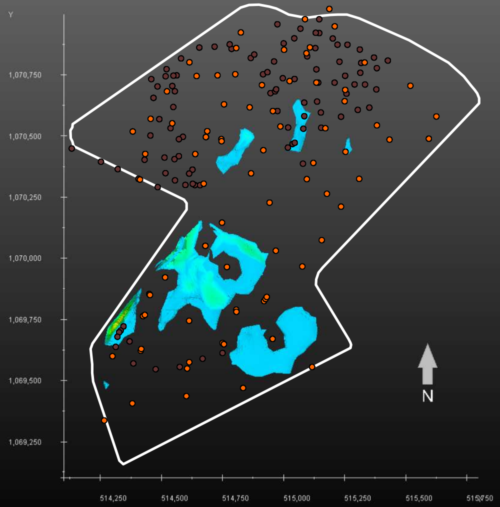
West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	–	–	A-20

PRELIMINARY DRAFT

Area 2 - Radium - Uncertainty - 0-12 - Showing values above 10% of scale



Uncertainty

High

Low

NCC Locations

Boring Locations

The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

Notes:

In EVS, uncertainty is high where concentrations are predicted to be relatively high, but the confidence prediction is low. Therefore, it draws attention to areas where additional higher concentrations may exist. Uncertainty values should be considered unitless and their magnitudes cannot directly be used to assess the quality of a site assessment.

AREA 2 RADIUM UNCERTAINTY – 0-12' B2005GS SHOWING VALUES ABOVE 10% OF SCALE				
West Lake Landfill NPL Site OU-1 Remedial Design Bridgeton, St. Louis County, Missouri				
PARSONS Syracuse, NY				
PROJECT # 451662.02300	DATE: 12/27/2019	DRWN: –	CHKD: –	FIGURE # A-21

PRELIMINARY DRAFT

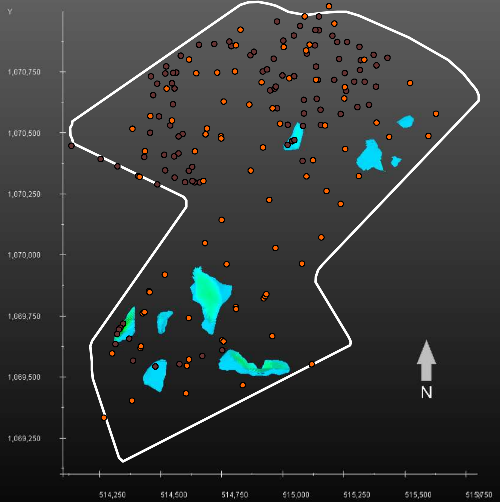
Area 2 - Radium - Uncertainty -12-16 - Showing values above 10% of scale

The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

NCC Locations

Boring Locations



Notes:

In EVS, uncertainty is high where concentrations are predicted to be relatively high, but the confidence prediction is low. Therefore, it draws attention to areas where additional higher concentrations may exist. Uncertainty values should be considered unitless and their magnitudes cannot directly be used to assess the quality of a site assessment.

AREA 2
RADIUM UNCERTAINTY – 12-16' B2005GS
SHOWING VALUES ABOVE 10% OF SCALE

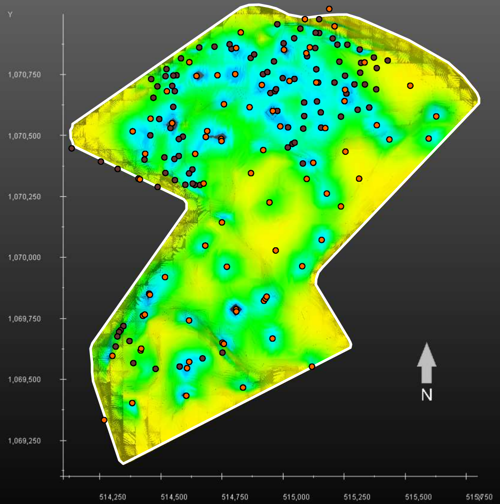
West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	–	–	A-22

PRELIMINARY DRAFT

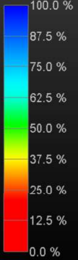
Area 2 - Thorium - Confidence - 0-12 - Showing values below 75% of scale



The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

Confidence



NCC Locations

Boring Locations

Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

AREA 2
THORIUM CONFIDENCE – 0-12' B2005GS
SHOWING VALUES BELOW 75% OF SCALE

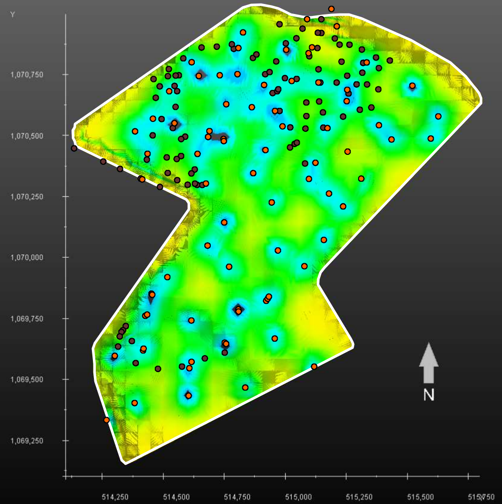
West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	–	–	A-23

PRELIMINARY DRAFT

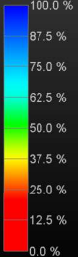
Area 2 - Thorium - Confidence - 12-16 - Showing values below 75% of scale



The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

Confidence



NCC Locations

Boring Locations

Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

AREA 2
THORIUM CONFIDENCE – 12-16' B2005GS
SHOWING VALUES BELOW 75% OF SCALE

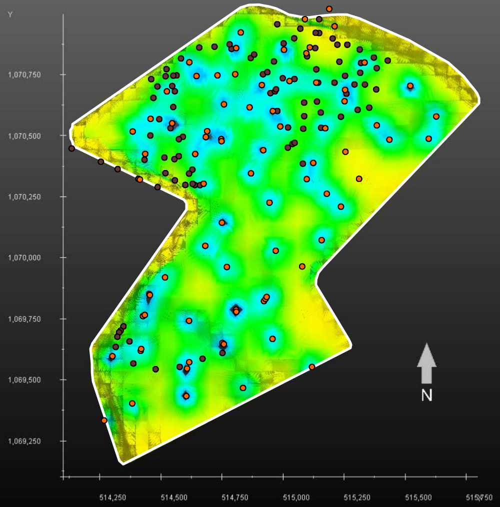
West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	–	–	A-24

PRELIMINARY DRAFT

Area 2 - Thorium - Confidence - 16-20 - Showing values below 75% of scale



The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

Confidence
100.0 %
87.5 %
75.0 %
62.5 %
50.0 %
37.5 %
25.0 %
12.5 %
0.0 %

NCC Locations

Boring Locations

Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

Confidence and uncertainty from 16-20 feet B2005GS are provided for thorium but not radium, as radium has insignificant distribution at depth.

AREA 2
THORIUM CONFIDENCE – 16-20' B2005GS
SHOWING VALUES BELOW 75% OF SCALE

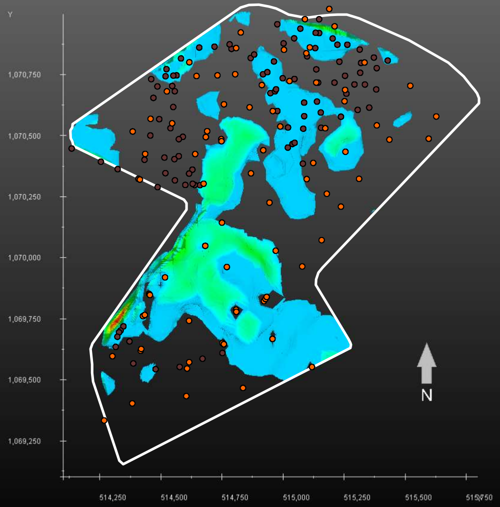
West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	–	–	A-25

PRELIMINARY DRAFT

Area 2 - Thorium - Uncertainty - 0-12 - Showing values above 10% of scale



Uncertainty

High

Low

The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

NCC Locations

Boring Locations

Notes:

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AREA 2
THORIUM UNCERTAINTY – 0-12' B2005GS
SHOWING VALUES ABOVE 10% OF SCALE

West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE:	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	–	–	A-26

PRELIMINARY DRAFT

Area 2 - Thorium - Uncertainty - 12-16 - Showing values above 10% of scale

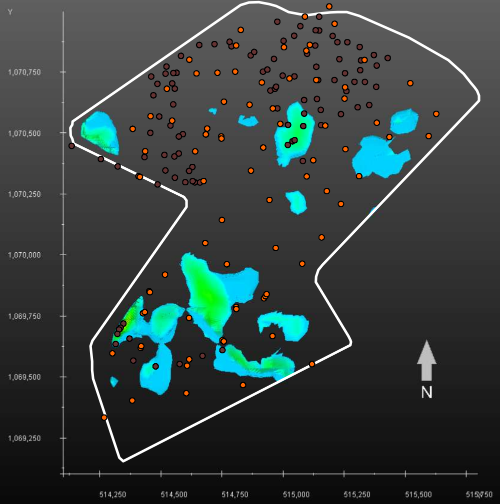
Uncertainty

The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

NCC Locations

Boring Locations



Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

AREA 2
THORIUM UNCERTAINTY – 12-16' B2005GS
SHOWING VALUES ABOVE 10% OF SCALE

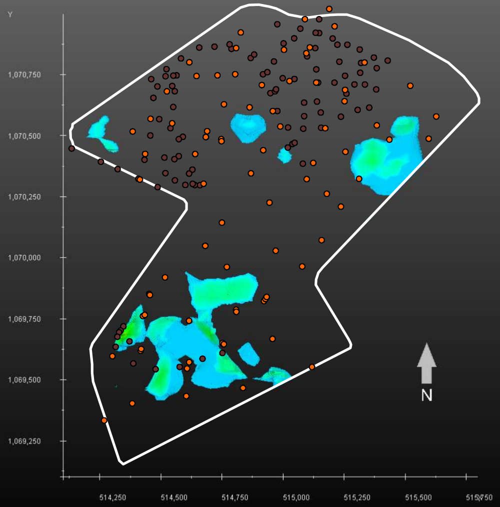
West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

PROJECT #	DATE	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	–	–	A-27

PRELIMINARY DRAFT

Area 2 - Thorium - Uncertainty - 16-20 - Showing values above 10% of scale



Uncertainty

The scale bar is based on all maps for this parameter (e.g. different depths), therefore not all colors may be represented, furthermore the map is a 2D view of a 3D thickness.

The limiting ends (highest and lowest values) of the scale may not exist on this map (e.g. confidence is never below 25%).

NCC Locations

Boring Locations

Notes:

Confidence is based on standard deviation of the estimated grid at each cell location. It should be considered a relative value only to help understand spatially where the lower and higher areas of confidence exist (distance from sampling locations). It should not be used as a quantitative basis or compared with other kriging confidence values.

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AREA 2
THORIUM UNCERTAINTY – 16-20' B2005GS
SHOWING VALUES ABOVE 10% OF SCALE

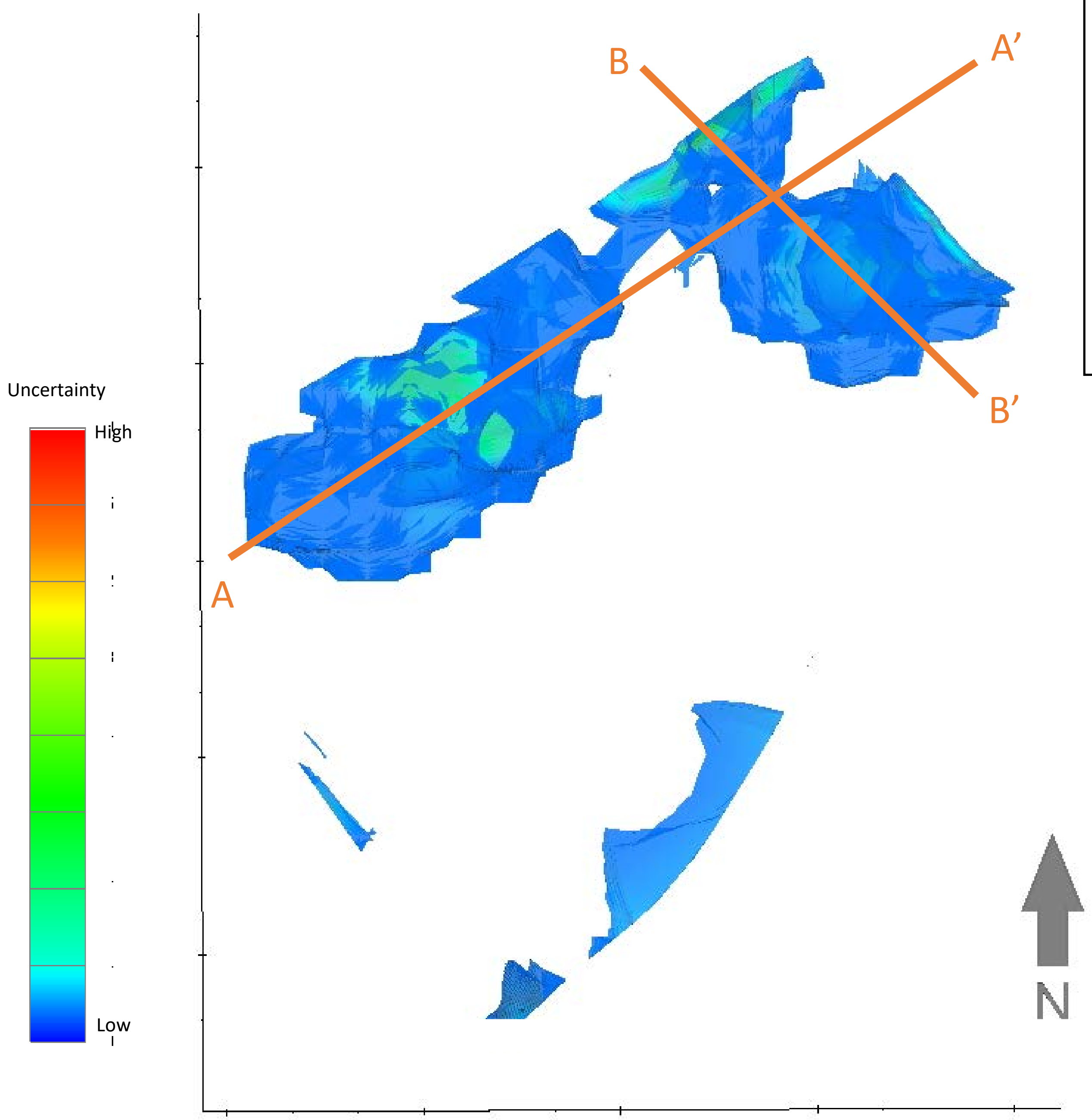
West Lake Landfill NPL Site OU-1 Remedial Design
Bridgeton, St. Louis County, Missouri

PARSONS
Syracuse, NY

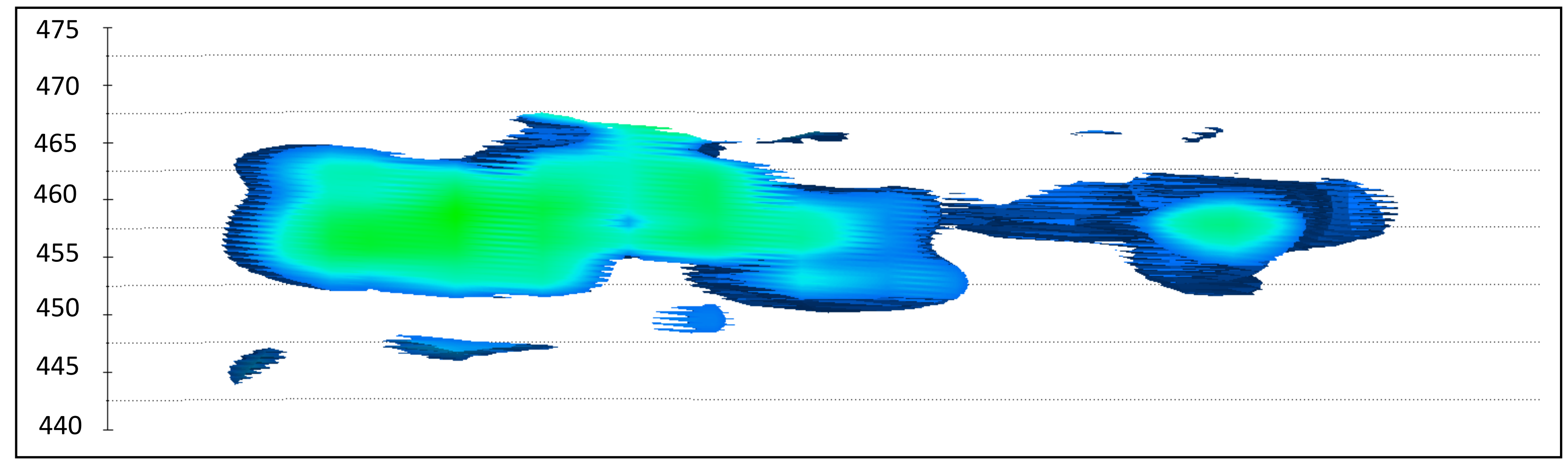
PROJECT #	DATE	DRWN:	CHKD:	FIGURE #
451662.02300	12/27/2019	–	–	A-28

Preliminary Draft

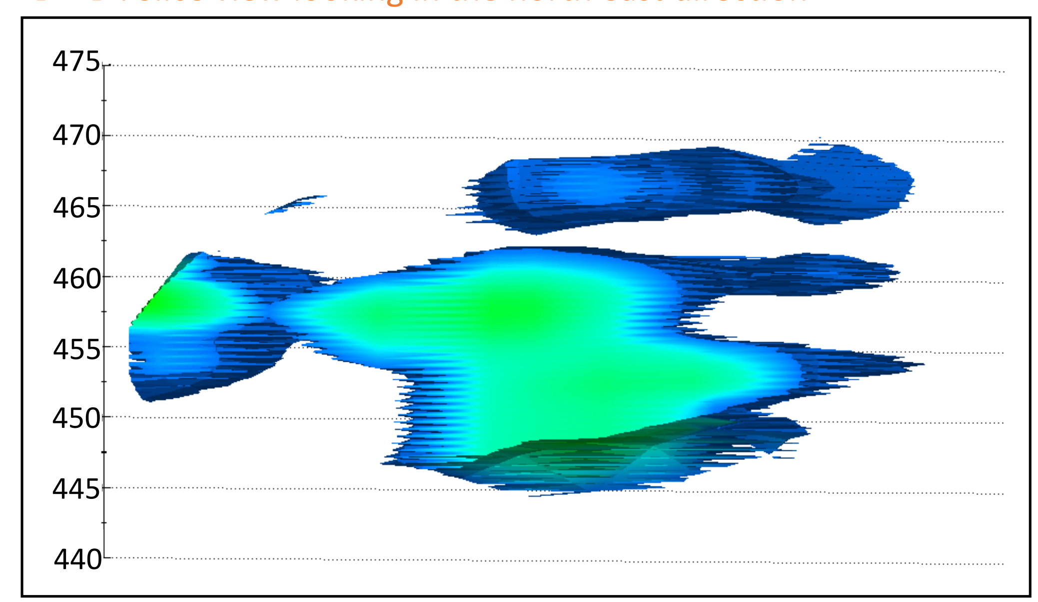
Plan view of uncertainty in of thorium in Area 1



A – A': Slice view looking in the north east direction



B – B': Slice view looking in the north east direction



Notes:

- Figure shows uncertainty of thorium in Area 1 from 0 to 20 feet B2005GS at greater than 5% of uncertainty scale to show more of the plume as compared with map in Attachment A.
- Slices are a vertical exaggeration of 8x, elevations in feet AMSL.
- Slices are through a 3D plume and shows some RIM "behind" the slice.

FIGURE 29

Area 1
Uncertainty Cross Section Conceptualization

West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

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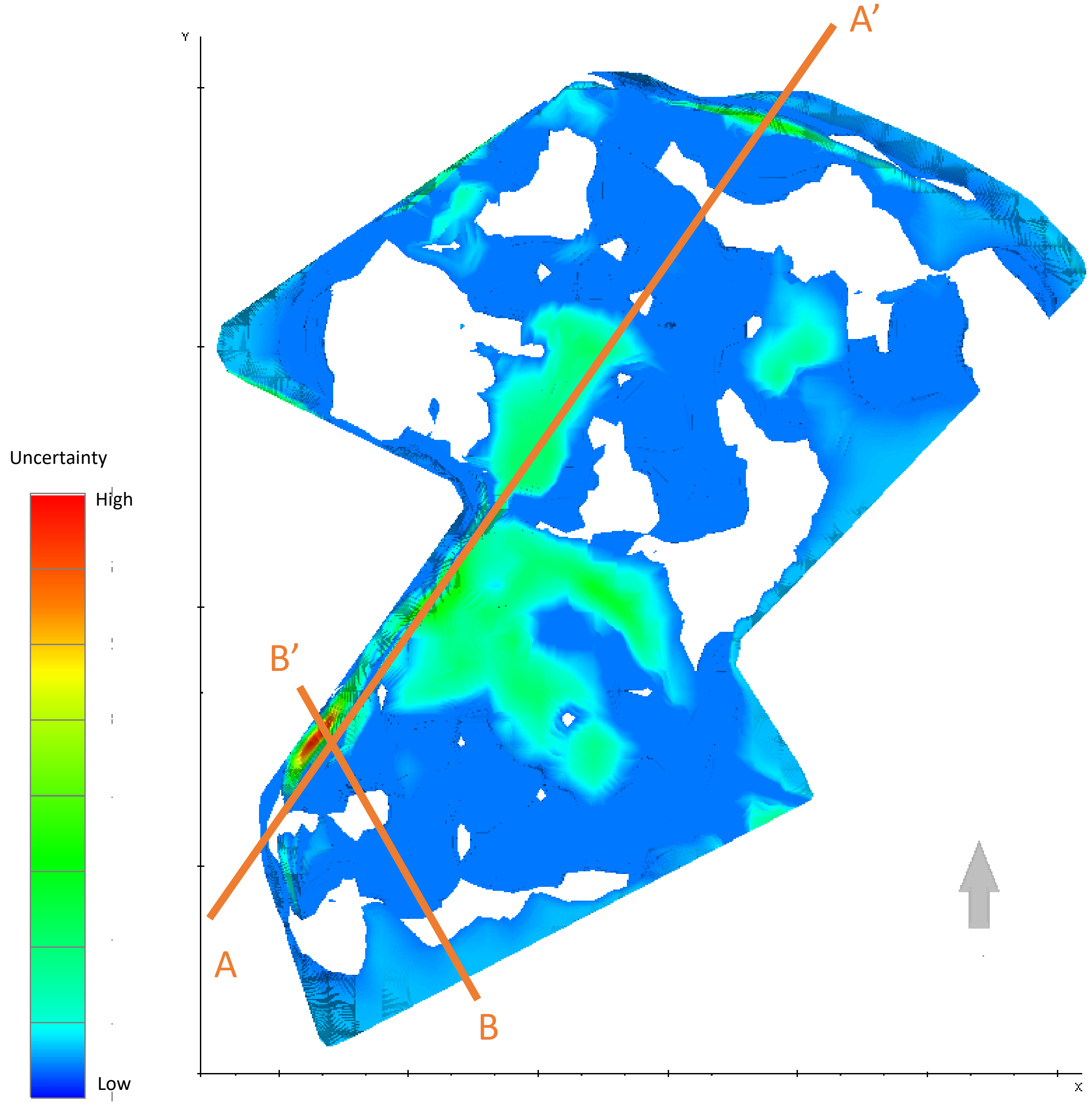
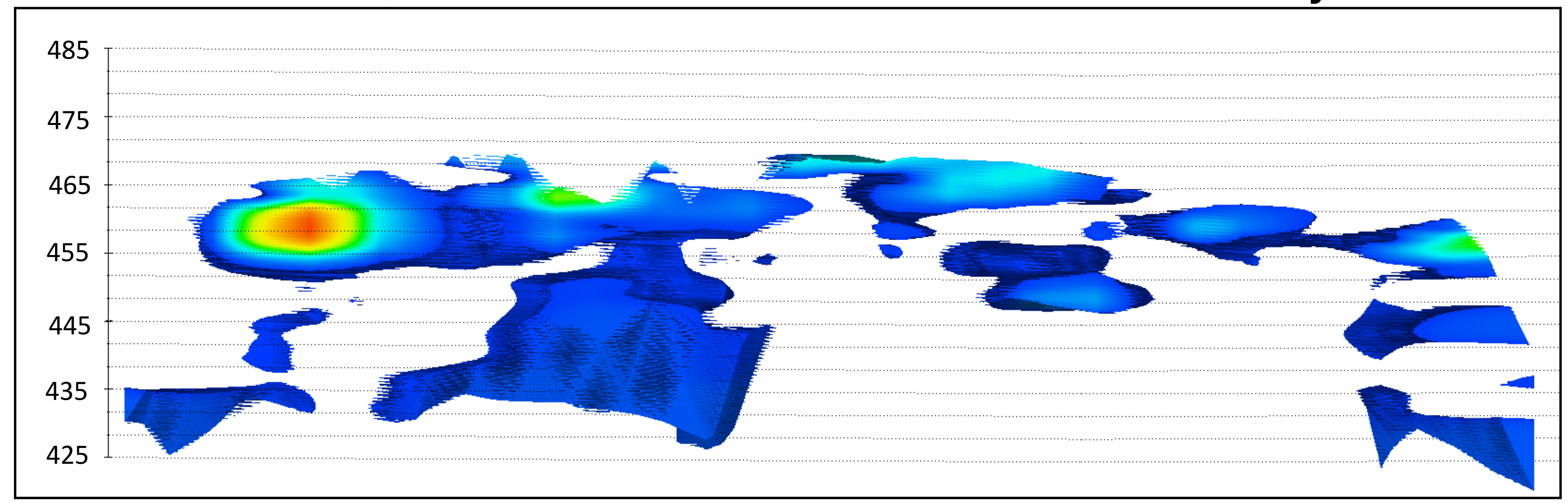
FILE NAME: P:\ WEST LAKE\\PREUM_EXC_PLAN\ FIGURE for MEMO A1_A2_Th_0-20ft_5%: KMW - JWS

Preliminary Draft

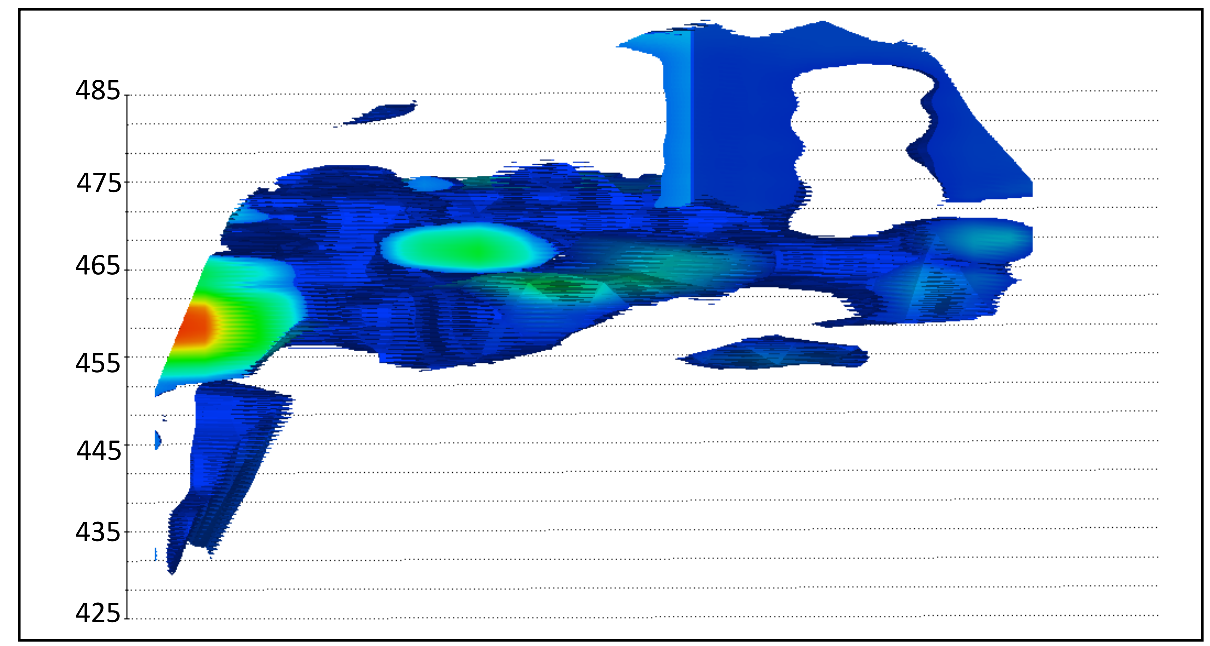
Plan view of uncertainty in of thorium in Area 2



A – A': Slice view looking in the north west direction



B – B': Slice view looking in the northeast direction



Notes:

- Figure shows uncertainty of thorium in Area 1 from 0 to 20 feet B2005GS at greater than 5% of uncertainty scale show more of the plume as compared with map in Attachment A.
- Slices are a vertical exaggeration of 8x, elevations in feet AMSL.
- Slices are through a 3D plume and shows some RIM "behind" the slice.

FIGURE A-30

Area 2
Uncertainty Cross Section
Conceptualization

West Lake Landfill Operable Unit 1,
Bridgeton, Missouri

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Volume → Concentrations → Total Activity

3D Extent of RIM

- Multiple Indicator Kriging
- Ordinary Kriging of probabilities
- Answers the question “What is the probability of being above 52.9 pCi/g
- Involves standard error
- Groups activities

Activity Concentrations

- Relative calculation
- Ordinary Kriging of regression estimated soft data
- Provides improved discretization of the activity concentrations i.e. avoids the grossly averaging data
- Limit to RIM Extent

Combined Volume and Concentrations

- Utilizes same concepts on same data
- Indicators are transformed from concentrations
- Concentrations from regression- Updated regression process improved beyond initial use – not revisited because of lack of need (before Total Activity Concept)
- Can be improved further with loess line adjustments and error matrix

Total Activity = Volume x Concentrations x Density

PRELIMINARY DRAFT

FIGURE A-31

Total Activity Calculation Conceptualization
West Lake
West Lake Landfill Operable Unit 1, Bridgeton, Missouri

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Appendix B – Total Activity Calculation Technical Memorandum

Technical Memorandum

Date: 01/23/2020

To: West Lake Team

From: Parsons Geostatistical Team

Subject: Updated West Lake Landfill OU-1 Total Activity Calculations for Preliminary Excavation Plan

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This memorandum discusses activity calculations undertaken as part of the preliminary excavation plan for the remedy for Area 1 and Area 2. The intent of this memorandum is to demonstrate the logic and progression of activity calculations as relating to the Record of Decision Amendment (RODA) requirement of removing material exhibiting the equivalent to the calculated total activity between 0 and 16 feet below 2005 ground surface (B2005GS), while potentially allowing isolated pockets of radiologically impact material (RIM) >52.9 pCi/g to be left in place. That said, achieving the equivalent total activity from 0-16 feet B2005GS becomes dependent on removal of additional activity from below 16 feet, preferably in areas where excavation to 16 feet is required.

The logic of this total activity analysis is provided in the following components:

1) Defining the governing equation for calculation of total activity for any depth interval, including 0-16 feet B2005GS.

2) Defining calculation of activity in sub-intervals between 0 and 16 feet B2005GS and deeper (i.e., 0-8 feet, 8-12 feet, 12-16 feet, 16-20 feet), then completing and summarizing these estimates.

3) Defining the equations and general process(es) (as an example calculation) for identification of isolated pockets of RIM >52.9 pCi/g that may potentially be left in place, while making up activity removal in intervals between 16 and 20 feet B2005GS where material is within the footprint of the known area to be excavated.

4) Outlining the activity calculations process based on kriging of activity concentrations in C-Tech EVS.

Each of these processes is explained below with supporting information provided in the attachments. The overall process is provided as a tool for understanding and estimating relative levels of activity with depth, as well as examples of how net total activity can be estimated (and eventually achieved) while leaving some isolated pockets of RIM >52.9 pCi/g between 8-16 feet B2005GS in place through the removal of additional (compensatory) RIM at depths between 16 and 20 feet B2005GS. This is an exercise of accounting for and balancing the RIM >52.9 pCi/g and the calculations are between computed activities for specific zones and areas are thus of a relative nature. Therefore, this relative calculation is a comparison of activities between different depths (and areas) using the same mathematical process. Since the same mathematical process is applied to each depth interval and / or spatial extent, the relative estimated comparison is valid for purposes of meeting the RODA requirements.

1) Governing equation for calculation of total activity between any interval while using 0-16 feet B2005GS as an example.

RIM activity calculation, as outlined here, is simply the volume of material multiplied by the activity concentration of the material and then multiplied by the density of the material. Within the gridded 3D model space, the total activity is then the summation of activities from each cell within a predefined lateral and vertical extent. As written mathematically, the total activity in the 3D grid space, within the areas > 52.9 pCi/g and between any depth interval below the 2005 topographic ground surface (B2005GS) is defined as (Equation 1):

Equation 1:

$$TAct = Act_{z_1-z_2} = \sum_{i=1}^{n}(v_i a_i)\rho_B$$

Where:

$\boldsymbol{TAct}$	= Total activity;
$\boldsymbol{Act_{z_1-z_2}}$	= Activity over the depth interval z_1 to z_2;
$\boldsymbol{a_i}$	= Activity concentration at grid cell i;
$\boldsymbol{v_i}$	= Soil volume of grid cell i;
$\boldsymbol{n}$	= Number of grid cells where RIM is > 52.9 pCi/g over depth interval z_1 to z_2;
$\boldsymbol{\rho_B}$	= Soil Bulk Density (weight of the dry soil/total soil volume)

Considering the total activity to be removed is the equivalent of total activity between 0-16 feet B2005GS in areas >52.9 pCi/g, Equation 1 can then be depth-limited where z1 = 0 and z2 = 16 feet B2005GS (Equation 2):

Equation 2:

$$TAct_{0-16} = \sum_{i=1}^{n}(v_{i\,0-16}a_{i\,0-16})\rho_B$$

For the calculation of activity, the bulk density of the material is assumed to be a constant fixed soil density value of 1.85 g/cm^3. However, because these calculations rest upon relative quantities (as noted above), the actual density of material does not affect the outcome of the activity-balancing calculations.

2) Defining and implementing the equations for calculation of activity in sub-intervals between 0 and 16 feet B2005GS and deeper (i.e. 0-8, 8-12, 12-16, and 16-20 feet B2005GS).

Understanding and estimating the activity-versus-depth relationship sets the basis for defining excavation areas in order to meet the RODA requirements. The governing equation (Equation 1) above can be discretized for discrete depth intervals between 0 and 16 feet B2005GS and deeper (i.e. 0-8, 8-12, 12-16, and 16-20 feet B2005GS) which then provides the estimated activity at the prescribed depths.

This depth-discretized summation of total activity into separate intervals can be defined by (Equation 3):

Equation 3:

$$TAct = TAct_{0-16} = A_{0-8} + A_{8-12} + A_{12-16}$$

Given Equations 1 through 3, the activity for each interval can be calculated for comparison. These values are provided below for comparison, in addition to the 16-20 feet B2005GS interval within the geostatistical model that Parsons transitioned from SSP&A in 2019, see below and in the technical memorandum titled West Lake Geostatistical Details Regarding Preliminary Excavation Plan, which is also an appendix to the Preliminary Excavation Plan.

Total Activity Estimation Summary – Without Excavation				
	Total Activity in RIM >52.9 pCi/g at Stated Depth Intervals (feet B2005GS)	**Area 1 (Ci)**	**Area 2 (Ci)**	**Total Area 1 and 2 (Ci)**
A	**Total Activity 0-16**	**42**	**190**	**233**
B	Activity in 0 to 8	16.6	147.1	164
C	Activity in 8 to 12	12.1	33.1	45
D	Activity in 12 to 16	13.4	10.2	24
E	Activity in 16 to 20	2.2	30.4	33

The above activities were calculated for the entire depth interval of RIM >52.9 pCi/g within each of Areas 1 and 2. These values include small unverified anomalies that may be defined by an isolated sample and / or larger isolated pockets.

From these initial estimates it can be observed that significantly more activity exists in Area 2 compared with Area 1 (190 Ci versus 42 Ci, respectively). Furthermore, in Area 1, approximately 69% of $TAct_{0-16}$ RIM >52.9 pCi/g is estimated to be present between 0 and 12 feet B2005GS, and 95% of activity in Area 2 exists between 0 and 12 feet B2005GS.

3) Defining the equations and general process(es) (as an example calculation) for identification of isolated pockets of RIM >52.9 pCi/g that can potentially be left in place, while compensating with activity removal in intervals between 16 and 20 feet B2005GS where material is within the footprint of the known area to be excavated.

Isolated pockets of RIM >52.9 pCi/g can be defined qualitatively by distance from excavation areas, volume, activity concentrations, potential overlying RIM (or lack thereof), and overburden. Knowing the associated risks and logistical constraints related to opening a “new” excavation in order to remove such isolated pocket of activity, the RODA allows for leaving some activity in place with the condition that total activity removed will remain the quantitative equivalent to the total activity of the RIM >52.9 pCi/g between 0-16 feet B2005GS. These will be computed on the same data set using the same geostatistical model to assure equivalency. As detailed in the Design Criteria Report (Parsons, December 2019): "*The RODA defines a requirement for the total radioactivity to be removed in the selected remedy to be equivalent to the total radioactivity represented by the combined radium and thorium greater than 52.9 pCi/g down to 16 feet below the 2005 topographic surface*." With the additional conditions that: *"[t]he RODA selected remedy generally requires removal of RIM greater than 52.9 pCi/g to a depth of 12 feet below the 2005 topographic surface but will include removal of some RIM between 12 and 20 feet below the 2005 surface and allow for isolated pockets of RIM greater than 52.9 pCi/g between 8 feet and 12 feet below the 2005 surface to remain in place.*"

Provided the allowance to leave some RIM >52.9 pCi/g in place and given that the total activity removed is the equivalent to the estimated total activity 0-16 feet B2005GS, a mathematical activity balance (similar to a mass balance) can be defined by the governing equation as (Equation 4):

Equation 4:

$$TAct = TAct_{0-16} = A_{0-8} + (A_{8-12} - A_{IP\ 8-12}) + (A_{12-16} - A_{IP\ 12-16}) + HSA_{16-z3}$$

Where:

$A_{IP\ z_1-z_2}$ = Area of isolated pockets of RIM over the depth interval z_1 to z_2.

HSz_3 = Hot spot activity in the excavation required below 16 feet B2005GS to balance A_{IP}

Given Equation 4 and the remedial objective (stated above): when the activity of excavated RIM deeper than 16 feet is greater than or equal to the RIM of isolated pockets left in place, the total activity 0-16 feet goal is met. Mathematically this is explained as:

$$A_{IP\ 8-12} + A_{IP\ 12-16} \leq HSA_{16-z_3}$$

then

$$TAct(removed) \geq TAct_{0-16}$$

An example of this process is provided in attachments (as well as the Figures 13 and 14 of the Preliminary Excavation Plan) where isolated pockets are identified, individually quantified, which then provides the basis for calculating the depth of excavation below 16 feet B2005GS required to meet the $TAct_{0-16}$ objective.

The process outlined in Equation 4 has been implemented in Areas 1 and 2, and resulting total activities removed by depth interval are summarized in the table below.

Activity Removal Summary				
	Total Activity Removed >52.9 pCi/g at Stated Depth Intervals (feet B2005GS)	**Area 1 (Ci)**	**Area 2 (Ci)**	**Total Area 1 and 2 (Ci)**
A	**Total Activity Removed 0-17**	**41.6**	**191.4**	**233**
Breakdown by Depth Interval				
B	Activity removal in 0 to 8	16.6	147.1	164
C	Activity removal in 8 to 12	12.1	33.0	45
D	Activity removal in 12 to 16	12.9	9.0	22
E	Activity removal in 16 to 17	0.0	2.2	2

Note: Activity removal shown on line E depicts activity from 16-17 ft, which compensates for potentially identified isolated pockets

4) Outlining the activity calculations process based on Kriging of activity concentrations in C-Tech EVS.

Total activity values for Areas 1 and 2 were achieved by utilizing 3D kriging methods on activity concentrations for combined radium (Ra) and thorium (Th). A combination of discrete analytical sample (hard) data and transformed normalized gamma response (soft) data were used in the kriged activity concentration dataset. All data had specified latitude, longitude and midpoint sample elevation relative to the 2005 topographic surface. For hard data, analytical results of activity concentrations for radium and thorium were added together to provide a combined activity concentration at each sample location. As no new data has been collected since the Final Feasibility Study (FFS), the SSP&A continuous cumulative distribution function (CDF) regression equations for the transformation of soft data (normalized gamma responses) to combined radium and combined thorium values were retained from SSP&A's geostatistical analysis. Detailed discussion of the steps and assumptions involved in the development of the regression lines for combined Th and combined Ra values can be reviewed in Section 1.2.2 of Appendix D of SSP&A's geostatistical report (Equations C-3 and C-4), as shown below.

$$Combined\ Ra\ Activity\ Concentration: log\ (Ra) = 1.02 \cdot log(gamma_{norm}) + 3.52$$

$$Combined\ Th\ Activity\ Concentration: log\ (Th) = 1.18 \cdot log(gamma_{norm}) + 4.56$$

Or rearranged to solve for activity:

$$Combined\ Ra\ Activity\ Concentration: Ra = 10^{1.02 \cdot log(gamma_{norm}) + 3.52}$$

$$Combined\ Th\ Activity\ Concentration: Th = 10^{1.18 \cdot log(gamma_{norm}) + 4.56}$$

The normalized gamma responses were transformed to an activity concentration for radium and thorium using their respective equations, and the resulting activity concentrations were added together to produce one activity concentration (combined radium and thorium) at a given screening interval.

Hard and soft activity concentration data were combined into one data set, and locations with multiple results were identified. If soft data were present for the same sample location as hard data, the hard data were retained, and the soft data were removed. If two instances of soft or hard data were present at the same sampling interval, the lowest activity concentration was retained to limit anomaly-based irregularities. The resulting data set, with duplicate results removed, was then kriged using the parameters described in the Technical Memorandum for Geostatistical Analyses, except for range and sill values which were set to autofit by EVS based on the data distribution. For these preliminary model estimates, the variogram was autofit within C-Tech EVS because the activity concentration dataset included a combination of radium and thorium values, and previously established range and sill values were based on indicator values. Future variogram modeling and sensitivity analyses will be conducted for the determination of range and sill values for the combined radium and thorium activity concentration datasets in Areas 1 and 2 using the expanded dataset that will be available after the Design Investigation is complete. Given the relatively insensitive nature of the variogram parameters (see Parsons 2020 Geostatistical Memorandum) it is unlikely the relative nature of the activity calculations will be affected by minor variations in variograms.

Total activity concentrations were 3D kriged below the 2005 topographic ground surface for each of Areas 1 and 2 (separately). The total activity concentrations calculations were then completed for the 3D volumes where RIM is estimated to have a greater than 50% probability of exceeding the threshold value of 52.9 pCi/g. Total activity was then calculated for the area within the RIM extent using EVS's Volumetrics module, which provides volume, soil mass, average concentration, and cell center for every cell in the grid. The soil volume (cubic feet [ft^3]) and average concentration (pCi/g) for each cell was used to determine the activity for the cell (pCi) using a fixed soil density value of 1.85 g/cm^3 (converted to 52,386.12 g/ft^3), as shown in the equation below. The activity for each cell was added together to determine the total activity within the RIM extent (RIM total activity), as outlined above.

$$Average\ Cell\ Activity\ Concentration\ \left(\frac{pCi}{g}\right) \cdot Voume\ of\ Soil\ in\ Cell\ (ft^3)$$
$$\cdot Density\ of\ soil\ (\frac{g}{ft^3})\ =\ Total\ Activity\ of\ Cell\ (pCi)$$

The potential difference between kriging activity concentrations based on regressions versus using multiple indicator kriging are likely inconsequential for the following reasons:

- Multiple indicator kriging is designed to provide probability of a location to be above a certain threshold and is not designed for estimating (activity) concentrations directly. By comparison, ordinary kriging of activity concentrations directly (as proposed) is specifically designed to estimated concentrations and is appropriate for this exercise.
- The calculations are a relative comparison and not absolute and therefore insensitive to the process on this level.
- Kriging based on regressions avoids back-translation from indicators which requires an additional step of interpolating from the (conditional) posterior CCDF.

Once the expanded data set is available (once the Design Investigation is complete), sensitivity testing can be used to evaluate the difference between using indicator for the total activity comparison versus kriged activity concentrations. Part of the Design Investigation will be structured to improve the regression relationships while simultaneously collecting a denser data set to characterize the site. This will include expanded evaluation of the “soft data” downhole and core scanning gamma detection techniques and their correlation to hard radium and thorium data.

ATTACHMENTS

PARSONS

Project:	West Lake Excavation Activity Balance Equations - Area 2	Job No.	451662	Revision	2
Subject:	West Lake Preliminary Excavation Plan	By	KW	Date	1/18/20
	Preliminary Draft - Activity Isolated Pockets Calculation 8-16 ft B2005GS	Checked	JWS	Date	1/18/20
Sheet:	A2- IP-Calc #1				

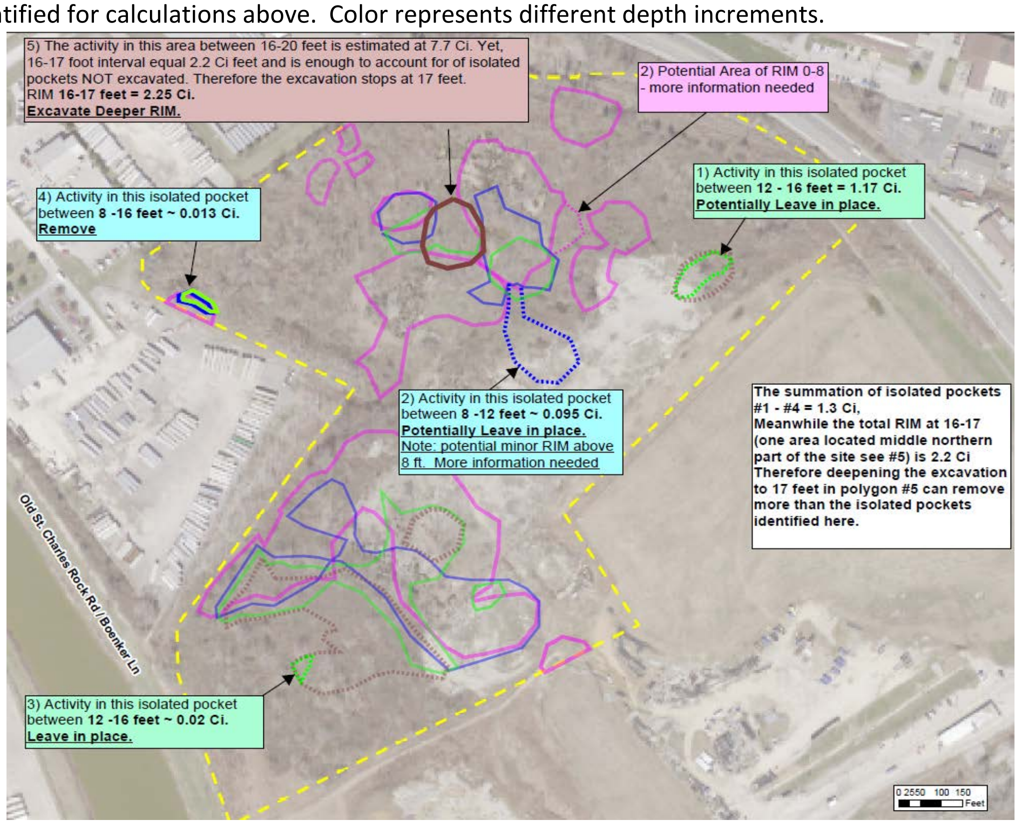
A_{IP} - Activity of Isolated pockets at specified depths

	Ci		
AIP $_{12\text{-}16}$ ***1 =***	1.17		
A $_{IP\ 8\text{-}16}$ ***2 =***	0.10		
A $_{IP\ 12\text{-}16}$ ***3 =***	0.02		
A $_{IP\ 8\text{-}16}$ ***4 =***	NA	excavate	0.01
A $_{IP\ 8\text{-}16}$ ***X =***	NA		
A $_{IP\ 8\text{-}16}$ ***X =***	NA		
A $_{IP\ 8\text{-}16}$ ***X =***	NA		
A $_{IP\ 8\text{-}16}$ ***(1-N) =***	***1.3***		

Notes:

- $A_{IP\ 8\text{-}16}$ # - these are "place holders" for calculations of addition isolated pocket
- Concentrations, volumes, and bulk density are outputs of the software C-Tech
- 8-12 and 12-16 intervals are grouped for this example calculation

Below provides the RIM > 52.9 below 8 ft B2005GS as 1 feet "slice" polygons, with isolated pockets of RIM identified for calculations above. Color represents different depth increments.



PARSONS

Project:	West Lake Excavation Activity Balance Equations - Area 2	Job No.	451662	Revision	2
Subject:	West Lake Preliminary Excavation Plan	By	KW	Date	1/17/20
	Preliminary Draft - Activity Calculation 16-20 B2005GS	Checked	JS	Date	1/17/20
Sheet:	A2-16-20 Calc #2				

This sheet demonstrates the accounting RIM > 52.9 pCi/g deeper than 16 feet B2005GS that may potentially be excavated to balance the RIM > 52.9 pCi/g in isolated pockets that may be left in place. See Sheet A1-IP-Calc pg 2 for calcuations and demonstration of where this activity would be left in place.

	Ci
$A_{16\text{-}17}$ =	2.25
$A_{17\text{-}18}$ =	3.18
A18-20 =	2.30
	7.73

Notes:

- Concentrations, volumes, and bulk density are outputs of the software C-Tech EVS

Below provides the RIM > 52.9 below 16 ft B2005GS as 1 feet "slice" ploygons, with RIM idenified for calculations above.

$$IP1 = A_{IP\ 16\text{-}17} + A_{IP\ 17\text{-}18}\ A_{IP\ 18\text{-}19} + A_{IP\ 19\text{-}20}$$