SITE PLAN FOR THE HURRICANE ISLAND REACH

DREDGED MATERIAL MANAGEMENT PLAN WITH INTEGRATED ENVIRONMENTAL ASSESSMENT

POOL 11
DUBUQUE COUNTY, IA AND GRANT COUNTY, WI
UPPER MISSISSIPPI RIVER, RIVER MILES 591-608

FINAL

APPENDIX E-2

GEOTECHNICAL ENGINEERING

GEOTECHNICAL ENGINEERING REPORT

HURRICANE ISLAND REACH DMMP

CORPS ISLAND

HURRICANE ISLAND REACH DMMP

MISSISSIPPI RIVER

DUBUQUE COUNTY, IOWA

GRANT COUNTY, WISCONSIN

June 2016

US Army Corps
of Engineers ®
Rock Island District

GEOTECHNICAL ENGINEERING REPORT

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Executive Summary

This report is prepared in support of the Hurricane Island Reach Dredged Material Management Plan (DMMP). The Hurricane Island DMMP will provide a minimum 20-year maintenance dredging plan. The projected average dredging per 5-year event will be 50,000 cubic yards (CY) of sand, totaling 200,000 CY over 20 years. After 20 years, the dredged sand will be removed and this plan will be repeated for another 20 years.

Corps Island (RM 594.1), which is located downstream of Hurricane Island in the Upper Mississippi River, is one of several that was initially determined available for placing the dredged material. The other sites have been removed from further consideration as described in the main report. This report documents Corps Island's subsurface condition, the

geotechnical exploration and testing performed, and the geotechnical analyses used to evaluate the island and its capacity to bear up to 200,000 CY of dredged material over 20 years.

Placement of clean sand by hydraulic dredging within a clay capped sand berm is feasible. However, the slope of the sand pile shall be no steeper than 7H:1V in order to meet proper factor of safety. This will provide sufficient space on the island for 200,000 CY in 20 years. The calculations also show that the overburden layers of clay are expected to settle and consolidate under the weight of the clean sand placed here over the next 20 years. This consolidation will further strengthen the clay layers on the island and increase the factor of safety over time.

Project Description

The Rivers and Harbors Acts of July 3, 1930, February 24, 1932, and August 30, 1935 and a Resolution of the House Committee on Flood Control of September 18, 1944 authorized the 9-foot navigation channel and subsequent channel maintenance dredging.

The Rock Island District is preparing a long-term (20-40 year) DMMP, acquiring and implementing sites for the placement of dredged material in support of the operation and maintenance of the Upper Mississippi and Illinois Waterway nine-foot navigation channels. The program ensures that all practicable and reasonable alternatives for the placement of dredged material are fully considered on an equal basis. This includes the placement of dredged material in the least costly manner, at the most practicable location, and consistent with engineering and environmental requirements.

This analysis was completed in general accordance with EM 1110-2-1902 *Slope Stability* and EM 1110-2-1913 *Design and Construction of Levees*. The projected average dredging placement on Corps Island is 50,000 CY every 5-years.

Site Conditions

The Corps Island placement site will provide an area of roughly 11 acres for placement of dredged material, however this may require removal of some trees on the Island. The approximate maximum width of the island is 400 feet, but the analysis was calculated based on 420 feet maximum width center to center of the berms.

Subsurface Conditions

Six borings were taken with a hand auger on various islands during March of 2014. The locations and results are listed in Appendix A. Boring HI-14-01 shows different layers of soils on Corps Island. The island is comprised of 10-15 feet of overburden consisting of sandy lean to fat clay underlain by medium to fine sand. The average moisture content for the sandy lean to fat clay (CL-CH) of the only sample available from the island is 40%.

HI-14-01 was taken via boat near water's edge, and in 'wetter' soils. Soils at higher elevations near the trees located on Corps Island are expected to be dryer and firmer. For analysis purposes, the shear strength and angle of internal friction for different materials are assumed based on USCS soil classification and previous testing conducted on the similar soils within Rock Island District (see the Figure 1 in Appendix C).

Settlement

Significant settlement caused by the weight of the placed dredged material will occur. It's expected that the placement of excessive dredged material makes the sandy clay (CL) and the sandy lean to fat clay (CL-CH) layers to consolidate/drain, hence it increases the strength of the soil to an average of 450 psf for CL and over 320 psf for CL-CH in less than 20 years (see Figure 1 in Appendix C for cohesion vs water content relation). Specific settlement calculations were not performed, since any amount of settlement and consolidation will only serve to improve foundation strength and increase total capacity of the placement site.

Seepage

The return water from hydraulic dredging should be properly directed to the river at various locations along the placement site in order to avoid erosion and potential failure of the clay capped sand retention berm.

Stability

Stability was checked using Slope/W software for three different scenarios:

1. Rapid Draw-down. This scenario represents conditions within the bathtub site during a heavy rain event, or during a hydraulic dredging event at the maximum discharge pipe elevation of 30 feet.

2. Low water. This scenario represents conditions where no hydraulic dredging is occurring and with water level is at 5’ below flat pool.

3. Normal day. This scenario represents conditions where no hydraulic dredging is occurring and with water level at flat pool.

EM 1110-2-1902 and the Slope/W 2007 Engineering Book were used for this analysis. The most critical case is failure due to rapid draw-down.

Table 1: Factor of Safety for Stability

Analysis	Factor of Safety	Required F.S.
Rapid Draw-Down	1.1	1.1
Low Water	1.4	1.3
Normal Day	1.6	1.3

From Table 1, all design factors of safety (FS) meet the required minimum FS. However, in the rapid drawdown analysis, the FS is very close to the required FS. The required FS of 1.1 is from EM 1110-2-1902 which is for Earth and Rock-Fill dams when drawdown from maximum surcharge pool occurs. This is a conservative FS since a dam naturally requires a higher FS than a dredged material embankment since slope stability failure of a dam can cause significant economic loss or even loss of life. Hence a FS of 1.0 considered sufficient in the case of rapid drawdown for this project.

Because of the weight of the dredged sand pile on the saturated clay layer, a minimum slope of 7H:1V for the dredged sand embankment is required. This will provide more than 200,000 CY capacity needed for the project. Slope/W models input and output data can be found in Appendix B.

Berm

Dredge placement containment consists of building a clay-capped sand berm prior to placement of dredged material. Clay will allow vegetation to grow on the berm and provide some protection against any minor erosion that may occur from boat wake or wind-generated waves. A typical section of the proposed berm can be found in the Slope/W model in Appendix B.

A berm with approximately 5 feet height will be constructed of dredged sand and capped with existing clay on the island. The clay capping material will be semi-saturated in some parts and will need time to drain and some effort to achieve semi compaction. The stability of the berm was modeled using a slope of the berm of 4H:1V and a crest width of 10 feet. During the planning process the berms were widened to a crest width of 15 feet and a side slope of 5H:1V. However, since the subsurface material—not berm width—was the limiting factor in determining the maximum slope of the sand pile it was not necessary to update the modeling.

Borrow

The sand borrow for berm construction will likely come from Finley's Landing DMMP site or dredging within the navigation channel.

The clay borrow for berm capping will likely come from the Lock and Dam 11 forebay or the south side of the Corps Island. The material used for berm capping shall be sandy lean or sandy fat clay (CL, CH or CL-CH). Highly organic material and debris should be removed from excavated material prior to placement within the berm's embankment and/or foundation. In the case of using material on Corps Island, a trench would be excavated along the berm (within 15-20 feet from the berm toe) to provide capping material for the berm.

Riprap

Since the Mississippi river does not have a 'flashy' nature regarding rapid water depths, and from discussions with personnel from Rock Island District Hydraulics Branch, it was determined that riprap is not needed along the berm toe to protect it from erosion. Another reason is the low velocities of the current in the immediate area of the Corps Island.

Recommendations

It is recommended to have a geotechnical reassessment before placing each new layer of dredged material or every five years. The reassessment can provide valuable information in order to confirm foundation consolidation, as well as overall stability and erosion resistance of the placement area.

References

- EM 1110-2-1913 *Design and Construction of Levees*
- EM 1110-2-1902 *Slope Stability*
- Stability Modeling with Slope/W 2007 Version

Computer Programs:

- Geostudio, Version 7.17, Build 4921, GEO-SLOPE International, Ltd.

APPENDIX A

Boring Locations and Logs

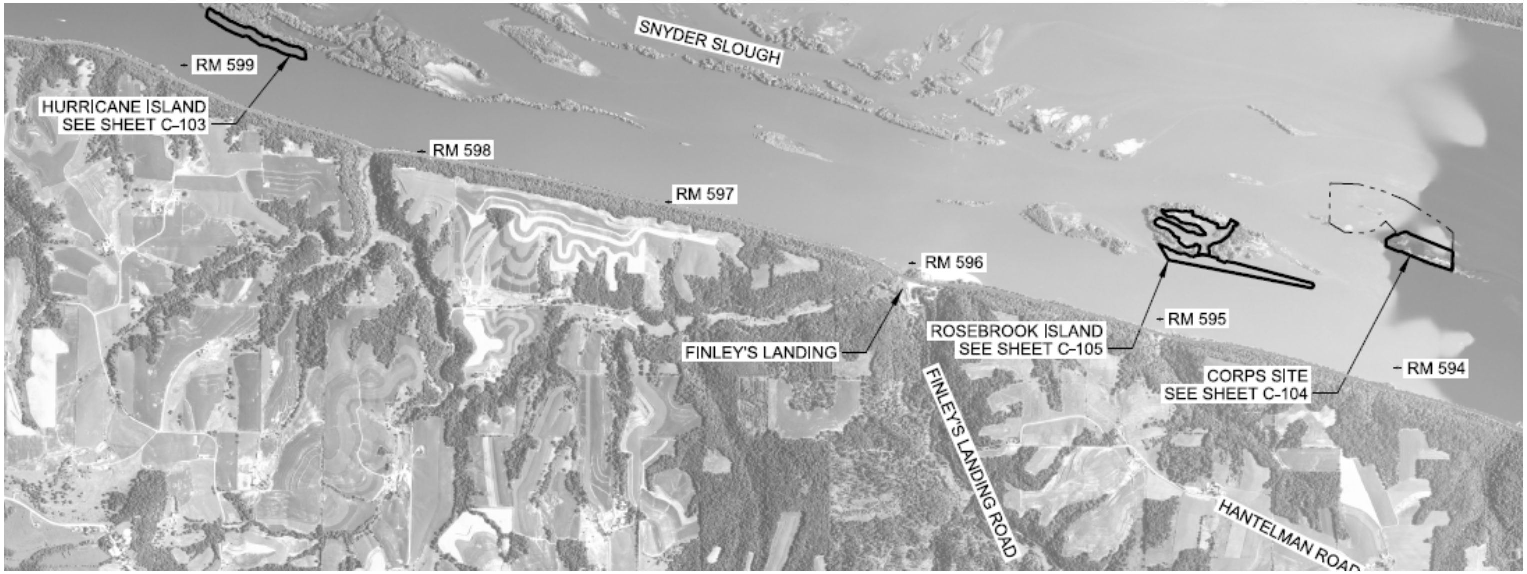


Figure 1: Corps Island Location

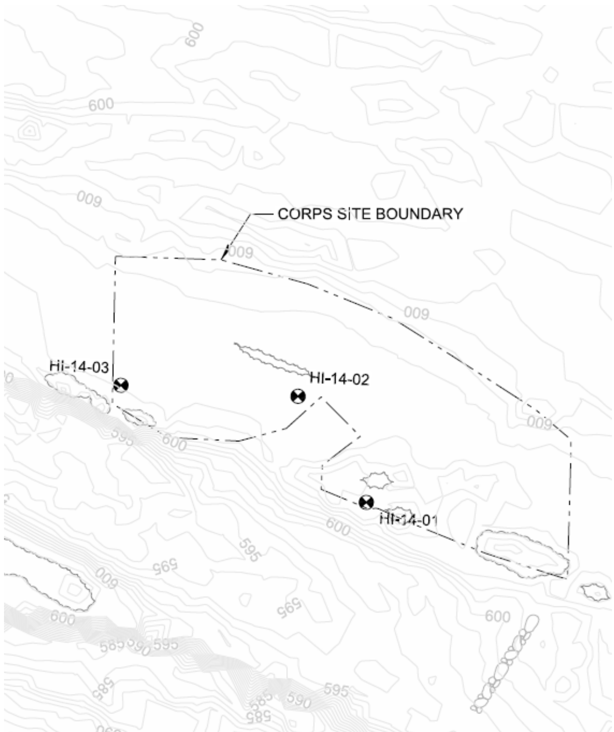


Figure 2: Location of HI-14-01 on Corps Site

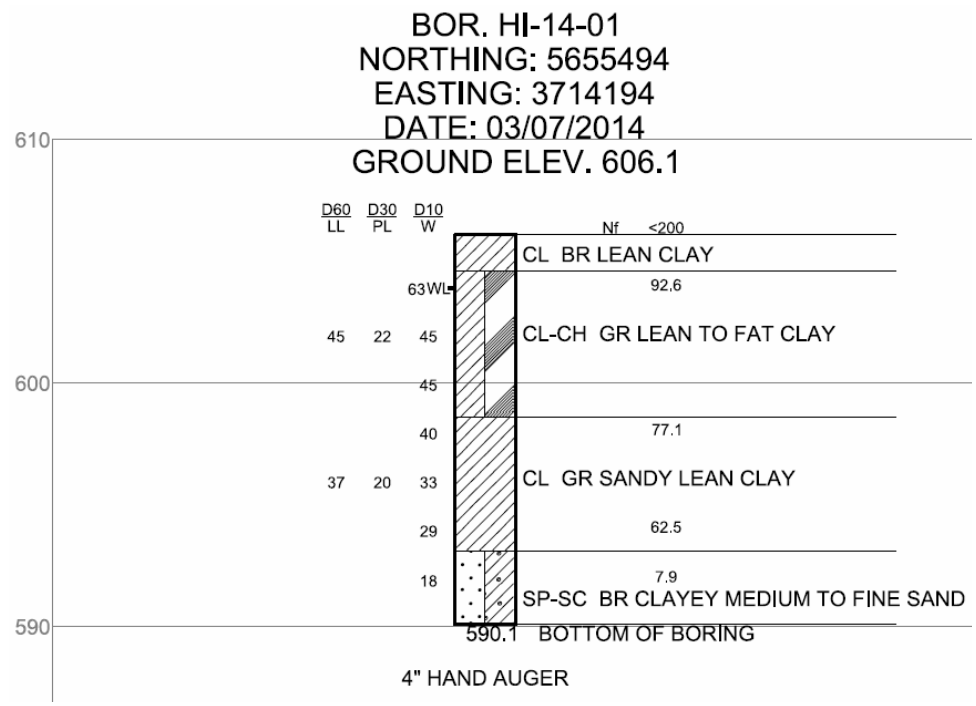


Figure 3: Boring on Corps Island

APPENDIX B

Stability

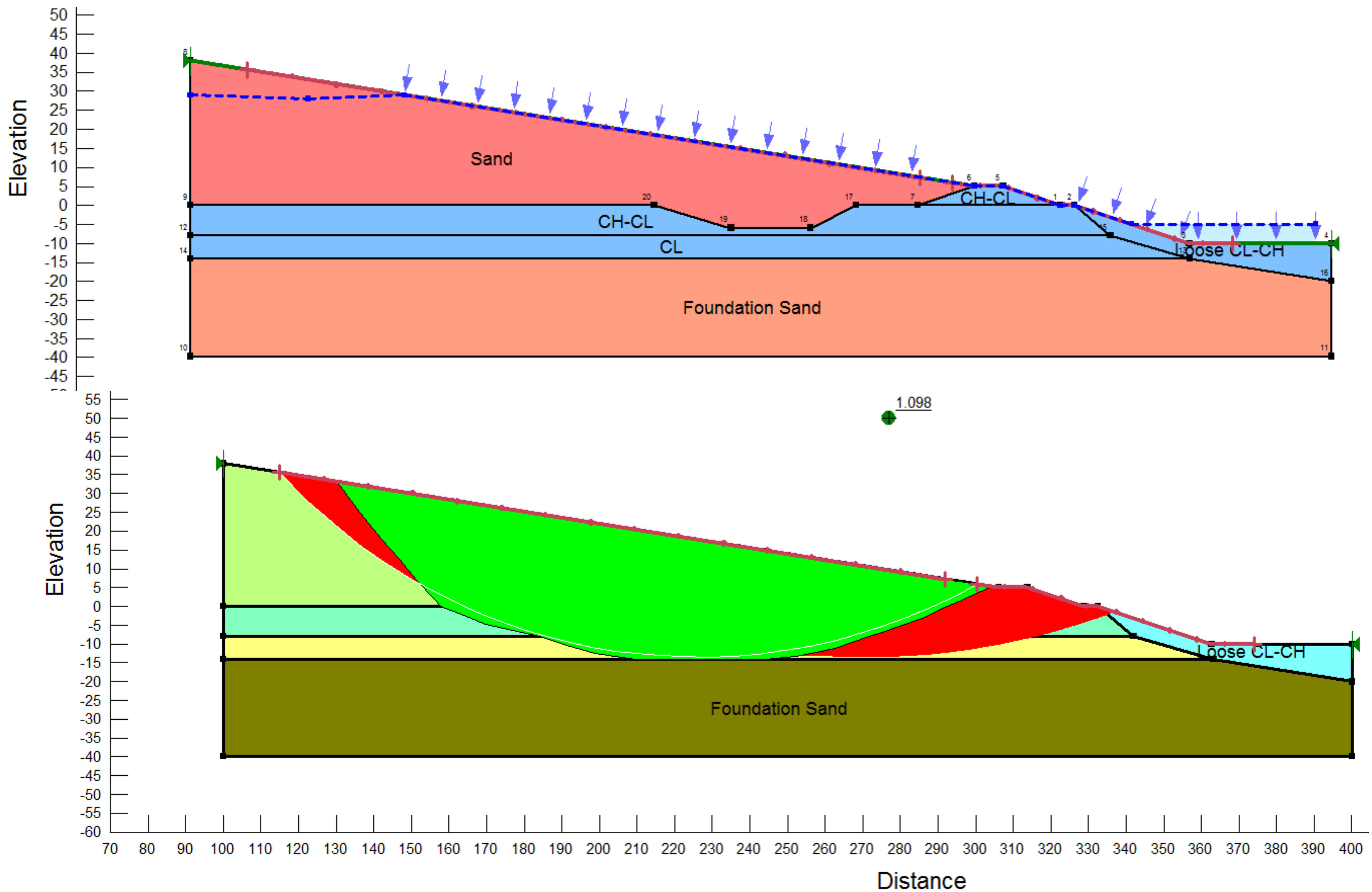


Figure 1: Slope Stability during Rapid Draw-Down

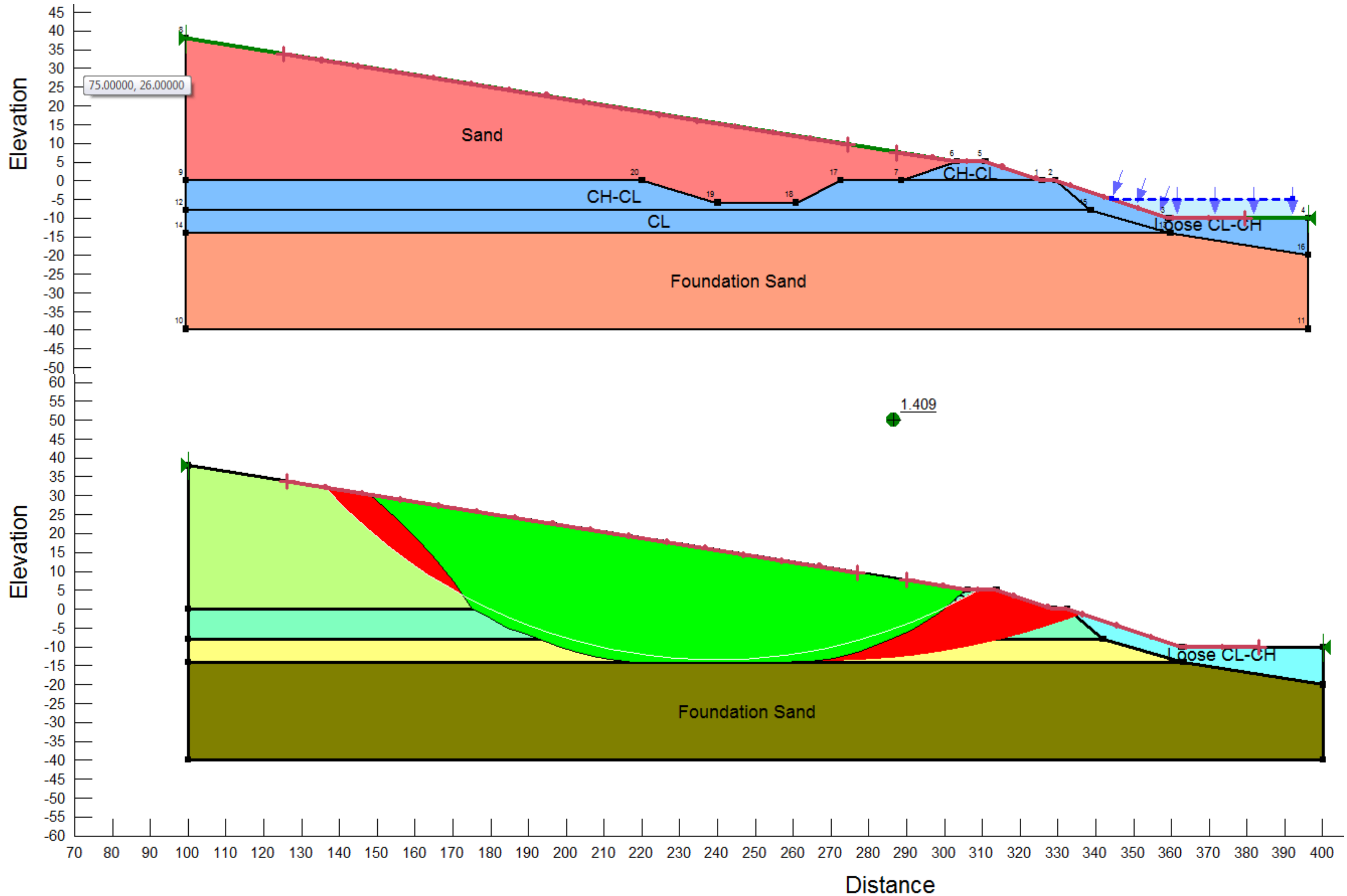


Figure 2: Slope Stability during Low Pool Level

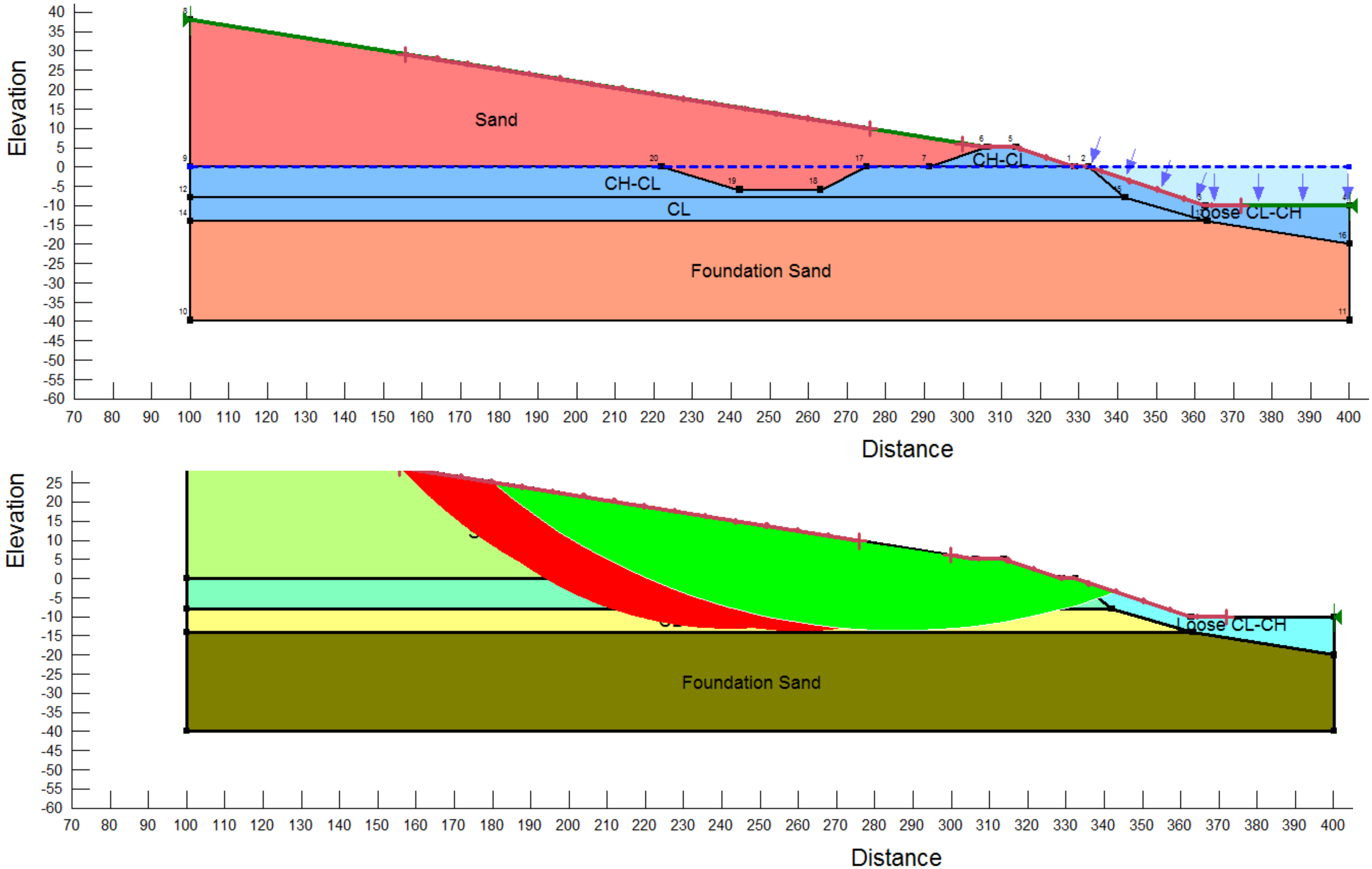


Figure 3: Slope Stability during Normal Situation

Rapid DrawDown

File Information

Created By: Yaghobi, Cyrus M MVR

Revision Number: 147

Last Edited By: Yaghobi, Cyrus M MVR

Date: 6/13/2016

Time: 12:19:48 PM

File Name: Corps Island.gsz

Directory: C:\Users\b5ecgcmy\Desktop\Geoslope\

Last Solved Date: 6/13/2016

Last Solved Time: 12:19:54 PM

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

Rapid DrawDown

Description: Corps Island Fully Loaded

Kind: SLOPE/W

Method: Spencer

Settings

Apply Phreatic Correction: No

PWP Conditions Source: Piezometric Line

Use Staged Rapid Drawdown: No

SlipSurface

Direction of movement: Left to Right

Use Passive Mode: No

Slip Surface Option: Entry and Exit

Critical slip surfaces saved: 10

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: 0.1 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

CL

Model: Mohr-Coulomb

Unit Weight: 115 pcf

Cohesion: 450 psf

Phi: 0 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Sand

Model: Mohr-Coulomb

Unit Weight: 122 pcf

Cohesion: 0 psf

Phi: 30 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Foundation Sand

Model: Mohr-Coulomb

Unit Weight: 122 pcf

Cohesion: 0 psf

Phi: 27 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

CH-CL

Model: Mohr-Coulomb

Unit Weight: 112 pcf

Cohesion: 320 psf

Phi: 0 °

Phi-B: 0 °

Pore Water Pressure

Piezometric Line: 1

Loose CL-CH

Model: Mohr-Coulomb

Unit Weight: 115 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: (115, 35.60013) ft

Left-Zone Right Coordinate: (269, 10.96149) ft

Left-Zone Increment: 15

Right Projection: Range

Right-Zone Left Coordinate: (281.25997, 9) ft

Right-Zone Right Coordinate: (374, -10) ft

Right-Zone Increment: 10

Radius Increments: 10

Slip Surface Limits

Left Coordinate: (100, 38) ft

Right Coordinate: (400.00456, -10) ft

Piezometric Lines

Piezometric Line 1

Coordinates

	X (ft)	Y (ft)
	100.00623	29
	131	28.00971
	156.2531	29
	306.26135	5
	313.76081	5
	328.75972	0
	332.50945	0
	347.50837	-5
	396	-5

Regions

	Material	Points	Area (ft^2)
Region 1	CH-CL	2,1,7,17,18,19,20,9,12,15	1675.9326
Region 2	Sand	6,8,9,20,19,18,17,7	4618.6222
Region 3	Foundation Sand	10,11,16,13,14	7688.7631
Region 4	CH-CL	7,6,5,1	112.49185
Region 5	CL	12,15,13,14	1515
Region 6	Loose CL-CH	4,16,13,15,2,3	373.07777

Points

	X (ft)	Y (ft)
Point 1	328.75972	0
Point 2	332.50945	0
Point 3	362.50728	-10
Point 4	400.00456	-10
Point 5	313.76081	5

Point 6	306.26135	5
Point 7	291.26244	0
Point 8	100	38
Point 9	100.02629	0
Point 10	100.02629	-40
Point 11	400.00456	-40
Point 12	100	-8
Point 13	363	-14
Point 14	100	-14
Point 15	342	-8
Point 16	400.00456	-20
Point 17	275	0
Point 18	263	-6
Point 19	242	-6
Point 20	222	0

Critical Slip Surfaces

	Number	FOS	Center (ft)	Radius (ft)	Entry (ft)	Exit (ft)
1	Optimized	1.098	(226.149, 136.983)	78.12278	(130.815, 33.0699)	(304.013, 5.35973)
2	27	1.178	(226.149, 136.983)	150.442	(115, 35.6001)	(300.119, 5.98279)
3	148	1.192	(230.251, 129.718)	142.098	(125.267, 33.9576)	(300.119, 5.98279)
4	280	1.199	(239.64, 127.484)	141.051	(135.533, 32.315)	(309.59, 5)
5	269	1.205	(234.354, 122.453)	133.755	(135.533, 32.315)	(300.119, 5.98279)
6	59	1.206	(251.615, 199.712)	213.533	(115, 35.6001)	(327.922, 0.279245)
7	433	1.209	(269.078, 178.405)	192.412	(145.8, 30.6724)	(337.174, -1.55484)
8	180	1.218	(255.355, 190.185)	203.298	(125.267, 33.9576)	(327.922, 0.279245)
9	390	1.225	(238.456, 115.188)	125.411	(145.8, 30.6724)	(300.119, 5.98279)

10	401	1.227	(243.742, 120.219)	132.708	(145.8, 30.6724)	(309.59, 5)
11	380	1.228	(229.366, 88.595)	101.677	(145.8, 30.6724)	(290.689, 7.49139)

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	130.9075	32.945315	-307.79667	7.439765	4.2953503	0
2	Optimized	132.73605	30.483315	-150.10403	154.4985	89.199751	0
3	Optimized	135.0945	27.30782	53.817158	363.55799	178.82895	0
4	Optimized	138.51565	23.010245	330.35982	735.49753	233.90636	0
5	Optimized	144.0376	16.442285	753.71446	1304.8688	318.20909	0
6	Optimized	149.48405	10.225415	1154.9752	1825.6064	387.18908	0
7	Optimized	154.2302	4.848018	1502.1278	2283.5474	451.15283	0
8	Optimized	157.36205	1.335193	1715.2169	2573.5454	495.55621	0
9	Optimized	161.70915	-1.27674	1834.8472	3325.6251	0	320
10	Optimized	168.07735	-3.967215	1939.1149	3495.0567	0	320
11	Optimized	174.6744	-5.967215	1997.9881	3740.3538	0	320
12	Optimized	181.7303	-7.34624	2013.6378	3756.685	0	320
13	Optimized	188.6082	-8.9881325	2047.4438	3725.2426	0	450
14	Optimized	195.18625	-10.869058	2099.1853	3810.4554	0	450
15	Optimized	202.15115	-12.49332	2130.9681	3942.1907	0	450
16	Optimized	210.154	-13.574535	2118.5388	3990.2541	0	450
17	Optimized	218.2405	-13.973645	2062.6465	3956.7862	0	450
18	Optimized	225.33335	-13.976845	1992.1499	3828.7498	0	450
19	Optimized	232	-13.979855	1925.6999	3718.9498	0	450
20	Optimized	238.66665	-13.982865	1859.3999	3609.1498	0	450
21	Optimized	244.1157	-13.985325	1805.1236	3513.0217	0	450

22	Optimized	248.4607	-13.747785	1746.9216	3487.0636	0	450
23	Optimized	252.91925	-13.270795	1672.6353	3343.4419	0	450
24	Optimized	259.07425	-12.15465	1541.5217	3182.6047	0	450
25	Optimized	263.89015	-11.078	1426.2558	2954.5279	0	450
26	Optimized	268.81805	-9.4395	1274.8737	2735.0882	0	450
27	Optimized	273.9279	-7.617791	1110.1471	2329.723	0	320
28	Optimized	277.65455	-6.2892115	990.04508	2093.3537	0	320
29	Optimized	282.96365	-4.3964705	818.92552	1764.5452	0	320
30	Optimized	288.4403	-2.0734652	619.30479	1444.1846	0	320
31	Optimized	291.97665	-0.34841525	476.34837	1164.21	0	320
32	Optimized	294.1248	0.69944	389.50554	988.08667	0	320
33	Optimized	299.7858	3.379307	165.77629	426.03552	150.26074	0

Slices of Slip Surface: 27

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	27	118.56715	31.946555	-220.8694	241.36415	139.35166	0
2	27	126.56715	24.372985	235.76759	836.58077	346.87965	0
3	27	134.15665	18.01218	631.56768	1404.3052	446.14021	0
4	27	140.46995	13.3832	935.86395	1824.0566	512.79829	0
5	27	146.7832	9.2339345	1210.223	2201.4329	572.27529	0
6	27	153.09645	5.518752	1457.5255	2538.8663	624.31239	0
7	27	160.10355	1.8823325	1653.6668	2859.2394	696.0377	0
8	27	166.7089	-1.185161	1779.2473	3231.5546	0	320
9	27	172.2187	-3.4284445	1864.2037	3396.839	0	320
10	27	177.72855	-5.4232775	1933.6367	3535.6358	0	320
11	27	183.2384	-7.179994	1988.2704	3648.4675	0	320

12	27	188.99385	-8.764923	2029.6946	3725.6279	0	450
13	27	194.99495	-10.165118	2057.1737	3801.3454	0	450
14	27	200.99605	-11.309335	2068.5634	3847.9781	0	450
15	27	206.9972	-12.203475	2064.5029	3865.8812	0	450
16	27	212.99835	-12.85202	2045.0886	3855.6227	0	450
17	27	218.99945	-13.25816	2010.5158	3817.1338	0	450
18	27	225.33335	-13.419025	1957.3211	3755.0446	0	450
19	27	232	-13.30733	1883.7729	3666.3725	0	450
20	27	238.66665	-12.89917	1791.6625	3542.5171	0	450
21	27	245.5	-12.166685	1677.7948	3367.4899	0	450
22	27	252.5	-11.08973	1540.792	3138.2648	0	450
23	27	259.5	-9.6709275	1382.3066	2867.2218	0	450
24	27	264.65235	-8.4374925	1253.8949	2635.6512	0	450
25	27	270.65235	-6.652948	1082.6502	2258.8946	0	320
26	27	278.336	-4.0716605	844.8589	1811.2252	0	320
27	27	285.00795	-1.4187125	612.70957	1390.572	0	320
28	27	291.2876	1.414381	373.22859	940.54278	327.539	0
29	27	297.17495	4.4057745	127.79389	333.42027	118.71845	0

Slices of Slip Surface: 148

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	148	128.13335	30.99239	-180.40558	196.15364	113.24936	0
2	148	131.0086	28.018805	-0.5462955	401.75352	231.9525	0
3	148	134.1717	25.113	188.51665	657.04748	270.5064	0
4	148	140.4807	19.643005	545.27559	1144.7213	346.09013	0
5	148	146.78965	14.779795	864.18488	1582.4386	414.68398	0

6	148	153.0986	10.448628	1149.8833	1973.9435	475.77137	0
7	148	158.9179	6.8608145	1354.8865	2292.76	541.48152	0
8	148	164.24755	3.9154345	1485.465	2547.5796	613.21212	0
9	148	169.5772	1.2586525	1598.0371	2776.6133	680.45125	0
10	148	175.11715	-1.2107105	1696.8369	3083.5407	0	320
11	148	180.8674	-3.487326	1781.4424	3249.6444	0	320
12	148	186.6176	-5.4811345	1848.4766	3385.4809	0	320
13	148	192.3678	-7.204519	1898.6785	3492.1404	0	320
14	148	197.9186	-8.6253485	1931.9007	3556.648	0	450
15	148	203.27005	-9.7682685	1949.6897	3612.806	0	450
16	148	208.6215	-10.69801	1954.3695	3644.635	0	450
17	148	213.9729	-11.41879	1945.8344	3652.57	0	450
18	148	219.3243	-11.933805	1924.6126	3636.6421	0	450
19	148	225.33335	-12.255675	1884.6697	3598.8916	0	450
20	148	232	-12.330105	1822.8118	3532.8322	0	450
21	148	238.66665	-12.09126	1741.2866	3430.0157	0	450
22	148	244.625	-11.62651	1652.8471	3300.123	0	450
23	148	249.875	-10.993485	1560.9318	3150.0858	0	450
24	148	255.125	-10.160616	1456.5411	2975.9812	0	450
25	148	260.375	-9.1243035	1339.4647	2776.7302	0	450
26	148	264.12985	-8.2773875	1249.1201	2615.3948	0	450
27	148	267.6948	-7.3347285	1154.712	2391.9417	0	320
28	148	272.56495	-5.909757	1017.1819	2124.2172	0	320
29	148	278.31515	-3.958079	837.98062	1792.1144	0	320
30	148	284.94545	-1.3830505	611.10739	1382.5812	0	320
31	148	291.2251	1.4087555	374.20052	937.48167	325.21053	0

32	148	297.1541	4.400149	128.35287	333.40262	118.38553	0

Slices of Slip Surface: 280

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	280	137.4245	30.325395	-128.77825	131.47953	75.909743	0
2	280	142.1386	25.63346	175.53018	502.20388	188.60515	0
3	280	147.7844	20.507235	509.22556	954.63332	257.15629	0
4	280	153.4302	15.902345	810.3896	1365.1234	320.27572	0
5	280	159.13165	11.719445	1049.5728	1732.6272	394.36165	0
6	280	164.8888	7.917927	1229.3128	2061.2265	480.30557	0
7	280	170.64595	4.5033795	1384.8915	2356.8303	561.1491	0
8	280	176.40305	1.444233	1518.3114	2621.1349	636.71547	0
9	280	181.92205	-1.184436	1627.2392	2940.9935	0	320
10	280	187.20295	-3.4265095	1714.4352	3109.4683	0	320
11	280	192.4838	-5.420998	1786.2312	3251.4083	0	320
12	280	197.76465	-7.1789245	1843.1195	3367.9921	0	320
13	280	203.10445	-8.7240555	1886.1916	3445.5244	0	450
14	280	208.50315	-10.059186	1915.6932	3522.462	0	450
15	280	213.9019	-11.17133	1931.177	3574.2436	0	450
16	280	219.30065	-12.06583	1933.0001	3600.9596	0	450
17	280	225.33335	-12.799205	1918.5984	3610.2241	0	450
18	280	232	-13.320015	1884.528	3595.9106	0	450
19	280	238.66665	-13.523885	1830.7065	3544.7158	0	450
20	280	244.625	-13.454045	1766.8761	3461.4545	0	450
21	280	249.875	-13.170185	1696.7519	3353.0393	0	450
22	280	255.125	-12.689185	1614.3128	3220.9768	0	450

23	280	260.375	-12.009005	1519.4575	3064.9903	0	450
24	280	266	-11.047965	1403.3373	2854.4507	0	450
25	280	272	-9.769821	1263.6866	2584.1499	0	450
26	280	276.9374	-8.531261	1137.1078	2348.4597	0	450
27	280	281.9717	-7.0253665	992.88268	2049.8004	0	320
28	280	288.1655	-4.9156925	799.39691	1704.3311	0	320
29	280	293.44635	-2.879246	619.59746	1372.1805	0	320
30	280	297.81425	-0.98892	458.03472	1062.4979	0	320
31	280	303.12975	1.5791375	244.72667	651.29286	0	320
32	280	307.9255	4.0791375	57.46158	295.74653	0	320

Slices of Slip Surface: 269

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	269	137.42435	30.325385	-128.77712	130.89924	75.574712	0
2	269	142.13835	25.64671	174.71002	498.64751	187.0254	0
3	269	147.78425	20.55923	505.97458	945.49823	253.7591	0
4	269	153.43015	16.01458	803.38358	1349.3218	315.19756	0
5	269	159.2893	11.808466	1042.4449	1718.1704	390.13035	0
6	269	165.36175	7.9196545	1224.4776	2054.2909	479.09297	0
7	269	171.4342	4.4714885	1379.0147	2353.2352	562.46646	0
8	269	177.50665	1.4261345	1508.4314	2616.5025	639.74513	0
9	269	183.5773	-1.245573	1614.5913	2923.7029	0	320
10	269	189.6461	-3.5676405	1698.7695	3092.3847	0	320
11	269	195.71485	-5.560022	1762.525	3225.8009	0	320
12	269	201.7836	-7.2379545	1806.71	3325.2733	0	320
13	269	207.68165	-8.582892	1831.7231	3383.5378	0	450

14	269	213.409	-9.619917	1839.3147	3425.1329	0	450
15	269	219.13635	-10.402055	1830.9471	3437.601	0	450
16	269	224.5	-10.91477	1809.3484	3431.2478	0	450
17	269	229.5	-11.190275	1776.6089	3409.9522	0	450
18	269	234.5	-11.278335	1732.199	3366.598	0	450
19	269	239.5	-11.179325	1676.0977	3301.353	0	450
20	269	244.625	-10.88083	1606.3074	3203.0812	0	450
21	269	249.875	-10.371865	1522.1377	3070.3457	0	450
22	269	255.125	-9.652384	1424.8189	2912.0331	0	450
23	269	260.375	-8.7189105	1314.1628	2727.423	0	450
24	269	263.44465	-8.0990865	1244.7916	2607.8945	0	450
25	269	266.667	-7.3083015	1163.3218	2412.4081	0	320
26	269	272.22235	-5.796431	1013.5275	2122.2479	0	320
27	269	278.2911	-3.8311955	830.30467	1782.9755	0	320
28	269	284.87335	-1.343066	609.33514	1385.2989	0	320
29	269	291.153	1.4022795	375.33662	948.37588	330.84437	0
30	269	297.13005	4.393673	128.99723	339.27048	121.40132	0

Slices of Slip Surface: 59

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	59	119.693	31.91058	-220.87393	254.3011	146.82081	0
2	59	127.693	25.86377	140.50278	717.52206	333.14223	0
3	59	134.15665	21.42685	418.49145	1097.5695	392.06591	0
4	59	140.46995	17.42254	683.81735	1442.6121	438.09036	0
5	59	146.7832	13.71871	930.38229	1760.1715	479.07904	0
6	59	153.09645	10.297701	1159.3034	2051.2439	514.96207	0

7	59	159.55105	7.079693	1334.8958	2315.8366	566.34643	0
8	59	166.147	4.062822	1457.2429	2555.0724	633.83216	0
9	59	172.74295	1.3110655	1563.1087	2769.4989	696.50972	0
10	59	179.29795	-1.172497	1652.6887	3033.5402	0	320
11	59	185.812	-3.400175	1726.6529	3172.4673	0	320
12	59	192.326	-5.3968265	1786.2431	3286.6755	0	320
13	59	198.84005	-7.1691485	1831.7217	3376.7999	0	320
14	59	205.41425	-8.7352165	1863.9321	3433.8379	0	450
15	59	212.04855	-10.095992	1882.6143	3484.5399	0	450
16	59	218.68285	-11.23939	1887.659	3510.6735	0	450
17	59	225.33335	-12.17069	1879.3481	3522.1588	0	450
18	59	232	-12.891675	1857.8102	3519.0551	0	450
19	59	238.66665	-13.40172	1823.0383	3491.7113	0	450
20	59	245.5	-13.70452	1773.7008	3427.5937	0	450
21	59	252.5	-13.790285	1709.2711	3325.2572	0	450
22	59	259.5	-13.646415	1630.3155	3195.8182	0	450
23	59	266	-13.31447	1544.7651	3036.5842	0	450
24	59	272	-12.824135	1454.2758	2851.248	0	450
25	59	279.0656	-12.00926	1332.9218	2624.4984	0	450
26	59	287.1968	-10.79491	1175.9323	2347.0384	0	450
27	59	296.19725	-9.053845	977.43102	1974.0056	0	450
28	59	303.6967	-7.3549325	796.55182	1581.8162	0	320
29	59	310.01105	-5.6435615	664.15803	1338.3715	0	320
30	59	317.11765	-3.495191	460.2721	975.22339	0	320
31	59	323.83135	-1.206562	177.80555	461.81785	0	320
32	59	327.5551	0.13962265	16.345055	166.25242	0	320

Slices of Slip Surface: 433

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	433	147.0107	29.67872	-64.96676	68.267612	39.414324	0
2	433	152.23725	25.61406	201.45406	396.83552	112.80354	0
3	433	159.64935	20.194015	515.587	850.07318	193.11569	0
4	433	166.4418	15.702525	728.0498	1216.9402	282.26098	0
5	433	173.23425	11.60856	915.69997	1550.9304	366.75049	0
6	433	180.02675	7.8833975	1080.33	1853.2061	446.22022	0
7	433	186.81925	4.503283	1223.4416	2124.8198	520.41095	0
8	433	193.6117	1.448395	1346.2473	2366.6174	589.11099	0
9	433	200.0537	-1.170736	1445.3784	2629.7438	0	320
10	433	206.1453	-3.395823	1523.395	2775.718	0	320
11	433	212.2369	-5.392126	1587.1365	2897.3083	0	320
12	433	218.3285	-7.167039	1637.137	2995.2688	0	320
13	433	221.68715	-8.0794995	1660.4477	3027.5016	0	450
14	433	225.33335	-8.937345	1677.6217	3078.2934	0	450
15	433	232	-10.370411	1700.4592	3157.7644	0	450
16	433	238.66665	-11.55877	1708.0502	3209.6295	0	450
17	433	245.5	-12.524635	1700.0854	3223.7964	0	450
18	433	252.5	-13.2596	1676.17	3198.9129	0	450
19	433	259.5	-13.73682	1635.9686	3144.2386	0	450
20	433	265.19935	-13.95565	1592.7841	3068.6936	0	450
21	433	269.0784	-14	1556.8071	2993.0584	0	450
22	433	272.87905	-13.958095	1516.255	2908.7678	0	450
23	433	277.7104	-13.79446	1457.8133	2802.1049	0	450
24	433	283.1312	-13.474225	1383.7057	2677.8493	0	450
25	433	288.552	-12.999965	1299.9934	2534.8715	0	450

26	433	295.01215	-12.214055	1186.4635	2325.2824	0	450
27	433	302.5116	-11.04216	1038.4693	2038.9101	0	450
28	433	310.01105	-9.563865	908.78224	1802.2946	0	450
29	433	315.27165	-8.373655	803.09028	1620.9265	0	450
30	433	319.7768	-7.182019	635.01452	1280.6604	0	320
31	433	325.7654	-5.440773	401.7981	862.0149	0	320
32	433	330.6346	-3.884396	242.38507	575.73087	0	320
33	433	333.8636	-2.767072	144.49912	401.71869	0	320
34	433	336.19565	-1.918849	43.057971	166.32887	0	200

Slices of Slip Surface: 180

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	180	128.13335	31.656995	-221.87946	158.67965	91.613741	0
2	180	131.83735	28.715905	-42.017616	366.67712	211.70113	0
3	180	136.6044	25.246085	186.1619	654.46301	270.37377	0
4	180	144.46385	19.85832	541.59529	1117.7807	332.66079	0
5	180	152.32335	14.98879	864.68679	1535.1176	387.07343	0
6	180	159.66195	10.858673	1097.9899	1879.7394	451.3433	0
7	180	166.47965	7.3822875	1246.8539	2159.8098	527.09537	0
8	180	173.29735	4.220779	1376.0201	2411.1887	597.65488	0
9	180	180.11505	1.3582995	1486.5792	2634.5562	662.78485	0
10	180	186.83935	-1.1870155	1578.2901	2895.0464	0	320
11	180	193.47025	-3.433728	1652.2626	3034.6069	0	320
12	180	200.10115	-5.429922	1710.6545	3147.4476	0	320
13	180	206.73205	-7.1832095	1753.951	3234.076	0	320
14	180	213.0356	-8.636037	1781.6239	3284.2042	0	450

15	180	219.01185	-9.815072	1795.4796	3325.0781	0	450
16	180	225.33335	-10.85585	1797.3199	3354.6015	0	450
17	180	232	-11.739175	1785.8439	3370.6779	0	450
18	180	238.66665	-12.39932	1760.586	3361.2139	0	450
19	180	245.5	-12.843815	1720.1175	3314.0979	0	450
20	180	252.5	-13.062885	1663.8358	3228.1099	0	450
21	180	259.5	-13.04068	1592.5259	3113.6381	0	450
22	180	266	-12.81199	1513.4208	2967.4233	0	450
23	180	272	-12.408205	1428.3208	2792.923	0	450
24	180	279.0656	-11.68421	1312.5504	2577.8315	0	450
25	180	287.1968	-10.561827	1161.3933	2312.3164	0	450
26	180	295.9629	-8.958482	973.82371	1961.5513	0	450
27	180	303.46235	-7.318242	796.60371	1578.7496	0	320
28	180	310.01105	-5.589648	660.79485	1329.0131	0	320
29	180	317.11735	-3.472329	458.85504	970.27717	0	320
30	180	323.83045	-1.200923	177.47959	459.51981	0	320
31	180	327.5545	0.13962265	16.357689	164.88683	0	320

Slices of Slip Surface: 390

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	390	146.73655	29.66797	-64.967052	66.00469	38.107826	0
2	390	149.8181	26.519265	139.05138	316.14127	102.24289	0
3	390	154.1081	22.424565	405.06386	670.51892	153.26055	0
4	390	158.97035	18.24619	643.90974	1028.5879	222.09404	0
5	390	164.4048	14.029135	852.80628	1388.3269	309.18299	0
6	390	169.83925	10.263063	1033.547	1712.6708	392.0923	0

7	390	175.2737	6.900668	1189.1056	2003.8551	470.39588	0
8	390	180.70815	3.905186	1321.7729	2263.7405	543.84522	0
9	390	186.1426	1.2475655	1433.3556	2493.3594	611.9935	0
10	390	191.4683	-1.054412	1523.8287	2757.7378	0	320
11	390	196.6853	-3.0304975	1595.0481	2901.6483	0	320
12	390	201.9023	-4.747187	1650.0847	3017.8393	0	320
13	390	207.1193	-6.215511	1689.6345	3107.1071	0	320
14	390	212.33625	-7.4444095	1714.2291	3170.4156	0	320
15	390	218.47235	-8.569624	1723.184	3207.0952	0	450
16	390	224.5	-9.4192495	1716.0303	3231.9916	0	450
17	390	229.5	-9.8782755	1694.7401	3233.1206	0	450
18	390	234.5	-10.13622	1660.9329	3211.0009	0	450
19	390	239.5	-10.19432	1614.6441	3165.4905	0	450
20	390	244.4959	-10.053134	1555.9566	3089.0624	0	450
21	390	249.48775	-9.7123165	1484.8546	2981.2832	0	450
22	390	254.4796	-9.1702665	1401.1842	2849.1387	0	450
23	390	259.4714	-8.4243335	1304.7997	2692.2307	0	450
24	390	262.48365	-7.8992065	1241.9167	2553.8794	0	320
25	390	266	-7.122821	1158.4063	2396.1589	0	320
26	390	272	-5.614195	1004.3648	2099.2385	0	320
27	390	277.17535	-4.074913	856.65903	1824.177	0	320
28	390	281.5261	-2.5730395	719.50941	1579.9979	0	320
29	390	285.87685	-0.888707	570.96059	1312.4604	0	320
30	390	291.0688	1.3947415	376.64452	948.14823	329.95782	0
31	390	297.102	4.386135	129.74772	340.82069	121.86304	0

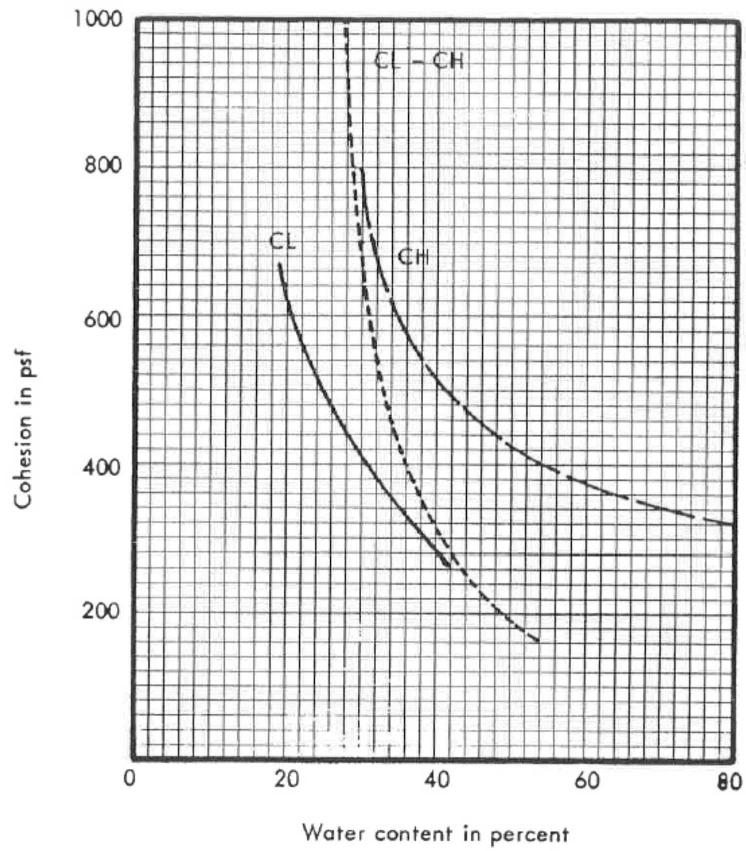
Slices of Slip Surface: 401

	Slip Surface	X (ft)	Y (ft)	PWP (psf)	Base Normal Stress (psf)	Frictional Strength (psf)	Cohesive Strength (psf)
1	401	146.73755	29.66801	-64.967793	66.172315	38.204604	0
2	401	149.8196	26.51415	139.37404	317.24572	102.69426	0
3	401	154.1086	22.399645	406.61615	673.78569	154.2504	0
4	401	158.86035	18.26396	643.90646	1028.4376	222.00913	0
5	401	164.07485	14.13529	849.47035	1380.259	306.45095	0
6	401	169.2894	10.409502	1029.9036	1700.6068	387.23068	0
7	401	174.50395	7.046623	1187.682	1991.33	463.98637	0
8	401	179.71845	4.015015	1324.7949	2254.098	536.53341	0
9	401	184.93295	1.2892585	1442.8205	2490.0223	604.60223	0
10	401	190.2877	-1.209475	1545.2872	2780.5709	0	320
11	401	195.78265	-3.4841415	1632.369	2951.0683	0	320
12	401	201.2776	-5.4775245	1701.9015	3091.8742	0	320
13	401	206.77255	-7.202858	1754.7711	3203.8555	0	320
14	401	212.64	-8.7524095	1792.8339	3281.2537	0	450
15	401	218.88	-10.100054	1814.5475	3350.9389	0	450
16	401	224.5	-11.061725	1818.5096	3392.3534	0	450
17	401	229.5	-11.69807	1808.3115	3412.1712	0	450
18	401	234.5	-12.142545	1786.1108	3410.0964	0	450
19	401	239.5	-12.397085	1752.0836	3386.0677	0	450
20	401	244.625	-12.4596	1704.8195	3330.2121	0	450
21	401	249.875	-12.32068	1643.7461	3241.4843	0	450
22	401	255.125	-11.97319	1569.6394	3127.8543	0	450
23	401	260.375	-11.41548	1482.4227	2988.6183	0	450
24	401	266	-10.573275	1373.7174	2794.656	0	450
25	401	272	-9.40878	1241.1526	2540.505	0	450

26	401	276.4824	-8.377405	1132.0456	2337.6695	0	450
27	401	281.2892	-7.0189945	999.29489	2063.2438	0	320
28	401	287.938	-4.8633655	798.40628	1706.5454	0	320
29	401	293.43295	-2.812102	615.54274	1369.6243	0	320
30	401	297.774	-0.967731	457.12643	1065.5694	0	320
31	401	303.1029	1.5803065	244.9234	655.24795	0	320
32	401	307.9255	4.0803065	57.389262	297.38598	0	320

APPENDIX C

Cohesive Shear Strength vs. Water Content



NOTE:

1. Cohesive shear strength curves derived from shear strength data supplied by Rock Island District for Mississippi River alluvial soils in the District, and shown on Plates , ,and .

COHESIVE SHEAR STRENGTH VS
WATER CONTENT

Figure 1: Cohesive Shear Strength vs Water Content

SITE PLAN FOR THE HURRICANE ISLAND REACH

DREDGED MATERIAL MANAGEMENT PLAN WITH INTEGRATED ENVIRONMENTAL ASSESSMENT

POOL 11
DUBUQUE COUNTY, IA AND GRANT COUNTY, WI
UPPER MISSISSIPPI RIVER, RIVER MILES 591-608

FINAL

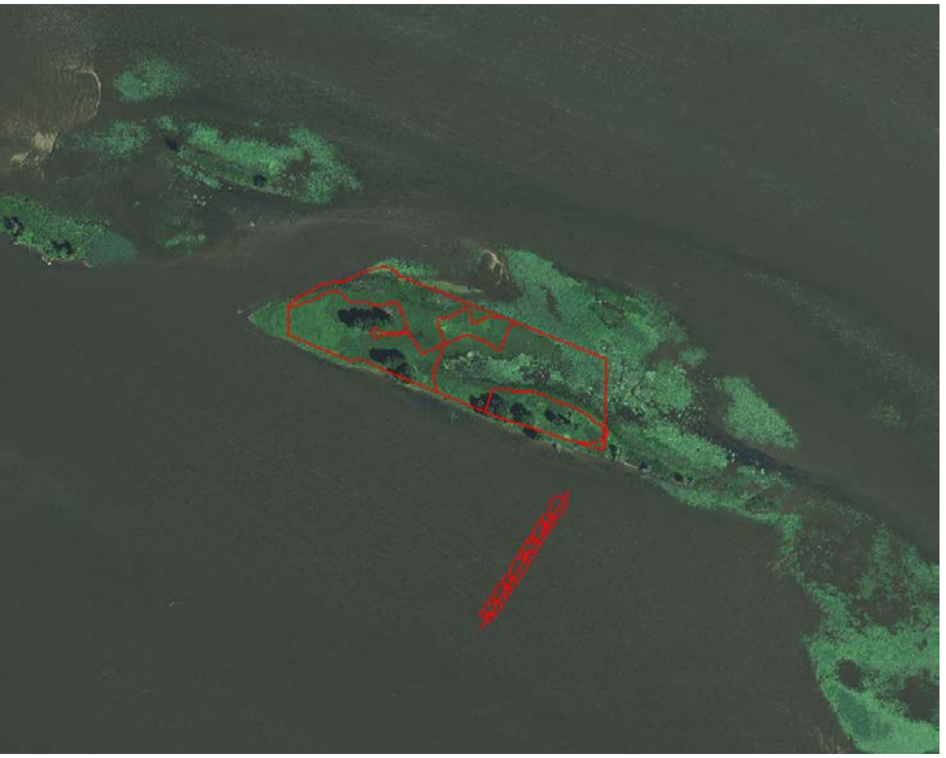
APPENDIX E-3

HYDROLOGY & HYDRAULIC ENGINEERING

Hurricane Recommendations EC-H

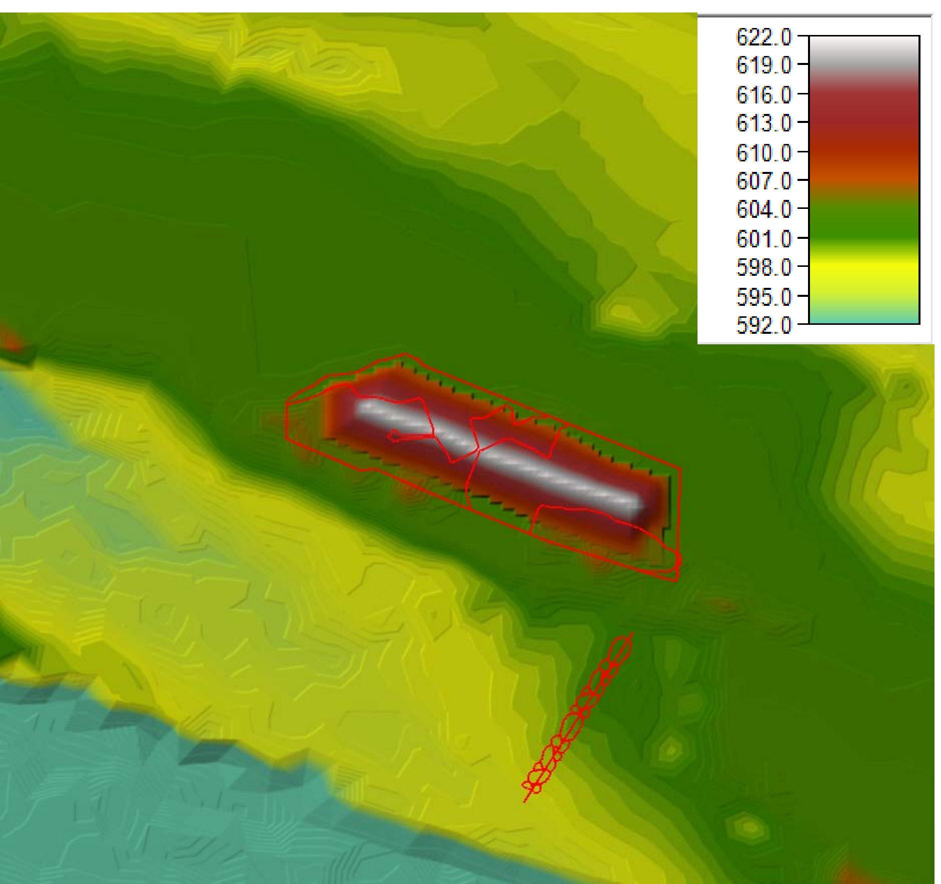
20APR16

Bathtub

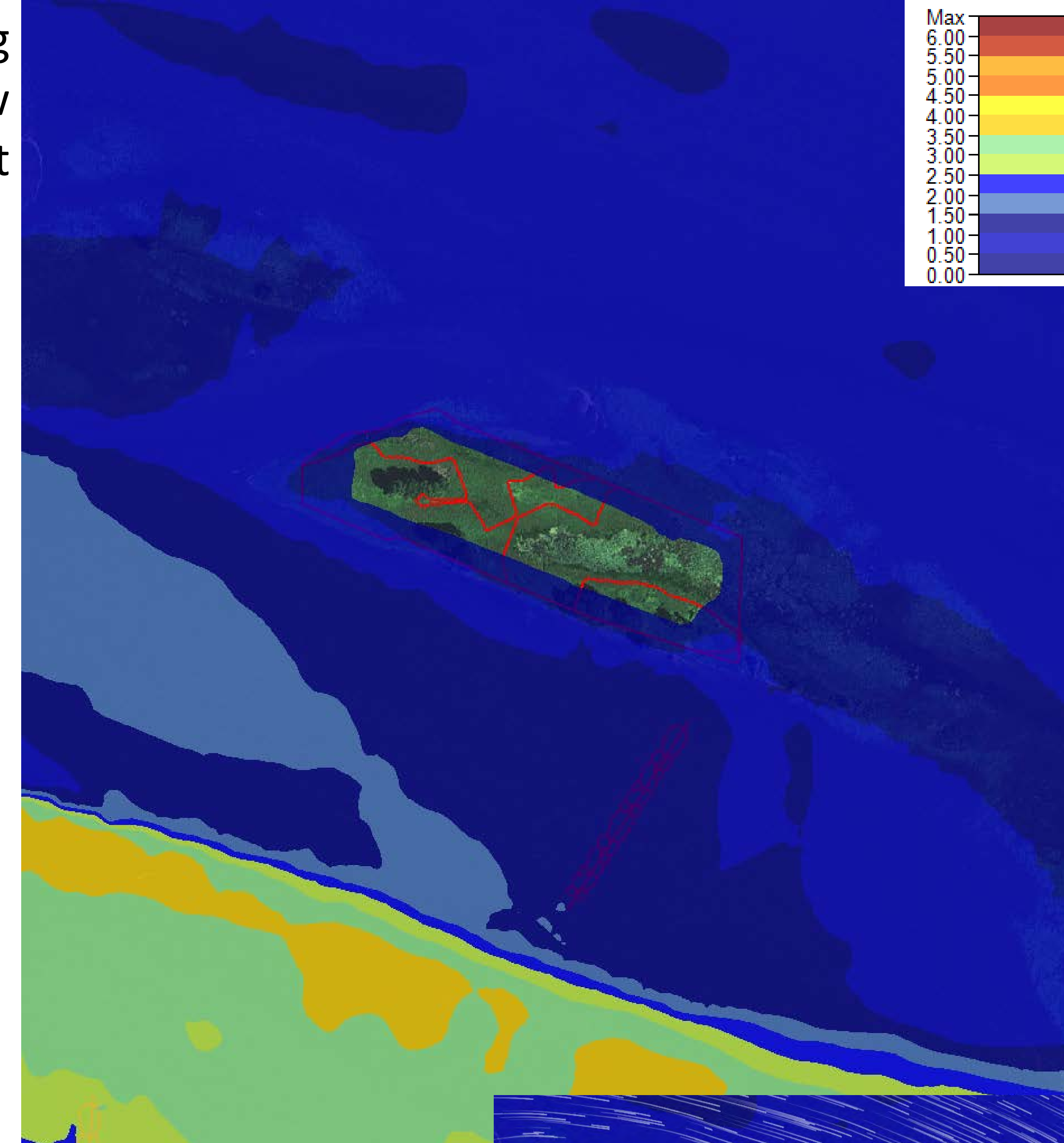


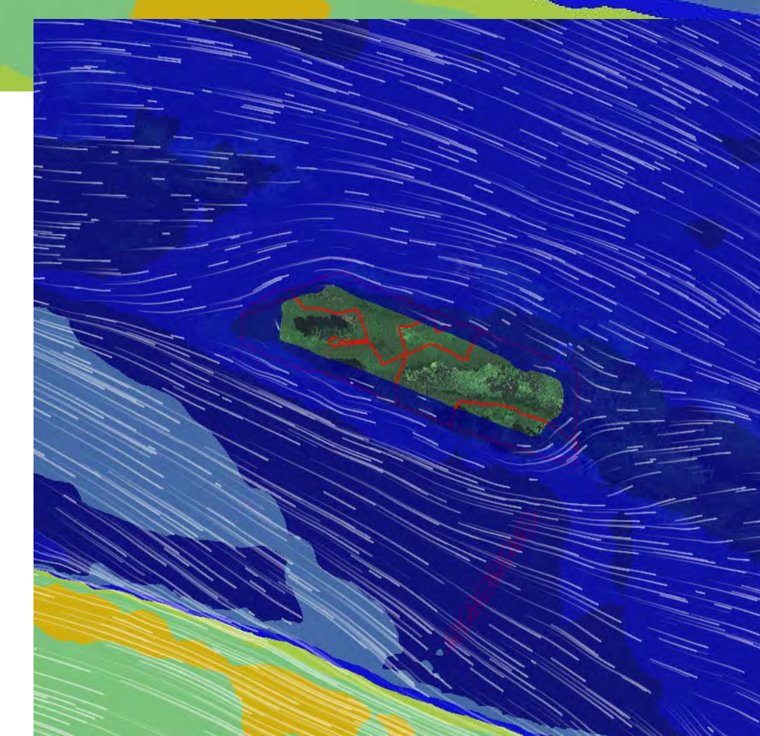
Layout

Contours of Elevation (Topography)



Velocities Bordering Bathtub at the 2-yr Flow Event





Recommendation

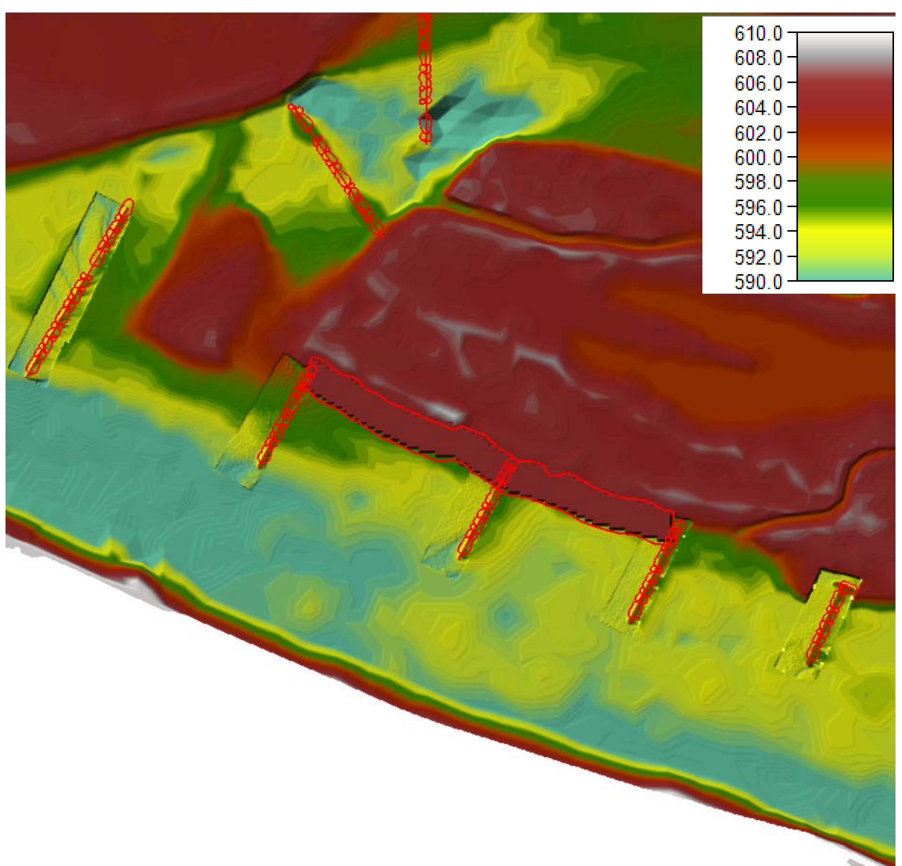
Velocities bounding the perimeter $< 1\ ^{ft}/_{sec}$

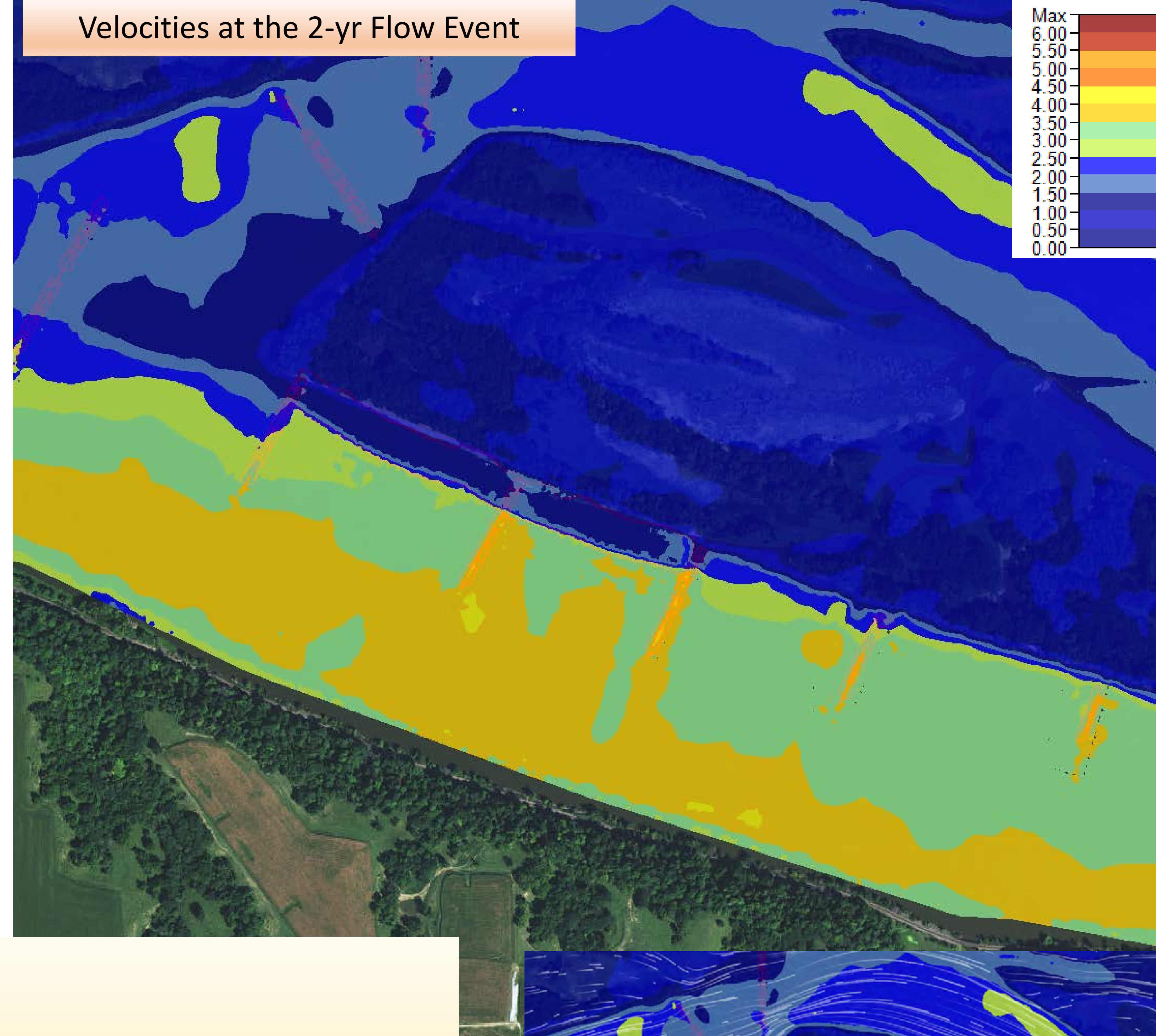
No riprap required to hold dredged material in place

Hurricane Island Bankline Placement Upper

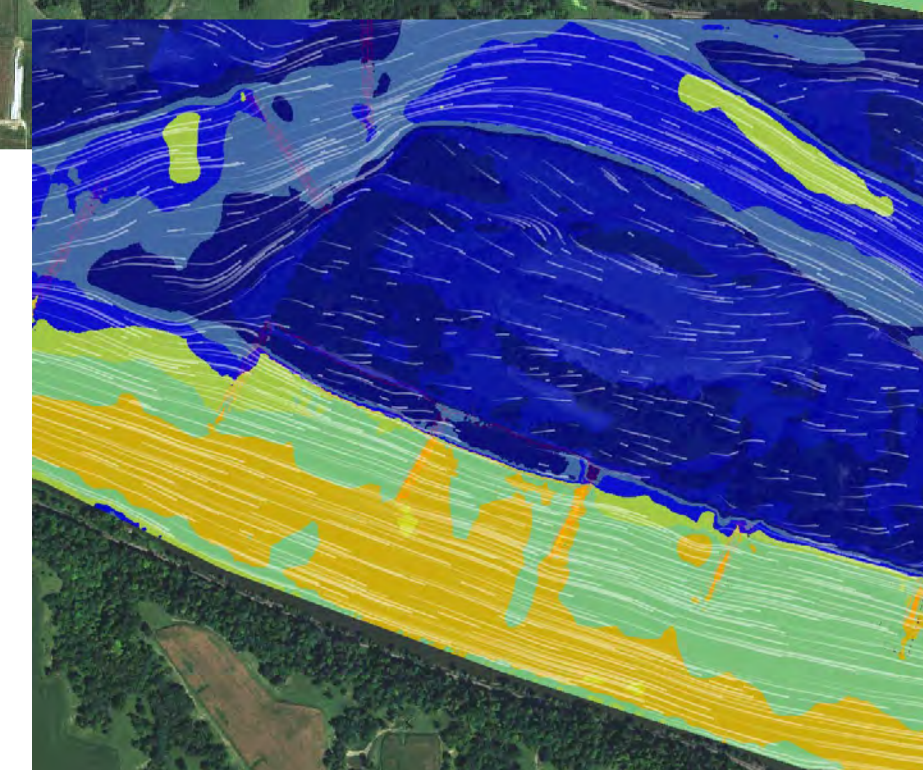
Layout

Contours of Elevation (Topography)





Velocities at the 2-yr Flow Event



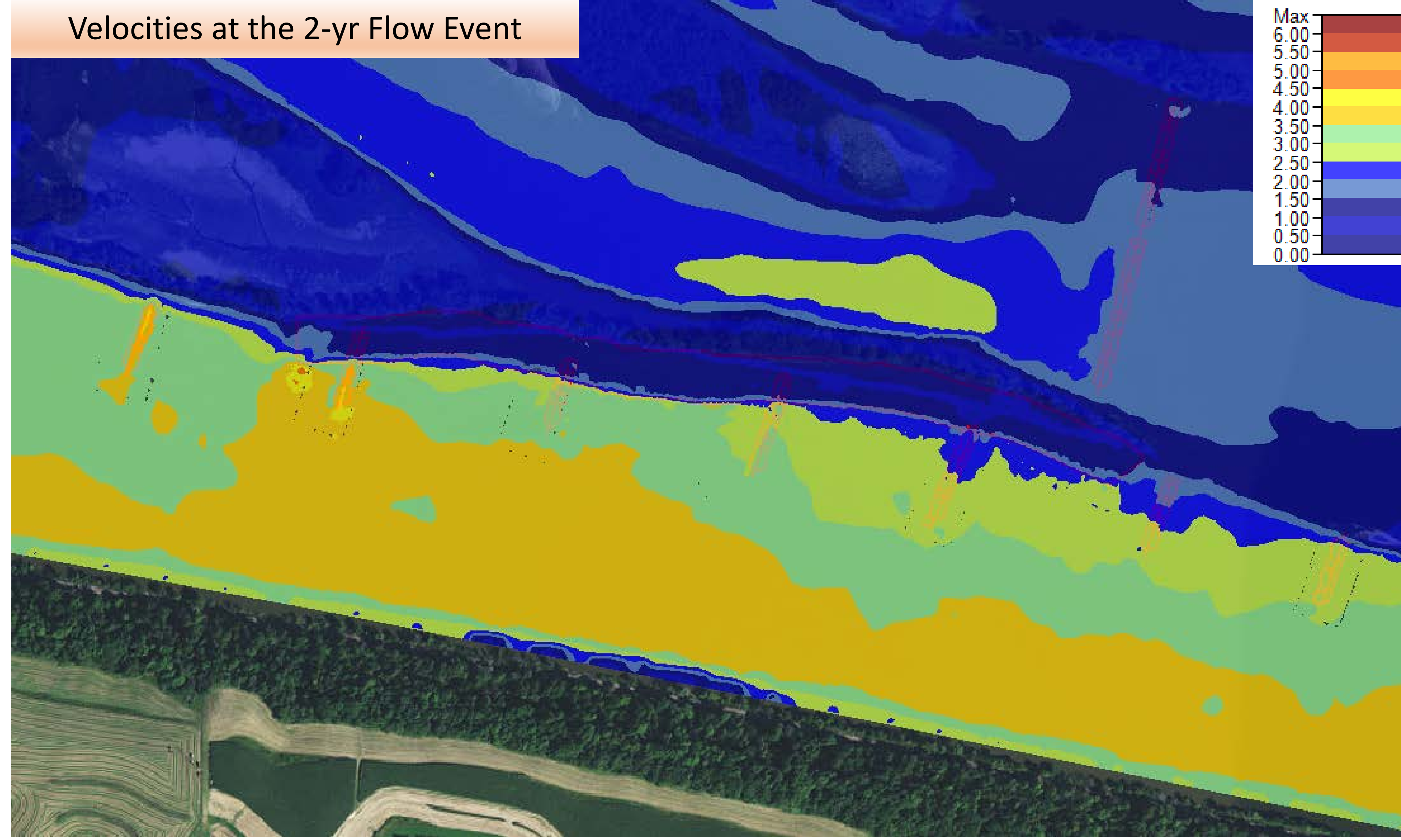
Recommendation:

Velocities bounding the perimeter range from 2.5 to 3.5 $^{ft}/_{sec}$
Bank protection will be required to hold dredged material in place.

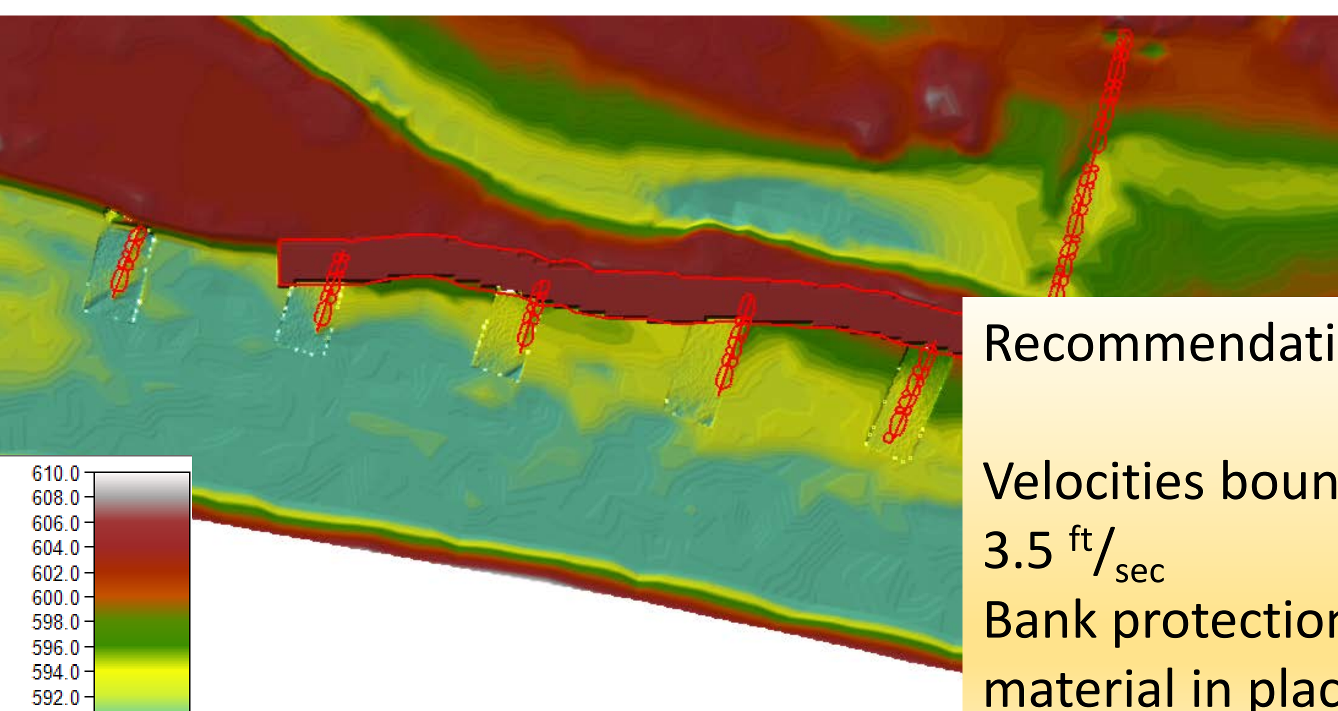
ALSO:
Three wings currently ~ at project grade of 595, if these were raised to 600 (3' below FP), velocities along the bankline placement are decreased ~0.3 $^{ft}/_{sec}$ a, not enough of a decrease to remove the necessity for placement.

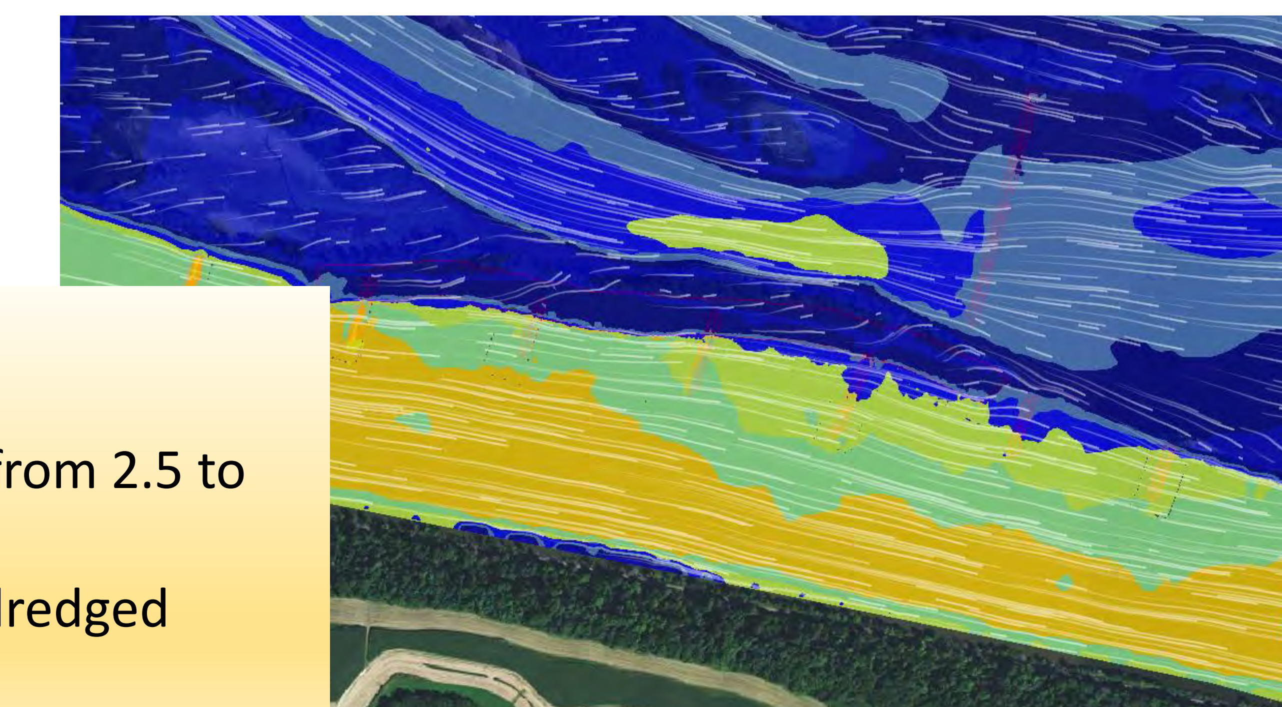
Hurricane Island Bankline Placement Lower

Layout



Contours of Elevation (Topography)





Recommendation:

Velocities bounding the perimeter range from 2.5 to 3.5 $^{ft}/_{sec}$

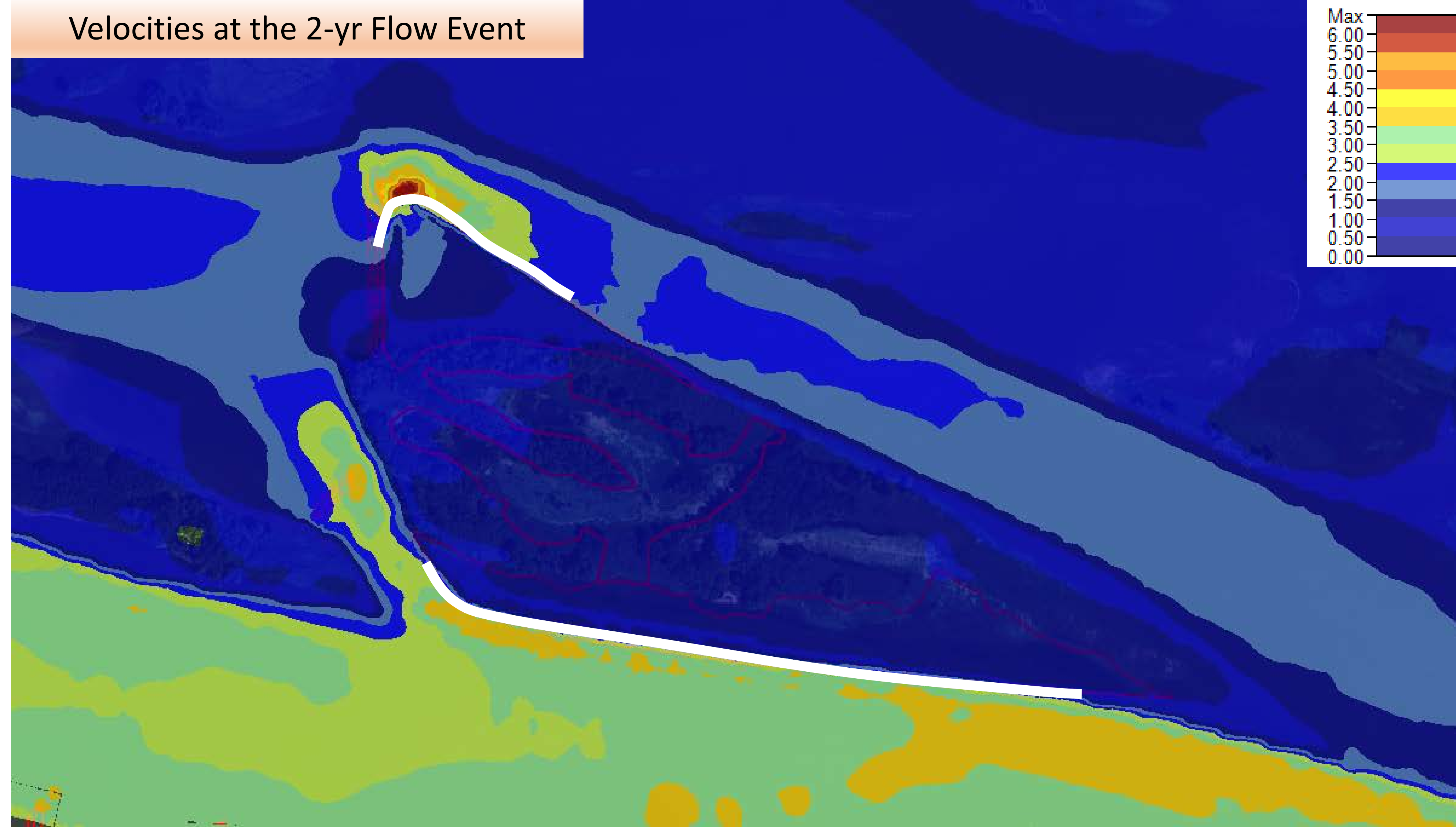
Bank protection will be required to hold dredged material in place

Rosebrook Island

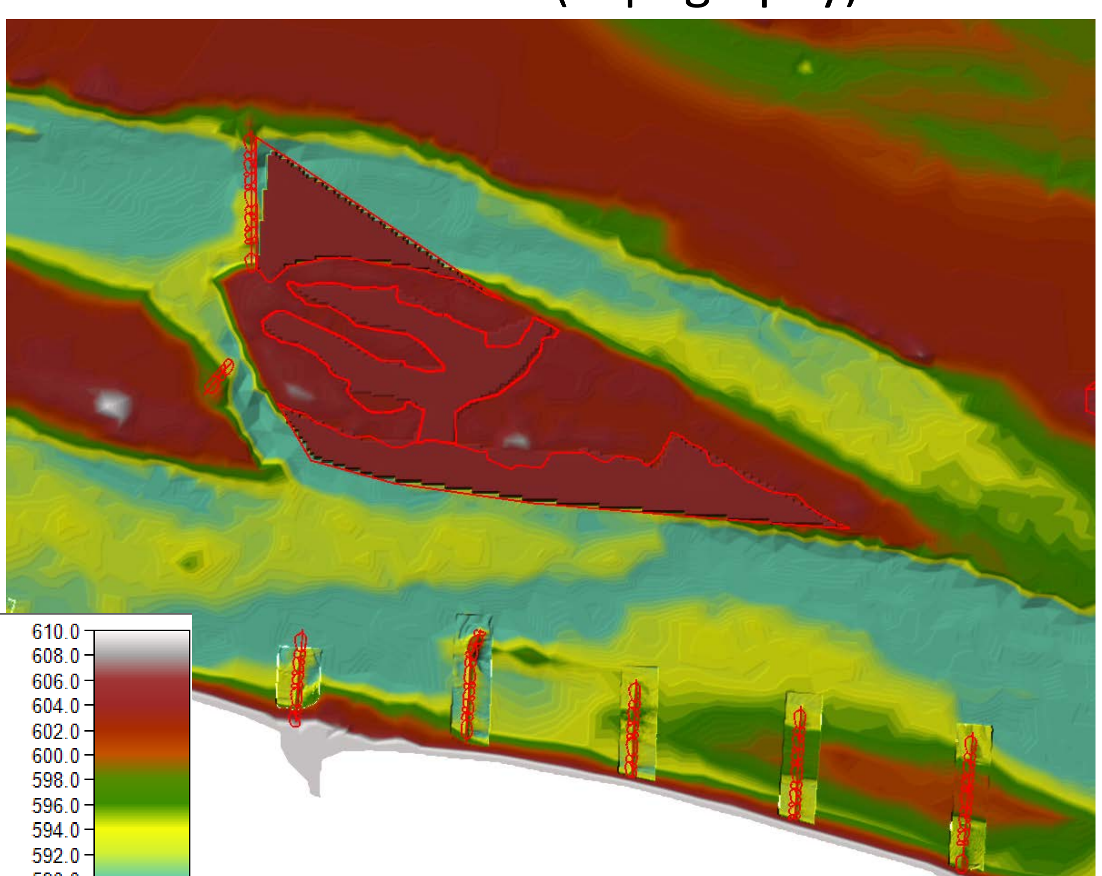
Bankline Placement, Island Placement, Side Channel Placement

Layout

Velocities at the 2-yr Flow Event



Contours of Elevation (Topography)

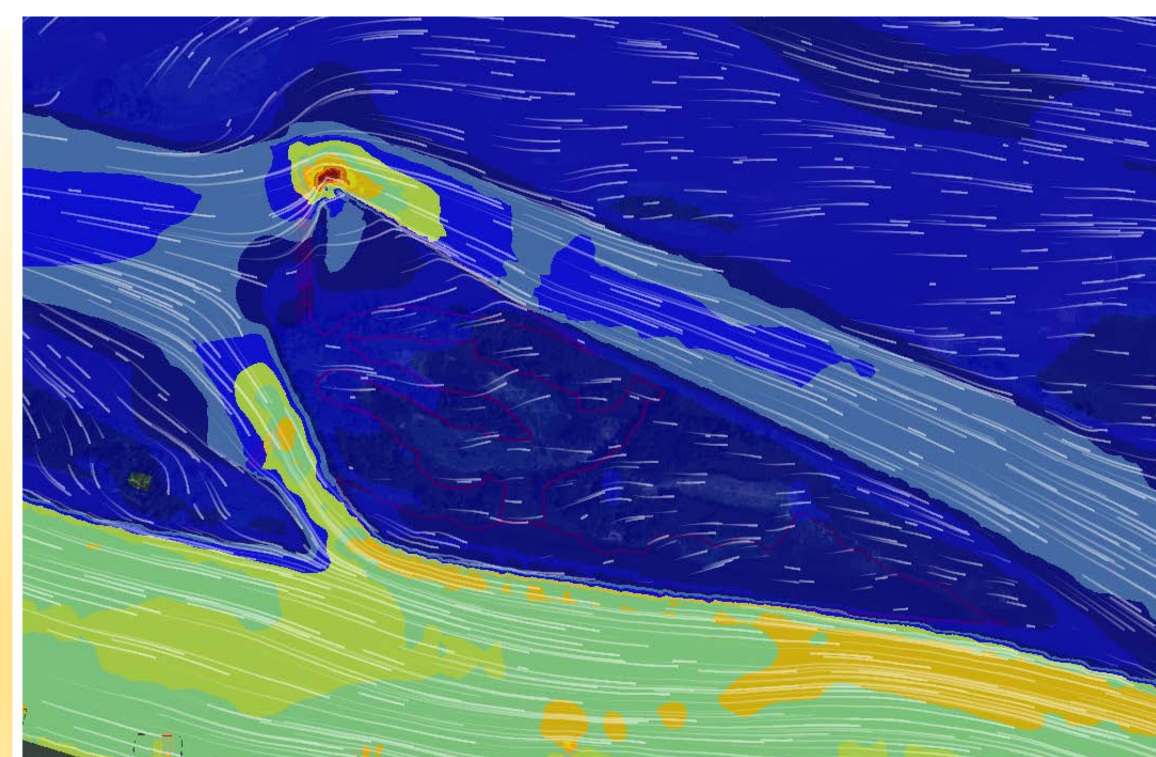


Recommendation:

Bankline Placement - Velocities bounding the majority of the perimeter > 2.5 $^{ft}/_{sec}$, recommend ~2,900 feet of bank protection as shown above.

Island Placement – Velocities over the placement < 1.0 $^{ft}/_{sec}$, Bank protection will not be required to hold dredged material in place

Side Channel Placement - Velocities bounding the perimeter are high in some areas, recommend ~1,100 feet of bank protection with the extent as shown above.

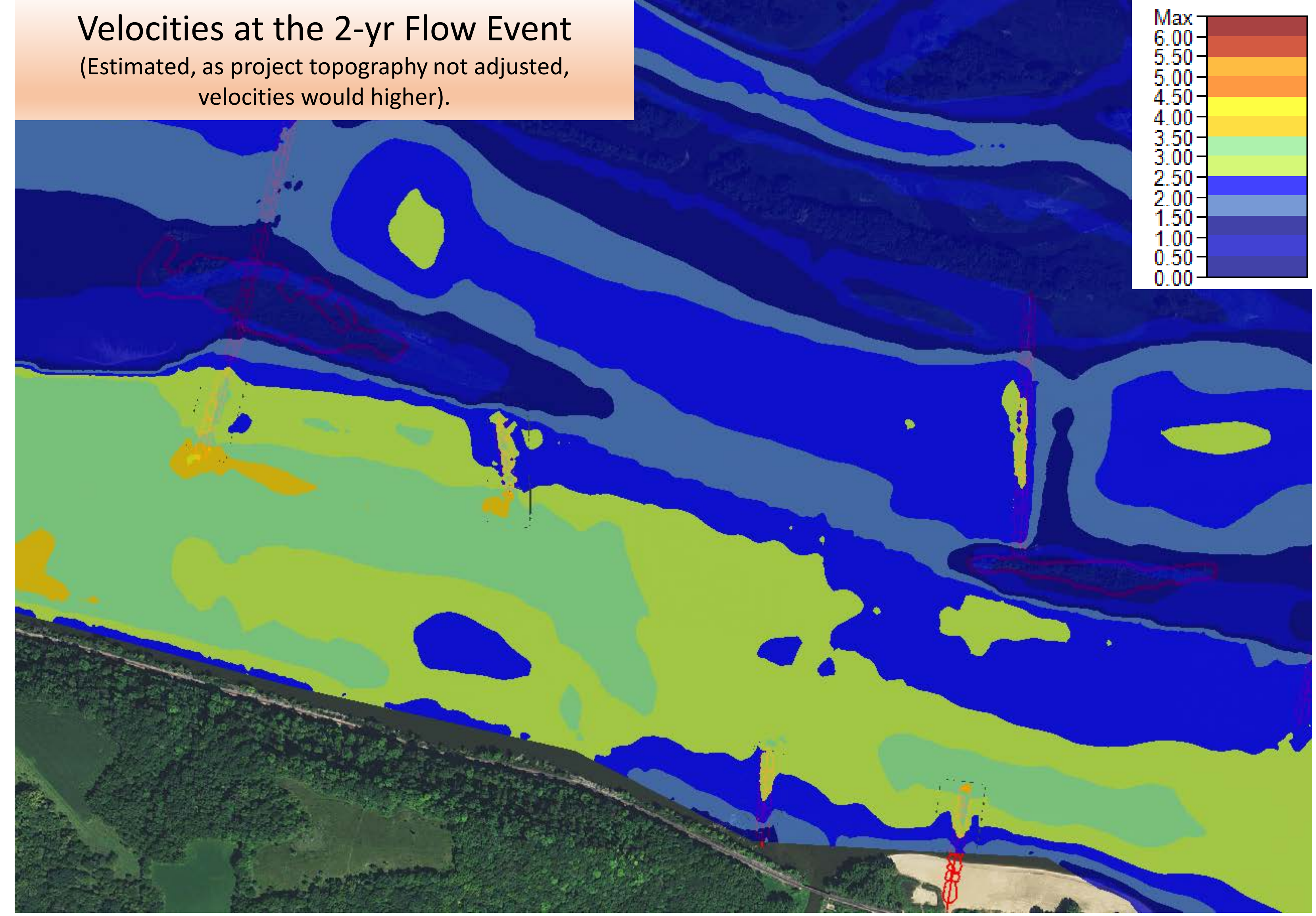


Islands 205, 207 Placement

Layout

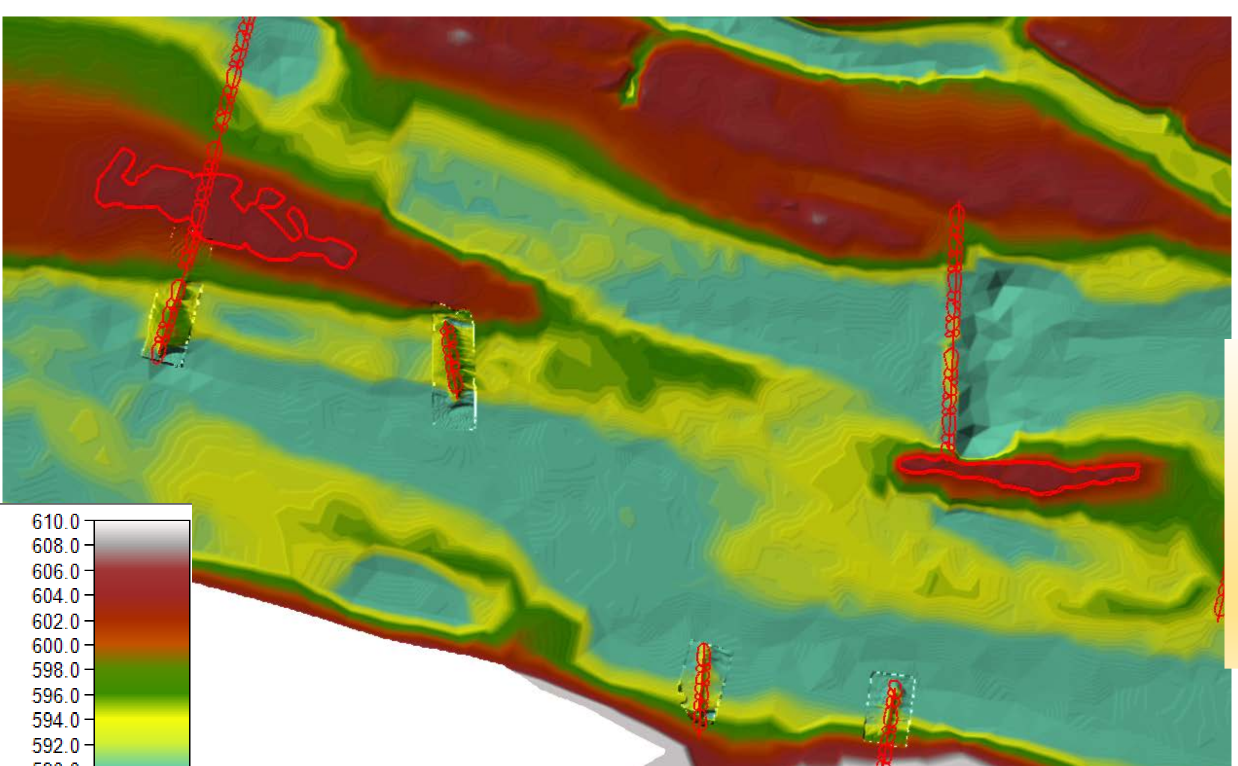
Velocities at the 2-yr Flow Event

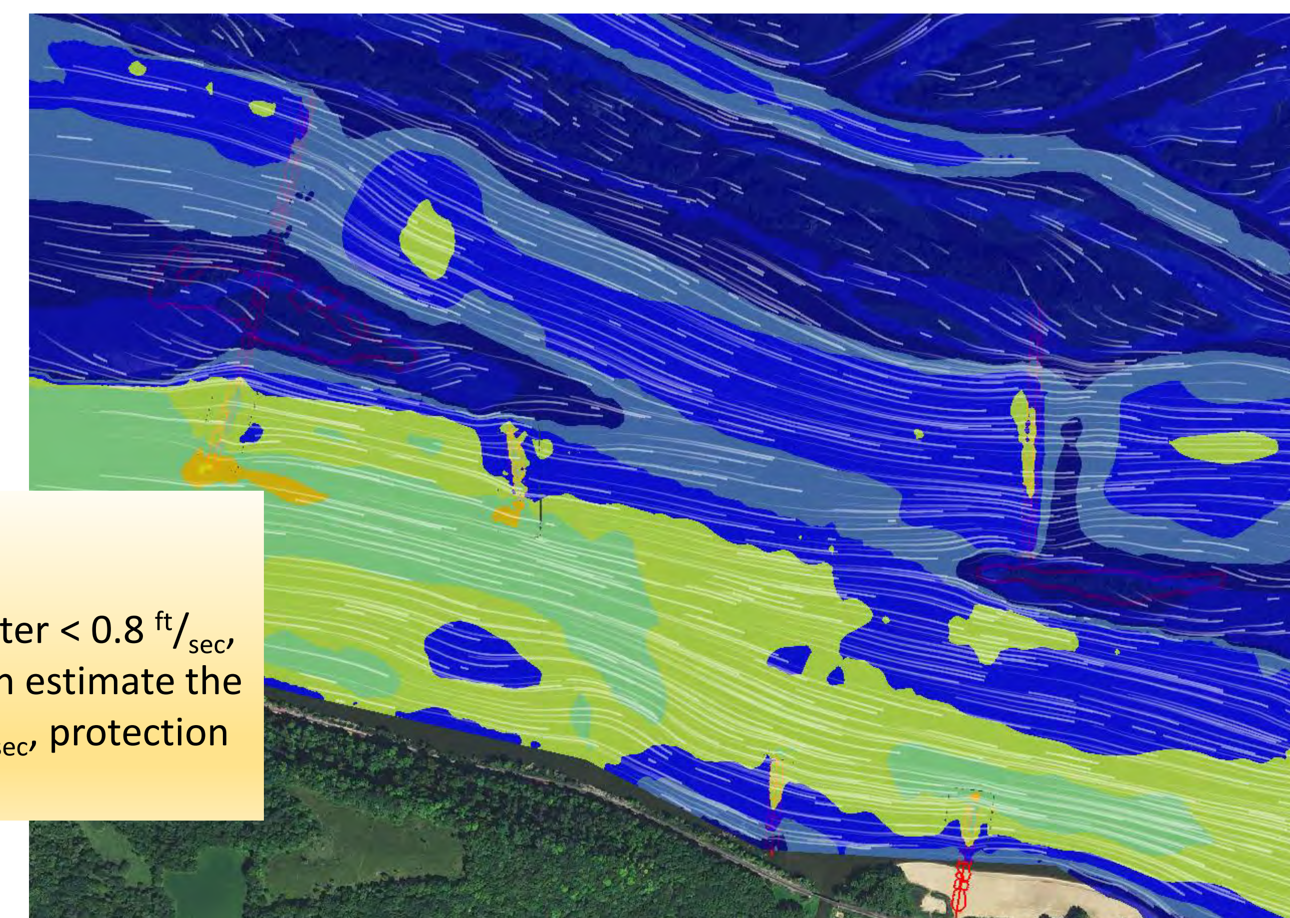
(Estimated, as project topography not adjusted, velocities would higher).



Contours of Elevation (Topography)

(Project topography not adjusted to reflect this alternative)

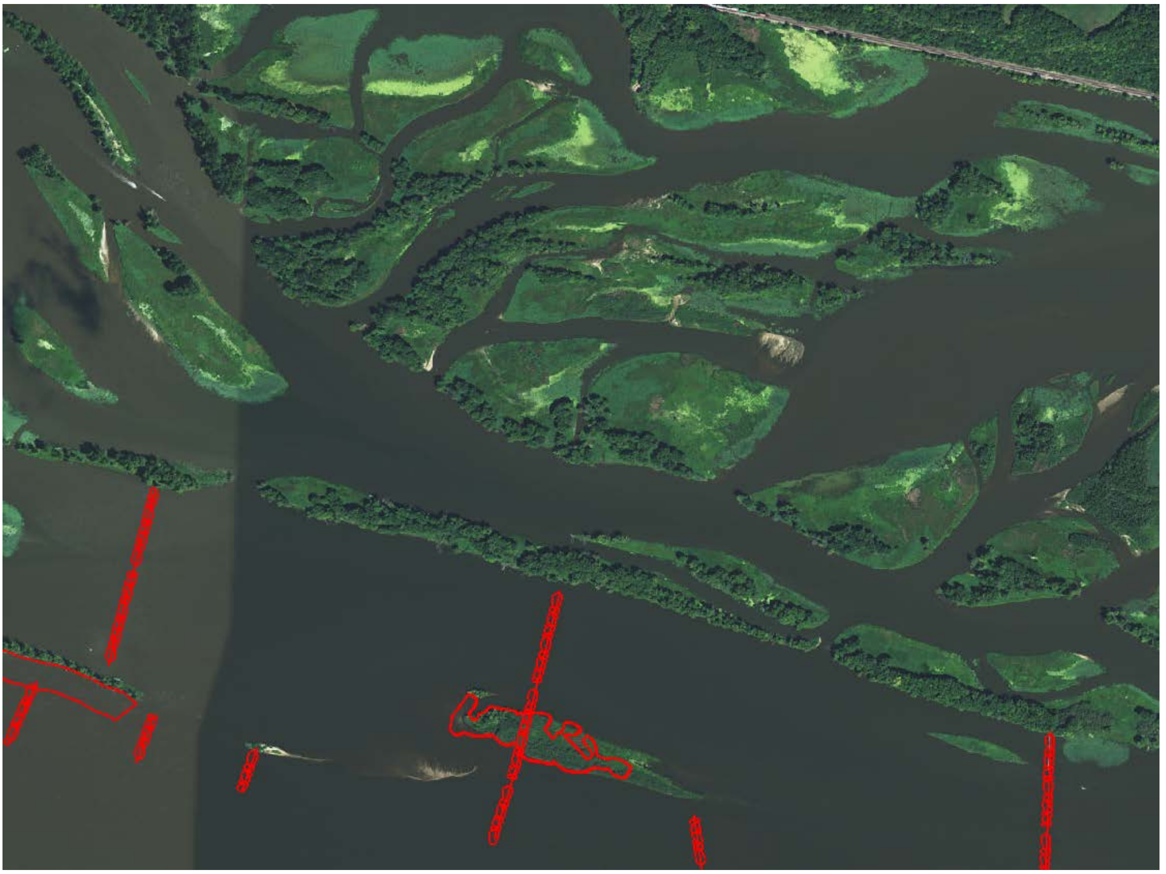




Recommendation:

Velocities over and bounding the perimeter < 0.8 $^{ft}/_{sec}$, if project topography were installed, then estimate the velocities would be increased to ~ 1.2 $^{ft}/_{sec}$, protection would not be justified.

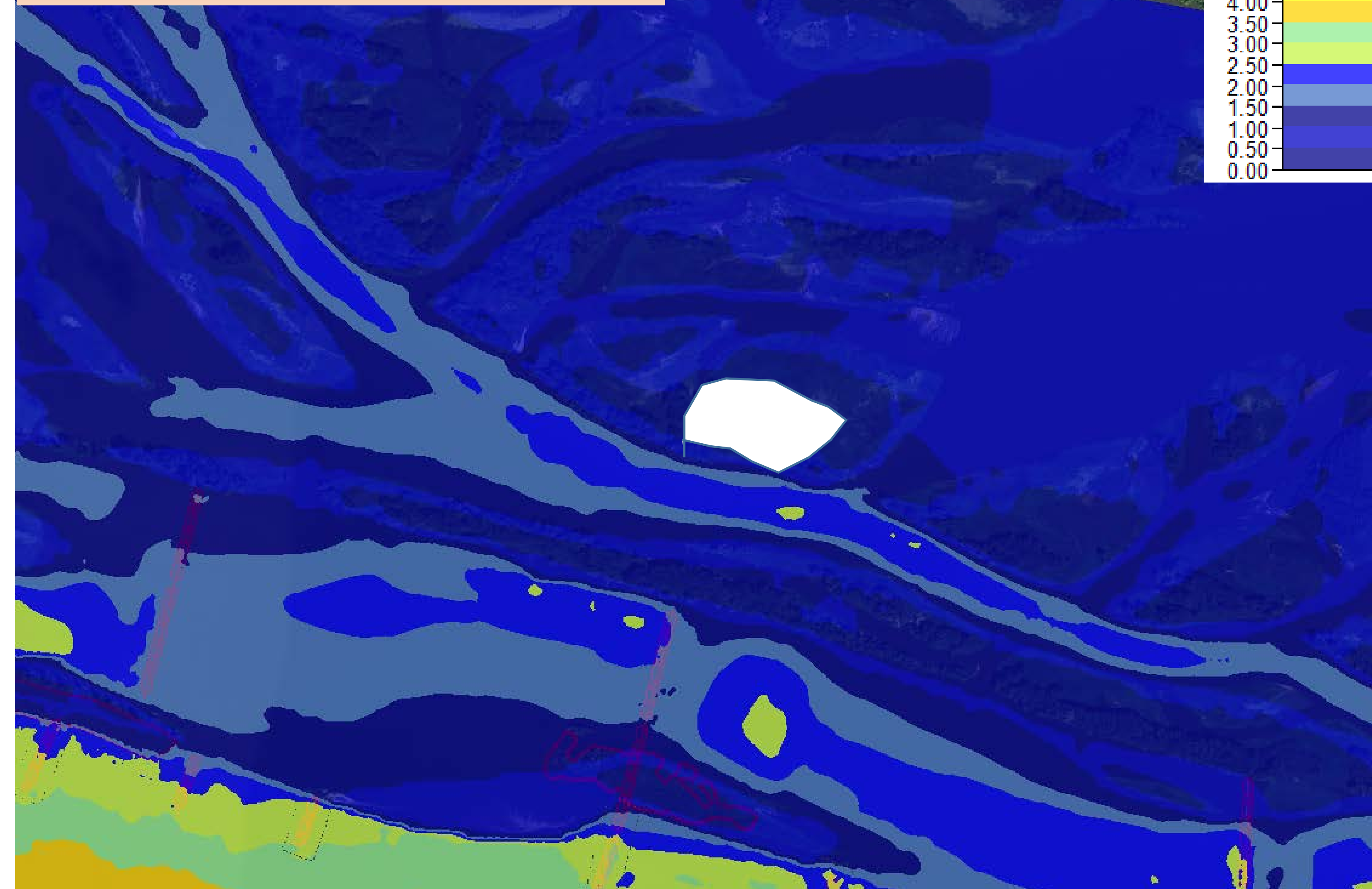
Snyder Slough Placement



Layout

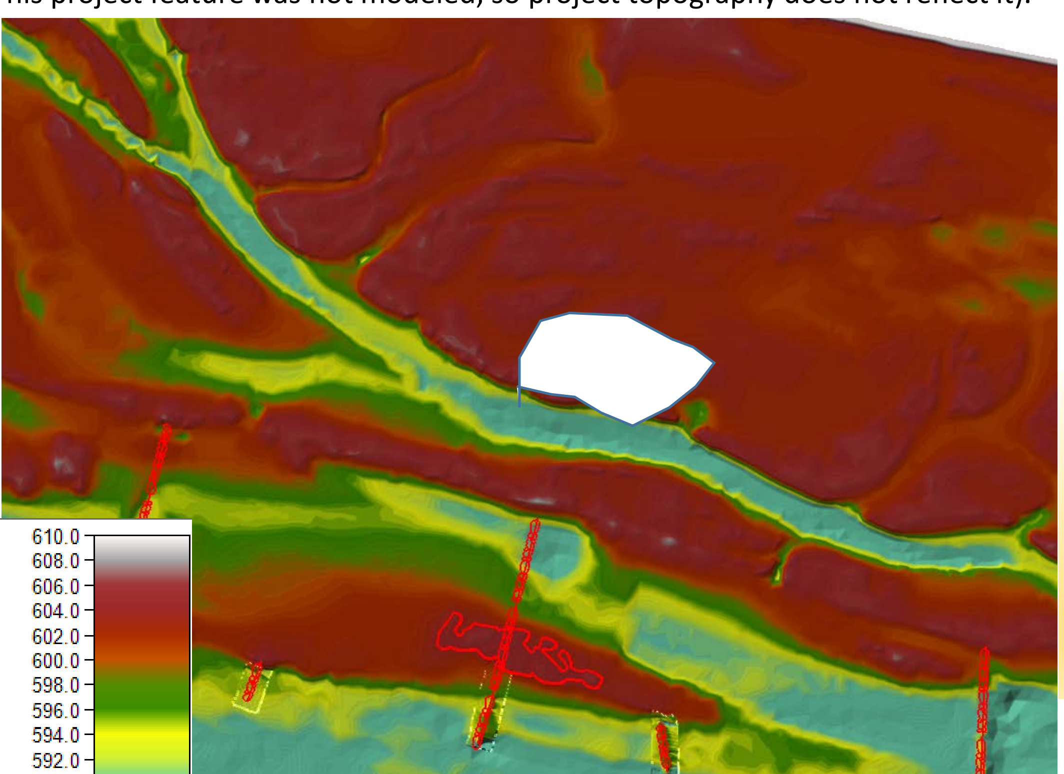
Velocities at the 2-yr Flow Event

(Estimated, as project topography not adjusted, velocities would higher).



Contours of Elevation (Topography)

This project feature was not modeled, so project topography does not reflect it).



Recommendation:

Velocities over and bounding the perimeter < 0.5 $^{ft}/_{sec}$, if project topography were installed, then estimate the velocities would be increased to < 1.0 $^{ft}/_{sec}$, protection would not be justified.