ANCHOR QEA

720 Olive Way, Suite 1900
Seattle, Washington 98101
Phone 206.287.9130
Fax 206.287.9131
www.anchorqea.com

MEMORANDUM

To:	William Hague, John Morris, and Richard Galloway, Honeywell International	**Date:**	September 30, 2013
From:	John Laplante, Mark Reemts, and Ram Mohan, Anchor QEA, LLC	**Project:**	110287-11.01
Re:	Updated Slope Stability Evaluation – Former Buffalo Color Site, Buffalo, NY Proposed Remedial Dredging Scenarios Near Area A – Marine Mattress		

INTRODUCTION

This memorandum presents updated results of slope stability evaluations and recommendations in support of proposed remedial dredge designs adjacent to the former Buffalo Color Site. The area in question is located within the Buffalo River Area A at Dredge Management Units (DMUs) 9 and 10, adjacent to the shoreline slope and marine mattress. The objective of this memorandum is to evaluate various best management practices (BMPs) near the toe of the marine mattress area so that BMPs can be implemented in the field by the contractor to try to minimize potential slope stability issues during and after dredging.

Slope stability was previously evaluated at DMUs 9 and 10 to assess the draft remedial dredge design for this area. The results of the analyses and recommendations were provided in a memorandum on March 20, 2012 (Anchor QEA 2012). Since performing the initial evaluations in 2012, additional data have been provided to Anchor QEA for purposes of refining the slope stability model. The additional data included the following:

- Post-dredge surveys performed by the United States Army Corps of Engineers (USACE) following maintenance dredging in April 2013
- Data from three soil borings performed in July, 2013 by Nothnagle Drilling, Inc., along the shoreline within DMU 9 and DMU 10
- Diver-assisted surveys of the marine mattress toe performed in May 2013

Previous analysis indicated that the existing slope in this area has a factor of safety that is lower than target factors of safety provided in engineering design guidance documents. The previously proposed dredge design resulted in a lower factor of safety (near 1.0), indicating potential slope movement that could compromise the upland soil-bentonite slurry wall and/or result in loss of material into the river during or following dredging. Methods of backfill or shoring to reduce the impacts of the removal of dredged material are limited in the area due to the close proximity of the federal navigation channel, which ranges in distance from 2 to 3 feet to at most 15 feet away from the toe of the marine mattress. Efforts to stabilize the slope through added material would result in material placement within the navigation channel footprint and in some cases within the authorized depth; therefore, mitigation measures were considered by Anchor QEA, and several options were evaluated and presented as possible solutions.

Although the recently provided additional data have allowed for a more refined slope stability analyses, our conclusions regarding the shoreline stability during and after remedial dredging have not fundamentally changed, for the most part. Updates to the slope stability model, analytical results, and conclusions are discussed in the following sections.

UPDATES TO THE SLOPE STABILITY MODEL

Recent topographic and bathymetric surveys performed by Niagara Boundary and Mapping Services in April 2013 in support of shoreline restoration work planned along Area A were used to update the existing mudline adjacent to the marine mattress. Using available data, a cross section was developed through the marine mattress and shoreline slope at the steepest point along the shoreline, and where the proposed dredge limits have the closest approach to the marine mattress. The geology of this cross section was then modeled, and the stability at this location was evaluated using Rocscience SLIDE version 6.024 software. The location and extent of the cross section considered is shown on Figure 1.

A series of recent borings were performed by Nothnagle Drilling, Inc., for BIDCO Marine Group, Inc., to support the Buffalo Color shoreline restoration. Three of these borings adjacent and waterward of the marine mattress (i.e., BH-09, BH-10, and BH-11) were utilized, which allowed for a more accurate model of the clay thickness and depth to bedrock to be used in the updated stability analysis. Based on this new information, the clay layer is demonstrated to be thicker than was anticipated from previously available data.

Additionally, mapping of the marine mattress toe was performed in May 2013, which revealed that the overall footprint of the marine mattress extends much further into the river than previously documented. The geologic model, therefore, was updated to include this recently provided as-built information from the diver-assisted survey of the marine mattress. The location of the borings and survey results of the marine mattress toe are shown on Figure 1.

Previous analyses assumed an extreme low-water event of 565 feet (IGLD 85). The river surface water elevation has been reassessed and assumed to be consistent with the Lake Erie low-water datum of 569.2 feet (IGLD 85).

ANALYSES AND RESULTS

The existing shoreline adjacent to DMUs 9 and 10 has a lower factor of safety than values recommended in engineering design guidance documents, regardless of whether future dredging is performed or not; however, the marine mattress slopes appear to be stable under existing conditions based on visual observations, as well as reports from on-site personnel. Removal action with dredging initiating at the marine mattress toe and extending vertically downward to the proposed dredge elevation is modeled to have a factor of safety of approximately 1.0. Although theoretically stable, the results do not guarantee that that the slope is safe from some deformations or distortion. The potential for slope movements are most prevalent and are theoretically most likely to occur if a vertical cut were to be made at the toe of the slope. Because of this low factor of safety, alternative dredge offsets and slopes adjacent to the marine mattress were evaluated using the updated slope stability model.

Note that offsets and slopes were selected based on similar approaches elsewhere in the remedial dredge prism design and typical stable slopes for soft sediments. Offsets included both 5-foot and 15-foot offsets from the toe of the mattress, and slopes included vertical cuts 1 horizontal to 1 vertical [1H:1V], 2H:1V, and 3H:1V. Current dredge prism design for the rest of the remedial project incorporates offsets of 5 feet from existing structures and natural shorelines. Existing design also incorporates 1H:1V slopes adjacent to natural shorelines as well as 2H:1V slopes adjacent to city-owned critical structures. In addition, 3H:1V slopes were incorporated as typical soft sediment stable slopes for evaluation during design. Evaluated scenarios for alternative dredge prisms and associated factor of safety are presented in Table 1.

Table 1
Slope Stability Modeling Results

Scenario	Removal Action	Estimated Factor of Safety
Existing	Existing Condition (Post-USACE Maintenance Dredging)	1.15
Baseline	Vertical Slope Cut at Marine Mattress Toe to Proposed Dredge Prism	1.06
Alternative 1	Vertical Slope Cut with 5-foot Offset from Marine Mattress Toe	1.07
Alternative 2	Vertical Slope Cut with 15-foot Offset from Marine Mattress Toe	1.09
Alternative 3	1H:1V Slope with 5-foot Offset from Marine Mattress Toe	1.09
Alternative 4	2H:1V Slope with 5-foot Offset from Marine Mattress Toe	1.10
Alternative 5	3H:1V Slope with 5-foot Offset from Marine Mattress Toe	1.13

Note:
H:V = ratio of horizontal distance (H) to vertical distance (V) along a slope

The results presented above demonstrate that all of the dredge scenarios considered result in a factor of safety that is less than a typical design target value of 1.3 to 1.5. The potential failure planes modeled represent deep-seated, global slope movement. In addition to these deep-seated surfaces, shallower failures that daylight below the marine mattress toe but above the initiation of remedial dredging are also possible.

The factor of safety is slightly higher when horizontal offsets and flatter cut slopes are used. For a 5-foot horizontal offset from the toe of the marine mattress, and using a dredge cut slope of 3H:1V, the resulting factor of safety is similar to that of the existing slope, indicating that the dredging action for this alternative only has a minor influence on the overall slope stability when compared to existing conditions.

CONCLUSIONS

Stability of the shoreline for a post-dredge scenario utilizing a vertical cut is predicted to be at risk of slope movements along the marine mattress area, and to potentially affect the soil-bentonite slurry wall. Slightly higher factors of safety of the slope are predicted when 2H:1V and 3H:1V sloped cuts are utilized with a 5-foot offset; however, these factors of safety are still well below engineering design guidance targets. None of the modeled scenarios achieve a factor of safety of 1.3 or higher, which is normally recommended by engineering design guidance documents. Analyses indicate that a dredge prism utilizing a vertical slope cut initiating at the marine mattress toe has the highest potential for slope movement. An alternate dredge design using a 5-foot offset and a 3H:1V slope would result in a factor of safety that is similar to that of the existing slope, indicating that the dredging action for this alternative has only a minor influence on the overall slope stability when compared to existing conditions.

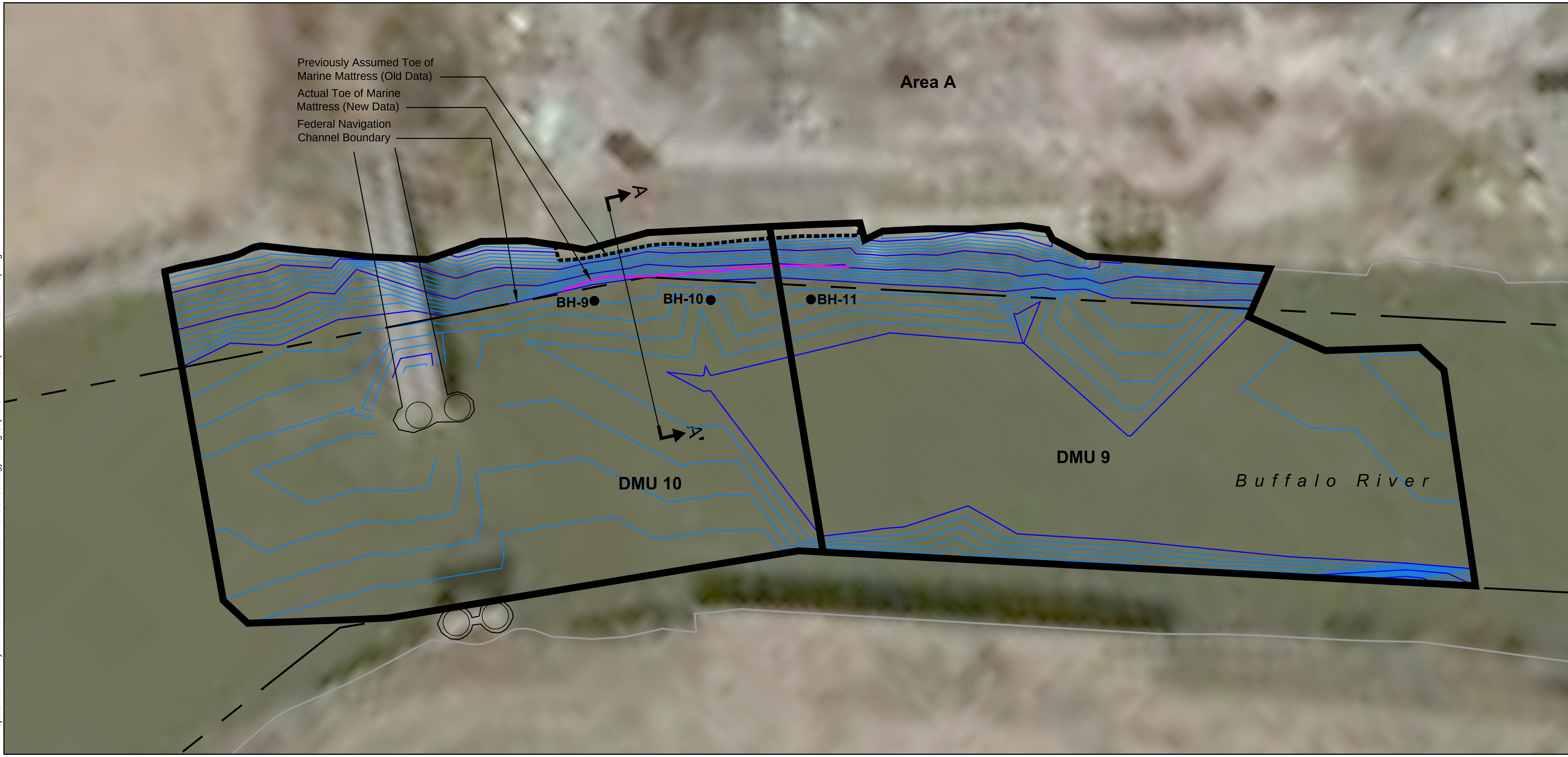
One BMP for marginally stable conditions is to conduct dredging in small areas at the toe of the slope, sequentially cutting "slots" along the toe and backfilling before cutting an adjacent slot. Sequencing the dredging in such a manner (the slot-cut approach) would allow for a more controlled dredging process and would provide the opportunity for adaptive management during construction whereby the length of the slot could be decreased if unstable conditions occurred. The tradeoff of the slot-cut approach is that when cutting the adjacent slot, equipment tolerance would dictate that some of the clean backfill material would also need to be removed so that full excavation of the target material could be ensured. In addition, placement of backfill to improve slope stability in this area would necessitate receiving USACE approval to add fill adjacent to, and in some cases, within the federal navigation channel footprint. Although the slot-cut approach could potentially reduce the risk of slope movements, the post-dredge factor of safety under that approach would also be similar to that of the existing condition.

Note that as part of the design phase evaluation of critical structures, the property owner, South Buffalo Development, LLC, has signed a liability waiver releasing Honeywell, U.S. Environmental Protection Agency, USACE, and their agents/consultants from future liability related to slope stability issues that could potentially result from dredging activities. Based on the limited options available, it appears that the 5-foot toe offset and 3H:1V dredge prism slope, with close monitoring to track slope movement, is the BMP most suited to this area of the river.

REFERENCES

Anchor QEA. "Slope Stability Evaluation: Proposed Dredge Scenarios for Area A and Area D." Technical Memorandum, December, 2011.

Anchor QEA. "Updated Slope Stability Evaluation: Proposed Dredging Scenario Area A – Marine Mattress." Technical Memorandum, March, 2012.



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SOURCE: Basemap and bathymetry prepared from CH2MHILL drawings, titled 'Existing Conditions' and 'Dredging Operations'.
HORIZONTAL DATUM: New York State Plane West, NAD83, U.S. Feet.
VERTICAL DATUM: North American Vertical Datum 1988 (NAVD88).

LEGEND:

- Proposed Dredging Contours (1' and 5')
- Actual Toe of Marine Mattress (New Data)
- Previously Assumed Toe of Marine Mattress (Old Data)
- Navigation Channel
- DMU Boundary
- Naturally-sloped Shoreline
- Borehole Location
- A A' Slope Stability Cross Section

0 100
Scale in Feet

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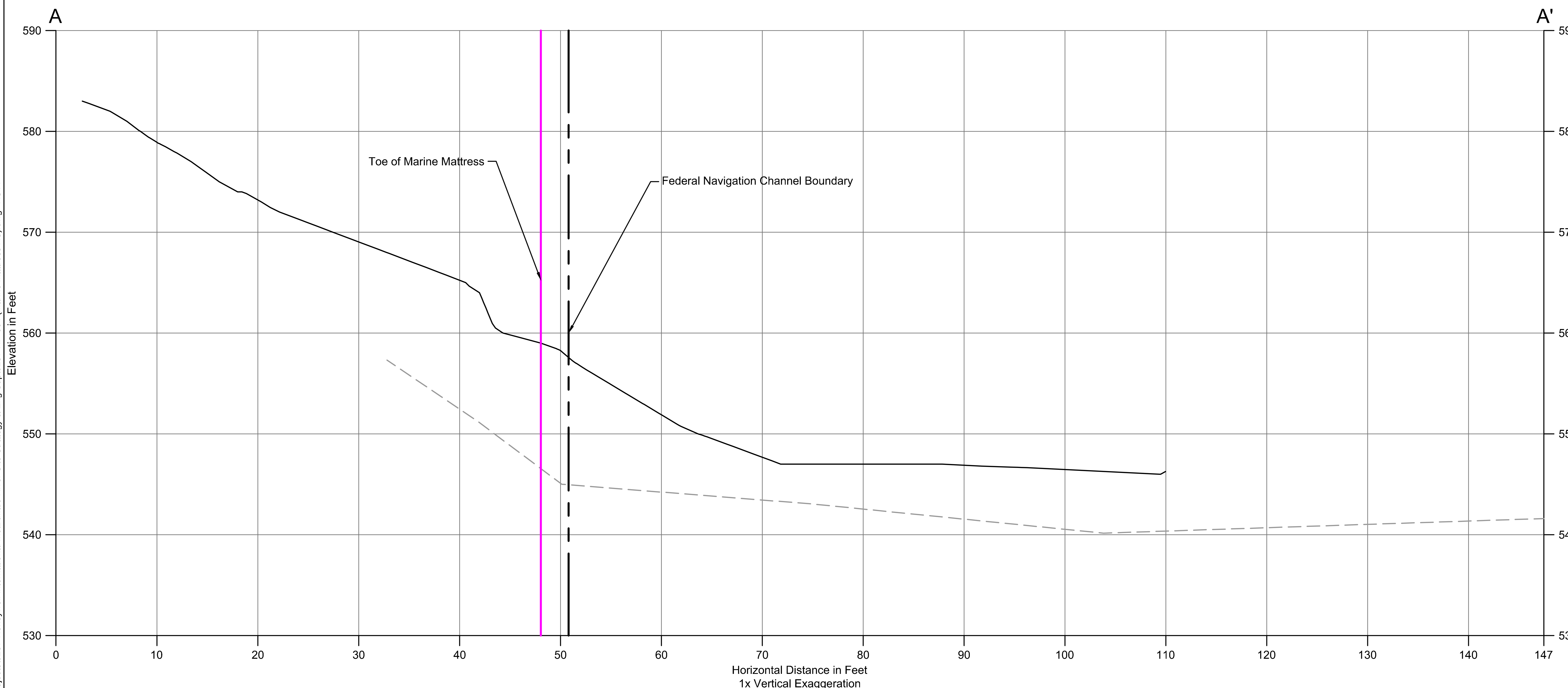
Figure 1
Marine Mattress Overview
Updated Slope Stability Evaluation
Former Buffalo Color Site



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LEGEND:

- Proposed Dredge Prism
- Existing Mudline (April 2013)
- Navigation Channel
- Toe of Marine Mattress

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Scale in Feet

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Figure 2
Marine Mattress Cross Section A-A'
Updated Slope Stability Evaluation
Former Buffalo Color Site