Honeywell

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June 9, 2016

To: Harry Warner, NYSDEC, Region 7 (1 bound)
Diane Carlton, NYSDEC, Region 7 (1 PDF)
Holly Sammon, Onondaga County Public Library (1 bound)
Samuel Sage, Atlantic States Legal Foundation (1 bound)
Mary Ann Coogan, Camillus Town Hall (1 bound)
Stephen Weiter, Moon Library (1 bound)
Joseph J. Heath, Esq. (1 bound)
Melissa Lewandowski, Solvay Public Library (1 bound)

Re: Letter of Transmittal – Onondaga Lake Repository Addition

The below document has been approved by the New York State Department of Environmental Conservation (NYSDEC) and is enclosed for your document holdings:

- Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design, Modified Protective Cap Areas RA-D2 Design Revision
  May 2016

Sincerely,

John P. McAuliffe

John P. McAuliffe, P.E.
Program Director, Syracuse

Enc.

cc: Timothy J. Larson, P.E., NYSDEC Project Manager
Chris Fitch, Brown and Sanford (ecopy)

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Division of Environmental Remediation, Remedial Bureau D
625 Broadway, 12th Floor, Albany, NY 12233-7013
P: (518) 402-9676 | F: (518) 402-9773
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May 26, 2016

Mr. John P. McAuliffe, P.E.
Program Director, Syracuse
Honeywell
301 Plainfield Road, Suite 330
Syracuse, NY 13212

Re: Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design, Modified Protective Cap RA-D2 Design Revision, Dated May 2016

Dear Mr. McAuliffe:

We have received and reviewed the above-referenced document, a copy of which was attached to Edward Glaza's May 25, 2016 email to my attention, and the revised version of the document appropriately addresses our previous comments. Therefore, the Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design, Modified Protective Cap RA-D2 Design Revision, dated May 2016, is hereby approved. Please see that copies of the approved document, including this approval letter, are sent to the distribution list selected for this site as well as the document repositories selected for this site.

Sincerely,

Timothy J. Larson, P.E.
Project Manager

ec: B. Israel, Esq, - Arnold & Porter
J. Davis - NYSDOL, Albany
M. Schuck - NYSDOH, Albany
M. McDonald – Honeywell
R. Nunes - USEPA, NYC
M. Sergott - NYSDOH, Albany
E. Glaza - Parsons

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June 8, 2016

Mr. Timothy J. Larson
New York State Department of Environmental Conservation
Division of Environmental Remediation
Remedial Bureau D
625 Broadway, 12th Floor
Albany, NY 12233-7016

RE: Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design, Modified Protective Cap RA-D2 Design Revision May 2016

Dear Mr. Larson:

Enclosed you will find one bound copy and one electronic (PDF and original) of the Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design, Modified Protective Cap RA-D2 Design Revision, dated May 2016.

Please feel free to contact Ed Glaza at 315-451-9560 or me if you have any questions.

Sincerely,

John P. McAuliffe, P.E.
Program Director, Syracuse

Enclosure

cc: Robert Nunes, USEPA (1 bound, 1 PDF)
Argie Cirillo, USEPA (Cover letter only)
Mike Spera, AECOM (1 bound, 1 PDF)
Bob Montione, AECOM (1 bound, 1 PDF)
Tara Blum, NYSDEC (1 bound, 1 PDF)
Kenneth Lynch, NYSDEC (1 bound)
Margaret Sheen, Esq. NYSDEC (Cover Ltr Only)
Harry Warner, NYSDEC (1bound, 1 PDF)
Mark Sergott, NYSDOH (1 PDF)
Norman Spiegel, Env. Protection Bureau (Cover Ltr Only)
Andrew Gershon, Env. Protection Bureau (Cover Ltr Only)
John Davis, Env. Protection Bureau (1 bound, 1 PDF)
Joseph Heath, Esq. (ec Cover letter only)
Thane Joyal, Esq. (1 PDF)

cc: (Continued)

Curtis Waterman (1 PDF)
Alma Lowry, Esq. (1 PDF)
Jeanne Shenandoah, Onondaga Nation (1 bound Plus ec Cover letter only)
Bill Hague, Honeywell (ec Cover Ltr Only)
Brian Israel, Arnold & Porter (1 PDF)
Steve Miller, Parsons (1 PDF)
Edward Glaza, Parsons (1 bound)
Joe Detor, Anchor QEA (1 PDF)

ONONDAGA LAKE CAPPING, DREDGING, HABITAT AND PROFUNDAL ZONE (SMU 8) FINAL DESIGN

MODIFIED PROTECTIVE CAP RA-D-2 DESIGN REVISION

Prepared for:

Honeywell

301 Plainfield Road, Suite 330
Syracuse, NY 13212

Prepared by:

PARSONS

301 Plainfield Road, Suite 350
Syracuse, NY 13212

ANCHOR QEA

290 Elwood Davis Road, Suite 318
Liverpool, NY 13088

MAY 2016

SUMMARY OF DESIGN REVISION

This cap design revision pertains to a portion of Remediation Area D (RA-D) where geotechnical investigations completed subsequent to the Final Design identified soft (low strength) sediment on relatively steep slopes. These sediments are softer than was identified during the Pre-design Investigation (PDI), and therefore a design revision is required in this area. For a capping project of the scale of Onondaga Lake Remediation, it is not unusual to expect to incur field conditions in minor areas throughout the implementation that may require adjustments to the cap system to achieve the remedial goals for the project. As discussed below, the modified protective cap (MPC) in this area will be protective for more than 1,000 years, consistent with the evaluation timeframe used in the final design.

The Modified Protective Cap (MPC) design shown in Figure 1 was determined to be stable based on geotechnical data collected subsequent to the Final Design and detailed geotechnical analysis, as presented in Attachment 1. This analysis incorporates the results from field investigations performed with equipment that is both more accurate than that used during the 2005 to 2008 pre-design investigation (PDI) and capable of assessing conditions in the deeper water portions of the lake where softer sediments have been identified. This included cone penetrometer testing (CPT), full flow penetrometer (FFP), and additional vane sheer testing (VST). In addition to the improved accuracy of these measurements, the use of these methods in areas of the site with previously placed cap materials has allowed an assessment of cap placement induced strength gain (from consolidation) in the sediment, which has been a key consideration in the slope stability assessments in some cap areas.

The evaluation of strength data collected between 2012 and 2015 indicate that the sediments in portions of the remediation areas are significantly softer than anticipated based on the PDI conducted prior to 2012. Comparison between the estimated strength parameters from the field VST data (from the PDI) and the post-PDI VST data conducted after 2012 indicates that, in general, the PDI data showed higher shear strengths for the shallow sediments than the recent (post-2012) data. The technical report titled "Development of Geotechnical Design Parameters for Lakebed Sediments in Onondaga Lake Capping Areas" (Geosyntec, October 2015) presents a comparison of the PDI and post-PDI sediment strength data.

The MPC designs were optimized to maximize the total thickness of the cap while still meeting the required factor of safety based on geotechnical considerations. The thicknesses and composition of the various layers comprising the MPC are shown below as well as on Figure 1. Chemical isolation modeling was completed to determine the granular activated carbon (GAC) application rates that will be protective for more than 1,000 years, consistent with the evaluation timeframe used in the final design, as documented in Attachment 2. The thickness and composition of the various layers comprising the MPC, including the updated GAC application rate based on this modeling is also listed below.

RA-D-2 (Multi-layer Cap) - GAC application rate of 1.53 lbs/sf

- 10.5-inch minimum sand habitat/erosion protection layer
- 4.5-inch minimum sand/GAC chemical isolation layer
- 3-inch minimum sand/siderite chemical isolation layer
- 3-inch minimum sand/siderite mixing layer

The water depth along the wall in this area is approximately 12 feet. Therefore, significant erosive forces due to boating activity are not expected in this area and thus sand is an appropriate habitat/erosion protection layer in this area, consistent with the habitat/erosion protection layer substrate specified in the Final Design for this area.

Siderite is incorporated into the RA-D2 MPC to neutralize high pH and thus promote biodegradation of organic contaminants. The 3-inch sand/siderite mixing lift has already been placed throughout the MPC area and the 3-inch sand/siderite chemical isolation layer has already been placed throughout the majority of the MPC area. Cores will be collected in this area prior to placement of the sand/GAC layer to verify that these sand/siderite layers remain intact at the specified thicknesses assumed in the model, and that additional sand/siderite material will be placed in the first and/or second lifts if needed. Cap modeling of this area incorporates biodegradation. The siderite ore application rate will be consistent with the Final Design.

A comprehensive Construction Quality Assurance Plan (CQAP) (Parsons and AnchorQEA, 2012) has been developed and implemented to ensure that the cap is constructed consistent with the Final Design, including thickness and amendment application rate requirements. The construction verification methods will be revisited as necessary to ensure the MPC is constructed consistent with this design modification.

Post-construction monitoring and maintenance of the capped areas throughout the lake, inclusive of the MPC area addressed in this design revision, will be performed to verify that the overall integrity of the cap is maintained so that it remains physically stable (i.e., does not erode) and chemically protective over time. Long-term monitoring of the caps will include physical monitoring to verify stability and sampling of the caps to verify their chemical integrity, as summarized below. Long-term monitoring will also include macrobenthic community sampling and documentation of vegetation recovery, as appropriate. Details of the monitoring methods, frequencies, and procedures and response actions will be developed based on joint discussions with NYSDEC and will be presented in the Onondaga Lake Monitoring and Maintenance Scoping document (OLMMS).

Physical monitoring of the capped areas, including the MPC area included in this design revision, will involve verifying that the various layers of cap material placed are stable and intact using a combination of methods including bathymetric surveys, sediment probing and coring, and/or other geophysical methods. The cap integrity will be monitored routinely and following wind/wave, tributary inflow, ice scour or seismic events that exceed a threshold design magnitude, consistent with USEPA (2005) recommendations. The frequency of routine monitoring will be greater initially after construction (e.g., multiple monitoring events within the first 5 to 10 years), and reduced over time once the monitoring is able to establish a consistent pattern of cap performance.

Chemical monitoring will involve measuring chemical concentrations within the caps to verify that contaminants are not moving through or accumulating within the cap at rates and concentrations that exceed specified remedy success metrics. Samples will also be collected within the MPC areas as the different cap configurations in these areas may result in different monitoring approaches, depths, and/or compliance points. The frequency of routine monitoring may be reduced over time once the monitoring is able to establish a consistent pattern of cap performance. Details of the chemical monitoring methods, frequencies, locations, sampling intervals, procedures, and response actions will be developed based on joint discussions with NYSDEC and will be presented in the OLMMS for NYSDEC review and approval.

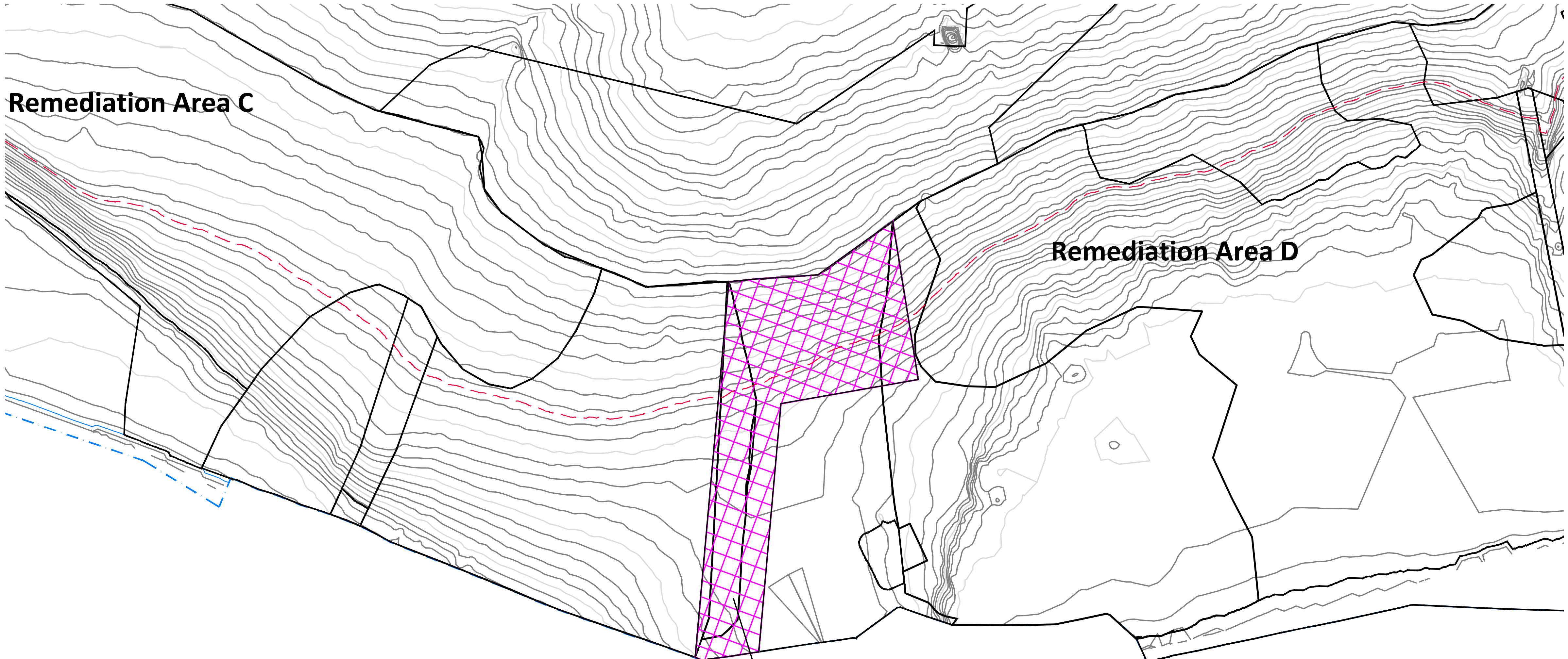
In the event that the monitoring plan discussed above identifies areas where the cap may not be performing consistent with expectations, follow-up assessments and/or response actions will be implemented. Follow-up assessments/actions may include additional investigation to further evaluate potential deficiencies, continued monitoring and assessment of overall remedy effectiveness over time, and/or placement of additional cap materials. Cap maintenance and response actions will be detailed in the OLMMS.

REFERENCES

Parsons and AnchorQEA. 2012. "*Construction Quality Assurance Plan Onondaga Lake Capping, Dredging and* Habitat"

Parsons and AnchorQEA. 2015. "*Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design Modified Protective Cap RA-D-1 Design Revision*"

United States Environmental Protection Agency. 2005. *Contaminated Sediment Remediation Guidance for Hazardous Waste Sites.* EPA-540-R-05-012. OSWER 9355.0-85. Office of Solid Waste and Emergency Response. December 2005.



H:\Syracuse1\CAD Projects\010139-ONONDAGA_LAKE\01013902\Figures\Construction Monitoring\FCF RA-D\RA_D_Modified Caps-05-19-16.dwg RA-D

May 19, 2016 4:19pm cyard

BATHYMETRY SOURCE:
Filename: EXG-Lake (Performed by: CR ENVIRONMENTAL, 2005)
HORIZONTAL DATUM: New York State Plane, Central Zone, North American Datum 1983 (NAD83), U.S. Feet
VERTICAL DATUM: North American Vertical Datum 1988 (NAVD88)

LEGEND:
Shoreline (elev. 362.5')
20-foot Depth Contour (elev. 342.5')

ANCHOR QEA

Figure 1
Modified Protective Cap RA-D-2
Remediation Area D
Onondaga Lake

ATTACHMENT 1

MODIFIED PROTECTIVE CAP RA-D-2
GEOTECHNICAL ANALYSIS

Written by:	**C. Carlson/M. Erten/M. Viswanath**	Date:	**5/25/2016**	Reviewed by:	**A. Ebrahimi/ J. Beech**	Date:	**5/25/2016**
Client:	**Honeywell**	Project:	**Cap Placement in Modified Protective Cap Area RA-D-2**	Project No.:	**GD5837**	Task No.:	**03**

SLOPE STABILITY ANALYSIS FOR CAP PLACEMENT IN MODIFIED PROTECTIVE CAP AREA RA-D-2

This report evaluates the geotechnical aspects of a modified protective cap (MPC) in Remediation Area D (RA-D-2) for various sequential cap lift placement configurations. RA-D-2 is located primarily within the cap-only corridor to the east of the bowl-shaped area in RA-D. On the east and west side of this cap-only corridor, RA-D has been dredged to slope downward toward the bowl-shaped area and the main portion of RA-D, consistent with the approved remedial design. The results of the slope stability analyses presented herein show that a MPC design in this area would consist of five lifts of cap, as shown in Figures 6 through 8. Out of these lifts, the first lift has been placed over the entire extent of RA-D-2, while the second lift has been placed in the majority of this area. The slope stability analyses show that the calculated slip surfaces during cap placement are deep; therefore, a practical additional wait time between lifts (a few weeks or a month) would not affect the strength gain of the deep sediments and would not improve cap stability. However, a typical one-week waiting period between the lifts is required during construction to control shallow slip surfaces.

The proposed MPC in RA-D-2 will be protective of the environment consistent with the intent of the Remedial Design, which will be documented in a separate submittal to the New York State Department of Environmental Conservation (NYSDEC).

INTRODUCTION

For a capping project of the scale of the Onondaga Lake Remediation project, it is not unusual to expect that during implementation, previously unforeseen field conditions in small areas may warrant adjustments to the cap system to achieve the remedial goals for the project. Evaluation of recently collected sediment strength data in RA-D-2 indicates that the sediments in this area are significantly softer than anticipated based on pre-design investigations (Geosyntec, 2015a). Therefore, modification of the cap designs detailed in the *Onondaga Lake Capping, Dredging, Habitat, and Profundal Zone Final Design* (Final Design) submittal in March 2012 is appropriate for RA-D-2.

Written by:	C. Carlson/M. Erten/M. Viswanath	Date:	5/25/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/25/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-D-2	Project No.:	GD5837	Task No.:	03

This slope stability calculation package was prepared in support of the cap stability evaluations and development for the RA-D-2 MPC. The locations of RA-D and the RA-D-2 MPC in Onondaga Lake are shown in Figure 1.

Sediment capping operations have been underway in Onondaga Lake since August 2012. The primary functions of the cap materials are to provide chemical and physical isolation for contaminated sediments and to reconstruct the habitat layer on the lake bottom. A portion of contaminated materials to the East and West of RA-D-2 as well as a small hot spot area within RA-D-2 were dredged prior to capping; these areas are referred to as "dredge and cap areas". The RA-D-2 area is mostly a "cap-only area."

This report evaluates the interim geotechnical slope stability condition of the cap after each lift of cap material is placed in the cap-only and dredge and cap areas. For the purposes of the slope stability analyses, each of the cap placement configurations was considered technically feasible and practical. Practical cap lift thicknesses based on input from the capping operations team, which are included in this evaluation, are:

- an average 4.5-in. lift of sand (i.e., minimum of 3-in. lift including a typical 1.5 in. of over-placement).

- an average 6-in. lift of sand (i.e., minimum 4.5-in. lift including a typical 1.5 in. of over-placement).

- an average 7.5-in. lift of sand (i.e., minimum 6-in. lift including a typical 1.5 in. of over-placement).

In this analysis, Cap Type J, which is the cap type specified in the Final Design for this area, includes a minimum of 6 inches of siderite mixed with medium sand, 9 inches of granular activated carbon (GAC) mixed with medium sand, and 12 inches of medium sand.

At the time of preparing this report, two layers of sand/siderite with an average of 4.5 in. per lift have been placed in the majority of the RA-D-2 area. In a small area near the shore, only one 4.5-in. lift has been placed. The cap in the dredge and cap areas on both the east and west sides of the RA-D-2 have been completed.

SLOPE STABILITY ANALYSES

The slope stability analyses were performed using Janbu's simplified method [Janbu, 1973] for block slip surfaces and Spencer's method [Spencer, 1973] for circular slip surfaces, as implemented in the computer program SLIDE, version 6.026 [Rocscience, 2013]. Spencer's method, which satisfies vertical and horizontal force equilibrium and moment equilibrium, is considered to be more rigorous than other methods, such as Janbu's simplified method [Janbu, 1973] and the simplified Bishop's method [Bishop, 1955]. However, Spencer's method often encounters numerical convergence difficulties when considering block slip surfaces. Therefore, Spencer's method was used for the circular slip surfaces, while Janbu's method was used for block slip surfaces.

The rotational and block modes of slope stability analyses are consistent with the methods presented in the RA-C-1 Report (Geosyntec, 2016).

Target Factor of Safety

Consistent with the RA-C-1 Report (Geosyntec, 2016), a target FS of 1.5 was selected for the analyses presented herein. The target FS (1.5) for the slope stability analysis of the cap is consistent with the target FS selected for previous slope stability analyses, including the FS used for stability analysis of the In-Lake Waste Deposit (ILWD) area included as Appendix H to the Final Design. The FS of 1.5 for the ILWD stability analysis was specified in the Statement of Work included as part of the Remedial Design/Action Consent Decree for the lake. Given the potential implications of additional cap movement, as demonstrated by the prior areas of cap movement, a FS of 1.5 is appropriate for this analysis consistent with prior stability analysis associated with the remediation design.

Subsurface Stratigraphy

Because the sediments in RA-D-2 are very soft, undisturbed samples were not obtained for laboratory testing to measure the shear strength and consolidation properties. Therefore, the information regarding the subsurface stratigraphy was obtained from in situ field testing techniques, including Full-Flow Penetrometer tests (FFP), as discussed in Geosyntec (2015a).

The locations of in situ tests within and adjacent to RA-D-2 are presented in Figure 2. These in situ tests provided information to characterize the in situ shear strength and consolidation properties of the soft sediments around RA-D-2. In May 2015, three FFPs (FFP-15-D1, D1A, and D2) and one vibracore (FFP-15-D1-VC) were conducted in RA-D-2. The reason for the selection of FFP-15-D1 (and also the repeated test at this location, FFP-15-D1A) was to evaluate the sediment strength and stability of the toe (or the feathering portion of the cap placement). FFP-15-D2 was selected to evaluate the subsurface condition in the cap-only area.

The FFP results and selected shear strength profiles for slope stability analyses are shown on Figures 3 through 5. Figure 4 shows that FFP data from FFP-15-D1 and D1A confirm the presence of very soft shallow sediments within the feathering area (with an undrained shear strength value of 25 psf in the top 6 ft) compared to a slightly higher undrained shear strength value of 45 psf from FFP-15-D2 in the cap-only area of RA-D-2. The extent of the weak deep layer (6 to 14 ft below the existing lake bottom) with the undrained shear strength value of 45 psf was interpreted based on the three collected FFPs (FFP-15-D1, D1A, and D2). This layer is significantly weaker than deeper soft sediments observed in most of remediation areas within the lake, where typical undrained shear strength values of more than 70 psf were observed in that depth.

GEOTECHNICAL STABILITY EVALUATION

Shear Strength Gain

The shear strength gain caused by an increase in vertical effective stress (in this case, as a result of cap placement) is proportional to the degree of consolidation, as described in the previous geotechnical design parameters report (Geosyntec, 2015a). In general, the shallow sediments within the thin layer cap area downslope of RA-D-2 are in a normally consolidated state and within RA-D-2 are in an overconsolidated state; therefore, no strength gain was considered for the shallow sediments within RA-D-2 in the slope stability analyses. The slope stability analyses presented in this report show that the controlling slip surfaces are deep; therefore a practical additional wait time between lifts (a few weeks to a month wait) would not affect the strength gain of sediments and therefore, would not improve cap stability. In general, the strength gain of sediments deeper than 6 ft below the lake bottom was neglected due to the long drainage path and negligible degree of consolidation within a practical few-week wait period. However, a one-week wait period between lifts is recommended to control shallow slip surfaces.

Geotechnical Parameters

The material properties used for the geotechnical slope stability analyses in this report are presented in Table 1 and Figures 3 and 4. In summary, the subsurface materials in the RA-D-2 MPC area consist of three strata: Soft Sediments, Marl, and Silt and Clay. Soft Sediments extend to a depth of about 14 ft. Marl lies between depths of about 14 and 60 ft. Silt and Clay is below depths of about 60 ft.

The development of geotechnical parameters of the lakebed sediments used for the slope stability analyses is described in the Geosyntec report titled *Development of Geotechnical Design Parameters for Lakebed Sediments in Onondaga Lake Capping Areas* (2015a).

ANALYZED CROSS SECTIONS

Three cross sections were selected as the critical cross sections for the slope stability analyses in RA-D-2 (Figure 2). Cross Section 1 spans laterally across the northern portion of the dredge-and-cap and cap-only areas of RA-D-2; Cross Section 2 extends longitudinally across the cap-only area of RA-D-2; and Cross Section 3 spans laterally along the southern portion of the dredge-and-cap and cap-only areas of RA-D-2. Cross Sections 1 and 3 were assumed to represent the stability conditions toward the dredge areas in both east and west sides of RA-D-2, while Cross Section 2 was used to verify the longitudinal stability of cap in the cap-only area. Cross Section 2 terminates before the barrier wall because this area is relatively flat along the cross section and therefore, is less critical than the area sloping toward SMU 8. All three cross-sections show the transition between the six-lift cap (i.e., full cap per Final Design) and the five-lift cap in RA-D-2. Figures 3 through 5 show the bathymetry, subsurface conditions, and selected strength profiles for Cross Sections 1, 2, and 3, respectively.

RESULTS OF SLOPE STABILITY ANALYSES

Figures 6 through 8 show the calculated slip surfaces and minimum FS for Cross Sections 1, 2, and 3, respectively, in the existing condition (i.e., prior to cap placement) and after each lift of cap is placed. In the slope stability analyses, it was assumed that the full cap thickness had been placed in the dredge and cap areas on both the east and west sides of RA-D-2 prior to placement of cap in the cap-only area to act as a buttress. It was also assumed that two lifts of siderite layer with an average thickness of 4.5 in. per lift have been placed in the majority of the RA-D-2 area, as shown in Figures 6 through 8.

For Cross Section 1, the calculated slip surfaces on the western side of the cap-only area of RA-D-2 (i.e., left end of Cross Section 1) are shown in Figure 6 and the minimum calculated FS are listed in the table below.

Lift	Lift 1	Lift 2	Lift 3	Lift 4	Lift 5	Lift 6	
Average Cap Thickness (in.)	4.5	4.5	6	6	7.5	7.5	4.5
Wait Before Placement (weeks)**	-	1	1	1	1	1	1
Calculated Minimum FS	2.20	2.01	1.84	1.66	1.50	1.31	1.41
Recommended for Placement	Completed	Completed*	Yes	Yes	Yes	No	No

* The second lift has not yet been placed on a small portion of the shoreline area in RA-D-2.

** The calculated slip surfaces during cap placement are deep (deeper than 6 ft); therefore additional wait time between lifts (more than one week) would not affect the strength gain of sediments and the cap stability due to the long drainage length and negligible consolidation of deeper sediments within a few weeks of wait time.

The calculated slip surfaces on the eastern side of the cap-only area of RA-D-2 (i.e., right end of Cross Section 1) generally resulted in higher calculated FS compared to the western side of RA-D-2 as presented in Figure 6.

Based on the results shown above, a full cap thickness per Final Design with total of six lifts of cap (existing 2 lifts of 4.5 in. + additional 2 lifts of 6 in. + 2 lifts of 7.5 in.) with one-week wait time between lifts is recommended in a portion of the area where the cap is yet to be completed (see Figure 6), while a total of five lifts of cap (existing 2 lifts of 4.5 in. + additional 2 lifts of 6 in. + 1 lift of 7.5 in.) with one-week wait time between lifts is recommended in RA-D-2. The calculated slip surfaces for the last four lifts of cap (i.e., Lifts 3 to 6) during cap placement are deep, through the weak layer with an undrained shear strength value of 45 psf at depths of approximately 6 to 14 ft below the lake bottom (see Figures 3 through 5); therefore, practical additional wait time between lifts (a few weeks to a month) would not affect the strength gain of sediments and the cap stability due to a long drainage path for the deep weak sediment and negligible degree of consolidation. The calculated FS after placement of Lift 6 in RA-D-2 with 7.5-in. thickness is 1.31 and with 4.5-in. thickness is 1.41, which is below the target FS of 1.5.

Cross Section 2 was analyzed to estimate the required feathering and extension into SMU-8 at the northern edge of RA-D-2. For Cross Section 2, the calculated slip surfaces are shown in Figure 7 and the minimum calculated FS are listed in the table below.

Lift	Lift 1	Lift 2	Lift 3	Lift 4	Lift 5			Lift 6		Lift 6
Average Cap Thickness (in.)	4.5	4.5	6.0	6.0	7.5			7.5	4.5	7.5
Wait Before Placement (weeks)**	-	1	1	1	1			1		
Feathering Distance (ft)	-	-	20	20	20	70	110***	20		160
Calculated Minimum FS	2.13	1.99	1.77	1.59	1.34	1.45	1.50	1.37	1.42	1.50
Recommended for Placement	Completed	Completed*	Yes	Yes	No	No	Yes	No	No	Yes

* The second lift has not yet been placed on a small portion of the shoreline area in RA-D-2.

** The calculated slip surfaces during cap placement are deep (deeper than 6 ft); therefore additional wait time between lifts (more than one week) would not affect the strength gain of sediments and the cap stability due to the long drainage length and negligible consolidation of deeper sediments within a few weeks of wait time.

*** The cap is required to be extended about 110 ft into SMU-8 in order to place Lift 5.

**** The cap is required to be set back about 160 ft in order to place Lift 6, as shown in Figure 7. Five lifts will be placed within this setback area (see Figure 7)

The calculated FS after placement of Lift 6 with smaller feathering (i.e., 20 ft) and with 7.5-in. thickness is 1.37 and with 4.5-in. thickness is 1.42, which are below the target FS of 1.5. Therefore, a 160-ft setback is required to place the full cap thickness per Final Design, as shown in Figure 7. The calculated 160 ft of feathering is due to the geometry of the slope and is required in order to improve the stability of the full cap within the flatter portion of slope in the area before Station 400 ft shown in Figure 7.

Based on the results shown above, a total of five lifts of cap (existing 2 lifts of 4.5 in. + additional 2 lifts of 6 in. + 1 lift of 7.5 in.) with one-week wait time between lifts, and the extensions into SMU-8 presented in the table above and Figure 7 are recommended in RA-D-2. The staggered downslope edge shown in Figure 7 is required due to the presence of a deep weak layer of soft sediments and relatively steeper slopes, as shown in Figure 4. This weak layer has an undrained shear strength value of 45 psf at depths of approximately 6 to 14 ft below the lake bottom. It should be noted that FFP-15-D1 and FFP15-D1A are located below the footprint of the feathering area and provided the geotechnical parameters that were considered in the slope stability analysis.

In the slope stability analysis presented in this report, various feathering and setback configurations were considered to place the maximum cap thickness with a calculated FS above the target FS of 1.5. For example, the cap placement considered in Cross Section 2 has been extended further outside and downslope of the cap-only area (in SMU-8), in order to place cap within the boundary of the cap-only area with a thickness close to the thickness in the original design. The site investigation program conducted in SMU-8 (Geosyntec, 2015b) has shown that sediments are extremely soft in SMU-8 and gradually become even softer as water depth increases, which would impact the cap stability. Therefore, further extension of cap into the SMU-8 was not considered.

For Cross Section 3, the calculated slip surfaces on the western side of the cap-only area of RA-D-2 (i.e., left end of Cross Section 3) are shown in Figure 8 and the minimum calculated FS are listed in the table below.

Lift	Lift 1	Lift 2	Lift 3	Lift 4	Lift 5	Lift 6	
Average Cap Thickness (in.)	4.5	4.5	6	6	7.5	7.5	4.5
Wait Before Placement (weeks)**	-	1	1	1	1	1	1
Calculated Minimum FS	-	2.09	1.84	1.68	1.50	1.29	1.39
Recommended for Placement	Completed	Completed*	Yes	Yes	Yes	No	No

* The second lift has not yet been placed on a small portion of the shoreline area in RA-D-2.

** The calculated slip surfaces during cap placement are deep (deeper than 6 ft); therefore additional wait time between lifts (more than one week) would not affect the strength gain of sediments and the cap stability due to the long drainage length and negligible consolidation of deeper sediments within a few weeks of wait time.

Similar to the results for Cross Section 1, the calculated slip surfaces on the eastern side of the cross section generally resulted in higher calculated FS compared to the western side of the cross section, as presented in Figure 8.

Based on the results shown above, a full cap thickness per Final Design with a total of six lifts of cap (existing 2 lifts of 4.5 in. + additional 2 lifts of 6 in. + 2 lifts of 7.5 in.) with one-week wait time between lifts is recommended in a portion of the area yet to be capped, while a total of five lifts of cap (existing 2 lifts of 4.5 in. + additional 2 lifts of 6 in. + 1 lift of 7.5 in.) with one-week wait time between lifts is recommended in RA-D-2. The calculated slip surfaces for the last four lifts of cap (i.e., Lifts 3 to 6) during cap placement are deep, through the weak layer with an undrained shear strength value of 45 psf at depths of approximately 6 to 14 ft below the lake bottom (see Figures 3 through 5); therefore, practical additional wait time between lifts (a few weeks to a month) would not affect the strength gain of sediments and the cap stability due to a long drainage path for the deep weak sediment and negligible degree of consolidation.

The recommended cap placement procedure in RA-D-2 includes a verification of successful placement of each lift by the operations team thru methods such as coring prior to proceeding with the subsequent lift. However, the monitoring and verification of successful lift placement will not provide information regarding whether additional lift placements would be stable; it only verifies that it was stable for what was already placed. Therefore, real time monitoring would not allow additional cap material to be placed.

Other engineering methods to improve stability and allow additional cap material placement, such as toe berms and keyways, were considered. However, the critical slip surfaces in the upslope-downslope direction are large and deep along the relatively continuous steep slope areas in RA-D-2 that could not practically be targeted for methods such as toe berms and keyways.

It should be noted that the potential for creep behavior (as stated in Geosyntec 2015a) would be offset by the strength gain due to consolidation with time, resulting in an increase in the calculated FS over time. Additional long-term analysis of slope stability for a representative cross section (Cross Section 2) was conducted. The calculated FS for the long-term condition (after consolidation of sediments under the cap loading is completed) in Cross Section 2 is 2.67 (compared to the calculated FS of 1.5, immediately after the cap placement) and greater than the commonly-selected target FS of 1.5 for the long-term condition. Also, the long-term presence and performance of the cap throughout the lake, including the MPC areas, will be verified as part of the long-term cap monitoring program.

CONCLUSIONS

Figure 9 shows the recommendation for cap placement in the modified protective cap area of RA-D-2. The results of the slope stability analyses for the placement of multiple lifts of cap with one-week wait periods between lifts show that, in general:

- the calculated slip surfaces for the last four lifts of cap (i.e., Lifts 3 to 6) are in general within the deeper soft sediments; therefore, longer wait time between cap lift placements would not improve the undrained shear strength of the deeper sediments or the calculated factor of safety due to a long drainage path and negligible degree of consolidation after a few weeks to a month of wait time, and

- a full cap thickness per Final Design with a total of six lifts of cap (existing 2 lifts with average 4.5-in. per lift of siderite + additional two lift with average 6 in. per lift of GAC + two lifts with average 7.5 in. of sand habitat layer) with one-week wait time between lifts and the extensions into SMU-8 are recommended in a portion of the area yet to be capped.

- a total of five lifts of cap (existing 2 lifts with average 4.5-in. per lift of siderite + additional one lift with 6 in. of GAC + one lift with 6 in. and one lift with 7.5 in. of habitat layer) with one-week wait time between lifts and the extensions into SMU-8 are recommended in RA-D-2.

Written by:	**C. Carlson/M. Erten/M. Viswanath**	Date:	**5/25/2016**	Reviewed by:	**A. Ebrahimi/ J. Beech**	Date:	**5/25/2016**
Client:	**Honeywell**	Project:	**Cap Placement in Modified Protective Cap Area RA-D-2**	Project No.:	**GD5837**	Task No.:	**03**

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Spencer, E. (1973), "*The Thrust Line Criterion in Embankment Stability Analysis*," Géotechnique, Vol. 23, No. 1, pp. 85-100, March 1973.

Table 1. Summary of Material Properties for the Slope Stability Analysis in Modified Protective Cap area RA-D-2

Material	Total Unit Weight (pcf)	Undrained Shear Strength, s_u (psf)
Soft Sediments	85	Selected as shown in Figures 3 and 4
Marl	100	220, for depth < 30 ft 440, for depth ≥ 30 ft
Silt and Clay	110	$\frac{s_u}{\sigma_v'} = 0.3$

Written by:	**C. Carlson/M. Erten**	Date:	**5/25/2016**	Reviewed by:	**A. Ebrahimi/ J. Beech**	Date:	**5/25/2016**
Client:	**Honeywell**	Project:	**Cap Placement in Modified Protective Cap Area RA-D-2**	Project No.:	**GD5837**	Task No.:	**03**

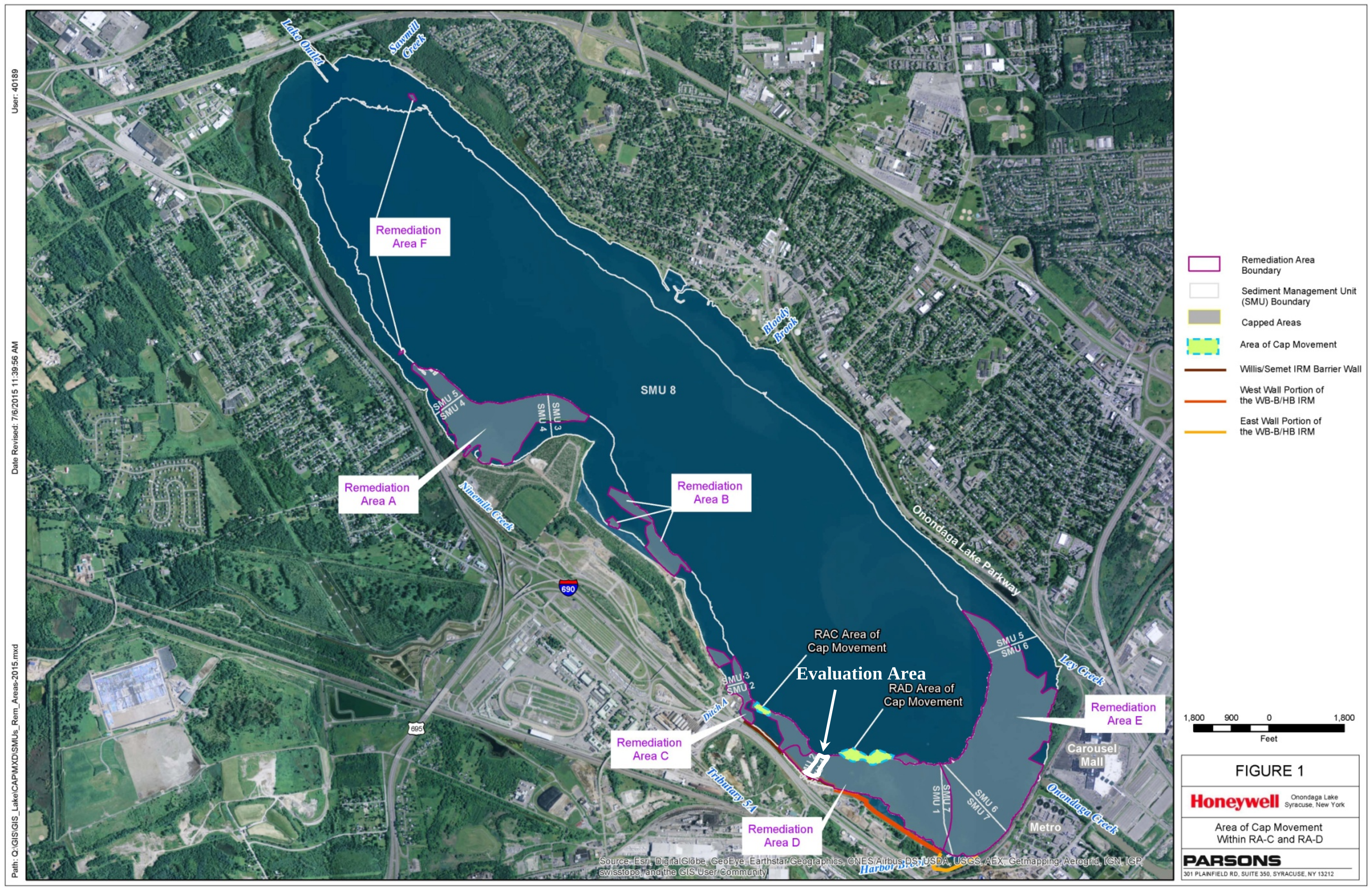

Figure 1. Remediation Area D (RA-D) and RA-D-2 among other Remediation Areas in the Onondaga Lake Capping Project.

Written by:	C. Carlson/M. Erten	Date:	5/25/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/25/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-D-2	Project No.:	GD5837	Task No.:	03

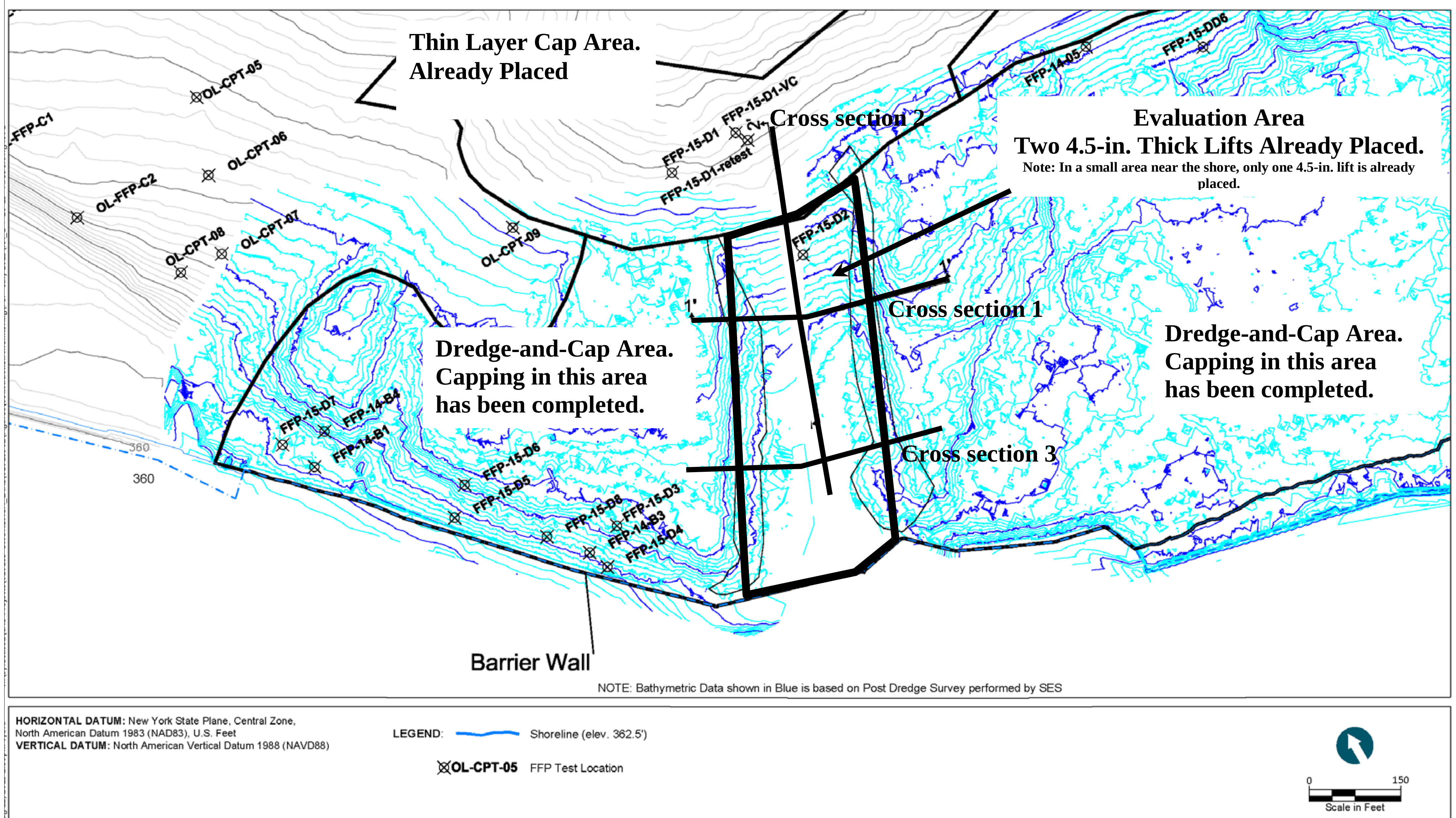

Figure 2. Map of modified protective cap area RA-D-2. This map also shows locations of in situ FFP and CPT tests and the two analyzed cross sections.

Written by:	C. Carlson/M. Erten	Date:	5/25/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/25/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-D-2	Project No.:	GD5837	Task No.:	03

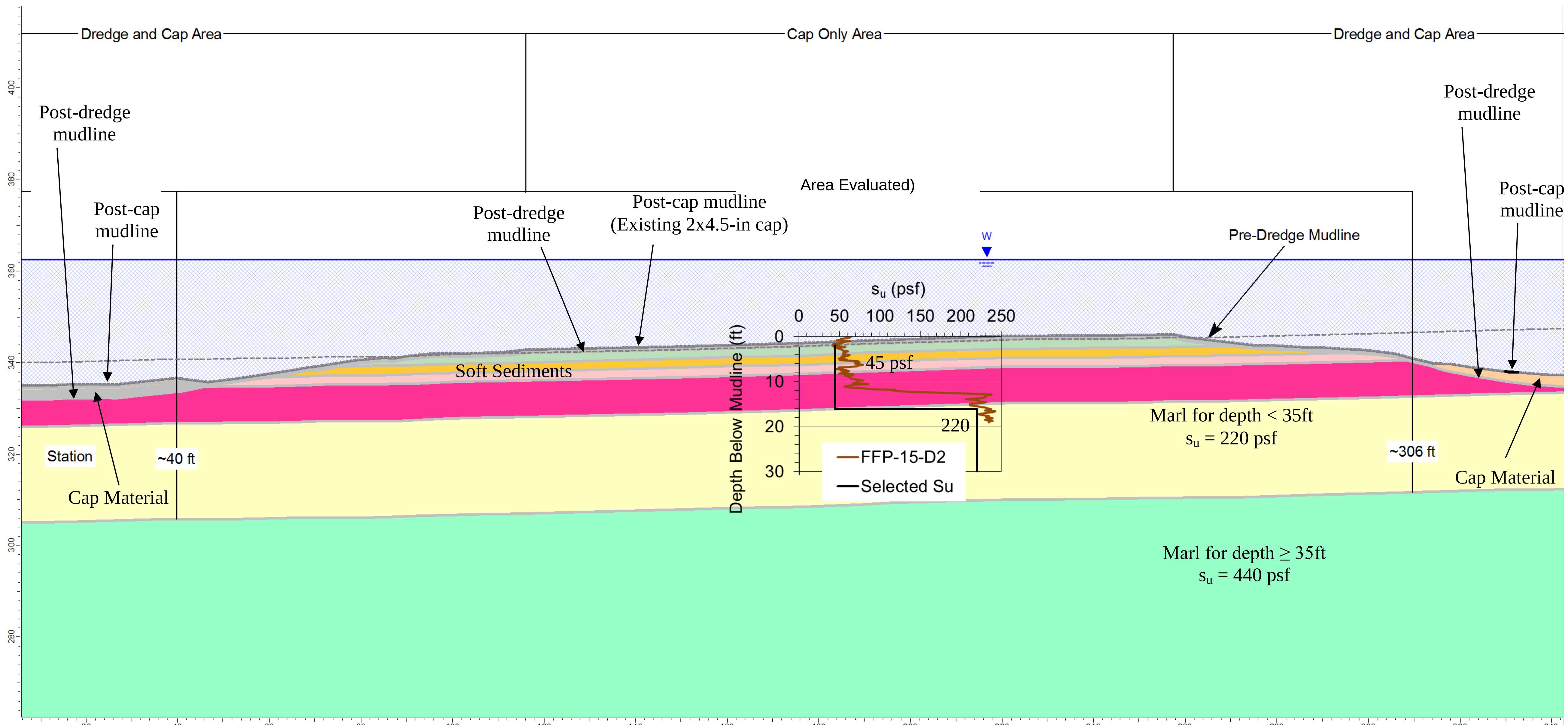

Figure 3. Subsurface stratigraphy and shear strength (s_u) profiles from the FFPs collected near Cross Section 1.

Written by:	C. Carlson/M. Erten	Date:	5/25/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/25/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-D-2	Project No.:	GD5837	Task No.:	03

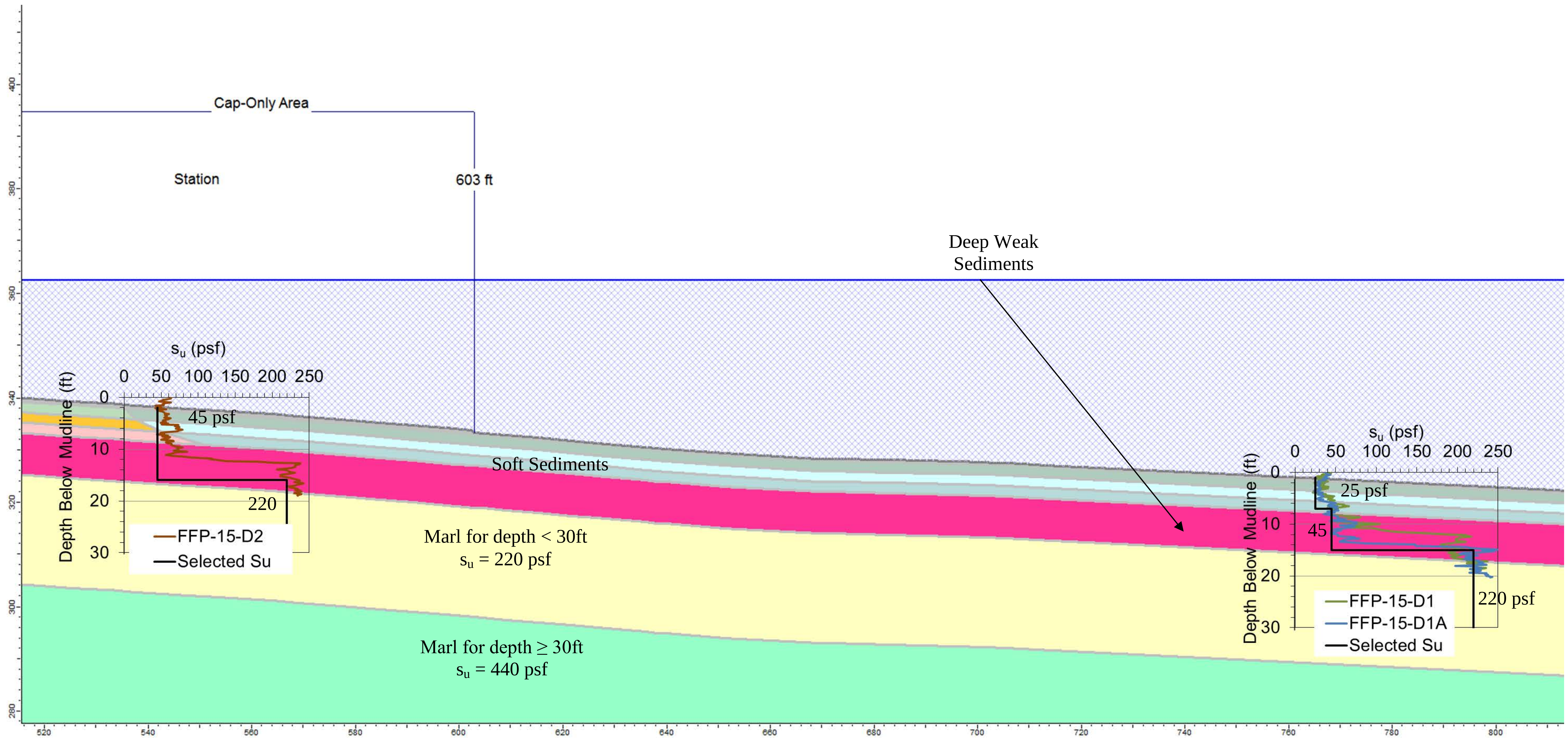

Figure 4. Subsurface stratigraphy and shear strength (s_u) profiles from the FFPs collected near Cross Section 2.

Written by:	C. Carlson/M. Erten	Date:	5/25/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/25/2016

Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-D-2	Project No.:	GD5837	Task No.:	03

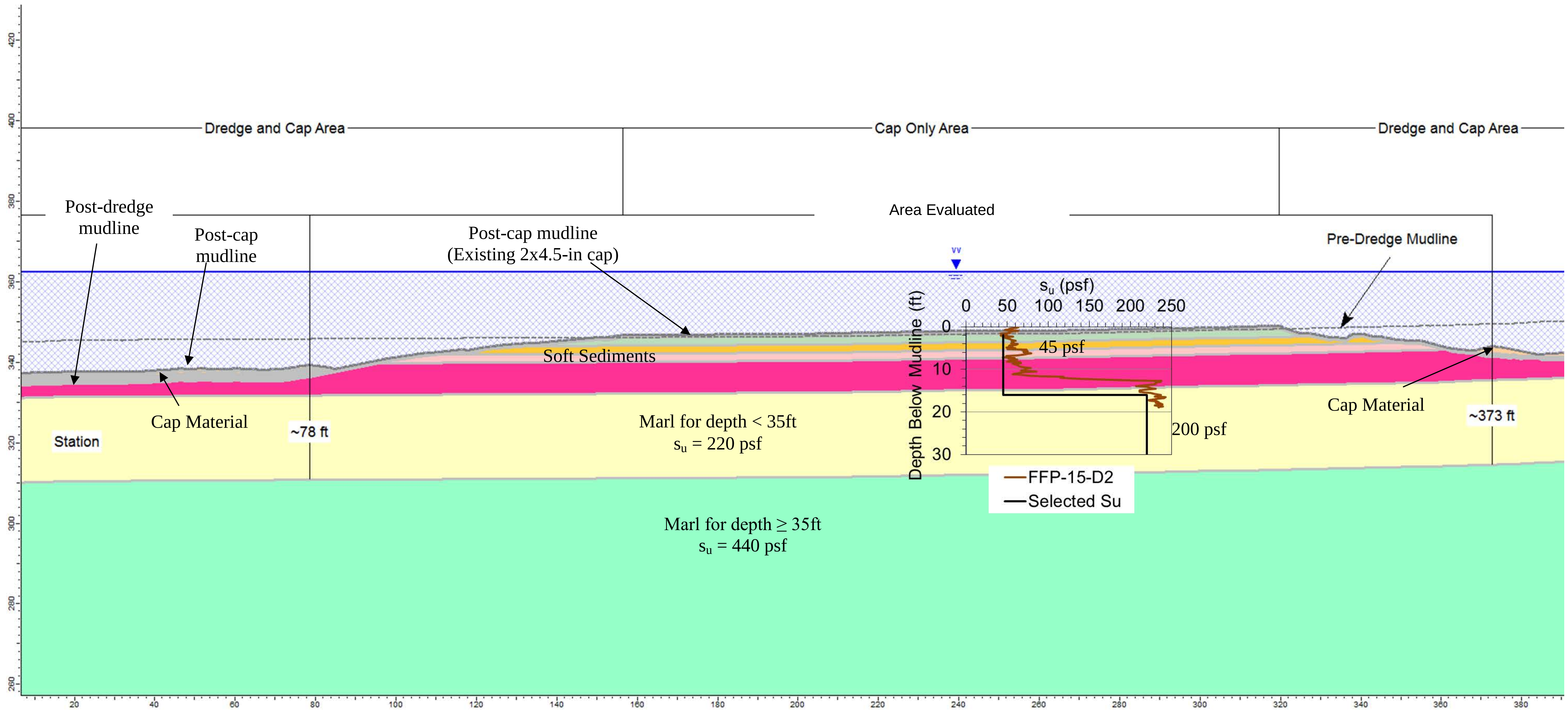

Figure 5. Subsurface stratigraphy and shear strength (s_u) profiles from the FFPs collected near Cross Section 3.

Written by:	C. Carlson/M. Erten	Date:	5/25/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/25/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-D-2	Project No.:	GD5837	Task No.:	03

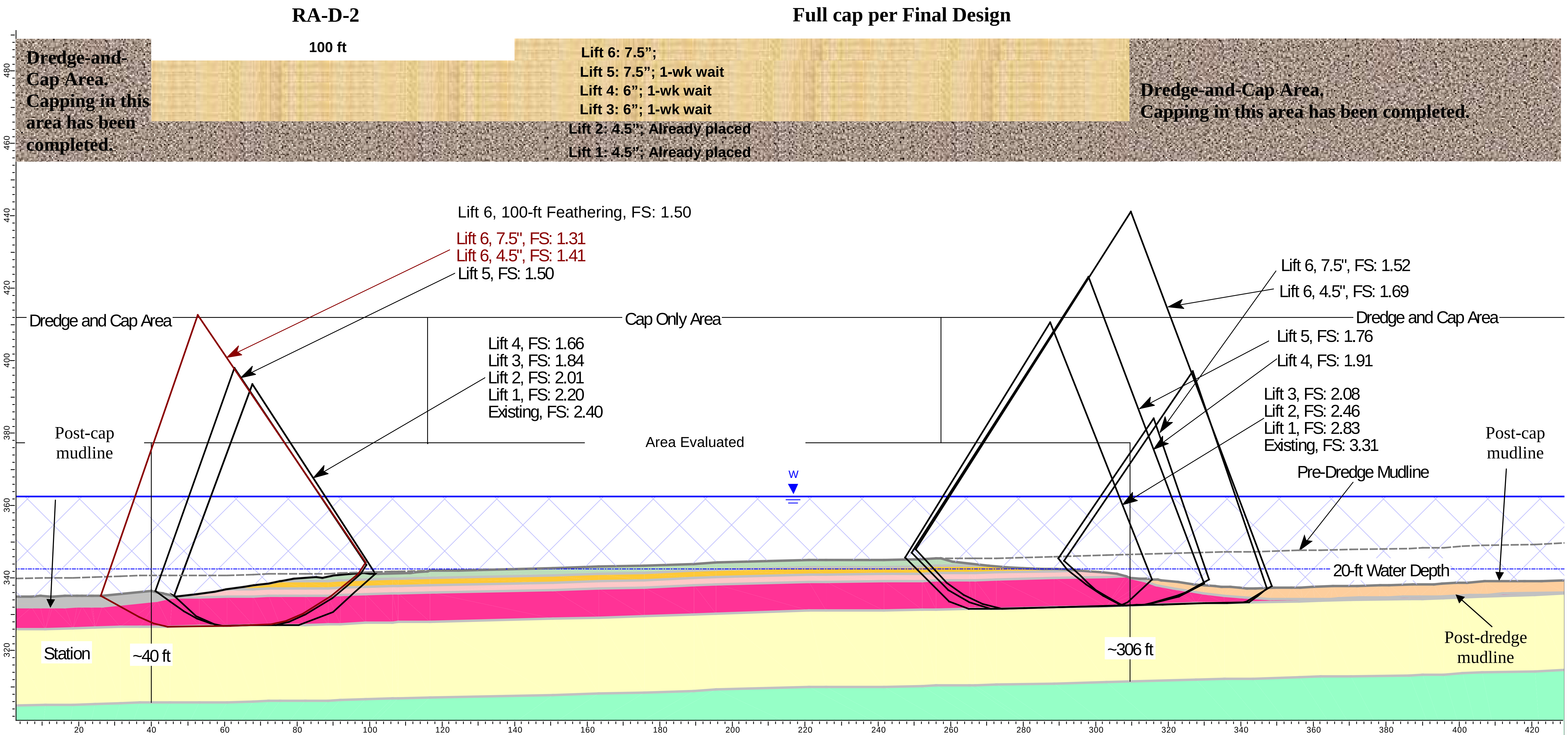

Figure 6. Calculated factors of safety and critical slip surfaces for Cross Section 1.

Written by:	C. Carlson/M. Erten	Date:	5/25/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/25/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-D-2	Project No.:	GD5837	Task No.:	03

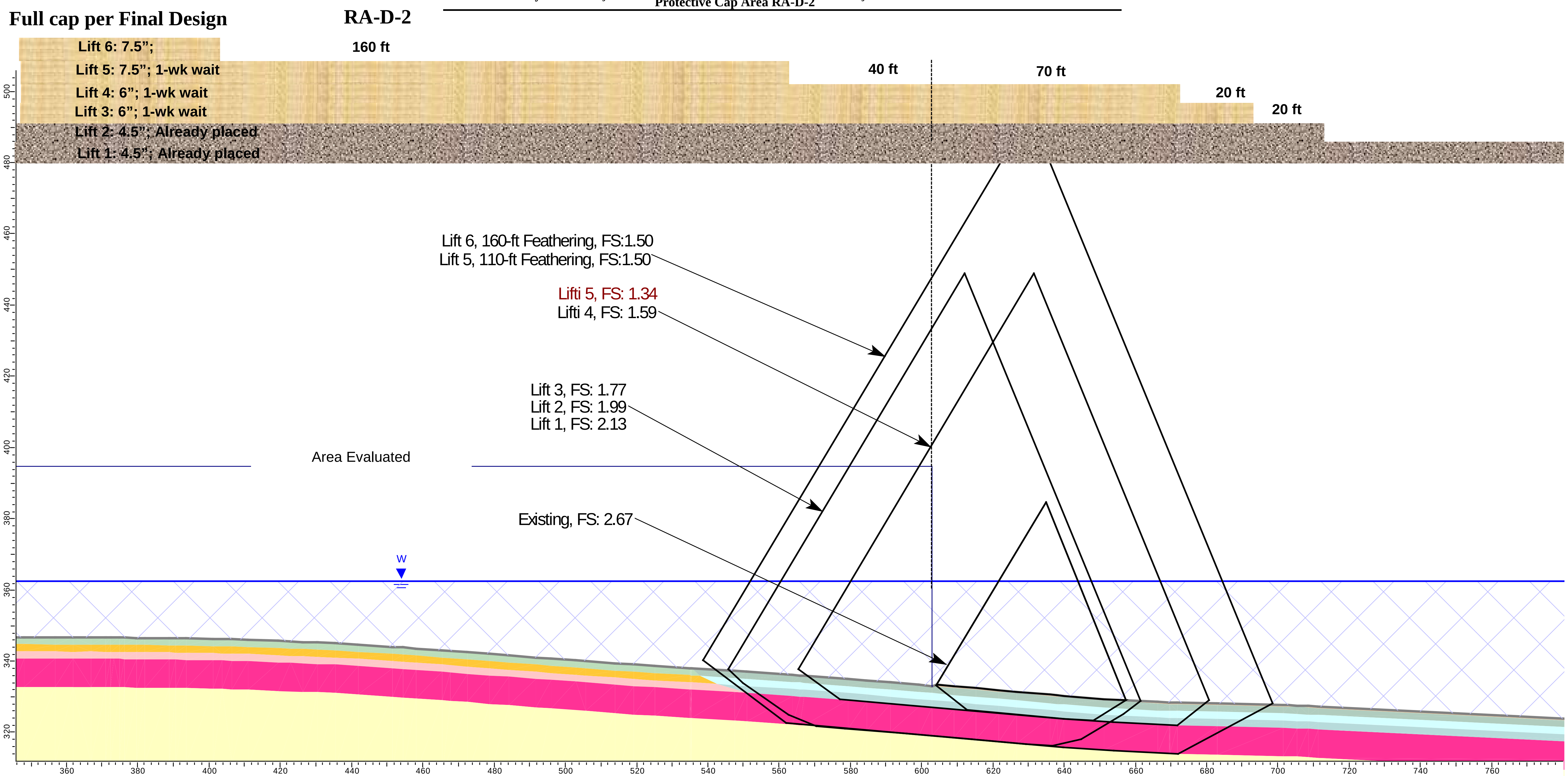

Figure 7. Calculated factors of safety and critical slip surfaces for Cross Section 2.

Written by:	C. Carlson/M. Erten	Date:	5/25/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/25/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-D-2	Project No.:	GD5837	Task No.:	03

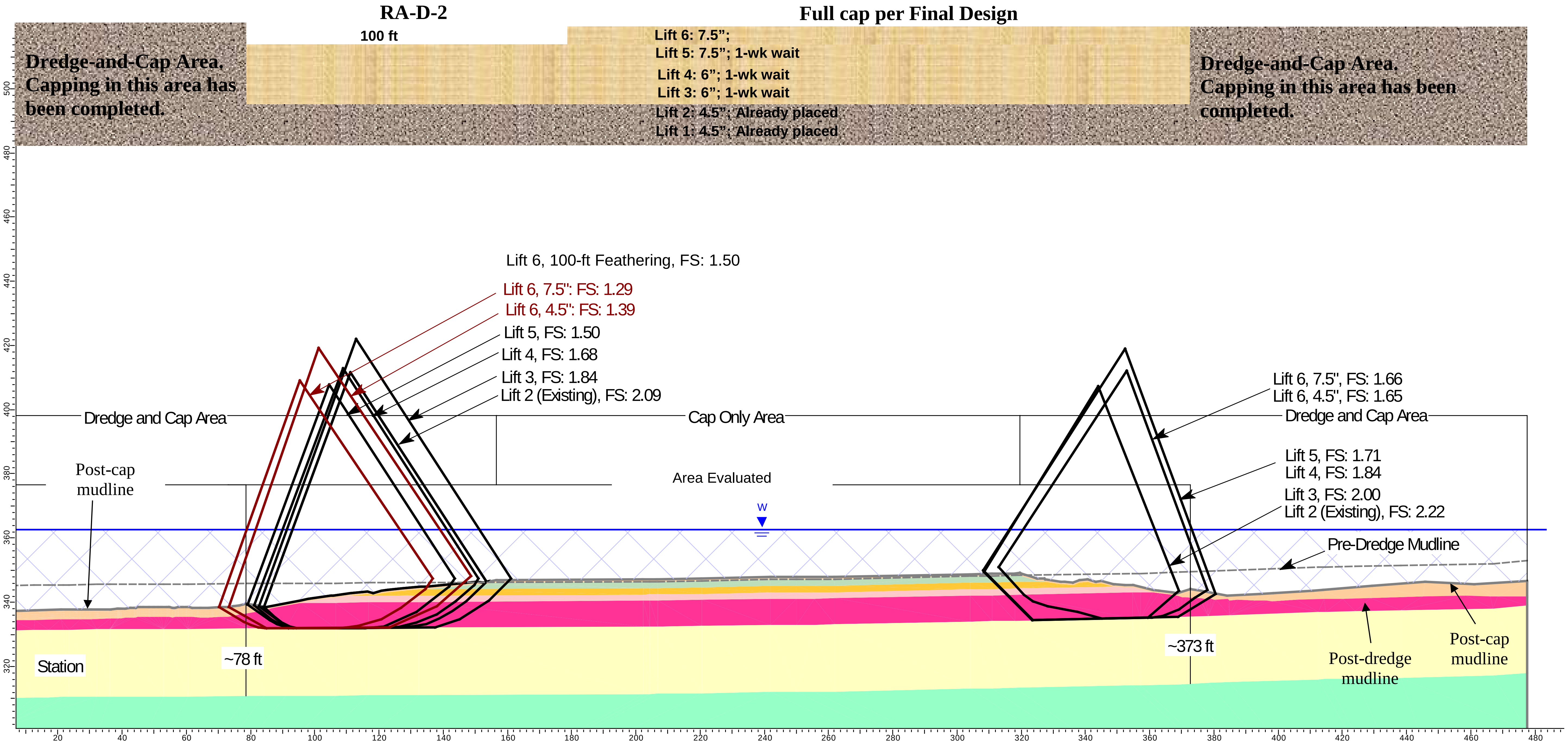

Figure 8. Calculated factors of safety and critical slip surfaces for Cross Section 3.

Written by:	C. Carlson/M. Erten	Date:	5/25/2016	Reviewed by:	A. Ebrahimi/ J. Beech	Date:	5/25/2016
Client:	Honeywell	Project:	Cap Placement in Modified Protective Cap Area RA-D-2	Project No.:	GD5837	Task No.:	03

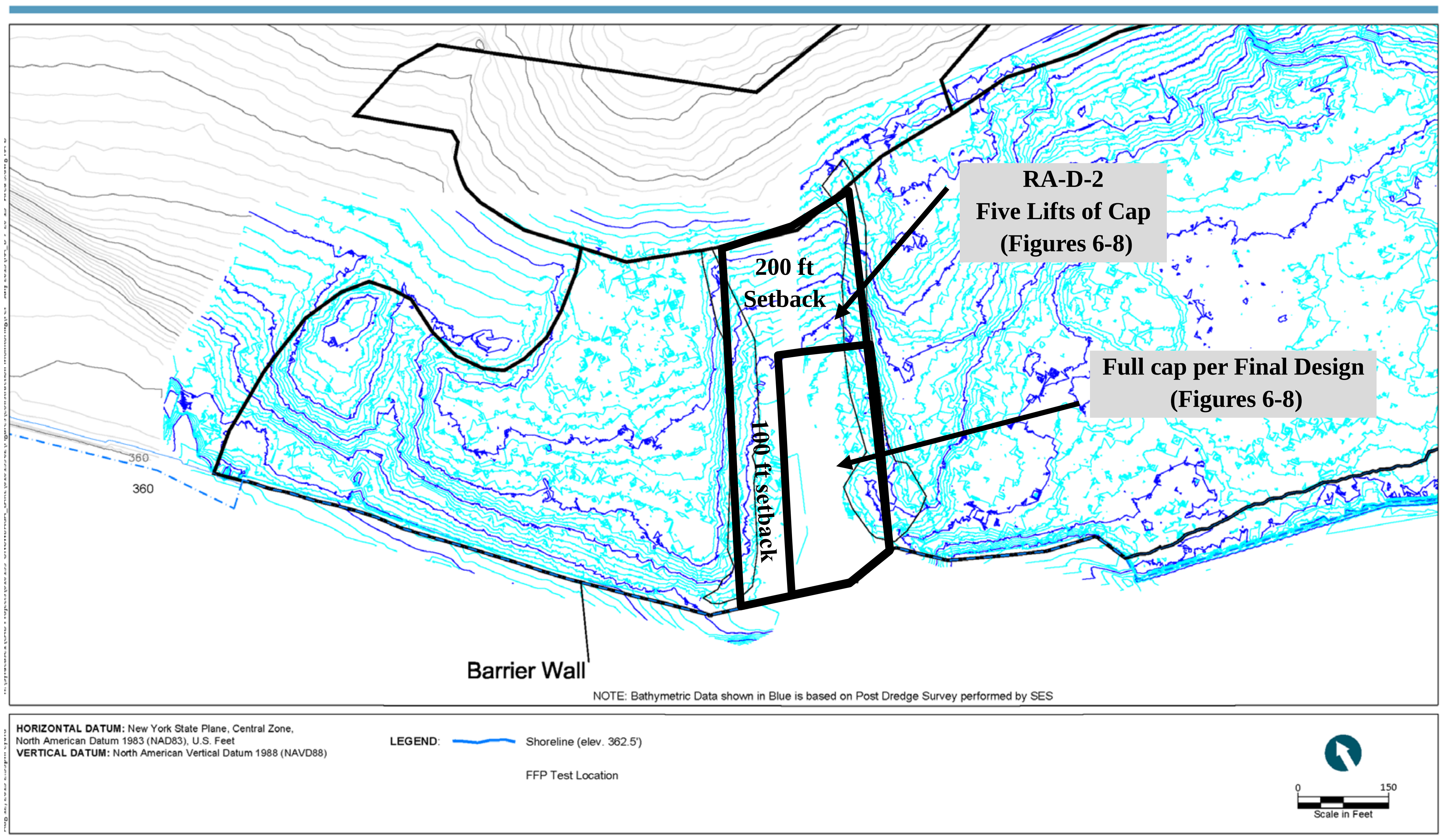

Figure 9. Recommended cap placement in modified protective cap area RA-D-2.

ATTACHMENT 2

MODIFIED PROTECTIVE CAP RA-D-2
CHEMICAL ISOLATION MODELING

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FINAL MEMORANDUM

To:	Ed Glaza, Parsons	**Date:**	May 25, 2016
From:	Deirdre Reidy and Kevin Russell, Anchor QEA, LLC	**Project:**	E50139-09.02
Cc:	Paul LaRosa and Ram Mohan, Anchor QEA, LLC		
Re:	Cap Modeling in Modified Protective Cap Area RA-D-2		

1 INTRODUCTION

This memorandum documents the numerical modeling conducted for the Modified Protective Cap (MPC) in Remediation Area (RA) RA-D-2. The modeling was conducted to verify the protectiveness of the MPCs and to develop granular activated carbon (GAC) application rates that would be required for this modified cap to be protective for more than 1,000 years, consistent with the evaluation timeframe used in the final design.

For a capping project of the scale of Onondaga Lake Remediation, it is not unusual to expect previously unforeseen field conditions in small areas that may warrant adjustments to the cap system to achieve the remedial goals for the project. Subsequent to the cap movements that were observed to have occurred in RA-C and RA-D, additional in situ data collection and geotechnical analyses were conducted in those two remediation areas as well as other portions of the lake. These recent geotechnical stability evaluations have indicated that the cap thicknesses developed as part of the final design (Parsons and Anchor QEA 2012) need to be revised in the small areas of cap movement, as well as in other small portions of Onondaga Lake RAs where the sediments are much softer than previously identified.

This memorandum consists of the following sections:

- Section 2 describes the general modeling approach used to evaluate the various modified cap configurations, as well as the modeling details specific to RA-D-2.
- Section 3 presents the GAC application rate required in RA-D-2 to meet the target criteria for more than 1,000 years.
- Section 4 presents a list of references.
- Attachment 1 includes the model files associated with the RA-D-2 MPC.

2 MODELING APPROACH

2.1 General Approach

The modeling approaches employed for the proposed MPC configurations identified from the geotechnical analyses can be simplified into the following three basic categories:

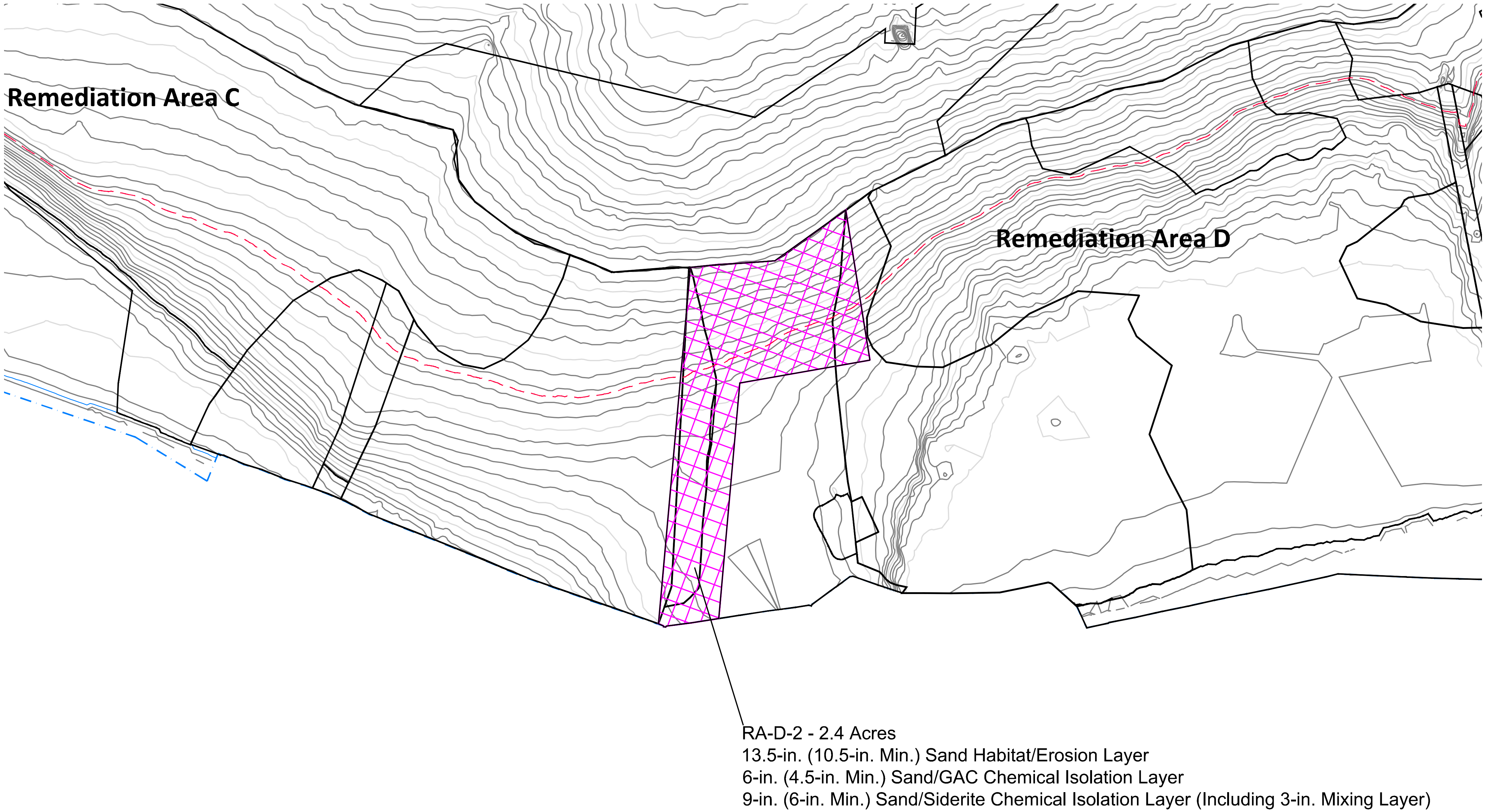
1. Multi-layer caps (simulated with the transient numerical model)
2. Mono-layer caps (simulated with the transient numerical model)
3. Modeling deposition effects for mercury (simulated with the Sediment Management Unit 8 [SMU 8] monitored natural recovery model)

Detailed descriptions of the modeling approach for each of these categories were provided in the first memorandum in this series (Anchor QEA 2015) and are not repeated here. Considerations specific to area RA-D-2 are described in the following subsection. These considerations include the site-specific cap configuration, chemical source term (i.e., initial sediment porewater concentrations), bioturbation depth, and biological decay rate.

2.2 Modeling Approach for the RA-D-2 Modified Protective Cap

Based on the results of the slope stability analysis, the MPC configuration for RA-D-2 will include a multi-layer cap, as shown on Figure 1, consisting of the following:

- 10.5 inches minimum of sand (habitat/erosion protection layer)
- 4.5 inches minimum of sand/GAC (chemical isolation layer)
- 6 inches minimum of sand/siderite (chemical isolation layer; lower 3 inches of which was excluded from modeling due to assumed mixing with underlying sediments [mixing layer])



H:\Syracuse1\CAD Projects\010139-ONONDAGA_LAKE\01013902\Figures\Construction Monitoring\FCF RA-D\RA_D_Modified Caps-05-19-16.dwg RA-D

BATHYMETRY SOURCE:
Filename: EXG-Lake (Performed by: CR ENVIRONMENTAL, 2005)
HORIZONTAL DATUM: New York State Plane, Central Zone,
North American Datum 1983 (NAD83), U.S. Feet
VERTICAL DATUM: North American Vertical Datum 1988 (NAVD88)

LEGEND:
Shoreline (elev. 362.5')
20-foot Depth Contour (elev. 342.5')

0 300
Scale in Feet

May 19, 2016 4:19pm cyard

ANCHOR QEA

Figure 1
Modified Protective Cap RA-D-2
Remediation Area D
Onondaga Lake

This multi-layer MPC was simulated in the model consistent with the final design cap configuration (except using the reduced thicknesses, as discussed in Section 2.1 of Anchor QEA [2015]). Multi-layer MPCs having a sand/siderite layer placed separately from the GAC-amended chemical isolation layer (which was the case for the RA-D-2 MPC) were evaluated incorporating biological degradation (which is expected to occur over the long term following porewater pH neutralization by siderite), consistent with the final design, as discussed in Section 2.1 of Anchor QEA (2015). Although a portion of this area is located in water depths greater than 6 meters and may be considered net depositional, that process was conservatively not incorporated into the modeling.

Chemical isolation cap modeling using the numerical transient model was conducted to develop the GAC application rate required for RA-D-2. No additional sediment or porewater chemistry samples have been collected in RA-D-2 since the final design. Therefore, initial porewater concentrations in this area were set to the 95th percentile porewater concentrations used during the final design for Model Area D-West.

The MPC thickness in RA-D-2 is less than the full-thickness cap that was used as the basis for the final design porewater flux estimates. Therefore, consolidation settlement and porewater flux estimates from the final design are considered conservative for this MPC evaluation.

All 25 of the organic chemicals evaluated during final design (i.e., volatile organic compounds, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls) were evaluated with the transient numerical model using deterministic simulations to identify the GAC application rate that would be needed to maintain concentrations below the applicable probable effects concentrations [PECs] and sediment screening concentrations [SSCs] for more than 1,000 years. Mercury was also evaluated with the transient numerical model to assess whether concentrations are predicted to be below the applicable PEC for more than 1,000 years.

Probabilistic modeling was not conducted for this MPC. During the final design, although probabilistic modeling was performed for 13 separate modeling areas, the GAC dose was increased in one model area only—WBB1-8, which is not an area of concern for these evaluations. In this area, the GAC application rate increased by less than 10%. These results indicate that the deterministic modeling drives the GAC application rate in nearly all cases and probabilistic modeling is not needed for the MPC evaluations.

3 RESULTS

The GAC application rate for the RA-D-2 MPC was developed based on the transient numerical modeling described in the preceding section. For the RA-D-2 multi-layer cap, where a designated habitat layer (sand) exists, compliance with the PECs and SSCs was assessed against the maximum concentration within the habitat layer. The transient numerical modeling was conducted starting with the minimal practical GAC application rate of 0.1 pound per square foot (lb/sf), and the application rate was increased as necessary to meet the PECs and SSCs for more than 1,000 years. Model results indicate that all 25 organic chemicals meet the target criteria for the duration of the simulation (in this case, more than 1,000 years) at the specified thickness and a GAC application rate of 1.53 lb/sf. In addition, numerical modeling results indicated that the thickness of the cap is sufficient to meet the mercury PEC of 2.2 milligrams per kilogram for more than 1,000 years.

4 REFERENCES

Anchor QEA (Anchor QEA, LLC), 2015. *Cap Modeling in Modified Protective Cap Area RA-D-1 and Adjacent Amended Thin-layer Cap in SMU 8.* Prepared for Parsons. October 2015.

Parsons and Anchor QEA, 2012. *Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design. Appendix B – Cap Modeling.* Prepared for Honeywell. March 2012.

ATTACHMENT 1
ONONDAGA LAKE CAP MODELING FILES FOR RA-D-2 MPC

ATTACHMENT 1: MODEL FILES

This attachment details the files and directory structure associated with the numerical modeling conducted for the Modified Protective Cap (MPC) Remediation Area (RA) RA-D-2. The following sections describe the files, folders, and subfolders that contain the cap modeling files.

Numerical Model

The numerical cap modeling files are contained in two subfolders:

1. Inputs
2. Outputs

The contents of each of these subfolders are described in this section. Please reference Attachment 4 to Appendix B of the final design (Parsons and Anchor QEA 2012[1]) for the numerical model code files and their descriptions. In addition, the structure and formatting of the input and output files for this numerical cap modeling is identical to that from the final design; differences in input values from the final design associated with using the model to represent the MPC are mainly what is described in the subsections that follow.

Numerical Model Inputs

The input file used for the simulation of the RA-D-2 MPC is located in the *Numerical_Model\Inputs* folder.

The input file is identical in format and layout to those described and included in Attachment 4 to Appendix B of the final design. The input file contains one tab per chemical modeled, as well as an *Input_Matrix* tab, which specifies the inputs for the various model parameters. Changes made to input values used in the final design for this MPC modeling effort (e.g., cap configuration, simulation parameters) are described in detail below.

[1] Parsons and Anchor QEA (Anchor QEA, LLC), 2012. *Onondaga Lake Capping, Dredging, Habitat and Profundal Zone (SMU 8) Final Design.* Prepared for Honeywell. March 2012.

RA-D-2

The input file for modeling the RA-D-2 MPC is titled *RA-D-2.xls*. Changes to this file, as compared to the Model Area D-West final design modeling, are highlighted in orange on the *Input_Matrix* tab, as well as the chemical-specific tabs, where applicable. The following changes were made:

1. The following inputs for cap configuration were specified for the purposes of developing granular activated carbon (GAC) amendment application rates for the MPC evaluation, for all chemicals:
    a. The habitat restoration layer thickness was set to a thickness of 26.67 cm.
    b. The chemical isolation layer thickness was set to a thickness of 11.43 cm.
2. The following changes were made in the "simulation parameters" section on each chemical-specific tab for numerical stability purposes:
    a. The minimum number of grid points was increased to 400.
    b. The minimum number of time steps was increased to 1,500.

Numerical Model Outputs

The numerical model output files are located in the *Numerical_Model\Outputs\Det_Output* folder. Within this folder, outputs for the model area evaluated are contained in a folder with the model area name. The outputs are saved in comma-delimited format (*.csv). Output file names used the same naming convention from the final design, which helps to understand the model scenario:

"Output_"<Model Area>"_"<Chemical Name Abbreviation>"_"<GAC Application Rate>"-"<Initial Concentration Type>

For file-naming purposes, the GAC application rate component of the file name does not include a decimal point. It should be understood that the decimal place is located between the first and second digits. For example, *Output_RA-D-2_EB_153-C95_UT2.csv* is the file containing outputs from the model simulation of ethylbenzene using the 95th percentile porewater concentrations in Model Area RA-D-2 (multi-layer MPC) with a 1.53 lb/sf GAC application rate.