UPPER MISSISSIPPI RIVER RESTORATION
FEASIBILITY REPORT
WITH INTEGRATED ENVIRONMENTAL ASSESSMENT

BEAVER ISLAND
HABITAT REHABILITATION AND ENHANCEMENT PROJECT

POOL 14, UPPER MISSISSIPPI RIVER MILES 513.0-517.0
CLINTON COUNTY, IOWA

APPENDIX G

GEOTECHNICAL CONSIDERATIONS

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FIGURES

ATTACHMENTS

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GEOTECHNICAL CONSIDERATIONS

I. PURPOSE

This appendix to the Feasibility Report presents the general geology and specific geotechnical analyses relevant to the Project. The geological information was taken and condensed from References A and B. The Rock Island District Engineering Division's Geotechnical Branch obtained representative soil borings, performed laboratory analysis and interpretation, and provided sufficient geotechnical analyses and recommendations to support the Project alternatives. Final exploration, subsurface characterization, and geotechnical design will be performed subsequent to approval of the Feasibility Report.

II. LOCATION

The area of the *Beaver Island Habitat Rehabilitation and Enhancement Project* (Project) is located along the right descending bank of the Upper Mississippi River in Clinton County, Iowa. It is in Pool 14 between river miles (RM) 513.0 and 517.0, adjacent to Clinton, Iowa. Areas considered as part of this Project and described as the "Project area" include Beaver Island, Beaver Slough, Albany Island, and Albany Slough.

III. SCOPE

The proposed Project would restore backwater habitat by excavating backwater channels to a depth of 8 feet below flat pool, providing overwintering and year-round habitat for fish. Excavated material will be used to enhance topographic diversity. These areas will be planted with mast producing trees. A rock closure structure will be constructed on the upstream end of Beaver Island to reduce overwintering water velocities and deflect sediment from entering the Project area from Beaver Slough. Rock will be used to construct a chevron at the head of, and bank protection for, Albany Island.

IV. PHYSIOGRAPHY

The Project area is situated within the Dissected Till Plains Section of the Central Lowlands Province of the Interior Plains. 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.

V. GEOLOGY

The Project lies entirely within the Mississippi River floodplain, which consists of alluvial soils at and near the surface and glacial deposits at depths. The surface stratum is usually clay varying in thickness from about 3 to 20 feet. This is underlain by a sand and gravel stratum which extends to an intermittent glacial till clay at a depth of 40 to 80 feet or to bedrock at a depth of 120 to 160 feet.

VI. SURFICIAL SOILS

The United States Natural Resources Conservation Service (NRCS) publishes soil surveys for most counties in the United States (Reference C). Information contained in these reports pertains to soil within 5 feet of the surface. These soils are mapped by soil series. A soil series is a group of soils having almost identical profiles. All soils of a particular series have horizons that are similar in compositions, thickness, and arrangement. Information in a pre-published soil survey indicated that the types of soils that are present in and around Beaver Island generally classify as Fluvent-Ambraw soil series, which is described as an alluvium product in the NRCS classification system. This series is described as frequently flooded and the water table is said to vary between ground surface and 1 foot deep. Figure G-1 shows the NRCS soil map.

VII. SUBSURFACE EXPLORATION

The District conducted subsurface exploration using 4-inch diameter Iwan style hand-augers in order to generally characterize the composition and engineering properties of the soils present at Beaver Island. Borings were taken at locations shown in Attachment 1. Samples were taken from each boring at sufficient intervals to classify all the strata encountered. Representative samples were taken for visual classification, moisture contents, and Atterberg Limit testing to verify classifications. Boring logs can be found in Attachment 1.

VIII. LABORATORY TESTING

All fine-grained samples were analyzed for water content. The average water content of the fine-grained samples was 54.9 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 1.5 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 51 and 41, and plastic limits expressed as an index between 22 and 20.

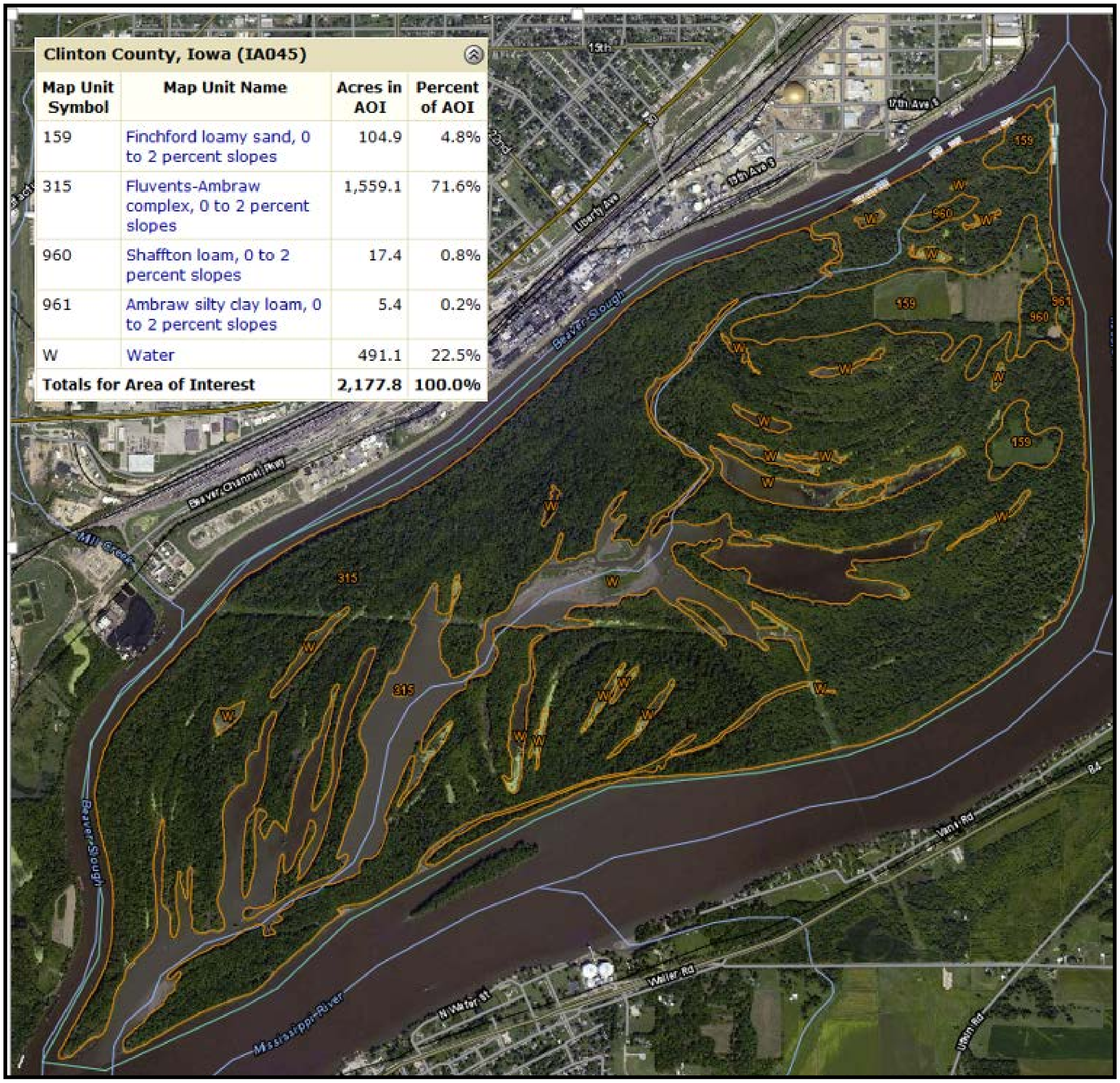

Figure G-1: NRCS Soil Survey Map of Beaver Island

IX. STRATIGRAPHY

Borings BI-14-01 through BI-14-03 were taken at the downstream end of Beaver Island. These borings were advanced approximately 14 feet deep from the top of water elevation. Below ground surface, a top layer of approximately 5 feet composed of soft lean clays (CL) and fat clays (CH) showed increasing stiffness with depth. Medium to fine sands underlie the upper clay layer.

Borings BI-14-04 and BI-14-05 were taken downstream and upstream of the upper cut, respectively. BI-14-04 showed similar stratigraphy to that found on borings BI-14-01 through BI-14-03. BI-14-05 showed similar materials to those found in all the other borings, although the thickness of the top clay layer was significantly thinner than that found on all other borings. The difference in layer thickness is most likely due to relatively higher flow velocities in this area.

X. SITE CHARACTERIZATION

In order to prepare the appropriate geotechnical analyses for design of the proposed Project features, it was necessary to characterize the Project area according to typical clay and sand foundation depths and strengths, typical embankment heights and strengths, and water depths. All boring logs and river bottom transects were analyzed in detail.

Top of sand foundation will be taken as EL 565.0. Sand foundation strength will be taken as 28 degrees angle of internal friction. Top of clay foundation will be taken as EL 572.0. Foundation clay unconsolidated-undrained (end-of-construction) shear strengths were obtained by the Rock Island District's moisture content correlation, as shown in Figure G-2.

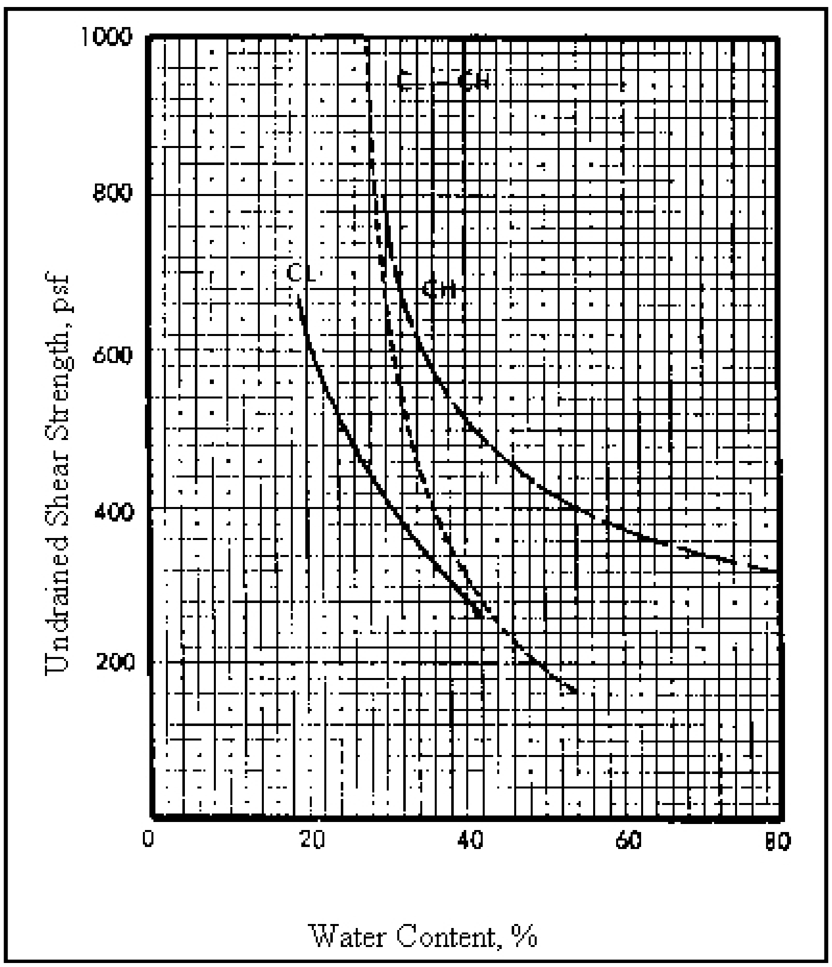

Figure G-2: MVR Unconsolidated-Undrained Shear Strengths

XI. DREDGING DESIGN

The Project includes mechanical dredging, which will provide both excavation for improved fish habitat and borrow material for uncompacted earth embankment construction.

The preferred dredging technique for clay is mechanical. Review of the boring logs indicates that the in-place uncompacted embankment borrow material is soft to firm clay. A mechanical dredging method is required to minimize disturbance of the borrow soils so that maximum possible soil strength is realized during and after uncompacted embankment construction. A three cubic yard minimum capacity clamshell bucket and excavators have been successfully utilized at similar restoration projects. A large-capacity clamshell bucket that is specifically designed for removal of any firmer in situ clays may be necessary. Approximately 15 percent of the total depth of dredging will occur below the clay layers in the underlying sand foundation.

Uncompacted earth embankments will be constructed using mostly (approximately 85 percent) mechanically-dredged fine sediments. It must be stressed that embankment construction by clamshell dredging of fine sediments is not ideal. Soil strength estimation is difficult, especially when placement is made under water, because compaction of cohesive soils cannot occur. The contractor will not be allowed to ‘throw’ the material from the clamshell, but must ‘place’ the clamshell on the placement area ground surface and then release the material in order to obtain maximum strength from the in situ borrow material.

XII. STABILITY

The foundation and embankment engineering properties were characterized previously in Sections X and XI of this appendix. An idealized dredge cut section was developed to determine stability (Figure G-3). In addition to those elevations and dimensions shown in the figure, the bottom of the dredge cut was taken as EL 563.0, and the top of the uncompacted earth embankment placement area was taken as 580.0.

Both drained and undrained clay foundation strength parameters were modeled with GeoStudio slope stability package (Reference E). As described in EM 1110-2-1902 (Reference F), the dredge cut will not be subjected to pool fluctuation, seepage, or earthquake forces. The in situ strength of dredge cut area soil prior to unloading was considered most critical due to the apparent strength gain from negative soil pore water pressures upon unloading. The program was run in the search mode, and numerous other surfaces were modeled, as shown in Attachment 2 to this appendix. The stability analyses of the dredge cut slope revealed that the drained condition was found to be the most critical and resulted in a factor of safety against sliding for the 4H:1V cut slopes of 1.37 (Figure G-4).

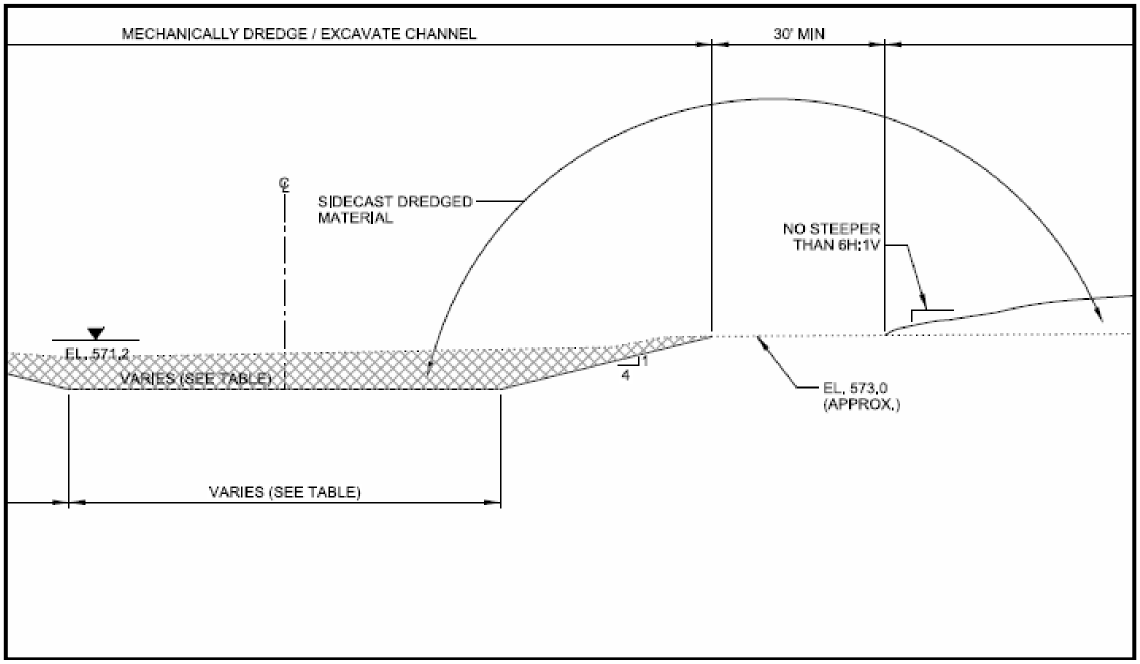

Figure G-3: Typical Section, Dredge Cut and Placement Area

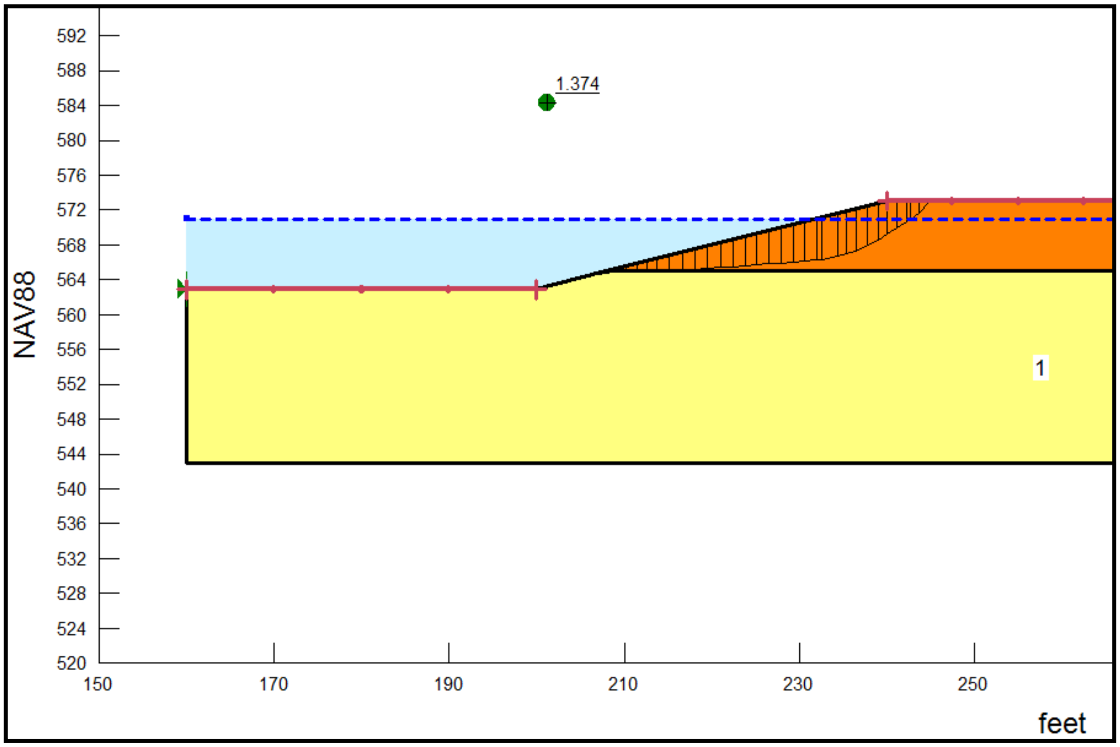

Figure G-4: Critical Slip Surface

The ideal recommendation is to place the cut slopes no closer than 30 feet from the toe of the uncompacted embankment and other dredged material placement areas in order to avoid influence on both the uncompacted earth embankment and the dredge cut stabilities. Contracting a mechanical dredge large enough to reach the entire placement area from the excavated channels may prove problematic. In this case, a minimum clearance distance of 20 feet can be allowed, as long as localized embankment and dredge cut slope failures are acceptable. Instantaneous isolated embankment and shallow foundation failures can be expected due to the unpredictable nature of the borrow material and placement method. Fine embankment and foundation soils will gain strength and greater stability with time as the cohesive soils are allowed to consolidate and drain. Double handling of dredged material or two or more passes by the dredge may also be necessary. In any case, construction contract duration will be structured to account for irregularities in both uncompacted earth embankment and cut slope strengths. The contract duration is expected to be more than three years to account for these, as well as, unpredictable flooding and embankment material drying, consolidation, and strength gain issues, which will dictate when all excavation can be completed. Previous similar successful projects have been completed with a three-year contract duration and/or separate stages for channel excavation and final shaping. This Project will include a second stage for both ‘final embankment shaping’ and all of the related habitat plantings that are planned.

XIII. 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 embankment, and
- 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.

Based upon similar projects, the shrinkage of the uncompacted embankment due to drying, desiccation, and consolidation is estimated at 15 percent. Additional surveys will be completed following the majority of settlement and shrinkage and shortly before commencement of Stage II – Final Shaping.

XIV. EROSION PROTECTION

Erosion protection stone is proposed for the chevron and bank protection for Albany Island and the Beaver Island closure structure. Hydraulic analysis and design (see Appendix H) was done to select a minimum rock gradation/thickness and slope that will resist both river current and wave attack for these features. The selected rock protection exceeded the minimum recommendation based upon ice flow considerations as follows:

- Albany Island Chevron - Iowa Class C Revetment, or equivalent
    - Nominal top size of 450 pounds
    - At least 50 percent of the stones weighing more than 275 pounds
    - At least 90 percent of the stones weighing more than 75 pounds

- Albany Island Bank Protection and Beaver Island Closure Structure - Iowa Class D Revetment, or equivalent
    - Nominal top size of 250 pounds.
    - At least 50 percent of the stones are to weigh more than 90 pounds
    - At least 90 percent of the stones are to weigh more than 5 pounds
    - 400-pound top size specified

The recommended thickness of the Albany Island bank erosion protection is two feet, and placed on a slope not exceeding 1.5H:1V. The Albany Island rock chevron and Beaver Island rock closure structure slopes will not exceed 1.5H:1V. Stability and settlement considerations are minimal for these features, since near-surface sand comprises their foundations.

The recommended rock erosion protection can be obtained locally.

XV. RECOMMENDATIONS

A. Uncompacted Earth Embankments

1. Provide slopes no steeper than 6H:1V.

2. Place the embankment material carefully. A minimum mechanical dredge bucket capacity of 3.0 cubic feet is recommended to minimize borrow material disturbance and to maximize uncompacted embankment strength.

3. Place uncompacted earth embankments no closer than 30 feet from dredge cuts.

4. Allow minimum 3-year contract duration to allow for adequate drying, desiccation, and consolidation prior to final shaping and planting stage.

B. Dredge Cuts

1. Dredge the cut slopes no steeper than 4H:1V.

2. Place the dredge cut slopes no closer than 30 feet from uncompacted embankment toes.

C. Rock Embankments

1. Provide slopes no steeper than 1.5H:1V.

2. Use Iowa Class C Revetment for the chevron and Iowa Class D Revetment (with 400-pound topsize) for the bank protection and closure structure.

XII. REFERENCES

A. Anderson, Wayne (1983), Geology of Iowa, The Iowa State University Press, Ames, IA.

B. Prior, Jean (1976), A Regional Guide to Iowa Landforms, Iowa Geological Survey, Iowa City, IA.

C. Web Soil Survey, (http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm) Natural Resources Conservation Service, U.S. Department of Agriculture, Washington, DC.

D. Duncan, J.M., Horz, R.C., and Yang, T. L. (1989), Shear Strength Correlations for Geotechnical Engineering, Department of Civil Engineering, Virginia Polytechnic University, Blacksburg, VA.

E. GeoStudio 2007, version 7.17. Copyright © 1991-2010 GEO-SLOPE International Ltd, Calgary, Alberta, Canada.

F. USACE (1970), EM 1110-2-1902, *Stability of Earth and Rockfill Dams*" U.S. Army Corps of Engineers, Washington, DC.

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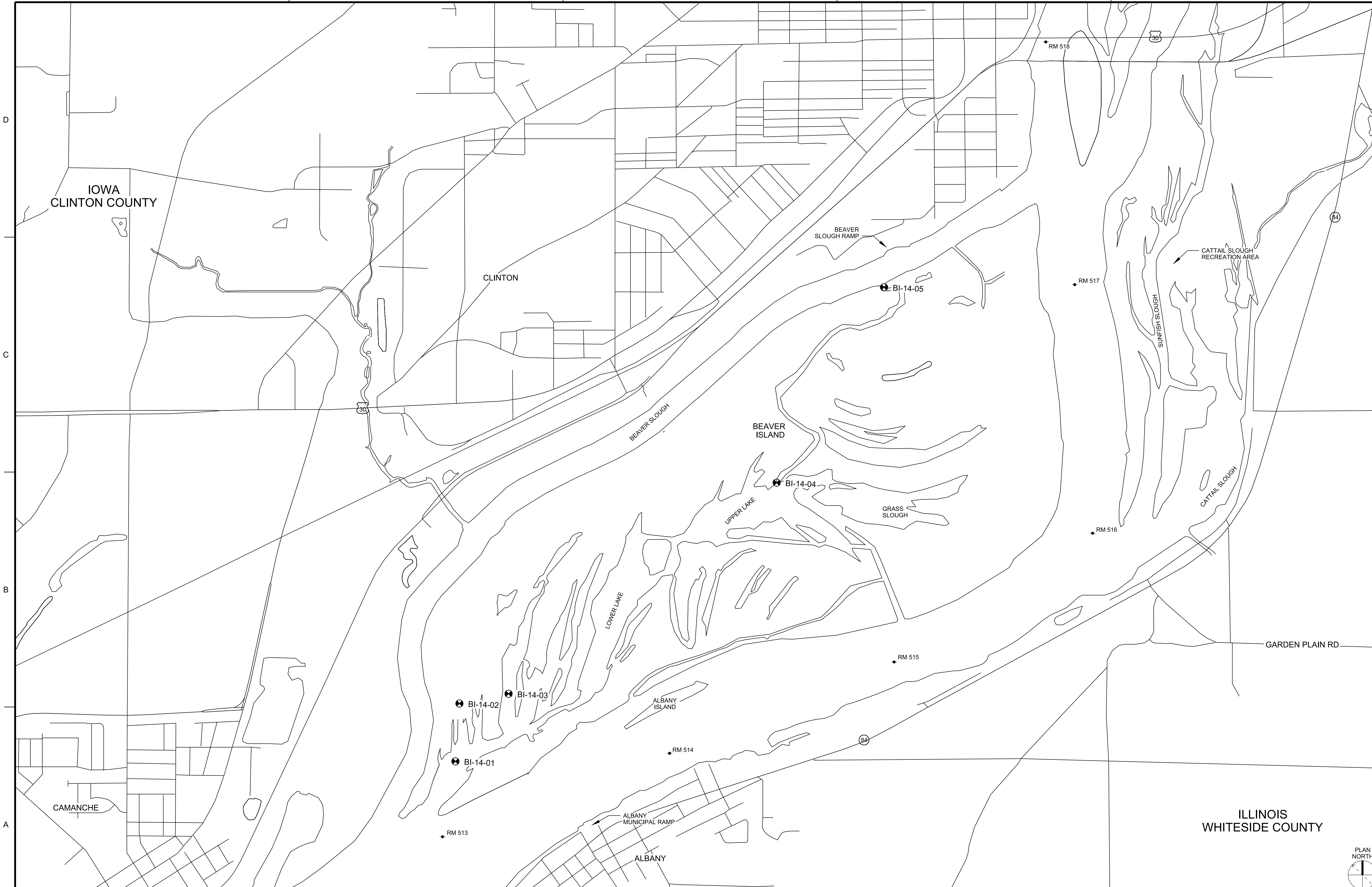
CLINTON COUNTY, IOWA

APPENDIX G

GEOTECHNICAL CONSIDERATIONS
ATTACHMENTS

Attachment 1

Boring Locations and Logs



A1 BORING PLAN

SCALE : 1"=1000'-0"

0 1000' 2000'

US Army Corps of Engineers®

MARK	DATE	DESCRIPTION	APPR.

U.S. ARMY CORPS OF ENGINEERS
ROCK ISLAND DISTRICT
ROCK ISLAND, ILLINOIS

DESIGNED BY: KNM		DATE:
DWN BY: WTT	CKD BY:	SOLICITATION NO.:
SUBMITTED BY:		CONTRACT NO.:
PLOT SCALE: AS SHOWN	PLOT DATE:	PROJECT CODE: EP109
SIZE: ANSI D	FILE NAME: EP109_B-101xxx.dgn	

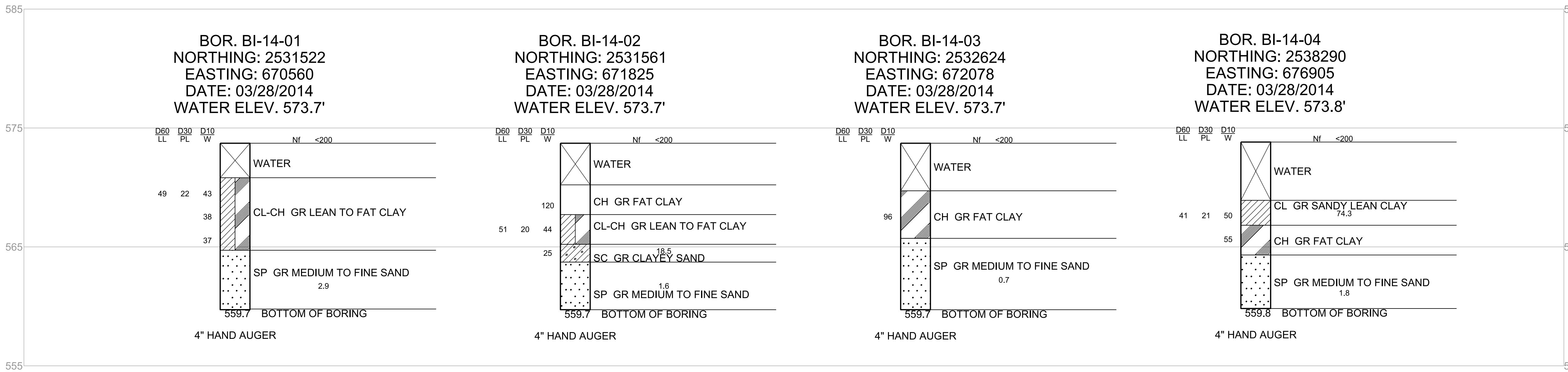
MISSISSIPPI RIVER
RIVER MILES 513.0-515.5
CLINTON COUNTY, IA
BEAVER ISLAND COMPLEX HREP
FEASIBILITY REPORT

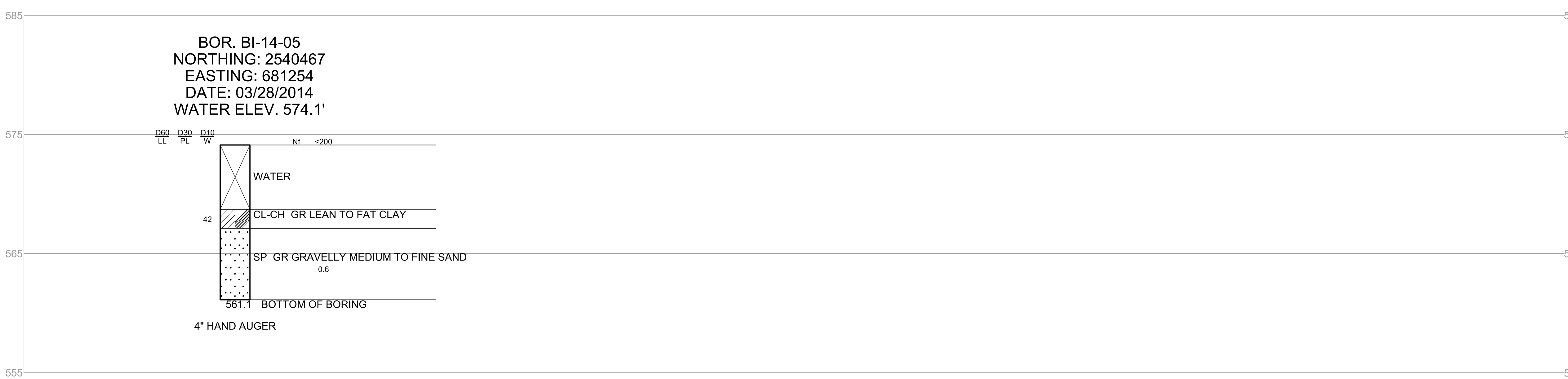
BORING PLAN

PLATE 4

Sheet ID
B-101

ELEVATIONS IN FEET NAVD 88





STATE PLANE: NAD 83 IOWA SOUTH 1402, US SURVEY FEET

DWG REF(s) : ______________

A1 BORING LOGS

SCALE : 1"=5'-0" 0 5' 10'

US Army Corps of Engineers®

MARK	DESCRIPTION	DATE	APPR.

DESIGNED BY: KNM | DWN BY: WTT | CKD BY: | SUBMITTED BY: | PLOT SCALE: AS SHOWN | PLOT DATE: | SIZE: ANSI D | FILE NAME: EP109_B-301xxx.dgn | DATE: | SOLICITATION NO.: | CONTRACT NO.: | PROJECT CODE: EP109

U.S. ARMY CORPS OF ENGINEERS
ROCK ISLAND DISTRICT
ROCK ISLAND, ILLINOIS

MISSISSIPPI RIVER
RIVER MILES 513.0-515.5
CLINTON COUNTY, IA
BEAVER ISLAND COMPLEX HREP
FEASIBILITY REPORT
BORING LOGS

PLATE 5

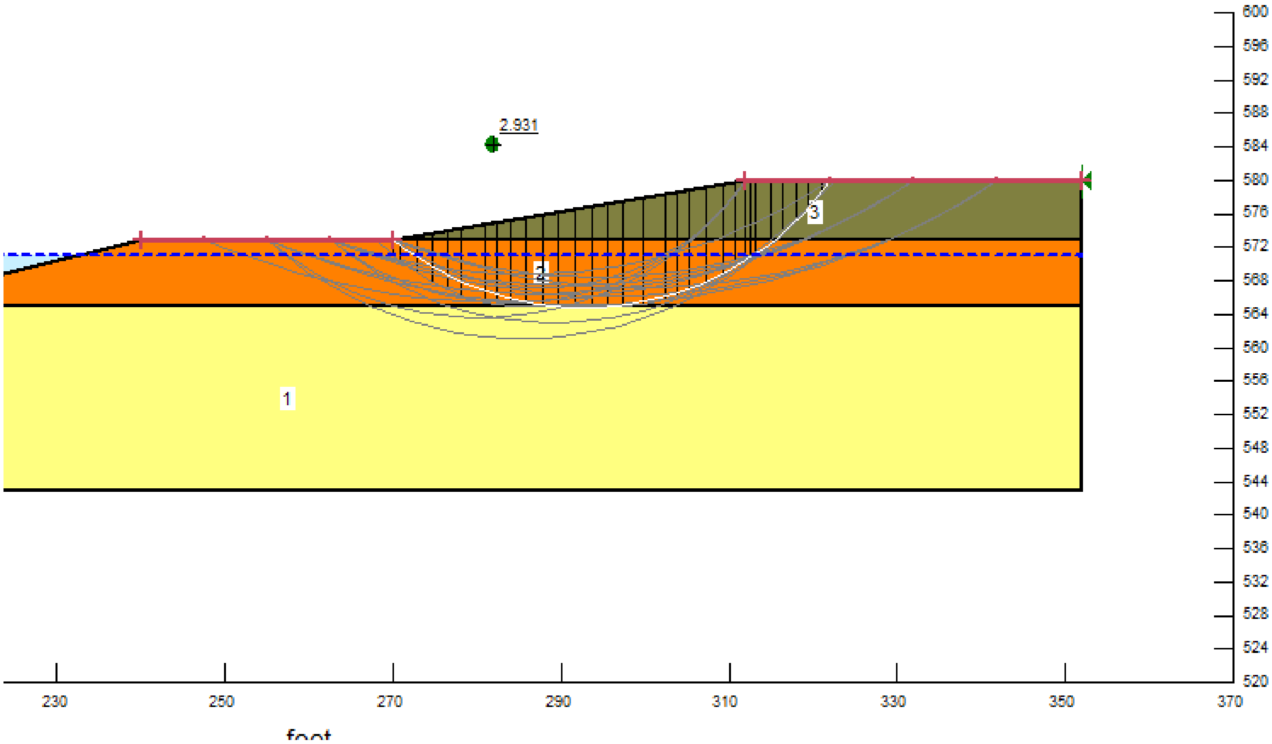
Sheet ID
B-301

Attachment 2

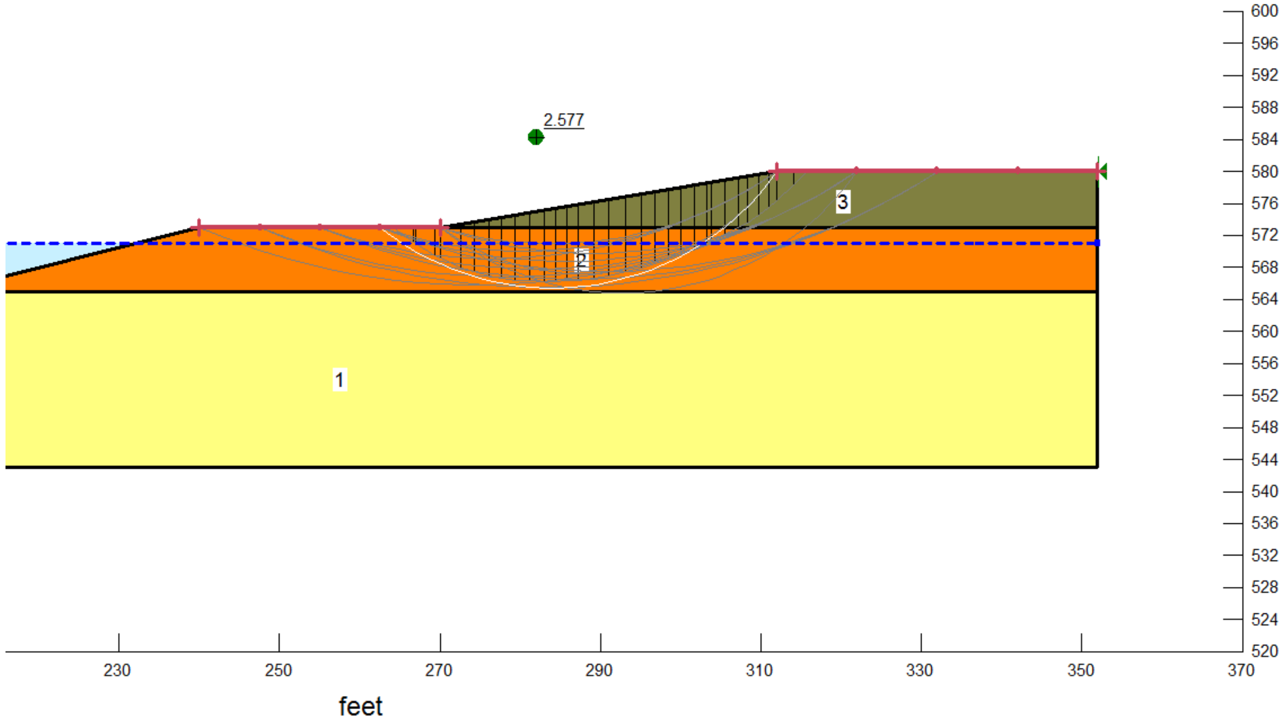
Stability Analyses

LEGEND

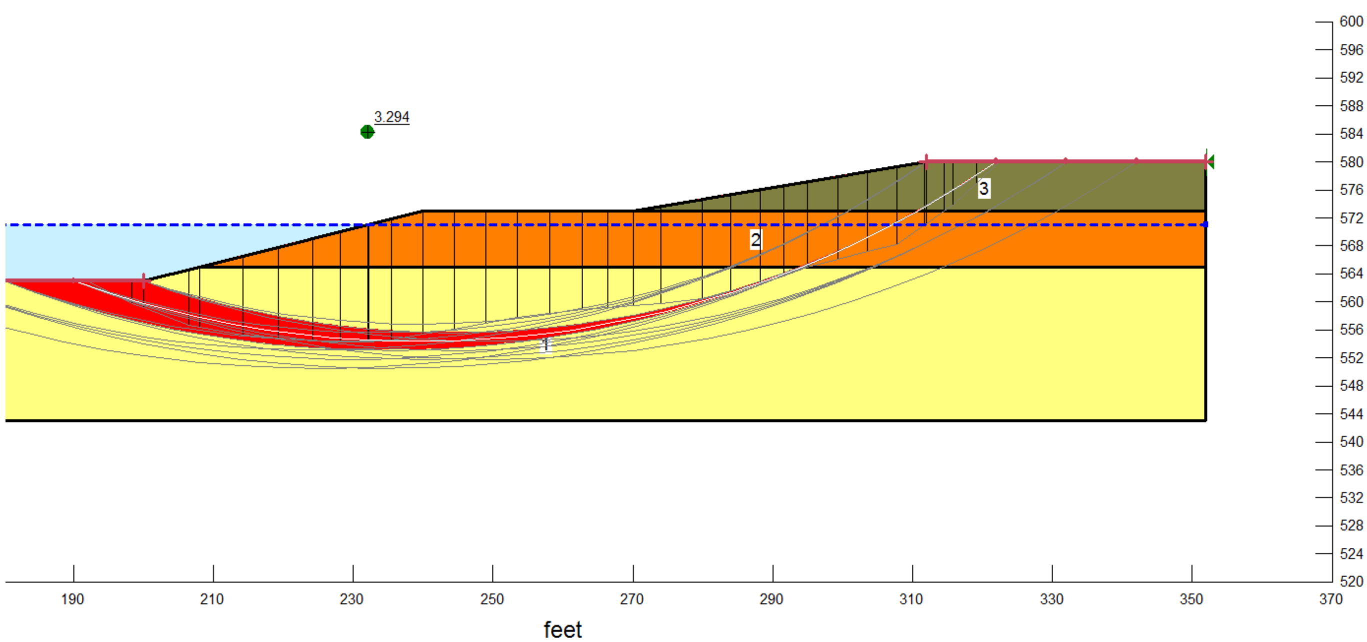
Material 1	**Sand**
Material 2	**Foundation**
Material 3	**Embankment**



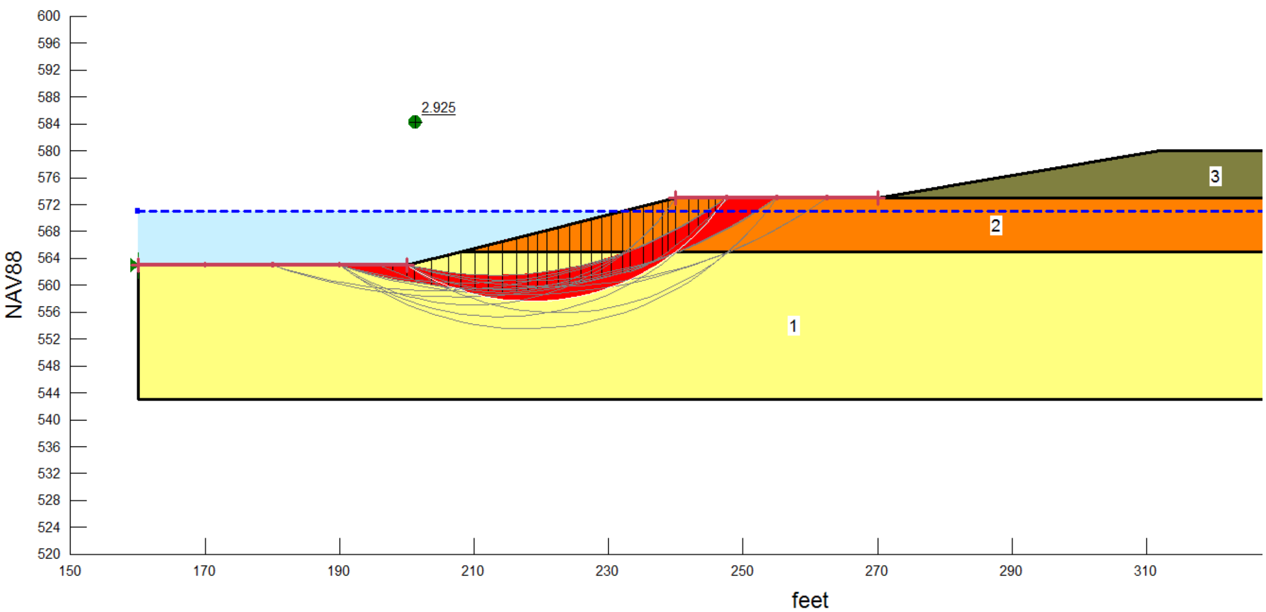
Embankment c=200 psf   Foundation c= 300 psf



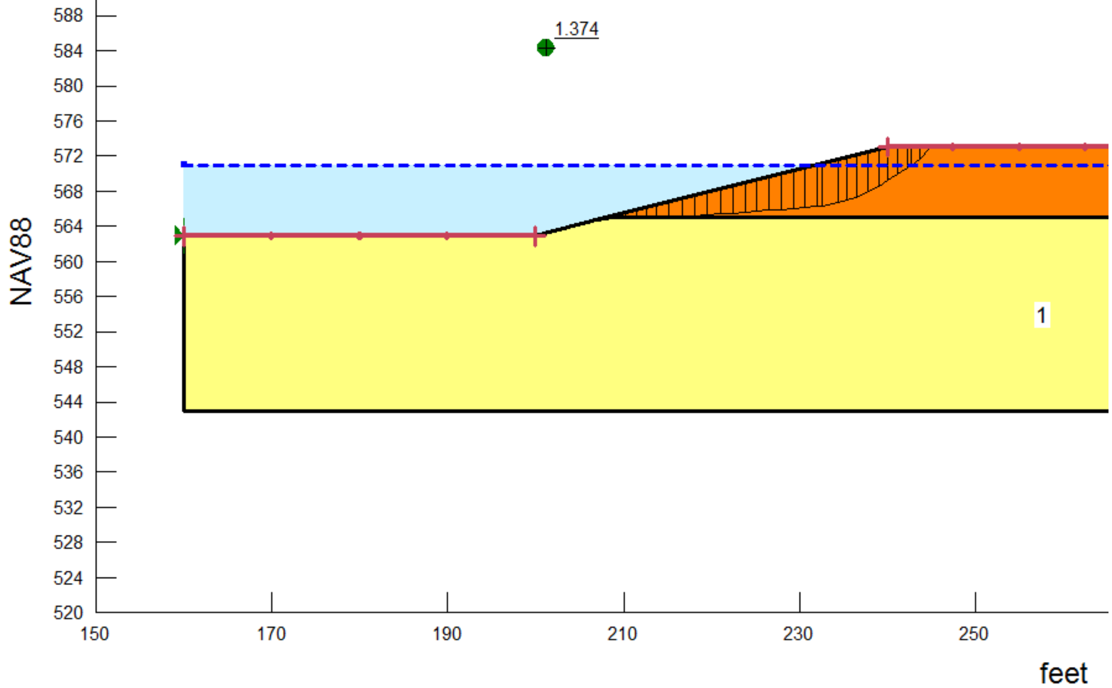
Embankment c=200 psf   Foundation ϕ = 19 degrees



Embankment c=200 psf   Foundation ϕ = 19 degrees



Embankment c=200 psf   Foundation c= 300 psf



Embankment c=200 psf   Foundation ϕ = 19 degrees

Slope Stability

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File Information

Title: Beaver Island
Created By: Kinney, Randall S MVR
Revision Number: 20
Last Edited By: Kinney, Randall S MVR
Date: 3/29/2016
Time: 5:54:07 AM
File Name: Beaver Island.gsz
Directory: P:\SLOPE STABILITY\GEO-SLOPE (from C drive Mar 29 2013)\GeoStudio2007\
Last Solved Date: 3/29/2016
Last Solved Time: 5:54:11 AM

Project Settings

Length(L) Units: feet
Time(t) Units: Seconds
Force(F) Units: lbf
Pressure(p) Units: psf
Strength Units: psf
Unit Weight of Water: 62.4 pcf
View: 2D

Analysis Settings

Slope Stability

Kind: SLOPE/W
Method: Spencer
Settings
- Apply Phreatic Correction: No
- PWP Conditions Source: Piezometric Line
- Use Staged Rapid Drawdown: No

Slip Surface
- Direction of movement: Right to Left
- Use Passive Mode: No
- Slip Surface Option: Entry and Exit
- Critical slip surfaces saved: 1
- Optimize Critical Slip Surface Location: Yes
- Tension Crack
  - Tension Crack Option: (none)

FOS Distribution
- FOS Calculation Option: Constant

Advanced
Number of Slices: 30
Optimization Tolerance: 0.01
Minimum Slip Surface Depth: 3 ft
Optimization Maximum Iterations: 2000
Optimization Convergence Tolerance: 1e-007
Starting Optimization Points: 8
Ending Optimization Points: 16
Complete Passes per Insertion: 1
Driving Side Maximum Convex Angle: 5 °
Resisting Side Maximum Convex Angle: 1 °

Materials

Sand

Model: Mohr-Coulomb
Unit Weight: 125 pcf
Cohesion: 0 psf
Phi: 28 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Foundation

Model: Mohr-Coulomb
Unit Weight: 120 pcf
Cohesion: 300 psf
Phi: 0 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Embankment

Model: Mohr-Coulomb
Unit Weight: 105 pcf
Cohesion: 200 psf
Phi: 0 °
Phi-B: 0 °
Pore Water Pressure
Piezometric Line: 1

Slip Surface Entry and Exit

Left Projection: Range
Left-Zone Left Coordinate: (240, 573) ft
Left-Zone Right Coordinate: (270, 573) ft
Left-Zone Increment: 4
Right Projection: Range

Right-Zone Left Coordinate: (312, 580) ft
Right-Zone Right Coordinate: (352, 580) ft
Right-Zone Increment: 4
Radius Increments: 4

Slip Surface Limits

Left Coordinate: (160, 563) ft
Right Coordinate: (352, 580) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	160	571
	352	571

Regions

	Material	Points	Area (ft²)
Region 1	Sand	10,11,9,3,2,1	4136
Region 2	Foundation	3,4,5,8,9	1024
Region 3	Embankment	5,6,7,8	427

Points

	X (ft)	Y (ft)
Point 1	160	563
Point 2	200	563
Point 3	208	565
Point 4	240	573
Point 5	270	573
Point 6	312	580
Point 7	352	580
Point 8	352	573
Point 9	352	565
Point 10	160	543
Point 11	352	543

Critical Slip Surfaces

	Slip Surface	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	2.931	(292.762, 600.551)	24.39037	(322.668, 580)	(267.913, 573)
2	108	3.296	(292.762, 600.551)	35.738	(322, 580)	(270, 573)

Slices of Slip Surface: Optimized

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	Optimized	268.95635	572.03835	-64.792716	233.99366	0	300
2	Optimized	270.0416	571.03835	-2.3925119	363.86082	0	300
3	Optimized	270.4322	570.67845	20.065299	417.66969	0	300
4	Optimized	271.772	569.70325	80.917361	528.55338	0	300
5	Optimized	273.75365	568.39595	162.49183	730.27813	0	300
6	Optimized	275.59025	567.3635	226.91615	857.15365	0	300
7	Optimized	277.28175	566.60585	274.19529	981.94728	0	300
8	Optimized	279.49045	565.8326	322.44514	1087.6326	0	300
9	Optimized	281.61935	565.32905	353.87026	1158.8658	0	300
10	Optimized	283.15125	565.1107	367.49334	1212.4404	0	300
11	Optimized	284.8887	565.0021	374.26674	1227.9815	0	300
12	Optimized	286.83175	565.0033	374.19468	1261.7947	0	300
13	Optimized	288.7748	565.0045	374.11748	1295.6595	0	300
14	Optimized	290.7178	565.0057	374.04543	1329.5242	0	300
15	Optimized	292.6608	565.0069	373.96823	1363.3889	0	300
16	Optimized	294.55405	565.0061	374.01738	1397.0794	0	300
17	Optimized	296.3975	565.0033	374.19097	1429.6819	0	300
18	Optimized	298.56035	565.12235	366.7664	1432.3417	0	300
19	Optimized	301.13855	565.511	342.51507	1409.2692	0	300
20	Optimized	303.1806	566.00835	311.47918	1360.407	0	300
21	Optimized	304.5906	566.46665	282.88021	1330.7963	0	300
22	Optimized	306.28705	567.1856	238.0201	1243.0471	0	300
23	Optimized	308.2699	568.1652	176.8896	1163.2428	0	300
24	Optimized	309.946	569.1449	115.75995	1039.4104	0	300

25	Optimized	311.31535	570.12465	54.622944	950.67953	0	300
26	Optimized	312.2694	570.80725	12.027266	884.34621	0	300
27	Optimized	312.8121	571.19555	-12.203252	840.15536	0	300
28	Optimized	314.06355	572.19555	-74.603118	710.49837	0	300
29	Optimized	315.74415	573.5777	-160.84964	586.57701	0	200
30	Optimized	317.2086	574.8079	-237.61497	461.72257	0	200
31	Optimized	318.73255	576.11285	-319.04294	333.10854	0	200
32	Optimized	320.2879	577.574	-410.21798	176.59772	0	200
33	Optimized	321.8747	579.19135	-511.12844	19.033698	0	200

Slices of Slip Surface: 108

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	108	270.66615	572.4757	-92.083541	164.75003	0	300
2	108	271.99845	571.4757	-29.685377	309.08245	0	300
3	108	273.57845	570.4182	36.304543	462.78369	0	300
4	108	275.40615	569.3284	104.30824	622.54018	0	300
5	108	277.23385	568.3793	163.5303	763.64728	0	300
6	108	279.06155	567.5587	214.7363	887.95937	0	300
7	108	280.88925	566.85715	258.51223	996.92547	0	300
8	108	282.71695	566.26735	295.31478	1091.6524	0	300
9	108	284.54465	565.7836	325.50061	1172.9651	0	300
10	108	286.37235	565.40145	349.34867	1241.5101	0	300
11	108	288.20005	565.11765	367.05796	1297.7619	0	300
12	108	290.026	564.92995	378.77459	1353.2192	518.12142	0
13	108	291.85025	564.8366	384.6	1383.4509	531.09843	0
14	108	293.6745	564.8366	384.6	1401.3153	540.5971	0
15	108	295.49875	564.92995	378.77459	1407.1097	546.77549	0
16	108	297.27695	565.1103	367.51791	1405.1161	0	300
17	108	299.00905	565.3744	351.03606	1393.4008	0	300
18	108	300.7412	565.72665	329.05385	1371.1843	0	300
19	108	302.47335	566.1697	301.40748	1338.0825	0	300
20	108	304.20545	566.70715	267.87126	1293.826	0	300
21	108	305.93755	567.3436	228.16	1237.9573	0	300

22	108	307.6697	568.0849	181.90537	1169.7327	0	300
23	108	309.40185	568.93845	128.64422	1088.528	0	300
24	108	311.13395	569.9136	67.793287	993.23206	0	300
25	108	312.4301	570.71645	17.692939	906.4659	0	300
26	108	313.52635	571.4757	-29.685377	811.84459	0	300
27	108	314.85865	572.4757	-92.083541	688.38522	0	300
28	108	316.3342	573.71085	-169.15513	570.11648	0	200
29	108	317.953	575.22685	-263.75214	411.53269	0	200
30	108	319.5718	576.9515	-371.37249	233.94353	0	200
31	108	321.1906	578.9355	-495.18259	33.395287	0	200