UPPER MISSISSIPPI RIVER RESTORATION FEASIBILITY REPORT WITH INTEGRATED ENVIRONMENTAL ASSESSMENT

GREEN ISLAND
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

POOL 13, UPPER MISSISSIPPI RIVER
RIVER MILES 545.9 THROUGH 548.7
JACKSON COUNTY, IOWA

APPENDIX E
ENGINEERING

ATTACHMENT C
GEOTECHNICAL ENGINEERING DESIGN

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1. PURPOSE

The goals of the Upper Mississippi River (UMRR) Green Island Levee Habitat Rehabilitation and Restoration Project (HREP) are to maintain, enhance and restore quality habitat for all native and desirable plant, animal and fish species and maintain, enhance, restore, and emulate a natural river process, structures and function for sustainable ecosystem. The objectives identified to these goals are (1) Increase the quality, quantity, and diversity of vegetation within the Green Island study area, including emergent, submerged aquatic and floodplain forest vegetation; (2) Improve sediment management across the Green Island study area, reduce the impacts of sedimentation to existing habitat, and increase storage capacity; (3) Restore Green Island aquatic ecosystems for fish and other aquatic organisms by increasing the quality and quantity of aquatic habitat available; (4) Improve water level management and sustainability of existing habitat and associated plant and wildlife resources within Green Island; (5) Restore bathymetric and topographic diversity within the Green Island study area.

This report is the Geotechnical Engineering Design Appendix of the subject project's Feasibility Report. This appendix documents known site and subsurface conditions, geotechnical design criteria, and analyses performed to support the study. This appendix also identifies geotechnical design risks and construction considerations for potential future design phases of the project. The limited data gathered, and analyses performed for this study were used to support an overall evaluation of the feasibility and Benefit to Cost ratios of proposed project features, which ultimately inform the decision discussed in the main Feasibility Report about the Federal interest in supporting the project beyond this study.

2. LOCATION

The study area is in Jackson County, Iowa, in Pool 13 of the Upper Mississippi River just east of the confluence with the Maquoketa River, between river miles 548.5 and 546.0 as shown in Figure C-1.. The study area is approximately 2,600 acres in size and lies entirely within the Green Island Wildlife Management Area, operated by Iowa DNR. The study area is adjacent to the previous HREP site known as Browns Lake to the east and a portion of the Upper Mississippi River Wildlife and Fish Refuge to the north. The area just north of the Project site has an active Dredge Material Management Placement site.

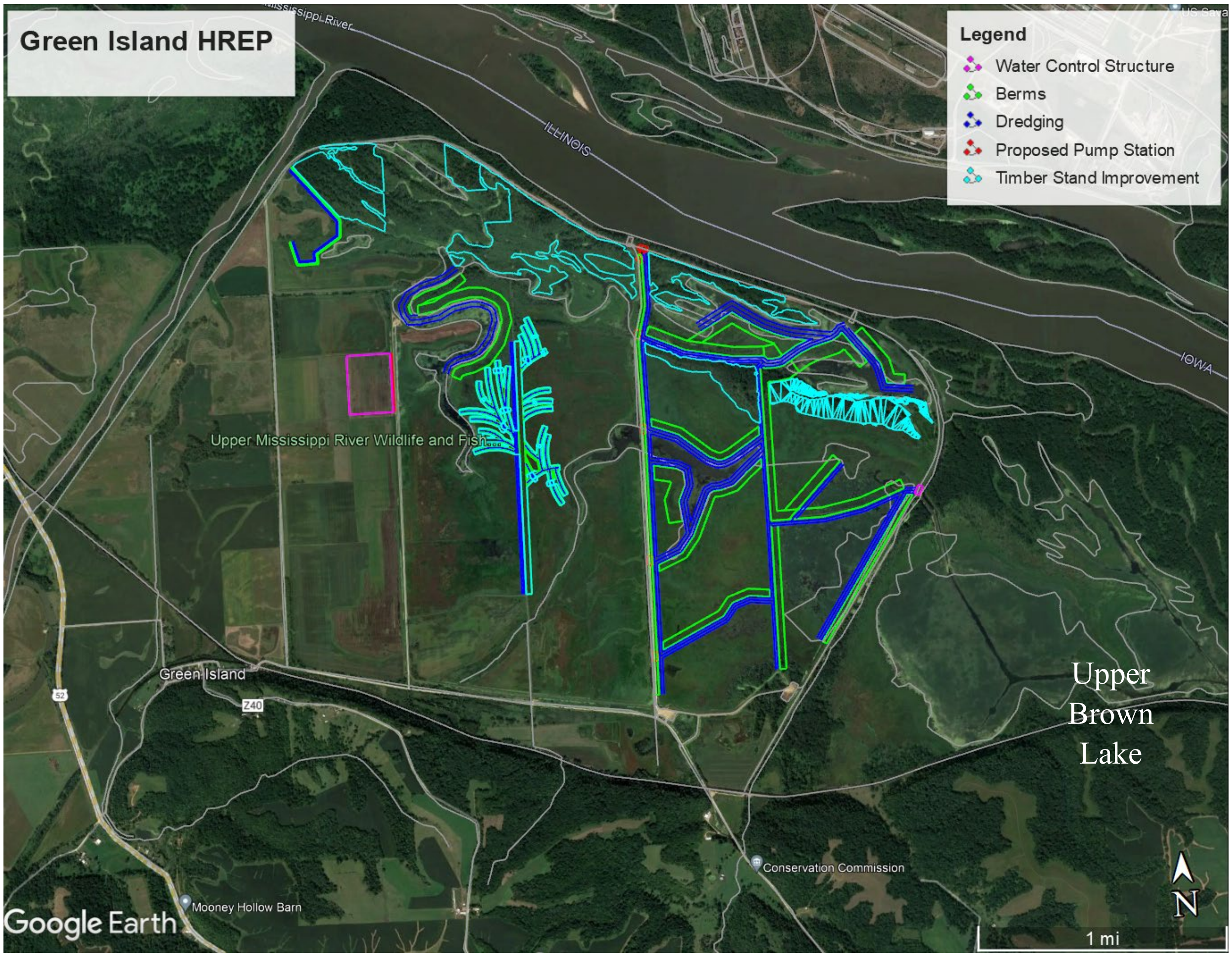


Figure C-1: Green Island Project Site

3. PROJECT DESCRIPTION

The proposed project would restore quality habitat for all native and desirable plant, animal and fish species by dredging material. The dredge material will be used to enhance topographic diversity. Timber stand improvement will take place in the project area. A swale will be built to manage water runoff and increase rainwater infiltration. Isolated ephemeral wetlands will be restored. It is also planned to install a sediment transport and deposit regime, water control structures to regulate pooled water elevations and to emulate more natural seasonal water elevations, and pumps for the distribution of water through the culverts.

The Green Island Levee and Drainage District (Levee District) consists of approximately 10.8 miles of levees protecting nearly 4,500 acres of land. While operated by Iowa DNR, land within the study area is primarily federally-owned by the Corps with limited portions owned by USFWS, with adjacent properties owned by the State of Iowa and private landowners as shown in Figure C-2. During construction of the Nine-Foot Channel Project, the Federal government acquired 2,575 acres of land within the Green Island area. In 1943, this land was made available to the USFWS, who later made the land available to the Iowa State Conservation Commission (now the Iowa DNR).

On April 29, 2023 the Green Island Levee and Drainage District began experiencing an overtopping breach. An approximate location and photos of the overtopping breach site are shown in Figure C-3. 2 days prior to the breach Iowa DNR noticed a small seep formed through the levee about halfway of the inside slope. A photo from May 18, 2023 from the overtopping branch site area is shown in Figure C-4.

Adjacent to Green Island to the east is the Brown's Lake HREP. Brown's Lake is a 453-acre backwater complex within the Upper Mississippi River National Wildlife and Fish Refuge. The Brown's Lake HREP was constructed in 1989 in order to address ongoing issues with sedimentation which was impacting the quality of habitat for native fish and migratory waterfowl. Project features focused on reducing sedimentation, improving water quality and restoring lost aquatic and floodplain habitats. Project features included a sediment deflection levee, improvements to existing channels, dredging and installation of a gated water control structure.

Water is pumped from the Mississippi River to the area by two 20,000 gallon per minute (GPM) pumps constructed during the REAP project. The pumps are unidirectional.

Figure C-2: Green Island Property Ownership

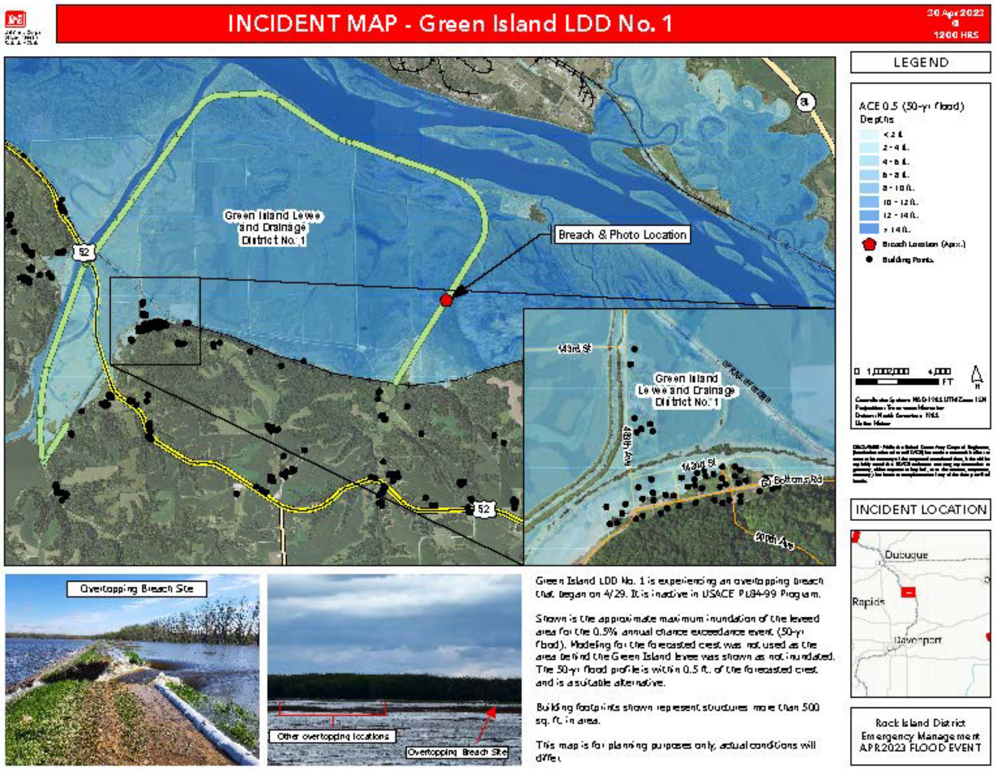


Figure C-3: Green Island Overtopping Breach Site Map

Figure C-4: Green Island Overtopping Breach Site Area

4. SUBSURFACE DATA

Subsurface data for the study was gathered from historic project records, available public records, and by completing a limited new borings as described below. The scope of site exploration was limited by project schedule and budget concerns but was considered adequate to provide the preliminary analyses and recommendations included herein. Additional exploration and testing would be necessary to provide design-level recommendations if the project is approved for future work.

4.1 Explorations.

Rock Island District conducted subsurface exploration using a 4” hollow stem auger, push tube, drive tube, and used historic boring logs in order to generally characterize the composition and engineering properties of the soils present at Green Island. Two boring logs from Iowa GS were utilized from the Iowa side near the project area. Two boring logs from IL Water, one being from a water well, were utilized from the Illinois side. Boring logs from the PL 84-99 Eligibility Inspection Report were utilized. Historic and new borings are shown in Figure C-5.

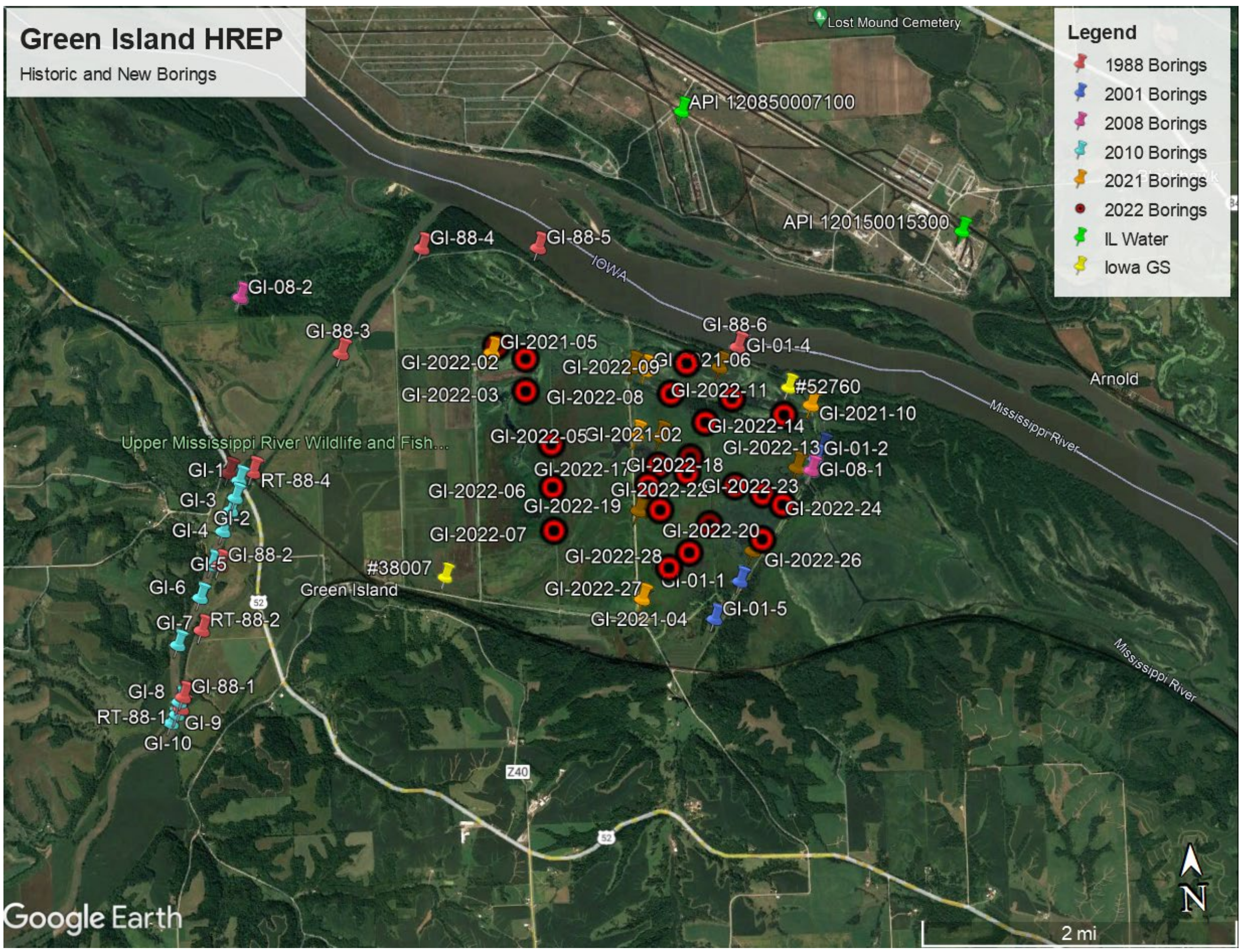


Figure C-5: Locations of Historic and New Borings

4.2 LABORATORY AND FIELD TESTING.

All samples were analyzed for water content. The average water content of the samples was 40.16 percent. All coarse-grained samples were analyzed for minus 200 sieve size content. The average minus 200 sieve size content of the coarse-grained samples was 56.17 percent by weight.

Atterberg limit tests were performed on several of the clay samples gathered throughout the site in order to confirm visual classifications. Results for liquid limits expressed as an index ranged between 42 and 139, and plastic limits expressed as an index ranged between 20 and 40.

Vane shear tests were conducted in the field in most of the boring holes. The average max shear strength and remolded shear strength on Green Island was 992.5 psf and 272.5 psf respectively.

5. GEOLOGY

Geology of the site was evaluated from historic project documents and available public records.

5.1 PHYSIOGRAPHY

The project area is located near the confluence of the Mississippi and Maquoketa Rivers in Iowa. The project area consists of shallow backwaters and is situated on soil regions composed of loess with bedrock outcrops.

The Project area is situated within the Mississippi Alluvial Plains Section in Jackson County, Iowa. Green Island Levee is located in the soil region classified as loess with bedrock outcrops as seen in Figure C-6. The Project area has little topographic relief and consists of shallow backwaters, bottomland, and islands that are subject to permanent high-water tables and annual flooding.

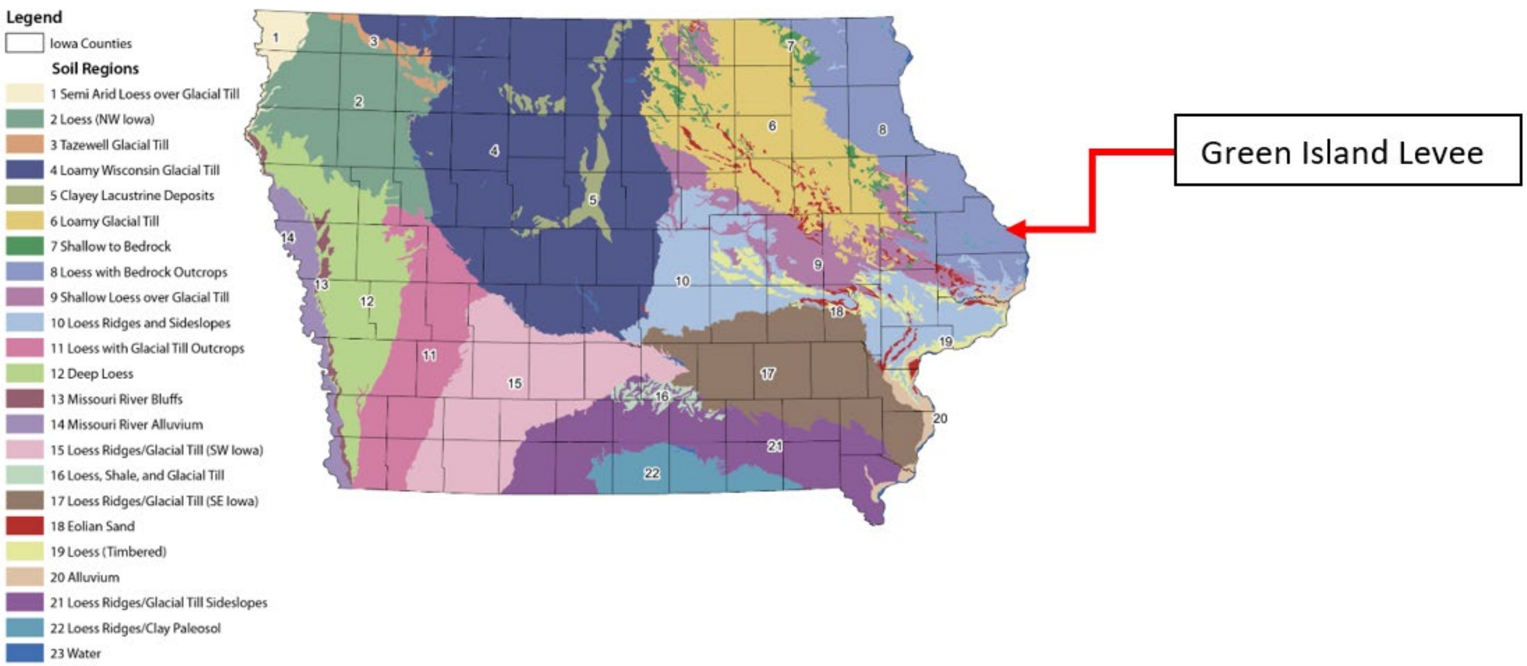


Figure C-6: Green Island Physiographic Location

5.2 SURFICIAL DEPOSITS

The general geology in the region is a fluvial loam of approximately 6-ft to 10-ft in depth overlying a series of fluvial sands and gravels created by previous river meanders to the bedrock depth at approximately 60-ft. BGL.

5.2.1 CLAY

Information contained in the NRCS Web Soil Survey in the top 5' indicate the dominant soil type present in and around the Project area is generally classified as the Aquolls, described as part of the Mollisol family, defined by a composition of temperate grassland soils with a dark, humus-rich surface layer containing high concentrations of calcium and magnesium. The second most dominant soil is classified as a silt loam by the NRCS soil texture classification triangle, which translates to a ML-MH to a OL-OH with trace sand. Both series are described as frequently flooded, poorly drained soil with a water table that varies between ground surface and 1 foot deep. The Project area NRCS Web Soil Survey and the map unit legend are shown in Figure C-7 and Figure C-8. Generally, these fluvial soils contain porous sands, silts (which can retain moisture), and humus or decaying organic matter and soluble minerals. Both gray and brown mottled clays also are present and range from lean to fat.

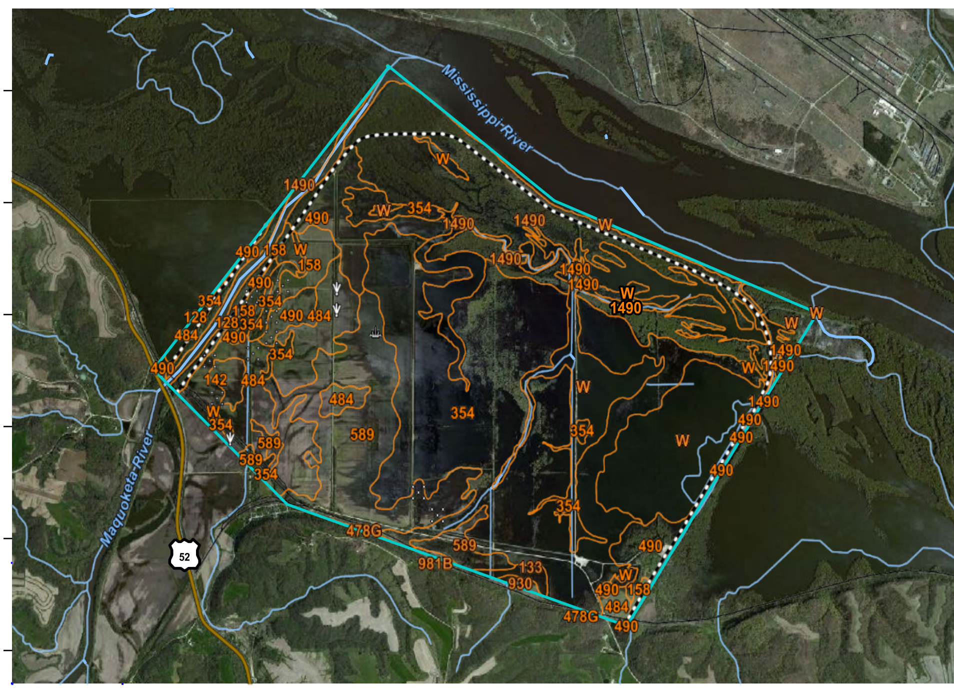


Figure C-7: Green Island Web Soil Survey Map

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
128	Chaseburg-Perks complex, 0 to 2 percent slopes	58.8	1.4%
133	Colo silty clay loam, 0 to 2 percent slopes	18.5	0.4%
142	Chaseburg silt loam, 0 to 2 percent slopes	26.2	0.6%
158	Dorchester silt loam, 0 to 2 percent slopes	81.7	1.9%
354	Aquolls, ponded, 0 to 2 percent slopes	1,382.1	32.0%
478G	Nordness-Rock outcrop complex, 18 to 60 percent slopes	3.5	0.1%
484	Lawson silt loam, 0 to 2 percent slopes	364.9	8.4%
490	Caneek silt loam, 0 to 2 percent slopes	284.8	6.6%
589	Otter silt loam, 0 to 2 percent slopes	464.4	10.8%
930	Orion silt loam, 0 to 3 percent slopes, occasionally flooded	8.0	0.2%
981B	Worthen silt loam, 2 to 5 percent slopes	4.0	0.1%
1490	Caneek silt loam, channeled, 0 to 2 percent slopes	733.2	17.0%
W	Water	888.0	20.6%
Totals for Area of Interest		**4,318.2**	**100.0%**

Figure C-8: Results of Project Area NRCS Web Soil Survey

5.2.2 SAND

Previous boring logs and the geomorphology of the region show that this area is a mature floodplain and the sand deposited in the area is highly inconsistent in size and gradation and is likely to contain multiple abandoned channels depositing high porosity lenses of GW-GP with the dominant material consisting of SW-SC to GM-GC.

5.2.3 BEDROCK

Although Ordovician rock of the Maquoketa Formation may underlie the project area, none of the hand auger or rotary drill borings encountered bedrock to depths of 40 feet. Typical depths to bedrock in this valley floodplain often reach 70 to 100 feet. Where bedrock is present, such as in the bluffs just south of Brown's Lake, the Maquoketa Formation is capped by younger Silurian rocks of the Niagaran Series. As one progresses down river from Green Island, a southward dip in the strata is more rapid than the fall in the river. The height to which the Maquoketa shale appears in the bluffs gradually decreases while the cap of the Niagaran constantly increases in thickness. In the bluffs adjacent to the project, the top of the Maquoketa appears about 15 feet above the floodplain while near Lainsville, 4 miles further eastward, the Niagaran limestone may be seen down to the very base of the bluffs.

6. STRATIGRAPHY

Borings GI-2021-01 through GI-2021-04 were taken in the road intersecting Green Island Rd near Densmore Lake. These borings were advanced approximately 15' from the ground surface with a $3\frac{1}{4}$" hollow stem auger. Below ground surface, a top layer of approximately 5' composed of lean clay with traces of gravel was obtained. The last 10’ was mostly fat clay with occasionally silty sandy clay, clayey sand, sand seam and sandy silt. Borings GI-2021-05 through GI-2021-12 were taken across the Green Island project site. These borings were advanced approximately from 3’ to 9’ with a drive tube, push tube, and 4” hand auger. Below ground surface inorganic clay was mostly obtained with occasionally clayey sand.

Well record #38007 was taken near Green Island Rd. Well record #52760 was taken near Snag Slough. The Iowa GS borings were advanced approximately 225’ to 500’ using rotary drilling. Below ground surface shale was mostly obtained with occasionally clay and limestone.

Borings API 120850007100 and API 120150015300 were taken in Savanna Ordnance Depo Farm. The IL Water borings were advanced approximately 1200’ from the ground surface. A top layer of approximately 155’ to 183’ composed of alluvium, sand, silty was obtained. The rest of the borings were composed mostly of dolomite, limestone, sandstone, and shale.

Borings GI-88-1 through GI-88-6 were taken on the Green Island levee. The borings were advanced approximately 4’ to 11’ from the ground surface. The PL 84-99 borings are composed of lean clay, sandy lean clay, clayey sand, and fat clay.

Borings GI-2022-01 to GI-2022-07 were gathered on the Westside of Green Island near Fish Lake and the Green Island Wildlife Management Area as shown in Figure C-9. The boring logs are shown in Figure C-10 and Figure C-11. Below ground surface, the top layer of approximately 2.5’ to 3’ was mostly composed of lean clay or fat clay with organics. Two of the borings had organics the entire depth of the boring. Lean clay or fat clay with sand content underlie the upper lean clay or fat clay with organics layer. Two of the borings transitioned to a poorly graded sand with clay layer and to a clayey sand layer.

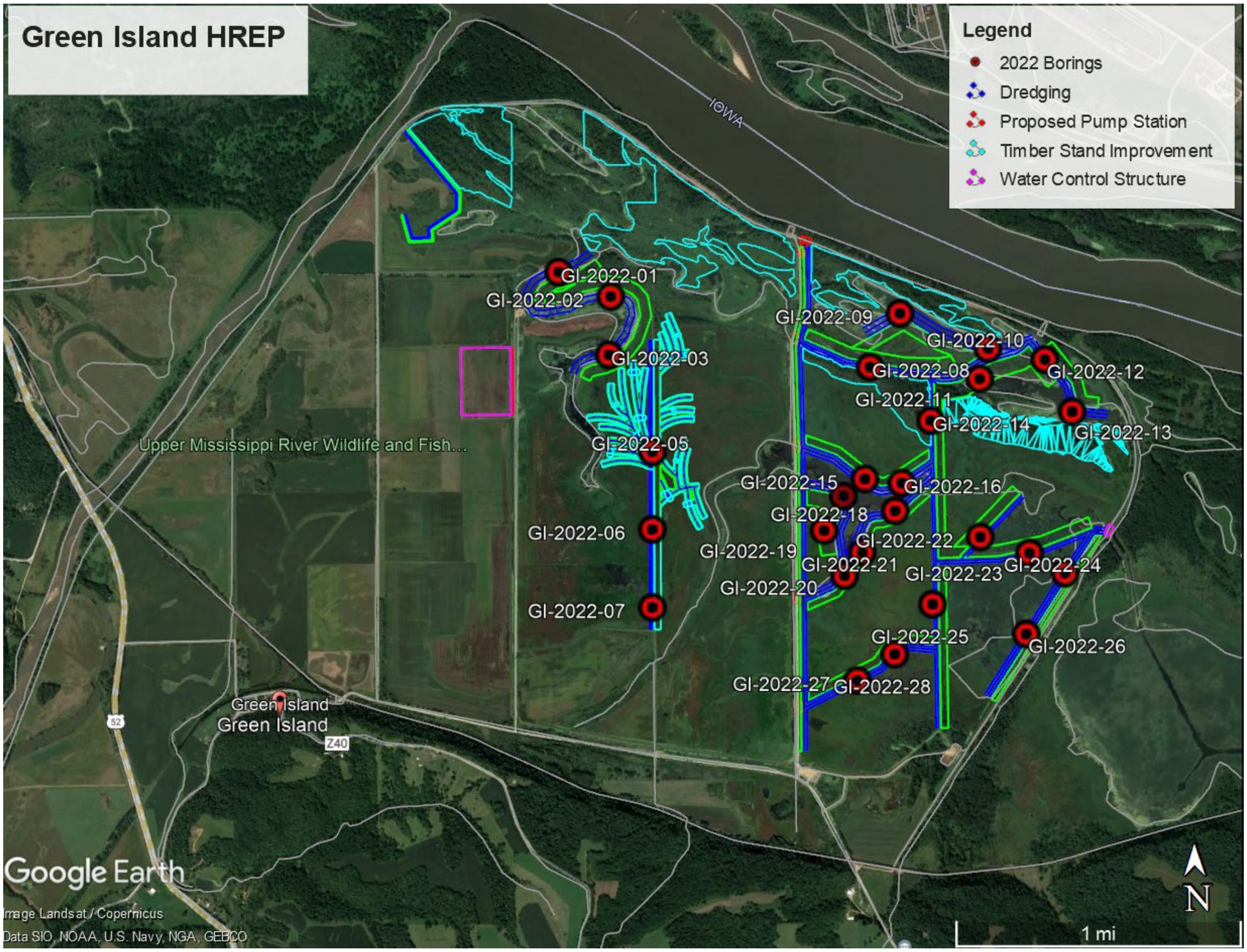


Figure C-9: GI-2022-01 to GI-2022-07 Borings

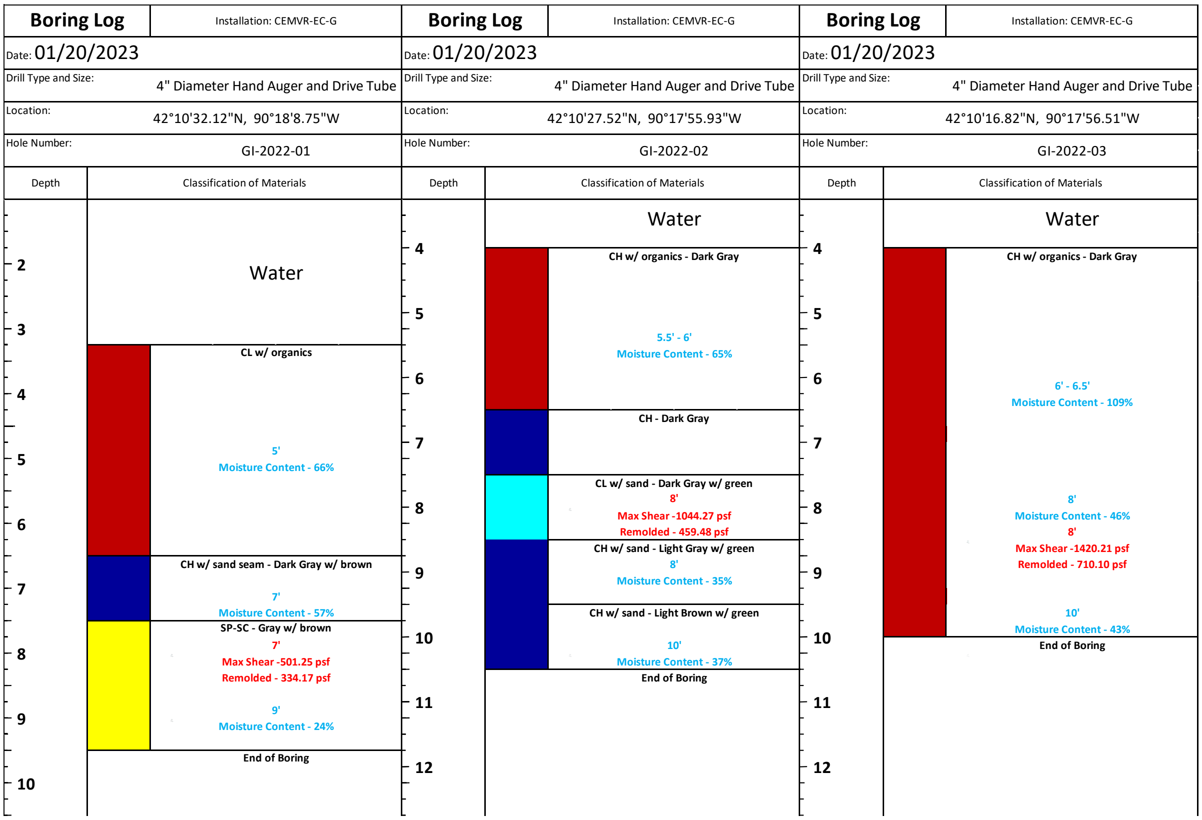


Figure C-10: Boring GI-2022-01, GI-2022-02, and GI-2022-03

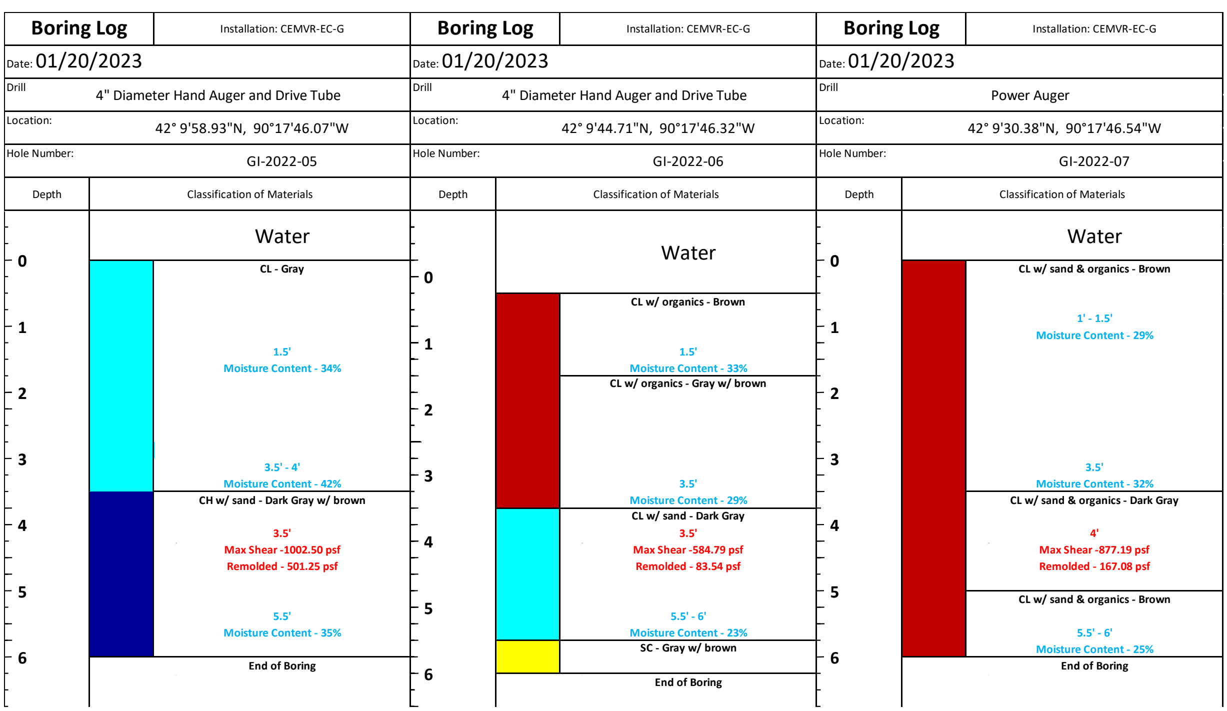


Figure C-11: Boring GI-2022-05, GI-2022-06, and GI-2022-07

Borings GI-2022-08 to GI-2022-13 were gathered on the Northeast section of Green Island as shown in Figure C-12. The boring logs are shown in Figure C-13 and Figure C-14. Below ground surface, the top layer of approximately 1.5' to 5.5' was mostly composed of fat clay with organics. GI-2022-11 boring had organics on the entire depth. Mostly clayey sand, poorly graded sand, and poorly graded sand with clay underlie the fat clay with organics layer. GI-2022-13 boring transitioned from a clayey sand to a fat clay with sand content layer.

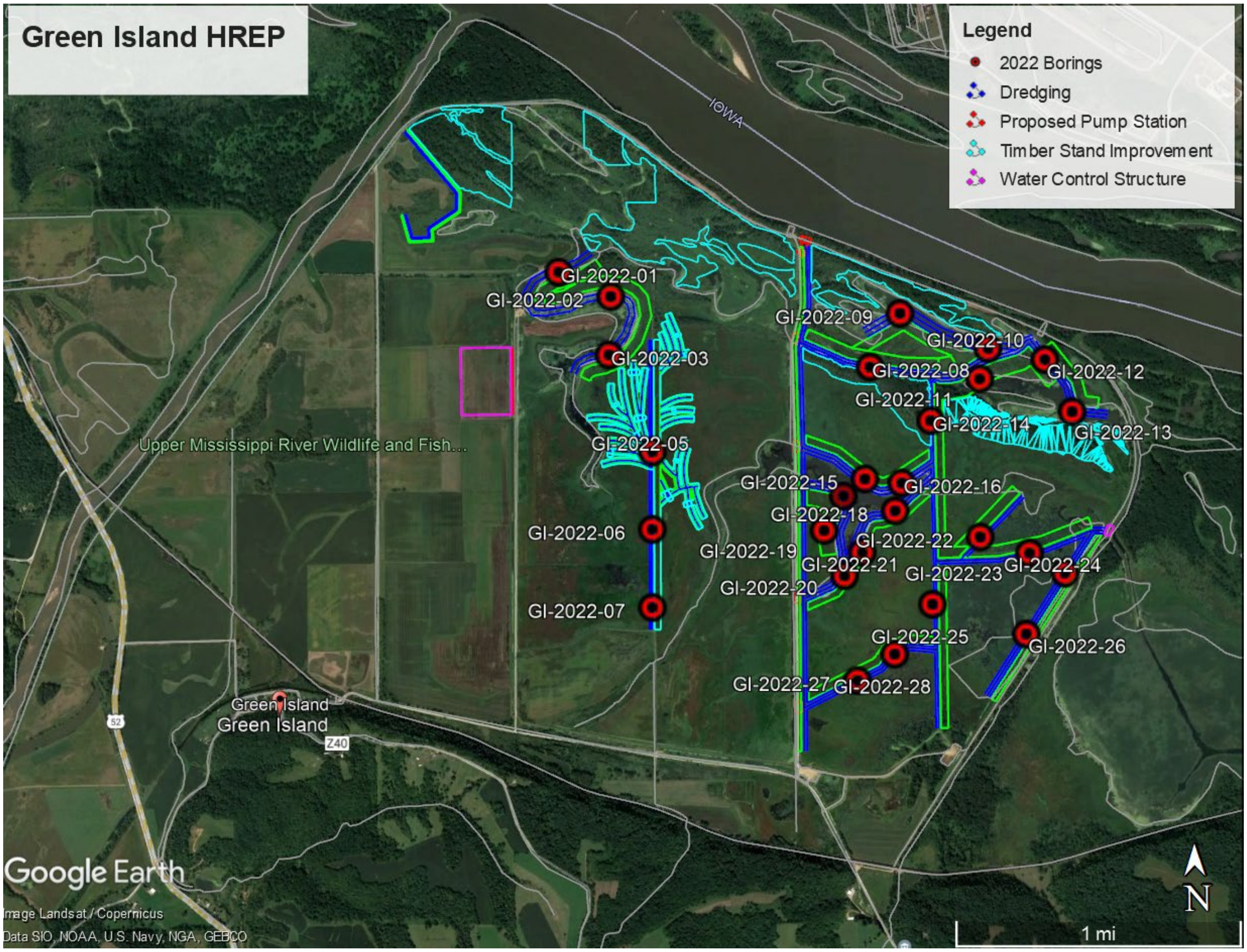


Figure C-12: GI-2022-08 to GI-2022-13 Borings

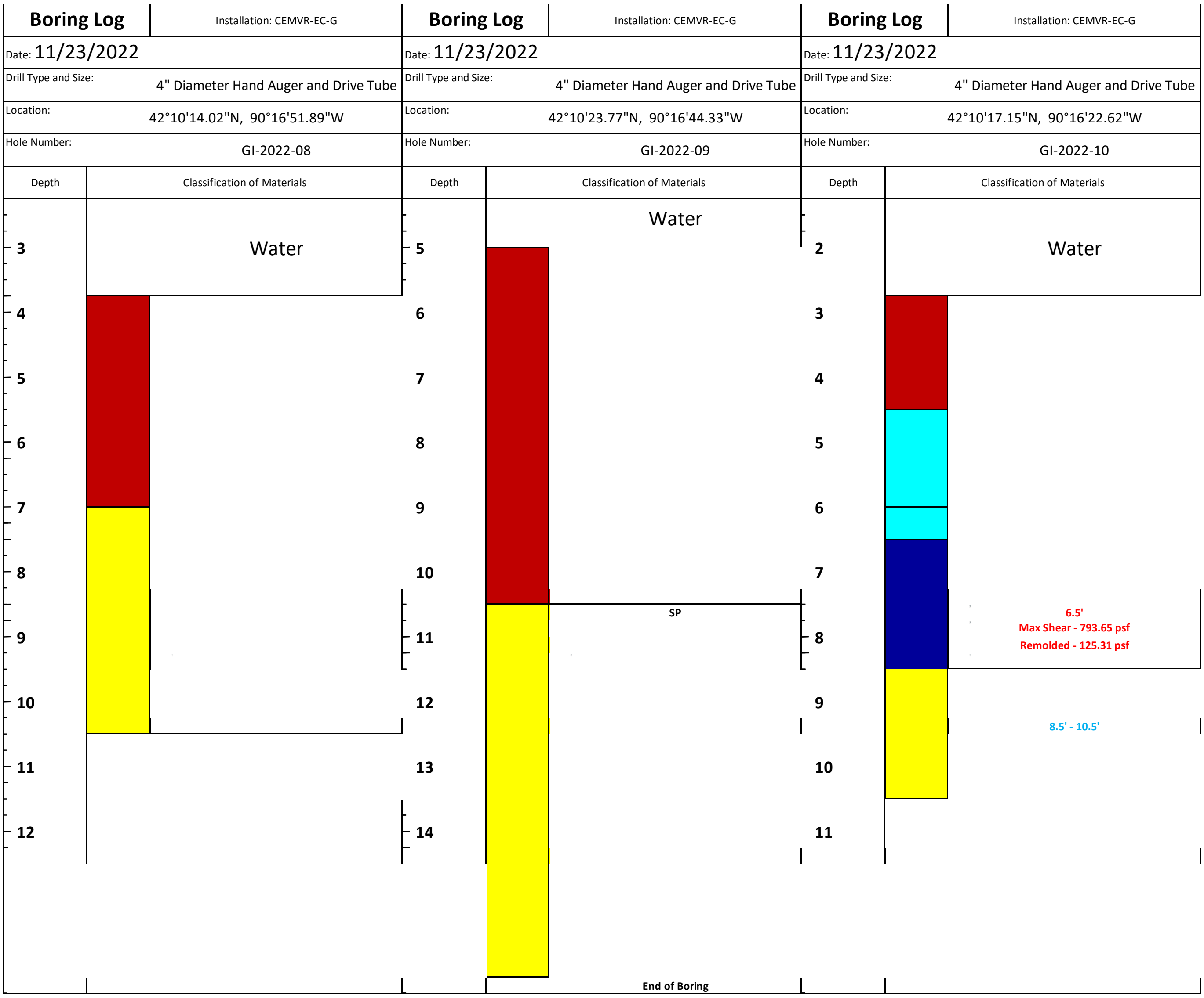


Figure C-13: Boring GI-2022-08, GI-2022-09, and GI-2022-10

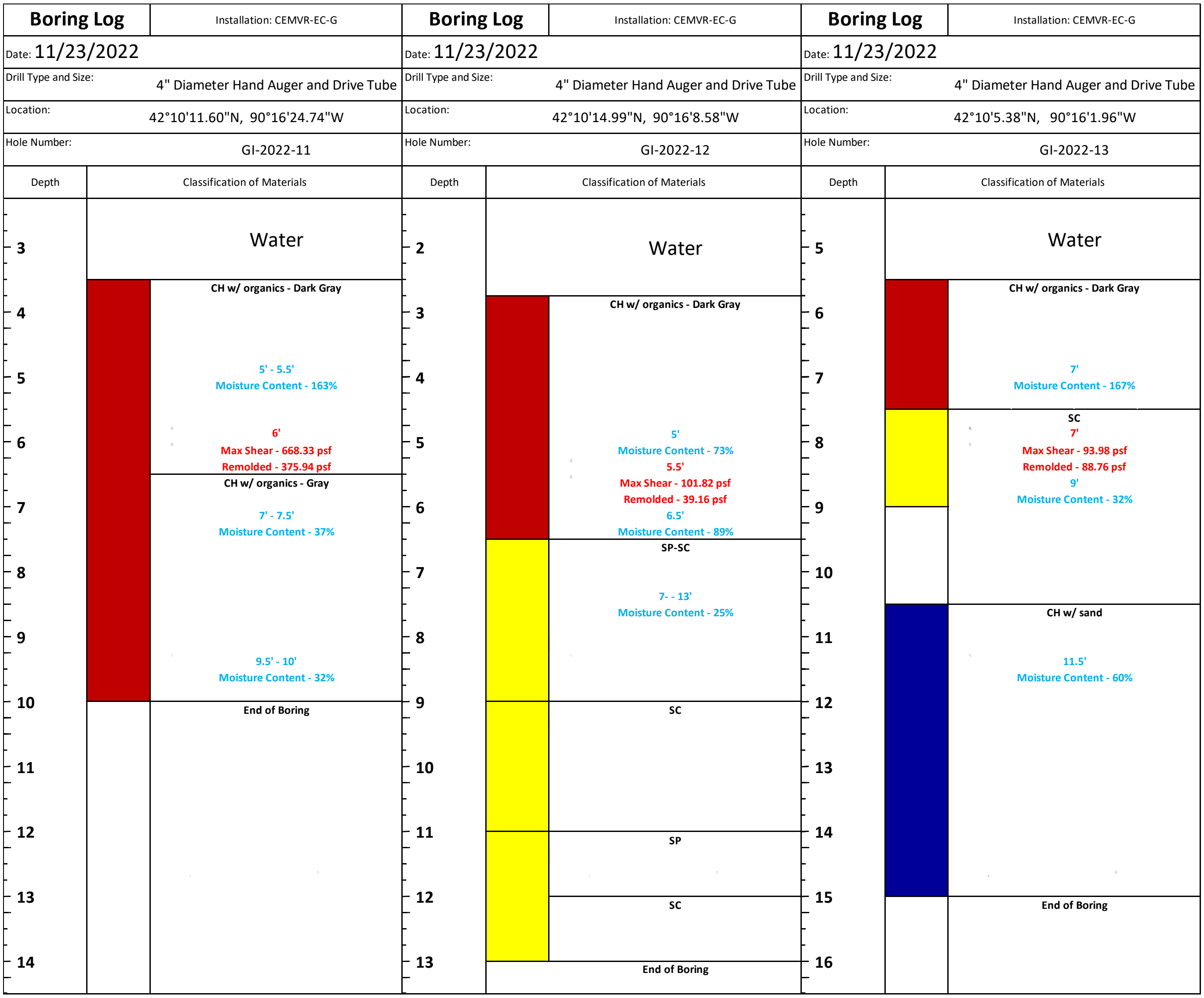


Figure C-14: Boring GI-2022-11, GI-2022-12, and GI-2022-13

Borings GI-2022-14 to GI-2022-22 were gathered on Desmore Lake as sown in Figure C-15. The boring logs are shown in Figures C-16, C-17, and C-18. Below ground surface, the top layer of approximately 1.5’ to 5.5’ was mostly composed of fat clay with organics. GI-2022-11 boring had organics on the entire depth. Mostly clayey sand, poorly graded sand, and poorly graded sand with clay underlie the fat clay with organics layer. GI-2022-13 boring transitioned from a clayey sand to a fat clay with sand content layer.

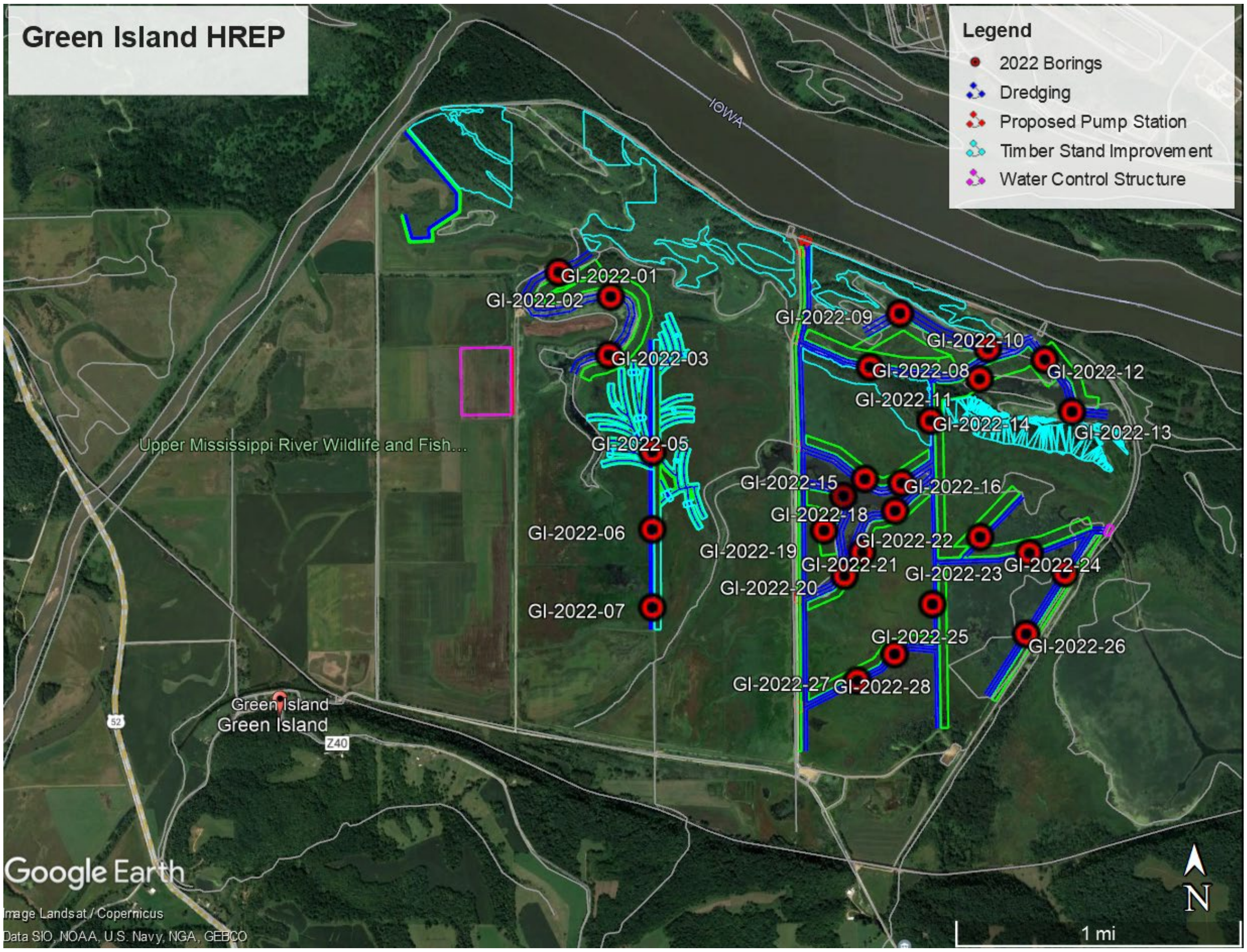


Figure C-15: GI-2022-14 to GI-2022-22 Borings

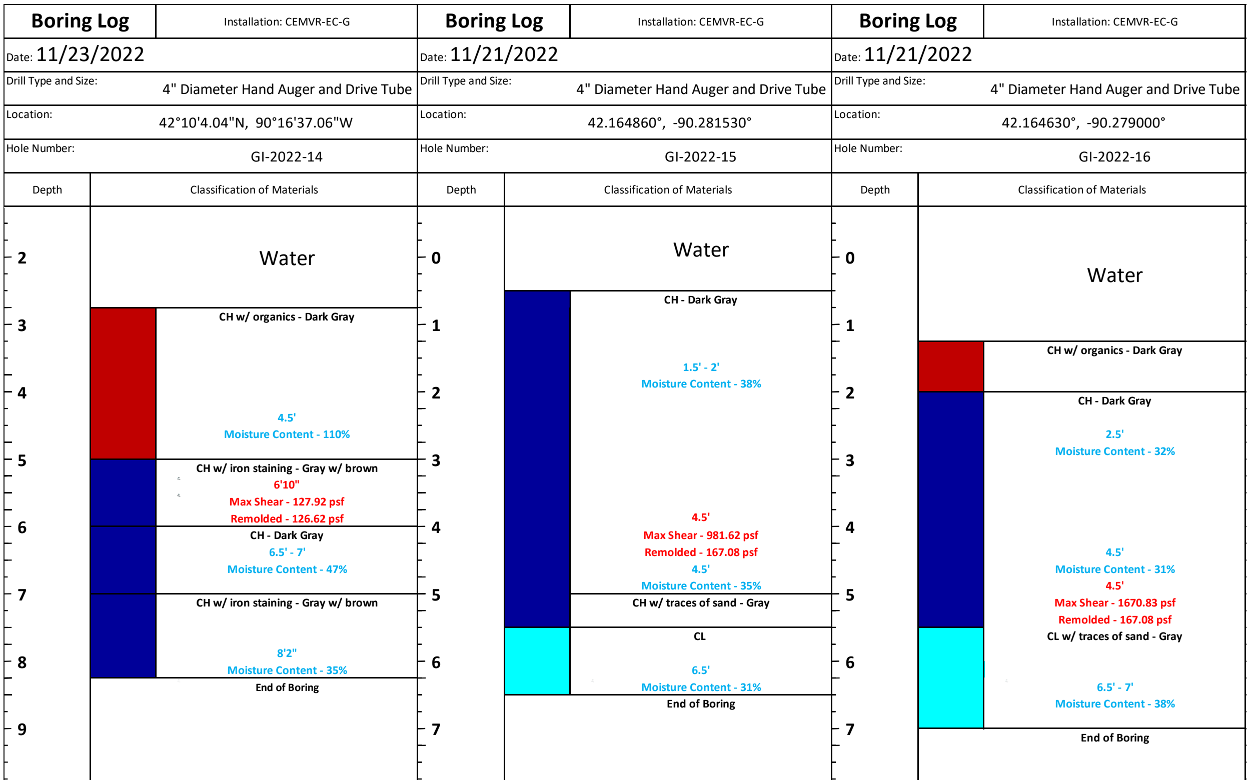


Figure C-16: Boring GI-2022-14, GI-2022-15, and GI-2022-16

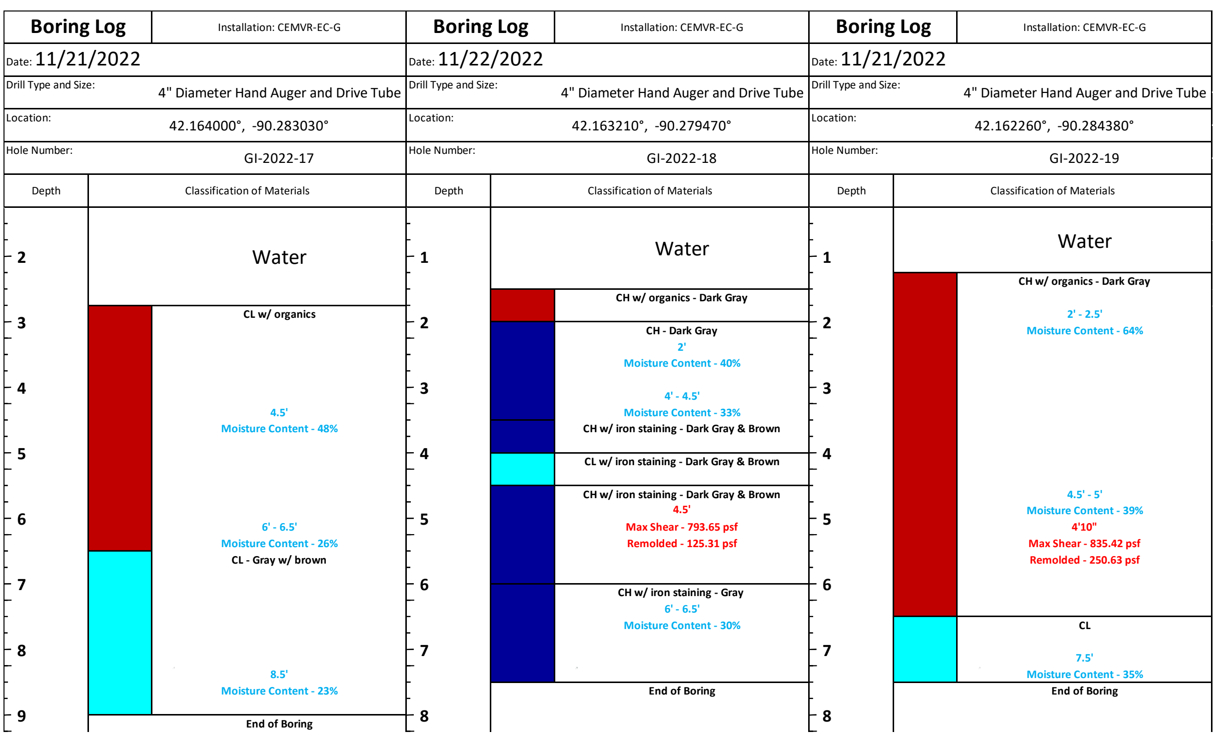


Figure C-17: Boring GI-2022-17, GI-2022-18, and GI-2022-19

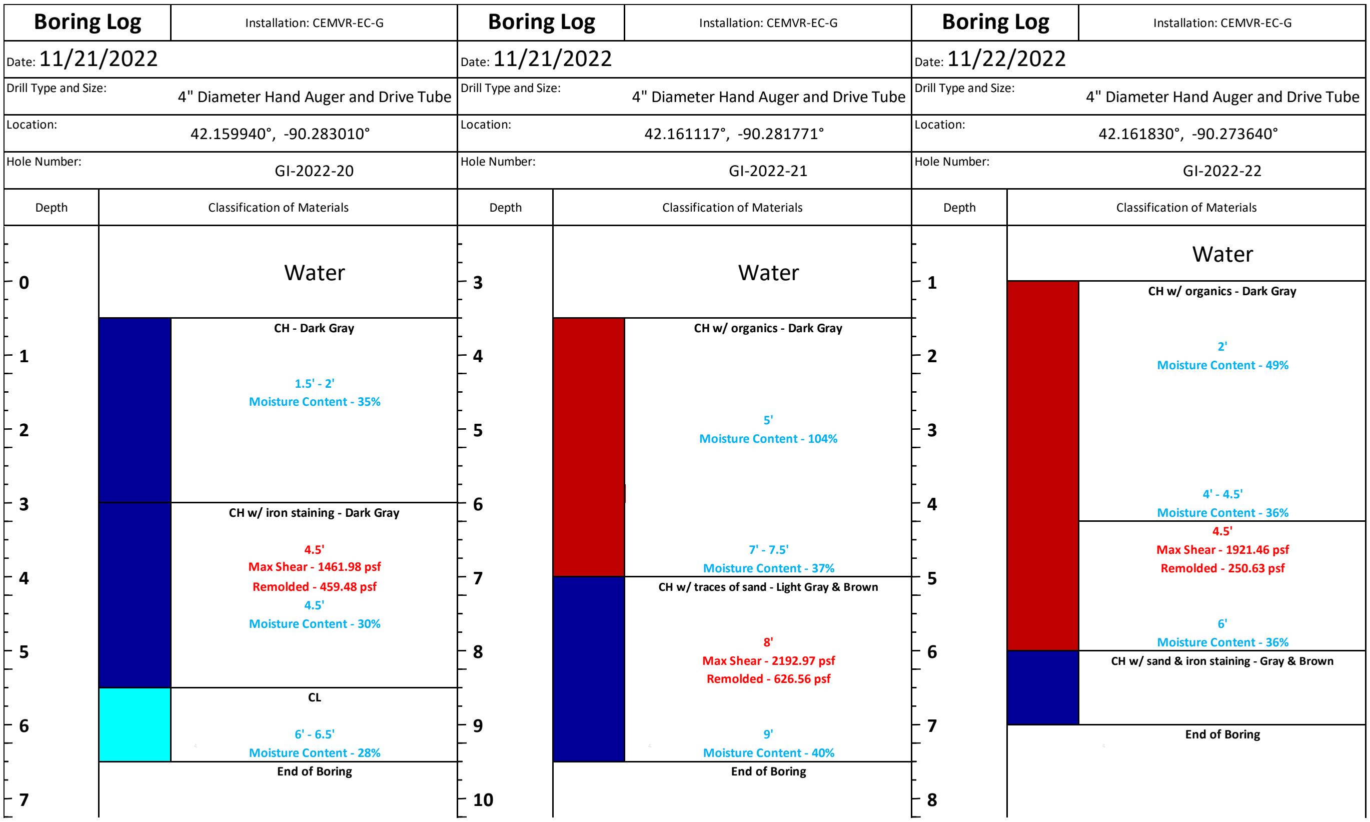


Figure C-18: Boring GI-2022-20, GI-2022-21, and GI-2022-22

Borings GI-2022-23 to GI-2022-28 were gathered on the Southeast section of Green Island as shown in Figure C-19. The boring logs are shown in Figure C-20 and Figure C-21. Below ground surface, the top layer of approximately 2.5' to 5' was mostly composed of fat clay with organics. Mostly fat clay with sand content underlies the fat clay with organics layer. GI-2022-28 boring transitioned from a fat clay with sand content to a silt layer.

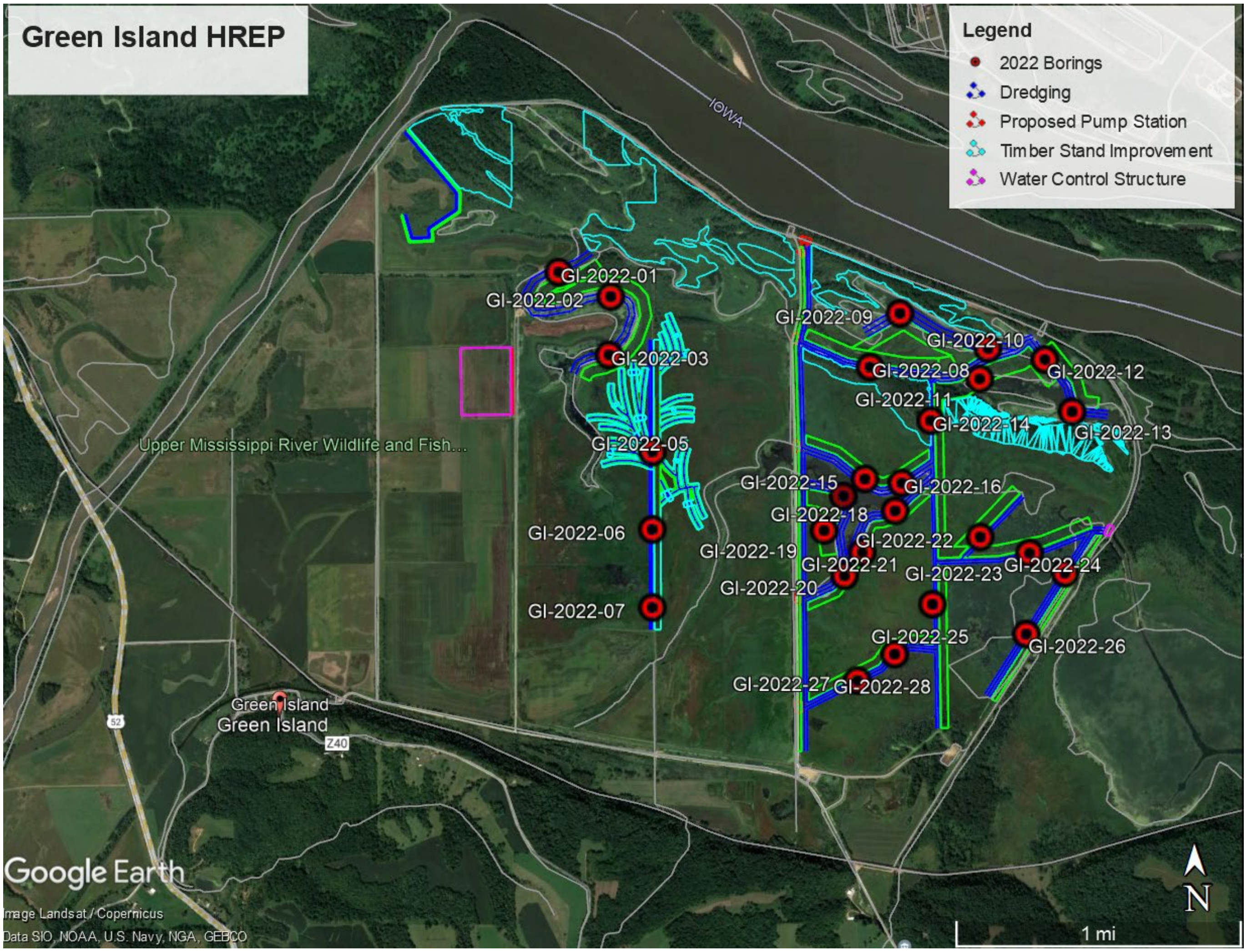


Figure C-19: GI-2022-23 to GI-2022-28 Borings

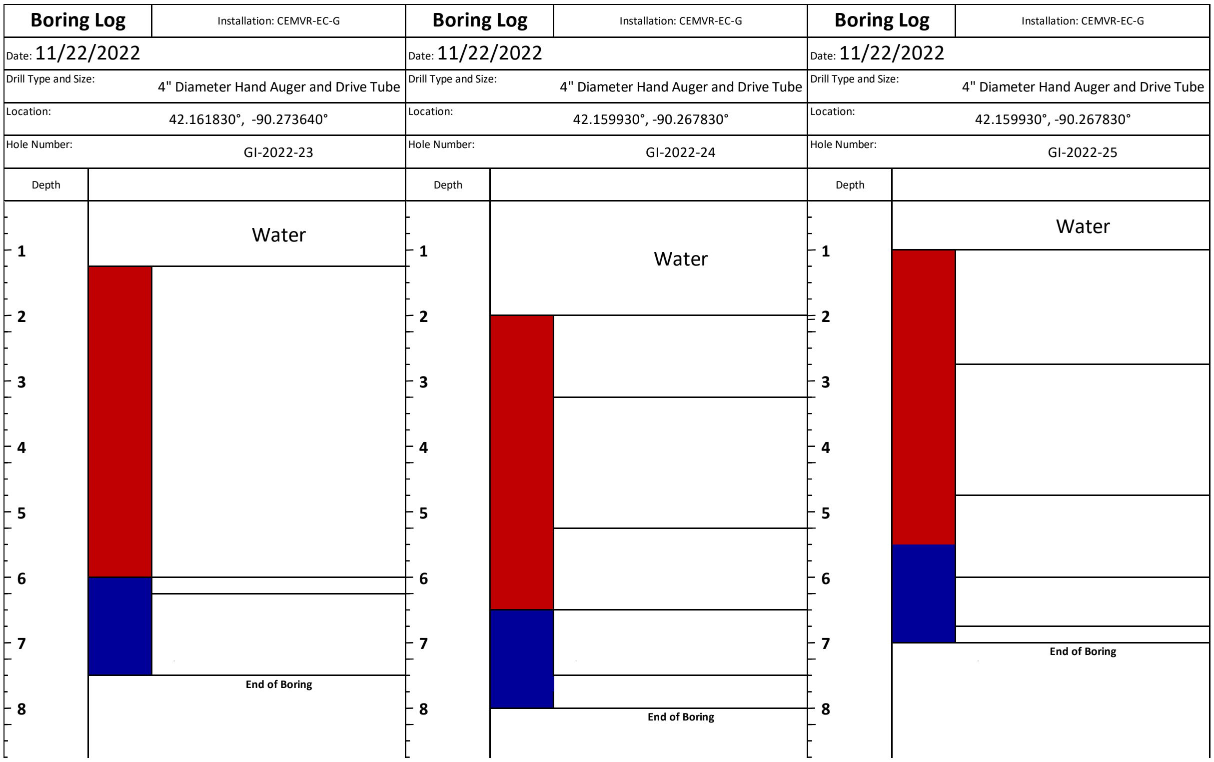


Figure C-20: Boring GI-2022-23, GI-2022-24, and GI-2022-25

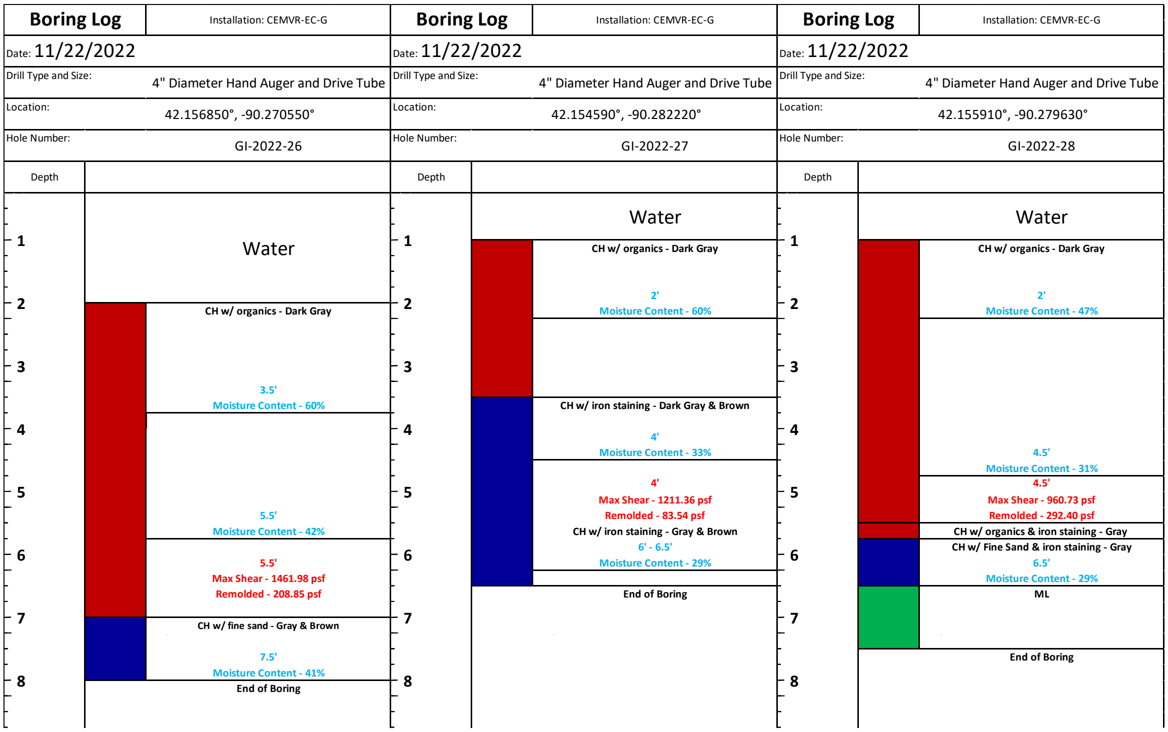


Figure C-21: Boring GI-2022-26, GI-2022-27, and GI-2022-28

Borings GI-2022-22 to GI-2022-26 were taken before the Green Island Levee and Drainage District began experiencing an overtopping breach on April 29, 2023. These borings are the closest to the overtopping breach area. Given that these borings have a top layer of fat clay it is assumed that most of the material stay in place during the overtopping breach. The soil classification that was conducted after gathering the hand auger borings in this area is still relevant for the preliminary design considerations.

7. PRELIMINARY DESIGN CONSIDERATIONS

Limited data was obtained for the study. Only preliminary analyses were performed, and more detailed exploration and analyses will be performed when the project advances to design phase.

7.1 SITE CHARACTERIZATION

In order to prepare the appropriate geotechnical analyses for design of the selected Project measures, it will be necessary to characterize the project according to typical clay and sand foundation depths and strengths, typical embankment heights and strengths, and water depths.

7.2 DREDGING DESIGN

Project measures include mechanical dredge cuts and deflection berms to provide access to project features and to improve wildlife habitat for plant, animal, and fish species. Hand auger borings and vane shear tests were conducted on Green Island with the overall objective to define overall site geology and engineering properties of site soil and collected samples for geotechnical lab testing. The geotechnical lab testing conducted on the samples provided a baseline for determination of side slopes on dredge cut locations and dredge placement sites. The Green Island project features A-01 and B-01 to B-13 are shown in Figure C-22. Channel and berm side slopes were determined for those features.

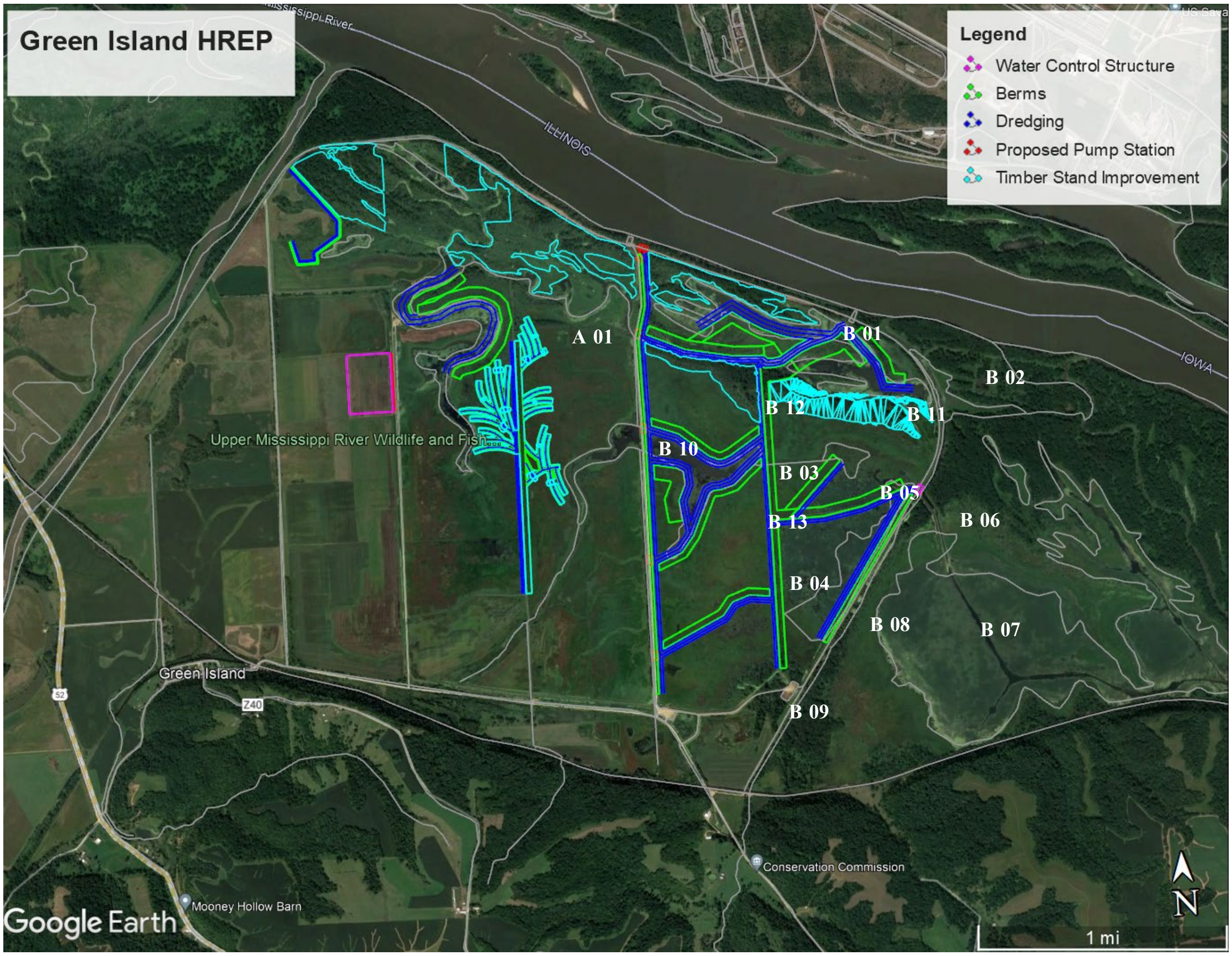
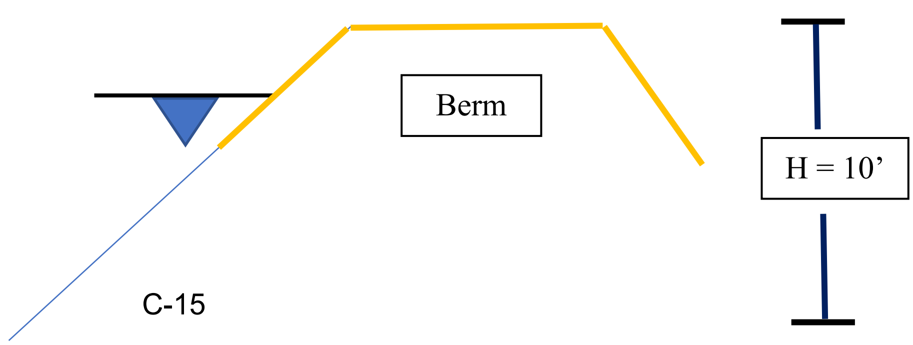


Figure C-22: Green Island Project Features A-01 and B-01 to B-13

7.2.1 FEATURE B-03 SIDE SLOPES CALCULATIONS

Figure C-23 shows a representation of the cross section of the proposed channel and berm on Green Island that was used for the slope stability calculations. The height between the top of the berm and the bottom of the channel is 10’. The height of the water is approximately 5’. Borings GI-2022-15 and GI-2022-16 were conducted on feature B-03 as shown in Figure C-24.



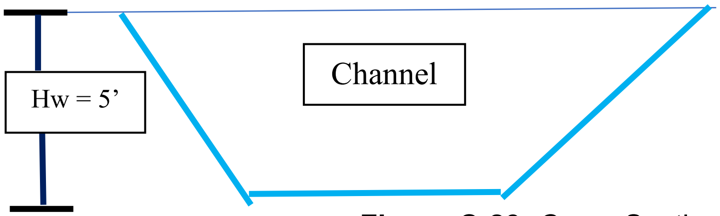


Figure C-23: Cross Section – Channel & Berm

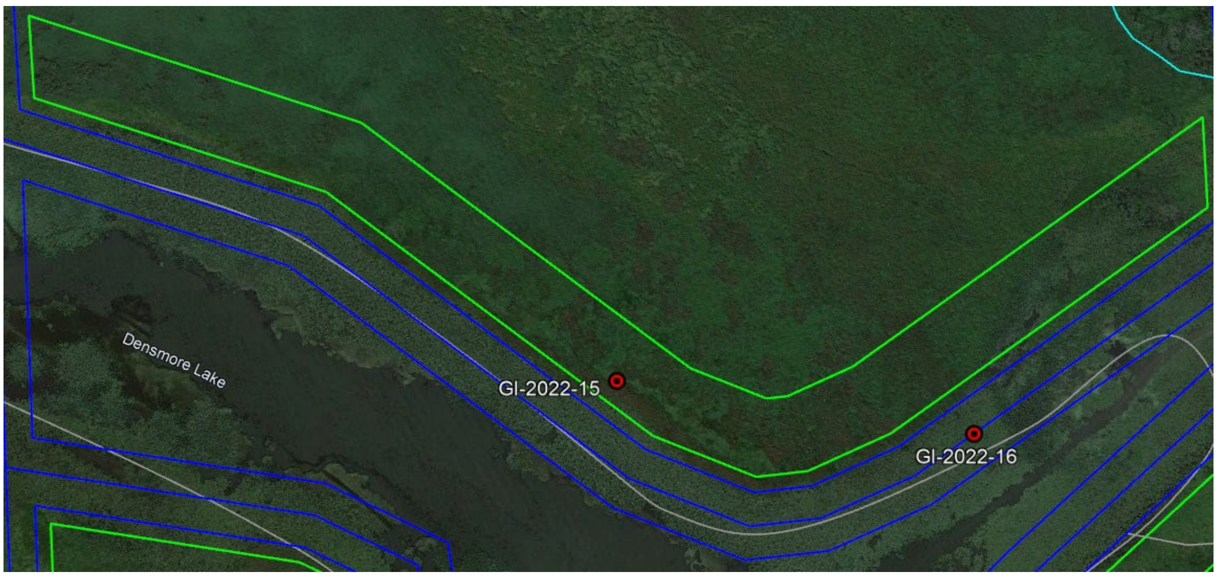


Figure C-24: Borings GI-2022-15 & GI-2022-16

Figure C-25 shows the soil classification and cohesion values for borings GI-2022-15 and GI-2011-16. The lowest cohesion value of 980 psf was used in the calculations. The borings show mostly a clay material with some sections having some sand content. For that reason, a unit weight of 130 pcf was used. The reduction factors were assumed to be 1. Slopes from 1H:1V to 5H:1V and in some cases slopes from 1H:1V to 8H:1V were used in the calculation of the factor of safety. The calculations using a slope 3H:1V is shown in Figure C-26. The results for the rest of the side slopes are provided in Section 7.2.2 Side Slopes Results.

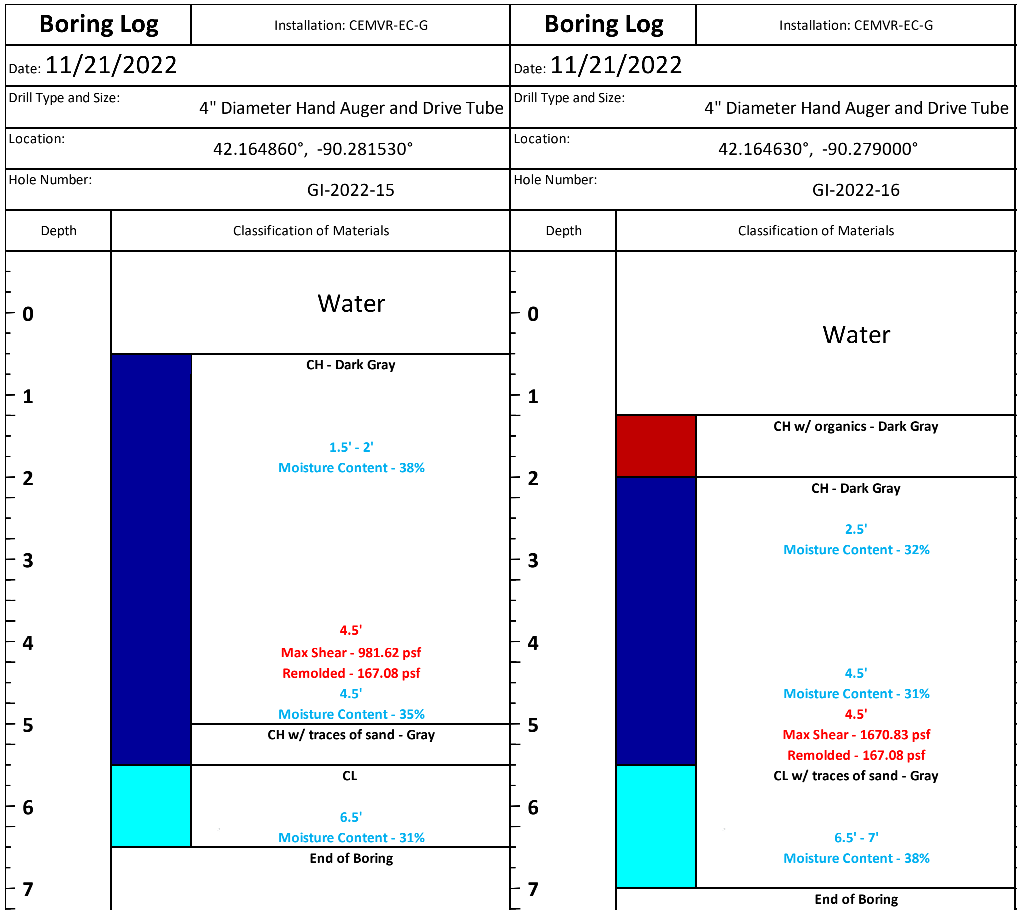


Figure C-25: Borings GI-2022-15 & GI-2022-16 Soil Classification & Cohesion Values

US Army Corps of Engineers Rock Island District | Green Island HREP Project | Calculated by: Josue Laborde-Rivera | Date: 01/24/2023

Slope Stability Calculations

Slope Stability Calculations on Feature B-03 using slope 3H:1V. (Reference: EM 1110-2-1902)

Parameters

$\gamma_s := 130\ pcf$	γ_s = Unit Weight of Soil
$\gamma_w := 62.4\ pcf$	γ_w = Unit Weight of Water
$c := 980\ psf$	c = cohesion
$H_w := 5\ ft$	Hw = Height of water
$H := 10\ ft$	H = Height of bottom of channel to top of berm
$\mu_q := 1.0$	μq = Surcharge Adjustment Factor
$\mu_w := 1.0$	μw = Submergence Adjustment Factor
$\mu_t := 1.0$	μt = Tension Crack Adjustment Factor
$D_w := 3$	Dw = Dredging Slope Width
$D_h := 1$	Dh = Dredging Slope Height

Calculations

$\beta := \left(\operatorname{atan}\left(\frac{D_h}{D_w}\right)\right) = 18.4\ deg$ — β = Slope Angle

$P_d := \frac{(\gamma_s \cdot H - \gamma_w \cdot H_w)}{\mu_q \cdot \mu_w \cdot \mu_t} = 988\ psf$ — Pd = Driving Force

A toe circle slope failure which is the most common type of slope failure is assumed for this analysis. Using a slope angle $\beta = 18°$ and intersecting the toe circle line we get a Stability number No = 7.25.

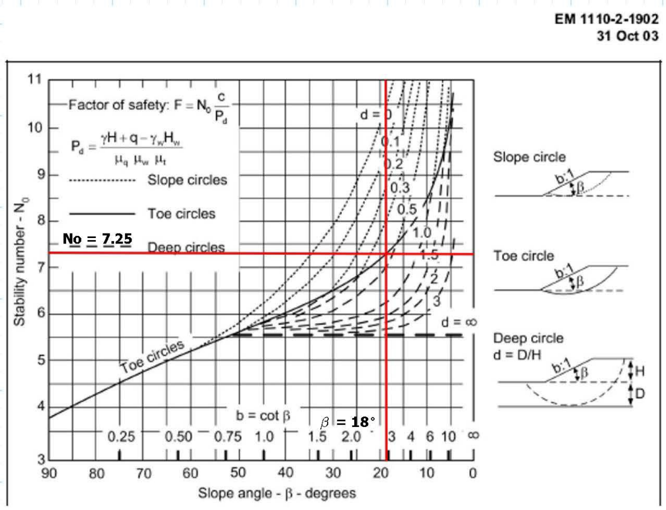


Figure 6: Slope Stability Chart

$N_o := 7.25$ — No = Stability Number

$FS := N_o \cdot \frac{c}{P_d} = 7.19$ — FS = Factor of Safety

A 3H:1V slope is adequate for Feature B-03.

1

Figure C-26: Feature B-03 Side Slopes Calculations

7.2.2 SIDE SLOPES RESULTS

Feature A-01 and B-01 to B-13 are shown in Figures C-27, C-30, C-33, C-36, C-39, C-42, C-45, C-48, C-51, C-54, C-57, C-61, C-64, and C-67. The boring logs with soil parameters that were used to determine the side slopes for the project features are shown in Figures C-28, C-31, C-34, C-37, C-40, C-43, C-46, C-49, C-52, C-55, C-58, C-59, C-62, C-65, and C-68. The factor of safety results is shown in Figures C-29, C-32, C-35, C-38, C-41, C-44, C-47, C-50, C-53, C-56, C-60, C-63, C-66, and C-69. The project features with low factor of safety results are shown in Figure C-70.

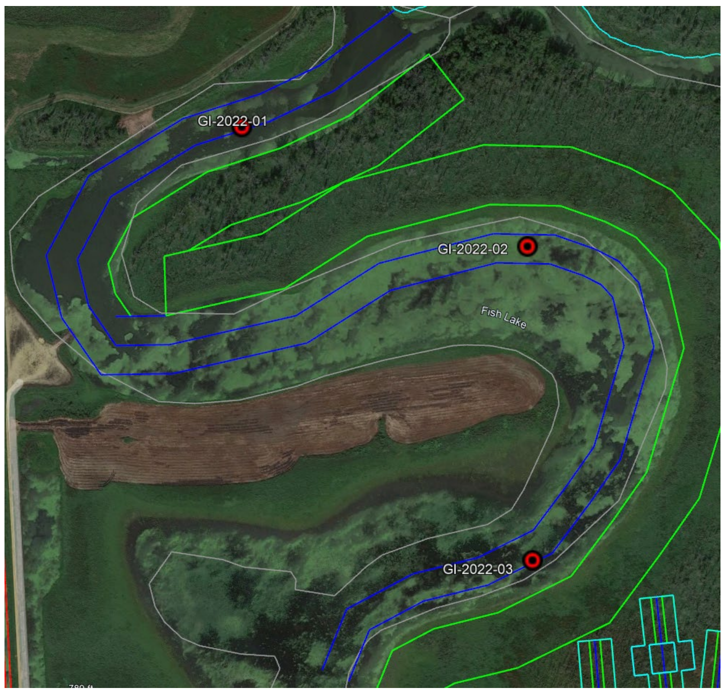


Figure C-27: Feature A-01

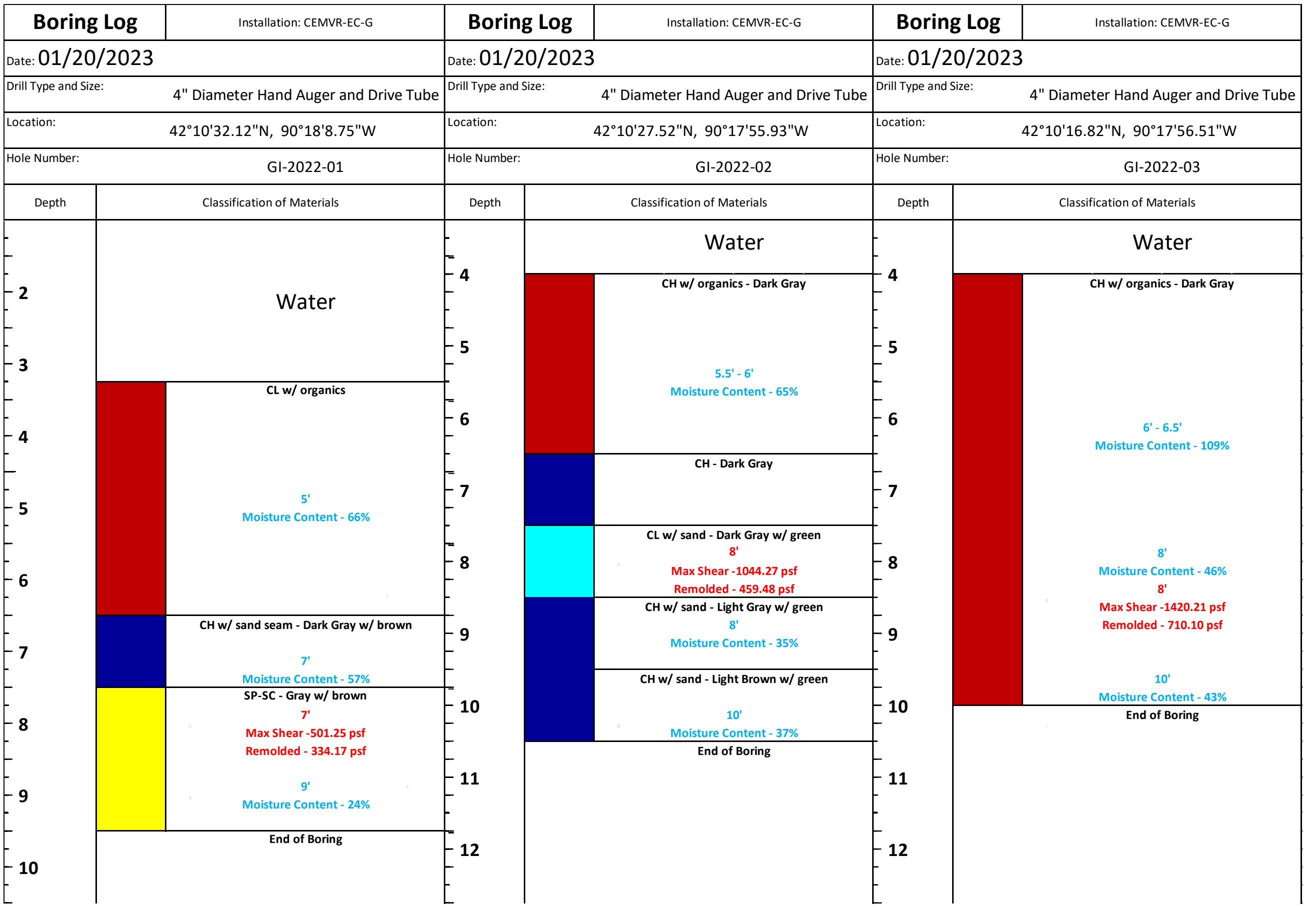


Figure C-28: Borings GI-2022-01, GI-2022-02 & GI-2022-03 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	μq	H (FT)	Hw/H	β	μw	μt	Pd (PSF)	No	FS
A-01	GI-2022-01	1	1	130	501	5	1	10	0.5	45.0	1	1	988	5.75	2.9
	GI-2022-02	2	1	130	501	5	1	10	0.5	26.6	1	1	988	6.75	3.4
	GI-2022-03	3	1	130	501	5	1	10	0.5	18.4	1	1	988	7.25	3.7
		4	1	130	501	5	1	10	0.5	14.0	1	1	988	7.75	3.9
		5	1	130	501	5	1	10	0.5	11.3	1	1	988	8.25	4.2
		6	1	130	501	5	1	10	0.5	9.5	1	1	988	8.5	4.3
		7	1	130	501	5	1	10	0.5	8.1	1	1	988	8.75	4.4
		8	1	130	501	5	1	10	0.5	7.1	1	1	988	9	4.6

Figure C-29: Feature A-01 Factor of Safety Results

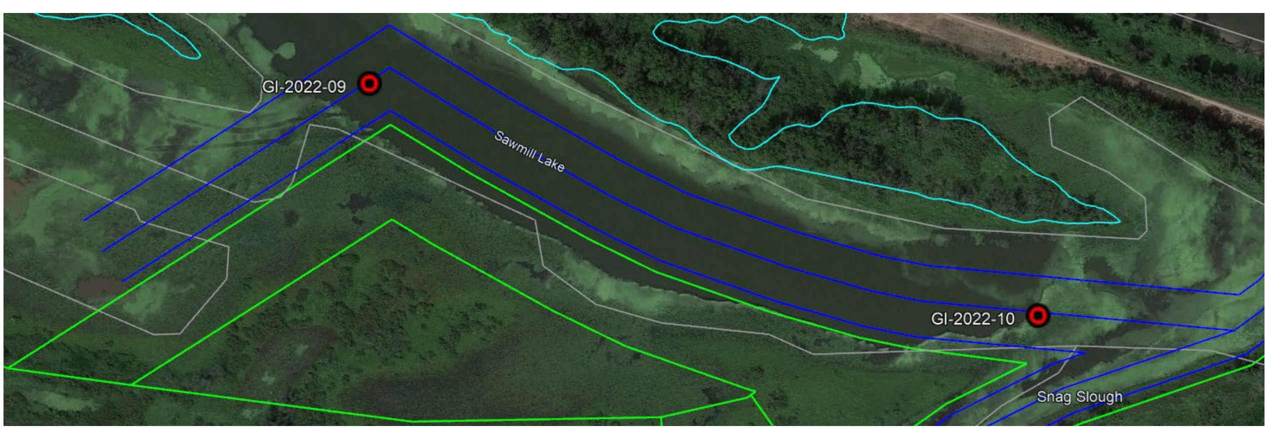


Figure C-30: Feature B-01

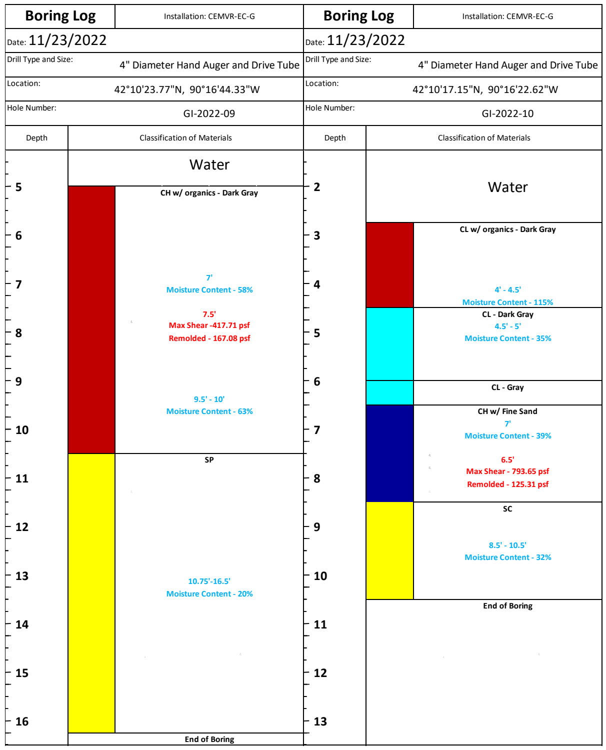


Figure C-31: Borings GI-2022-09, & GI-2022-10 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	μq	H (FT)	Hw/H	β	μw	μt	Pd (PSF)	No	FS
B-01	GI-2022-09	1	1	130	418	5	1	10	0.5	45	1	1	988	5.75	2.4327
	GI-2022-10	2	1	130	418	5	1	10	0.5	26.565	1	1	988	6.75	2.8558
		3	1	130	418	5	1	10	0.5	18.435	1	1	988	7.25	3.0673
		4	1	130	418	5	1	10	0.5	14.036	1	1	988	7.75	3.2788
		5	1	130	418	5	1	10	0.5	11.31	1	1	988	8.25	3.4904

Figure C-32: Feature B-01 Factor of Safety Results

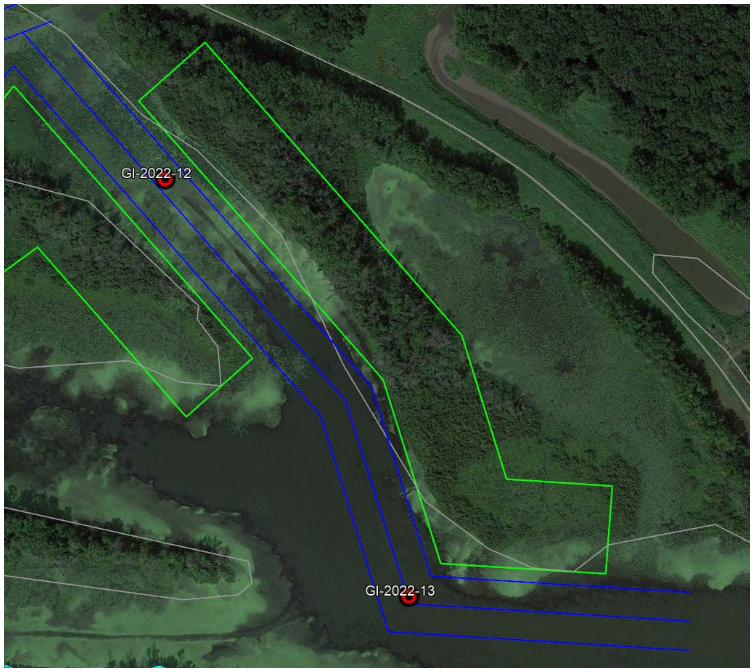


Figure C-33: Feature B-02

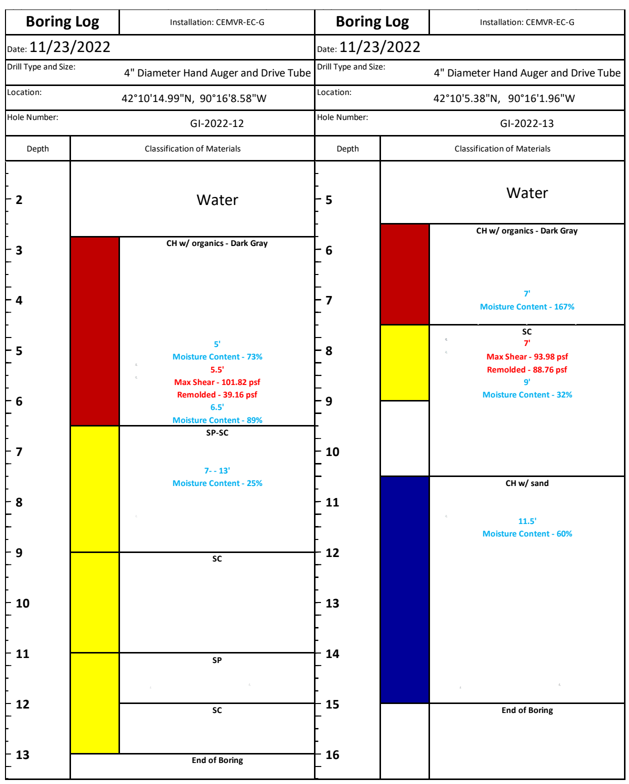


Figure C-34: Borings GI-2022-12, & GI-2022-13 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	µq	H (FT)	Hw/H	β	µw	µt	Pd (PSF)	No	FS
B-02	GI-2022-12	1	1	130	94	5	1	10	0.5	45	1	1	988	5.75	0.5471
	GI-2022-13	2	1	130	94	5	1	10	0.5	26.565	1	1	988	6.75	0.6422
		3	1	130	94	5	1	10	0.5	18.435	1	1	988	7.25	0.6898
		4	1	130	94	5	1	10	0.5	14.036	1	1	988	7.75	0.7373
		5	1	130	94	5	1	10	0.5	11.31	1	1	988	8.25	0.7849
		6	1	130	94	5	1	10	0.5	9.4623	1	1	988	8.5	0.8087
		7	1	130	94	5	1	10	0.5	8.1301	1	1	988	8.75	0.8325
		8	1	130	94	5	1	10	0.5	7.125	1	1	988	9	0.8563

Figure C-35: Feature B-02 Factor of Safety Results

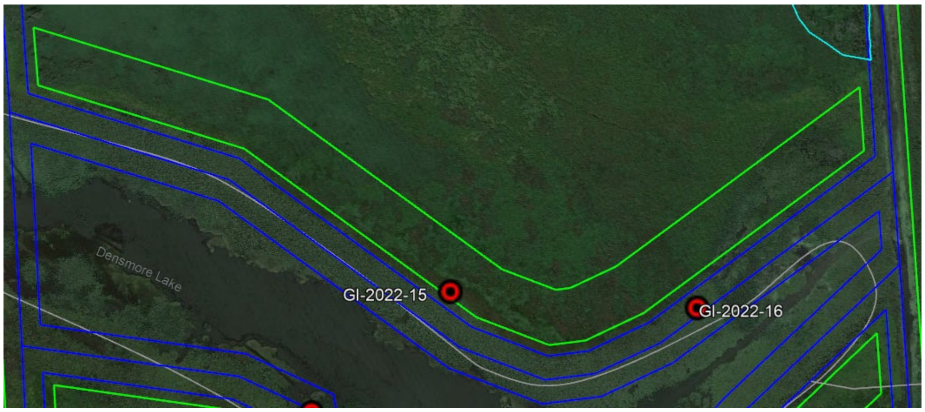


Figure C-36: Feature B-03

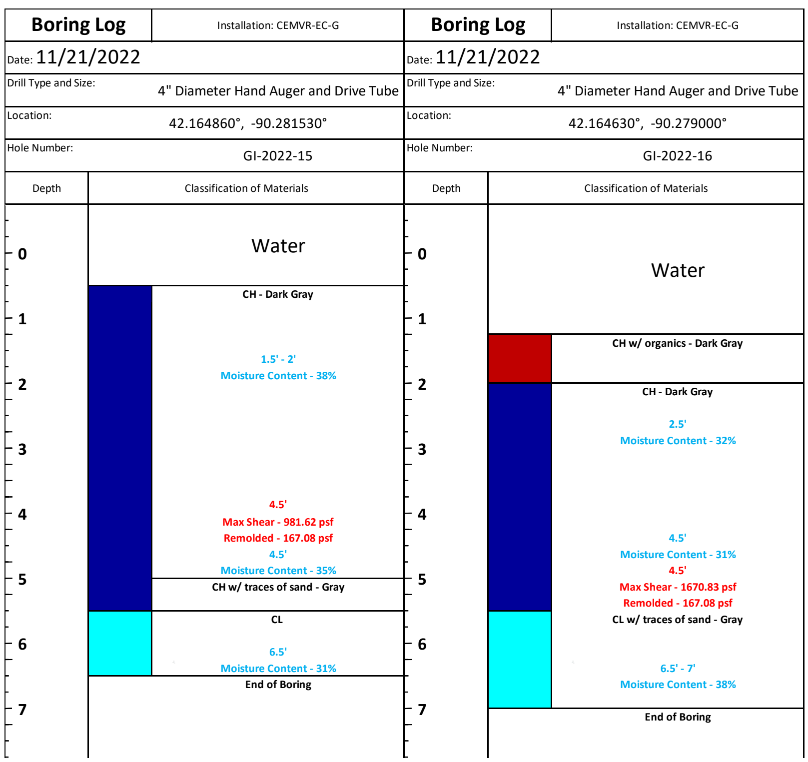


Figure C-37: Borings GI-2022-15, & GI-2022-16 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	µq	H (FT)	Hw/H	β	µw	µt	Pd (PSF)	No	FS
B-03	GI-2022-15	1	1	130	980	5	1	10	0.5	45	1	1	988	5.75	5.7034
	GI-2022-16	2	1	130	980	5	1	10	0.5	26.565	1	1	988	6.75	6.6953
		3	1	130	980	5	1	10	0.5	18.435	1	1	988	7.25	7.1913
		4	1	130	980	5	1	10	0.5	14.036	1	1	988	7.75	7.6872
		5	1	130	980	5	1	10	0.5	11.31	1	1	988	8.25	8.1832

Figure C-38: Feature B-03 Factor of Safety Results

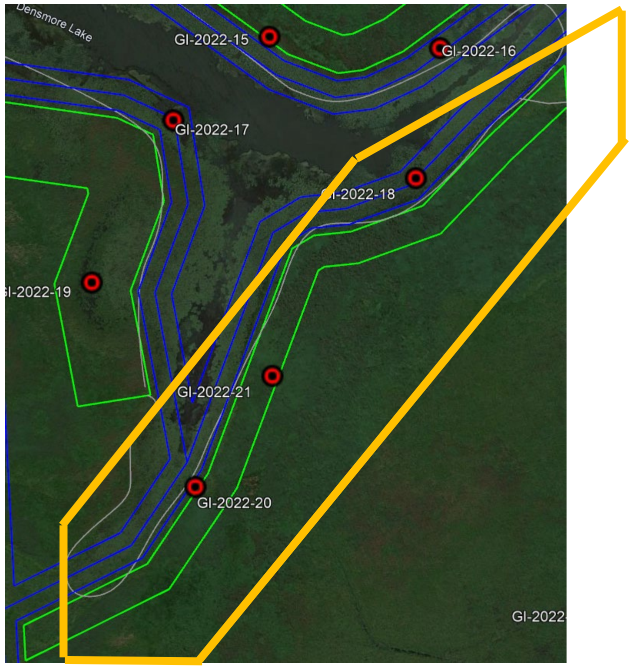


Figure C-39: Feature B-04

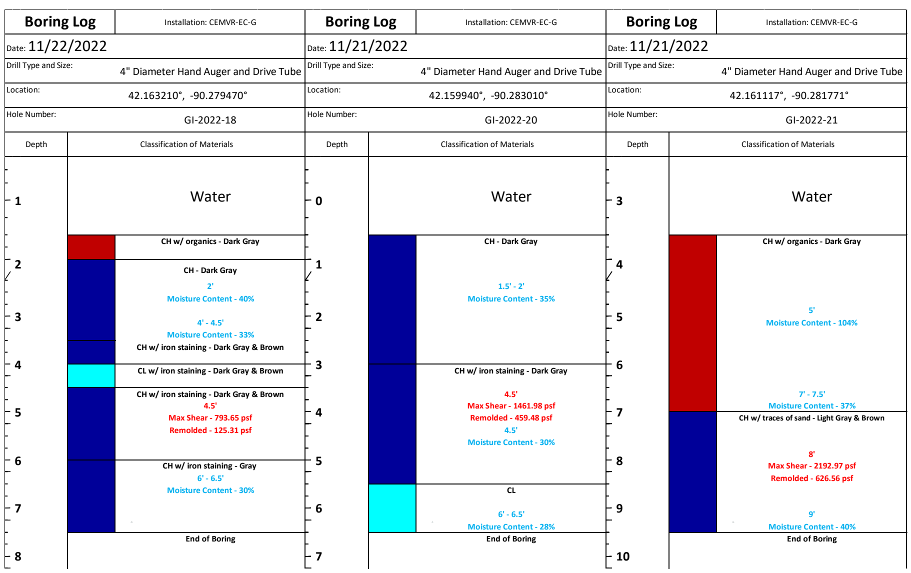


Figure C-40: Borings GI-2022-18, GI-2022-20 & GI-2022-21 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	µq	H (FT)	Hw/H	β	µw	µt	Pd (PSF)	No	FS
B-04	GI-2022-18	1	1	130	793.65	5	1	10	0.5	45	1	1	988	5.75	4.6189
	GI-2022-20	2	1	130	793.65	5	1	10	0.5	26.565	1	1	988	6.75	5.4222
	GI-2022-21	3	1	130	793.65	5	1	10	0.5	18.435	1	1	988	7.25	5.8238
		4	1	130	793.65	5	1	10	0.5	14.036	1	1	988	7.75	6.2255
		5	1	130	793.65	5	1	10	0.5	11.31	1	1	988	8.25	6.6271

Figure C-41: Feature B-04 Factor of Safety Results

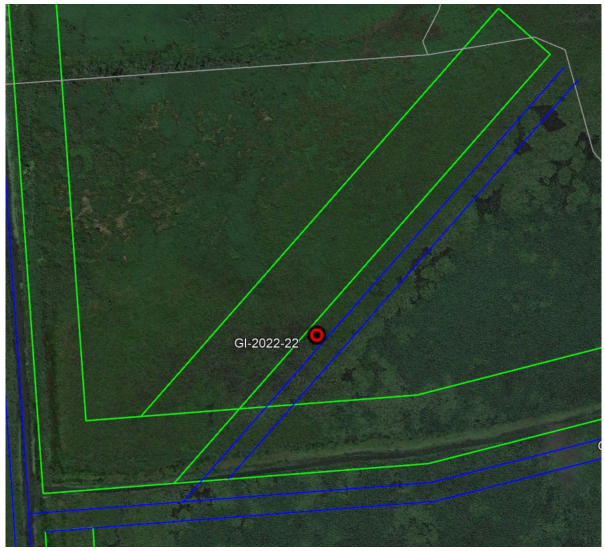


Figure C-42: Feature B-05

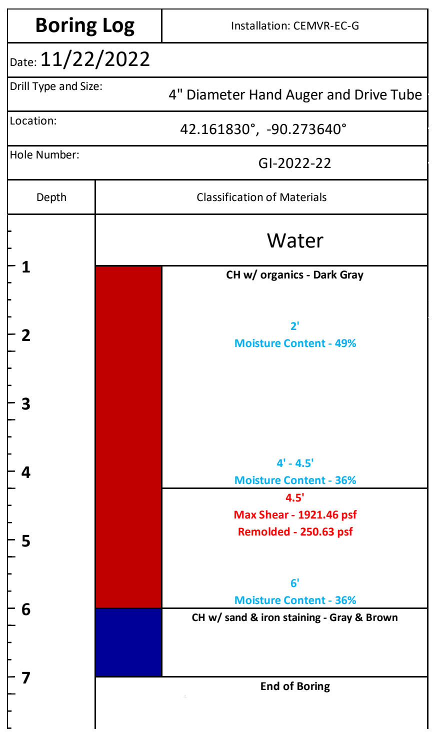


Figure C-43: Boring GI-2022-22 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	µq	H (FT)	Hw/H	β	µw	µt	Pd (PSF)	No	FS
B-05	GI-2022-22	1	1	130	1921	5	1	10	0.5	45.0	1	1	988	5.75	11.18
		2	1	130	1921	5	1	10	0.5	26.6	1	1	988	6.75	13.12
		3	1	130	1921	5	1	10	0.5	18.4	1	1	988	7.25	14.10
		4	1	130	1921	5	1	10	0.5	14.0	1	1	988	7.75	15.07
		5	1	130	1921	5	1	10	0.5	11.3	1	1	988	8.25	16.04

Figure C-44: Feature B-05 Factor of Safety Results

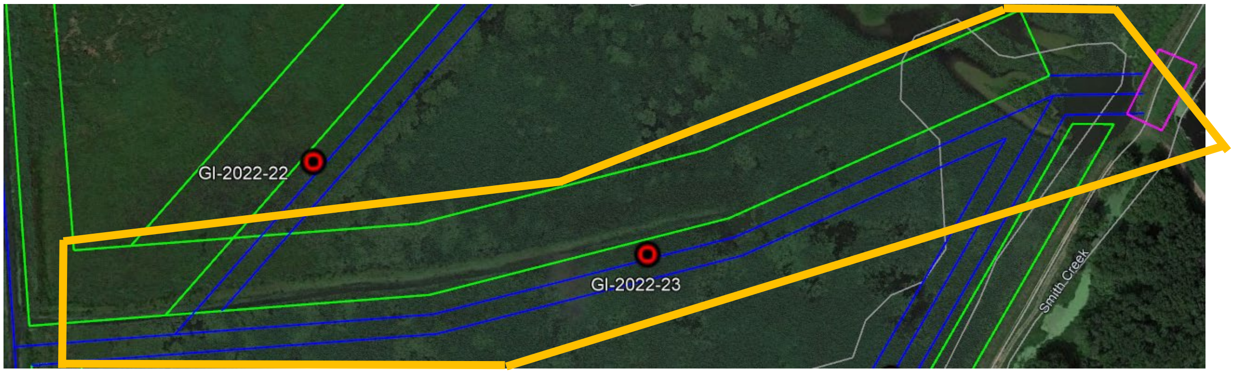


Figure C-45: Feature B-06

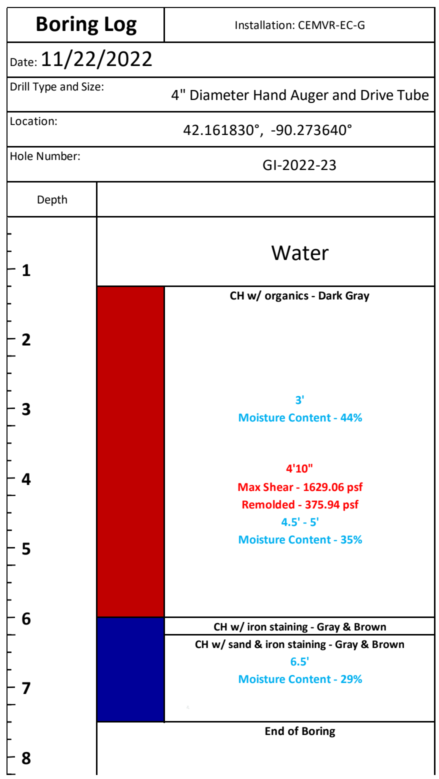


Figure C-46: Boring GI-2022-23 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	µq	H (FT)	Hw/H	β	µw	µt	Pd (PSF)	No	FS
B-06	GI-2022-23	1	1	130	1629	5	1	10	0.5	45.0	1	1	988	5.75	9.48
		2	1	130	1629	5	1	10	0.5	26.6	1	1	988	6.75	11.13
		3	1	130	1629	5	1	10	0.5	18.4	1	1	988	7.25	11.95
		4	1	130	1629	5	1	10	0.5	14.0	1	1	988	7.75	12.78
		5	1	130	1629	5	1	10	0.5	11.3	1	1	988	8.25	13.60

Figure C-47: Feature B-06 Factor of Safety Results

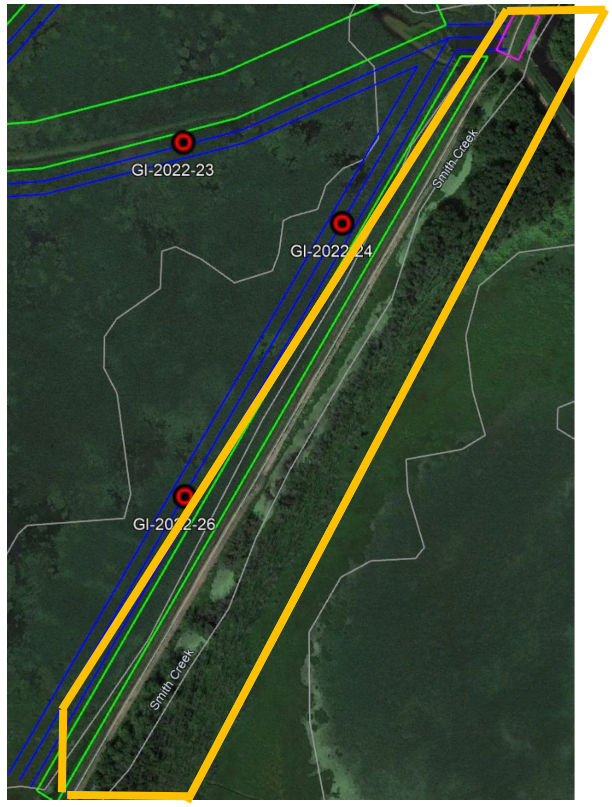


Figure C-48: Feature B-07

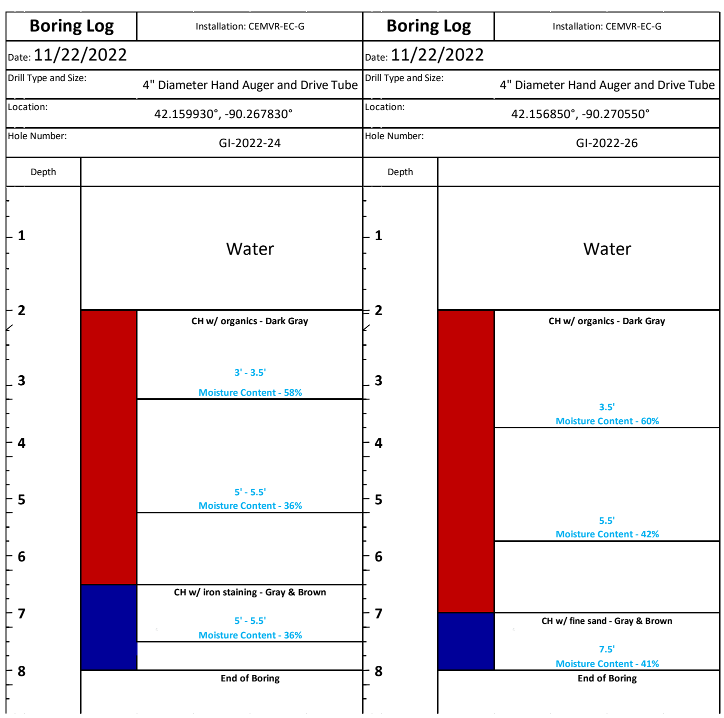


Figure C-49: Boring GI-2022-24 & GI-2022-26 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	μq	H (FT)	Hw/H	β	μw	μt	Pd (PSF)	No	FS
B-07	GI-2022-24	1	1	130	1462	5	1	10	0.5	45.0	1	1	988	5.75	8.51
	GI-2022-26	2	1	130	1462	5	1	10	0.5	26.6	1	1	988	6.75	9.99
		3	1	130	1462	5	1	10	0.5	18.4	1	1	988	7.25	10.73
		4	1	130	1462	5	1	10	0.5	14.0	1	1	988	7.75	11.47
		5	1	130	1462	5	1	10	0.5	11.3	1	1	988	8.25	12.21

Figure C-50: Feature B-07 Factor of Safety Results

Figure C-51: Feature B-08

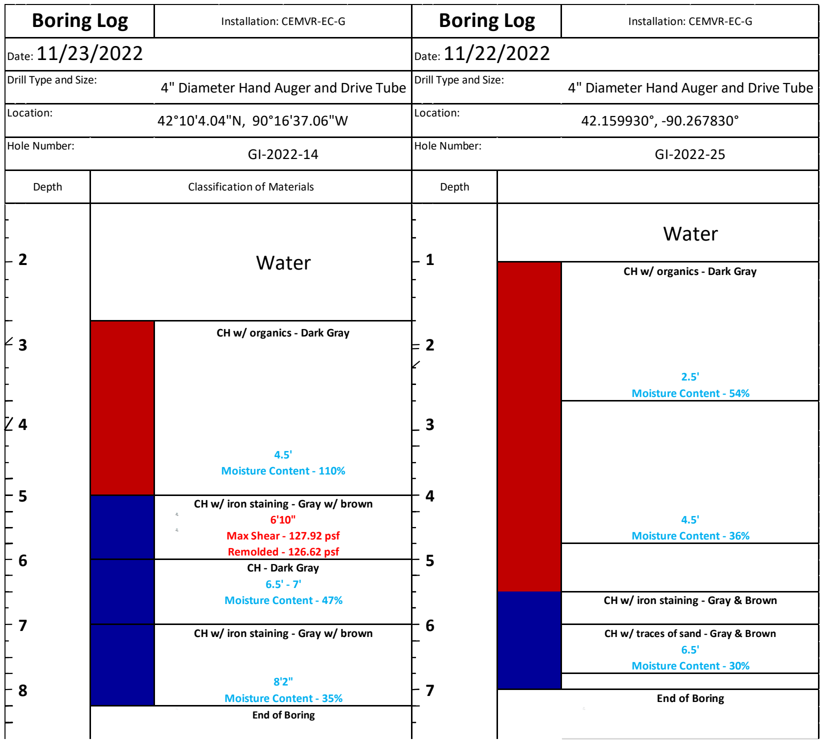


Figure C-52: Boring GI-2022-14 & GI-2022-25 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	μq	H (FT)	Hw/H	β	μw	μt	Pd (PSF)	No	FS
B-08	GI-2022-14	1	1	130	127	5	1	10	0.5	45.0	1	1	988	5.75	0.74
	GI-2022-25	2	1	130	127	5	1	10	0.5	26.6	1	1	988	6.75	0.87
		3	1	130	127	5	1	10	0.5	18.4	1	1	988	7.25	0.93
		4	1	130	127	5	1	10	0.5	14.0	1	1	988	7.75	1.00
		5	1	130	127	5	1	10	0.5	11.3	1	1	988	8.25	1.06
		6	1	130	127	5	1	10	0.5	9.5	1	1	988	8.5	1.09
		7	1	130	127	5	1	10	0.5	8.1	1	1	988	8.75	1.12
		8	1	130	127	5	1	10	0.5	7.1	1	1	988	9	1.16

Figure C-53: Feature B-08 Factor of Safety Results

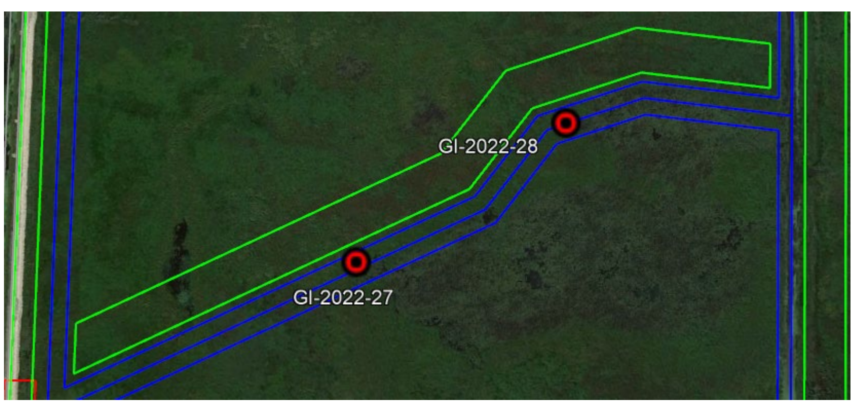


Figure C-54: Feature B-09

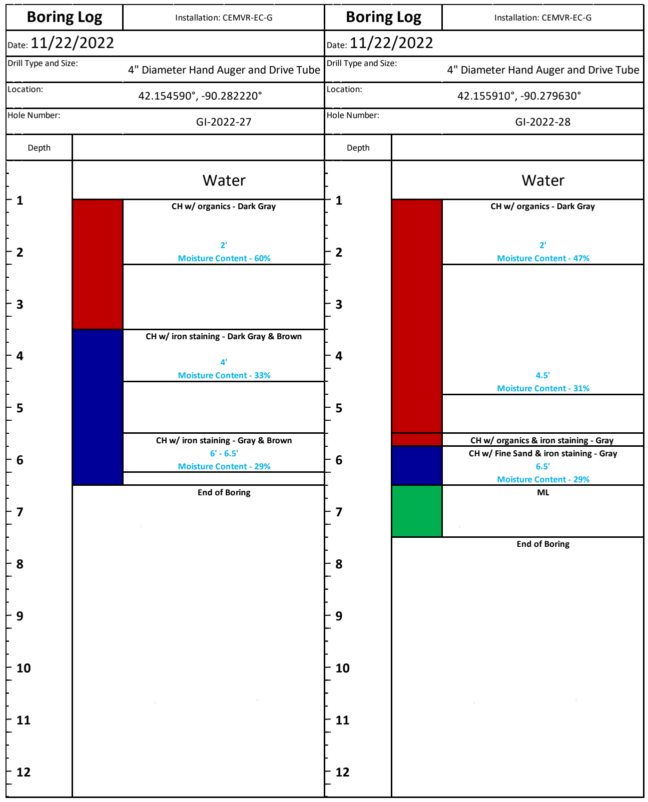


Figure C-55: Boring GI-2022-27 & GI-2022-28 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	µq	H (FT)	Hw/H	β	µw	µt	Pd (PSF)	No	FS
B-09	GI-2022-27	1	1	130	961	5	1	10	0.5	45.0	1	1	988	5.75	5.59
	GI-2022-28	2	1	130	961	5	1	10	0.5	26.6	1	1	988	6.75	6.57
		3	1	130	961	5	1	10	0.5	18.4	1	1	988	7.25	7.05
		4	1	130	961	5	1	10	0.5	14.0	1	1	988	7.75	7.54
		5	1	130	961	5	1	10	0.5	11.3	1	1	988	8.25	8.02

Figure C-56: Feature B-09 Factor of Safety Results

Figure C-57: Feature B-10

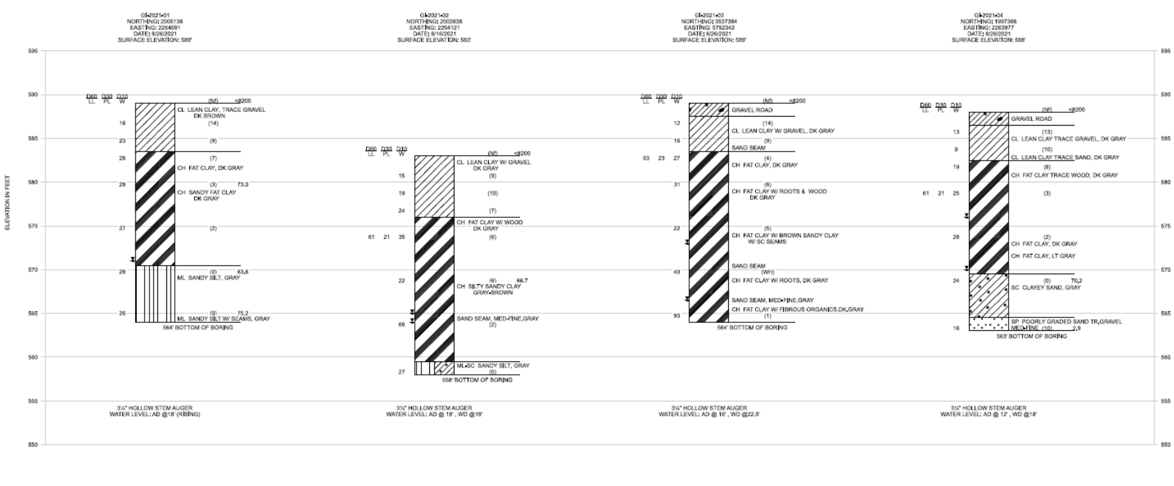


Figure C-58: Borings GI-2021-01, GI-2021-02, GI-2021-03 & GI-2021-04 Soil Parameters

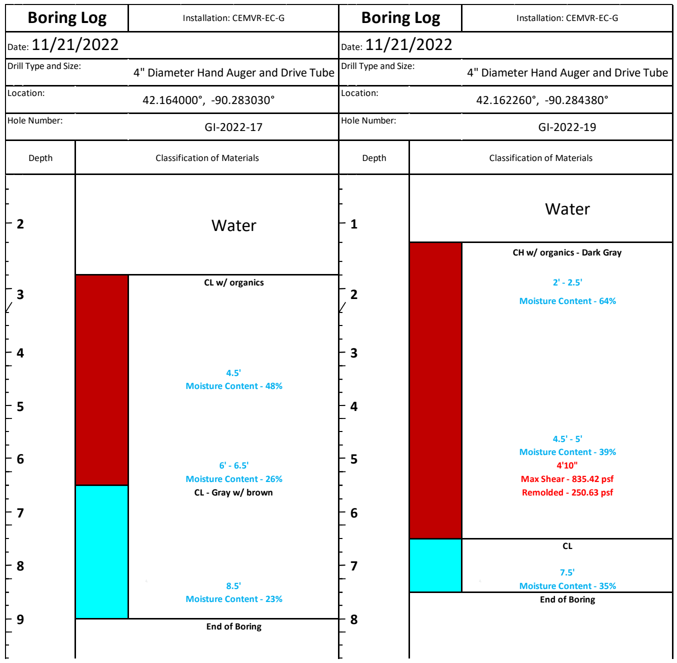


Figure C-59: Borings GI-2022-17 & GI-2022-19 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	μq	H (FT)	Hw/H	β	μw	μt	Pd (PSF)	No	FS
B-10	GI-2021-01	1	1	130	127	5	1	10	0.5	45	1	1	988	5.75	0.7391
	GI-2021-02	2	1	130	127	5	1	10	0.5	26.565	1	1	988	6.75	0.8677
	GI-2021-03	3	1	130	127	5	1	10	0.5	18.435	1	1	988	7.25	0.9319
	GI-2021-04	4	1	130	127	5	1	10	0.5	14.036	1	1	988	7.75	0.9962
	GI-2021-06	5	1	130	127	5	1	10	0.5	11.31	1	1	988	8.25	1.0605
	GI-2022-17	6	1	130	127	5	1	10	0.5	9.4623	1	1	988	8.5	1.0926
	GI-2022-19	7	1	130	127	5	1	10	0.5	8.1301	1	1	988	8.75	1.1247
		8	1	130	127	5	1	10	0.5	7.125	1	1	988	9	1.1569

Figure C-60: Feature B-10 Factor of Safety Results

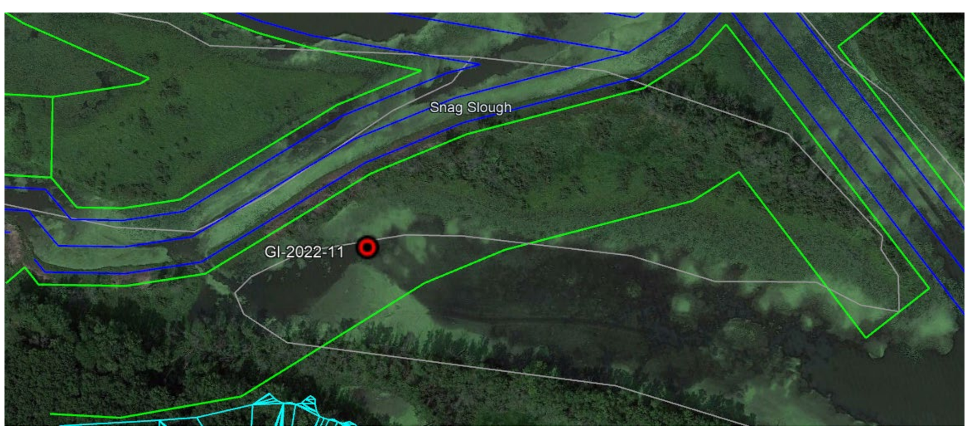


Figure C-61: Feature B-11

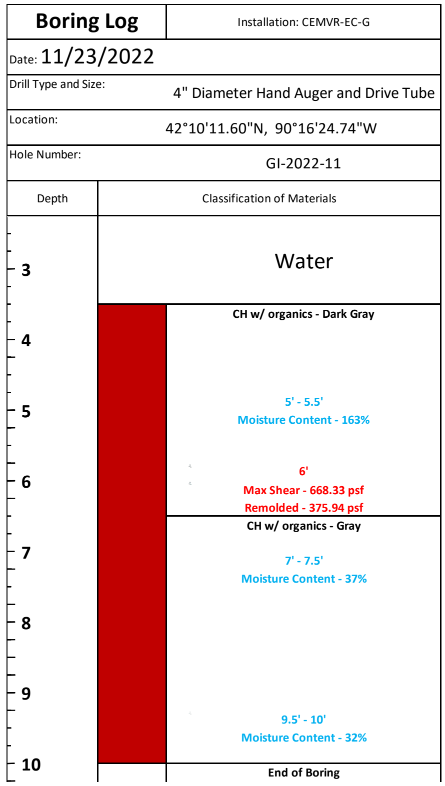


Figure C-62: Boring GI-2022-11 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	μq	H (FT)	Hw/H	β	μw	μt	Pd (PSF)	No	FS
B-11	GI-2022-11	1	1	130	668	5	1	10	0.5	45	1	1	988	5.75	3.8877
		2	1	130	668	5	1	10	0.5	26.565	1	1	988	6.75	4.5638
		3	1	130	668	5	1	10	0.5	18.435	1	1	988	7.25	4.9018
		4	1	130	668	5	1	10	0.5	14.036	1	1	988	7.75	5.2399
		5	1	130	668	5	1	10	0.5	11.31	1	1	988	8.25	5.5779

Figure C-63: Feature B-11 Factor of Safety Results

Figure C-64: Feature B-12

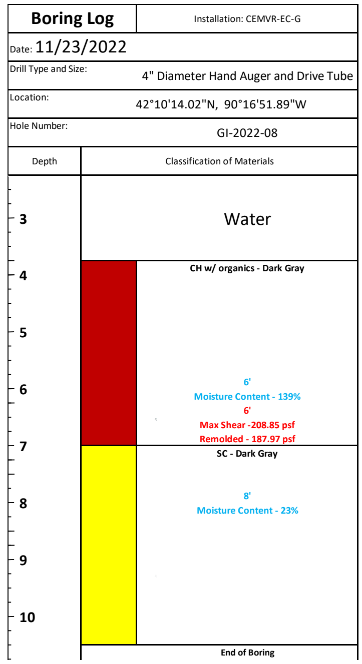


Figure C-65: Boring GI-2022-08 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	µq	H (FT)	Hw/H	β	µw	µt	Pd (PSF)	No	FS
B-12	GI-2022-08	1	1	130	209	5	1	10	0.5	45	1	1	988	5.75	1.2163
		2	1	130	209	5	1	10	0.5	26.565	1	1	988	6.75	1.4279
		3	1	130	209	5	1	10	0.5	18.435	1	1	988	7.25	1.5337
		4	1	130	209	5	1	10	0.5	14.036	1	1	988	7.75	1.6394
		5	1	130	209	5	1	10	0.5	11.31	1	1	988	8.25	1.7452
		6	1	130	209	5	1	10	0.5	9.4623	1	1	988	8.5	1.7981
		7	1	130	209	5	1	10	0.5	8.1301	1	1	988	8.75	1.851
		8	1	130	209	5	1	10	0.5	7.125	1	1	988	9	1.9038

Figure C-66: Feature B-12 Factor of Safety Results

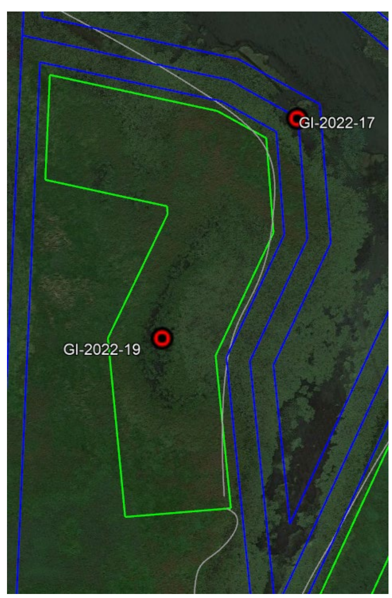


Figure C-67: Feature B-13

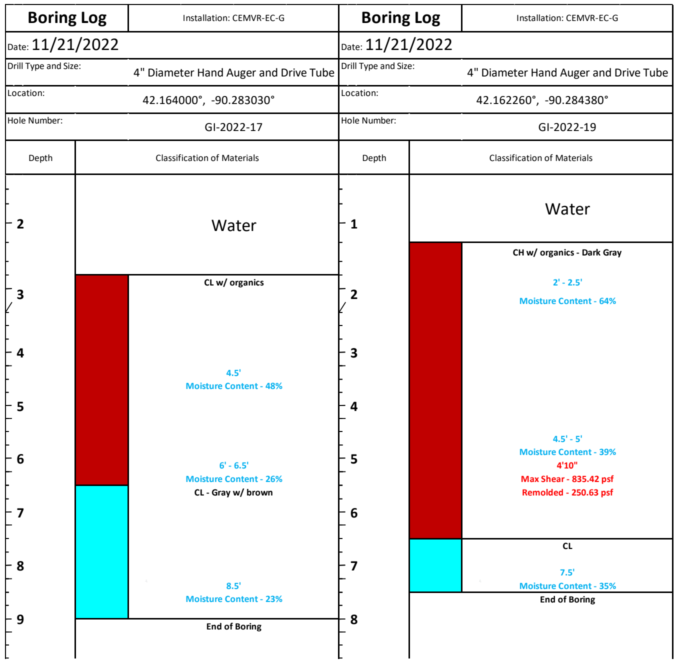


Figure C-68: Borings GI-2022-17 & GI-2022-19 Soil Parameters

Feature	Borings Used	Dredging Slope Width (FT)	Dredging Slope Height (FT)	Unit Weight (PCF)	Cohesion (PSF)	Hw (FT)	µq	H (FT)	Hw/H	β	µw	µt	Pd (PSF)	No	FS
B-13	GI-2022-17	1	1	130	840	5	1	10	0.5	45	1	1	988	5.75	4.8887
	GI-2022-19	2	1	130	840	5	1	10	0.5	26.565	1	1	988	6.75	5.7389
		3	1	130	840	5	1	10	0.5	18.435	1	1	988	7.25	6.164
		4	1	130	840	5	1	10	0.5	14.036	1	1	988	7.75	6.5891
		5	1	130	840	5	1	10	0.5	11.31	1	1	988	8.25	7.0142

Figure C-69: Feature B-13 Factor of Safety Results

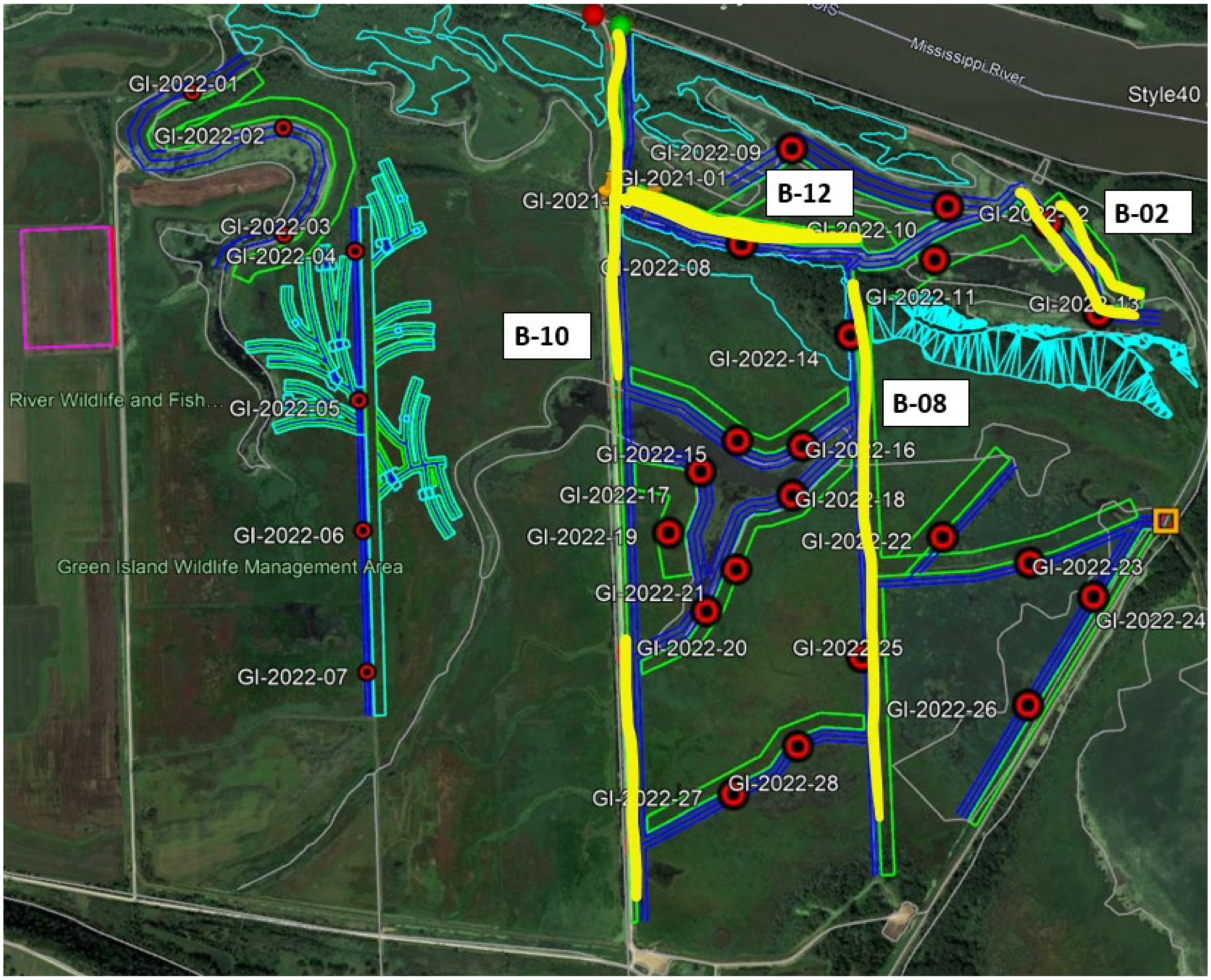


Figure C-70: Features with low factor of safety

7.2.3 RECOMMENDATIONS

Features A-01, B-01, B-03, B-04, B-05, B-06, B-07, B-09, B-11, and B-13 have high factor of safety results given the high cohesion values that were gathered in the field. This is an indication that there is a good clay material in these areas. 3H:1V side slopes is recommended on these features.

Features B-02, B-08, B-12, and upper and lower sections of B-10 had low factor of safety results given the low cohesion values that were gathered in the field and in some areas, we have historic boring data, but no cohesion values. Feature B-10 have boring logs done in 2021 shown in Figure C-58, but no cohesion values. 8H:1V side slopes is recommended on these sections. However, features B-10 and B-08 has a large distance compared to the boring data available on these areas. It is recommended gathering additional boring data on these specific sections which includes gathering cohesion values to reduce uncertainty on the exiting soil material to increase the likelihood of a reduction of the channel and berm side slopes for these areas.

7.1 EARTHWORK

Project measures include mechanical dredge cuts to provide access to project features and to improve wildlife habitat for plant, animal, and fish species.

7.2 SETTLEMENT AND SHRINKAGE

Settlement calculations are not considered relevant to this Project due to the following
• relatively thin top clay layer with minimal settlement
• unpredictable desiccation, drying, and consolidation shrinkage of the uncompacted berm
• significant time lapse (at least three years) for the majority of the foundation settlement and uncompacted embankment desiccation and drying to occur prior to 'final shaping' of the embankment.

Given that limited data was obtained for the study only preliminary analyses were performed, and more detailed exploration and analyses will be performed when the project advances to design phase.

7.3 STABILITY

A simple slope stability analysis was conducted on the PL 84-99 Eligibility Inspection Report. An internal angle of internal friction (Φ) of 30° was assumed. The existing landside slope of the green island levee is 1V:3H which creates an angle of inclination of embankment slope with horizontal (ß) of 18.43°. The factor of safety was calculated by the following equation $\frac{\tan \Phi}{\tan ß}$ which results in a factor of safety of 1.73 which is greater than the required 1.3.

The analysis provided in the section of Sta. 315+00 of the Green Island Levee above is representative of similar site conditions, but not necessarily applicable to specific proposed project features. The materials and slopes of the proposed project are not representative of those used in levee construction. It is recommended that a more thorough slope stability analysis be conducted for this project to obtain representative values.

7.4 SEEPAGE

According to the PL 84-99 Eligibility Inspection Report there was evidence of minor seepage with a rating A on the green island levee. A more detailed seepage analysis should be performed when the project advances to design phase.

7.5 STRUCTURAL FOUNDATIONS

A pump station is being proposed for the Green Island HREP project for water management measures. The location of the proposed pump station is shown in Figure C-71. Preliminary design considerations were developed for the structural foundations of the proposed pump station.

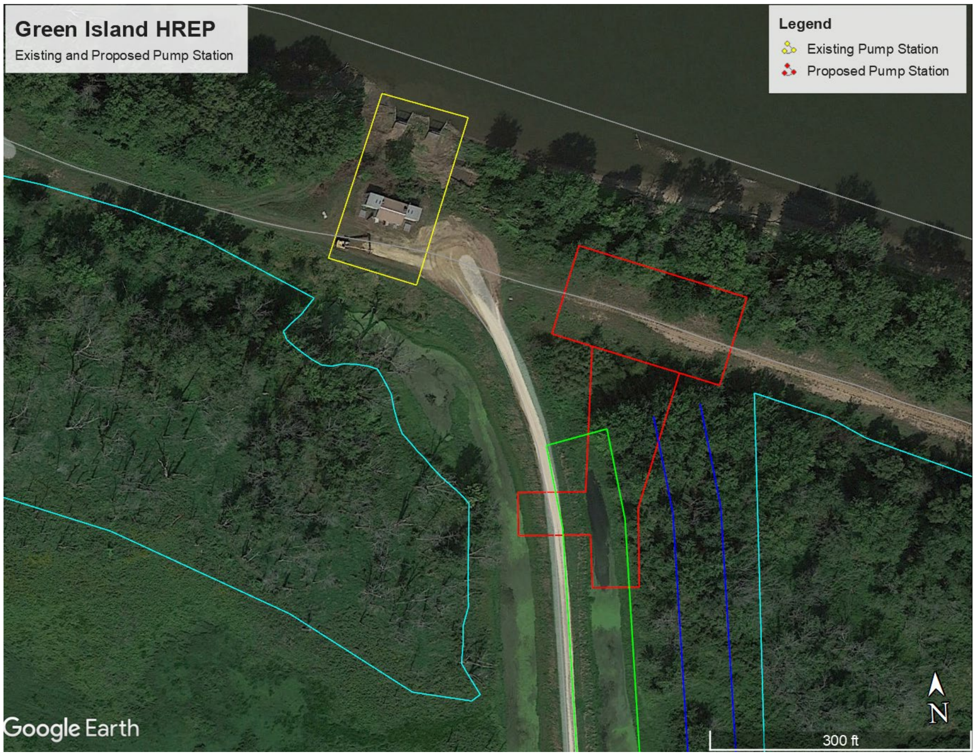


Figure C-71: Existing and Proposed Pump Station

Preliminary foundation design for the proposed pump station, wingwalls and other settlement sensitive structures should consider steel piles embedded into concrete footings. Considering the alternative drilled piles or shafts would need to be cased the recommended steel pile type is H-piles. Depending on the structural loads, the pile spacing estimate may range from 5 feet to 8 feet center to center. The site soil conditions suggest the piles will be friction piles as opposed to end bearing on bedrock and for the TSP can use an estimated length of 50 feet.

In addition to the pile supported foundations, the footings for the pump Station, wingwalls and other settlement sensitive structures are anticipated to be concrete with thicknesses to be designed by EC-DS. Given the variable, organic, compressive, saturated nature of the surface soils, consideration should be given to including a nominal thickness of stabilization stone beneath the footings as well as for the bedding materials for any culvert pipes.

The preliminary design considerations use the Rice Lake Pump Station as an example. A boring is being planned to be done in the proposed pump station location in the near future. With the boring data to be acquired a more detailed foundation design will be develop for the proposed pump station as the project advances to the design phase.

8. REFERENCES

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UPPER MISSISSIPPI RIVER RESTORATION
FEASIBILITY REPORT

GREEN ISLAND LEVEE
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

POOL 13 UPPER MISSISSIPPI RIVER, MILES 548.5 TO 546
JACKSON COUNTY, IOWA

JUNE 2023

ATTACHMENT A
SUBSURFACE DATA AND BORING LOGS

UPPER MISSISSIPPI RIVER RESTORATION
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HABITAT REHABILITATION AND ENHANCEMENT PROJECT

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ATTACHMENT B
PLAN SET

UPPER MISSISSIPPI RIVER RESTORATION
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JUNE 2023

ATTACHMENT C
PRELIMINARY SITE INVESTIGATION REPORT