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of Engineers ®
San Francisco District

Redwood City Harbor, California, Navigation Improvement Feasibility Study

Appendix D

Geotechnical Engineering

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1 Purposes of Report

This report summarizes the geotechnical information used to support the planning and Federal interest determination of a civil works navigation project in the Redwood City Harbor and San Bruno Shoal Channels. The project is referred to as the "Redwood City Harbor, California, Navigation Improvement Feasibility Study" or the "study" in this report. A brief summary of available geotechnical, O&M dredging, and spatial constraint information is summarized as possibly impacting and supporting the decision to select a 3H: 1V dredging excavation cut slope for the deepening project. Refer also to the Civil Design Appendix for additional information and discussion pertaining to these issues. Suggestions for additional data collection, analyses and study are also provided in brief summary. This report will serve as an appendix to the study's integrated feasibility study and environmental impact statement report.

2 Background

The study area is Redwood City Harbor, located in San Mateo County, CA on the southwest side of San Francisco Bay, about 18 miles south of San Francisco, CA. The study area includes two existing navigation channels: the Redwood City Harbor and San Bruno Shoal Channels (Figure 1). The Redwood City Harbor Channel extends from the mouth of Redwood Creek to deep water in the San Francisco Bay, while the San Bruno Shoal Channel is located northeast of San Francisco International Airport. Both channels currently have an authorized depth of 30 feet mean lower low water (MLLW) with 2 feet of allowable over depth maintenance dredging.

Figure 1. Study area

3 References and Summary of Previous Investigations

The primary reports used as references to assist with evaluating and selecting the feasibility-level excavation cut slope suitability are;

(1) – December, 2012 "Geotechnical Data Report" (GDR) prepared by Fugro, Inc. for HDR Engineering, Inc. & the US Army Corps of Engineers, San Francisco District (USACE);

(2) - May 20, 2011, Survey Report: Sub-Bottom Profiler Survey – Combined Bathymetry/Sub-Bottom Profile Survey – Redwood City and San Bruno Shoals Deepwater Ship Channels Final Report prepared by Seavision Underwater Solutions for the USACE and to a lesser extent;

(3) – September 23, 2011 Geotechnical Progress Report – Wharves 1 and 2 – by Treadwell and Rollo for the Port of Redwood City and;

(4) – February 17, 1999 "Geotechnical Investigation" Report prepared by Hultgren-Tillis Engineers for Moffat & Nichol Engineers for RMC Lonestar's Redwood City, California wharf facilities.

Sampling of soils in the study area indicates there are three broad generalizations of sedimentary units that may be encountered during excavations; (1) – Young Bay Mud; (2) – Bay deposits (Sand) and (3) – Old Bay Mud. Figures 2 (Plan of Fugro GDR Report borings), 3, 4, and 5 (cross sections from the above reports) demonstrate typical observed conditions.

The Young Bay Mud generally consists of very soft to soft, appears gray to grayish green and black, and has fine sands-to-fat clays grading form courser to finer gradations. These are the more recent marine sediments that are exposed at the mud-line throughout the project area at both channel locations. These soils have a high water contents, high plasticity, and often contain shell fragments and organics. In the Redwood City Channel, Young Bay Mud extends to depths between -24 and -54 feet with deeper occurrences generally trending towards the north end of the channel and shallower occurrences taking place to the south. As depth increases more consolidation results in stiffer clays in the Young Bay Mud.

Below the Young Bay Mud the soil encountered generally consists of soft to stiff gray to olive brown to light brown lean clay (CL's) with varying amounts of sand and lesser amounts of fat clay with sand, sand and clayey sand. This material has been characterized as alluvial deposits and generally has a lower water content and lower plasticity than the overlying Young Bay Mud. It has been classified as a sandier Bay Deposit found between the Young and Old Bay Mud deposits and is not consistently observed throughout the Bay Area but has been observed in the San Bruno Shoal area.

Underlying the Young Bay Mud is a firm, stiff, dark greenish-gray silty clay. It is typically very stiff and over-consolidated clay that is markedly different from overlying Young Bay Mud by virtue of the presence of greater compressive strength, thin sand and gravel lenses, and absence of shell fragments in the clay. This material may or may not impact selection of excavation cut-slope(s) because of stability but could impact selection of optimum dredging equipment type(s) depending on aerial extent and depth of occurrence by alternative.

Figure 2. Plan View of Redwood City Harbor Boring Locations from Fugro Geotechnical Data Report.

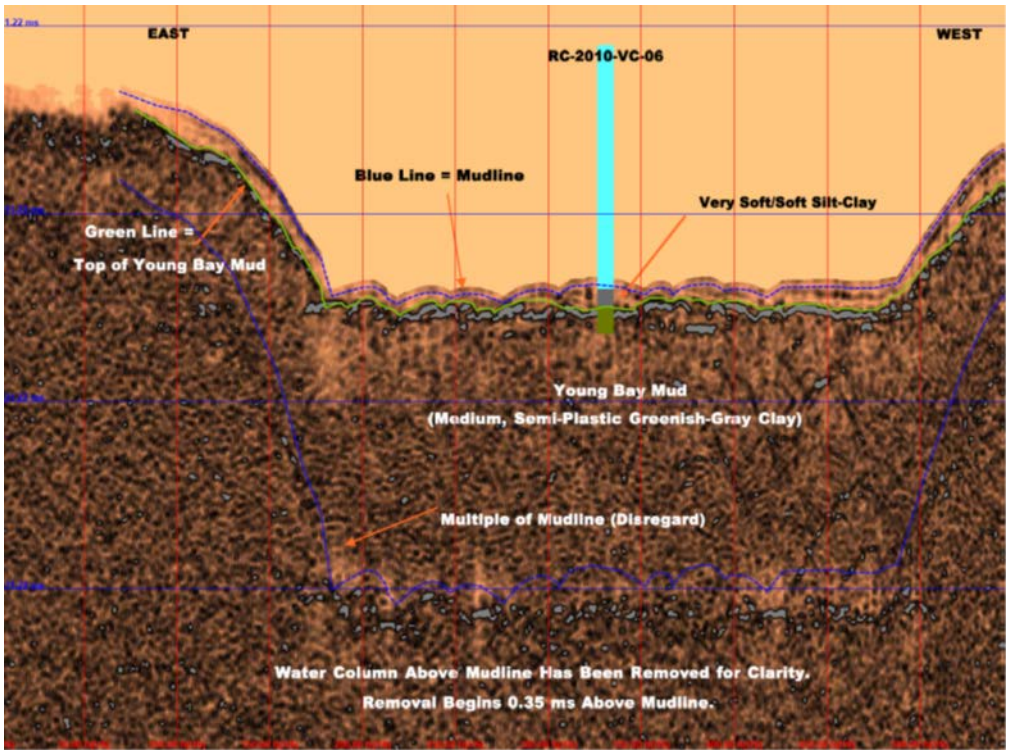

Figure 3. Typical Section – Station 124+00 – Redwood City Harbor Channel – Seavision Sub-Bottom Profiler Report.

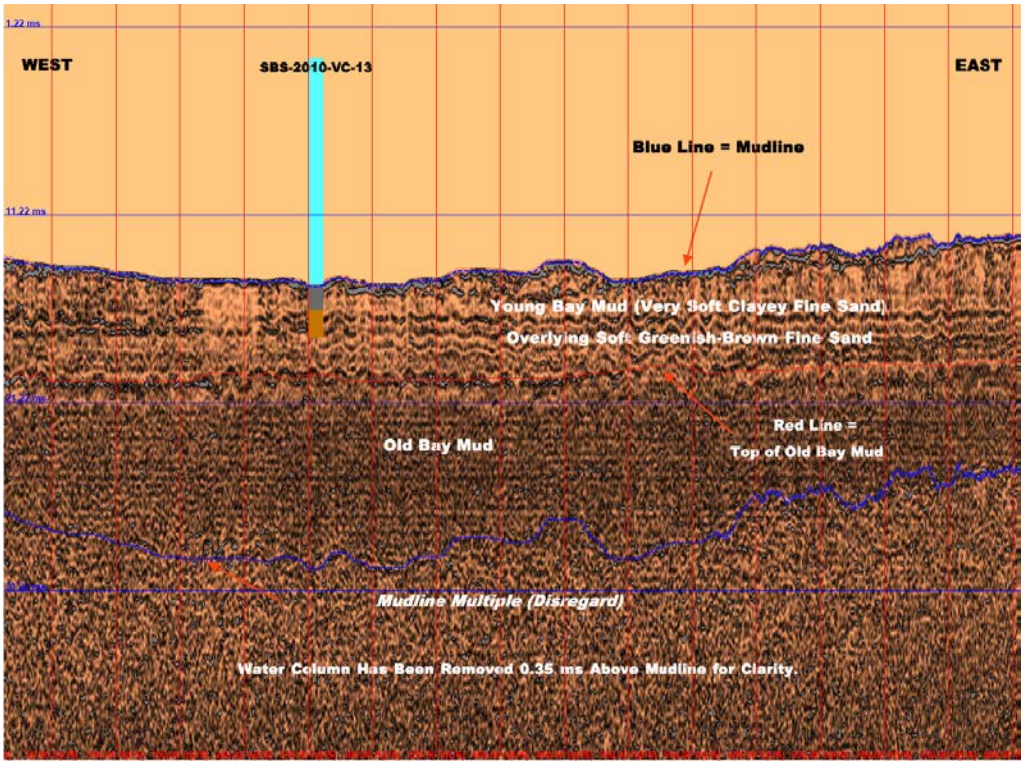

Figure 4. . Typical Section – Station 180+00 – San Bruno Shoals Channel – Seavision Sub-Bottom Profiler Report.

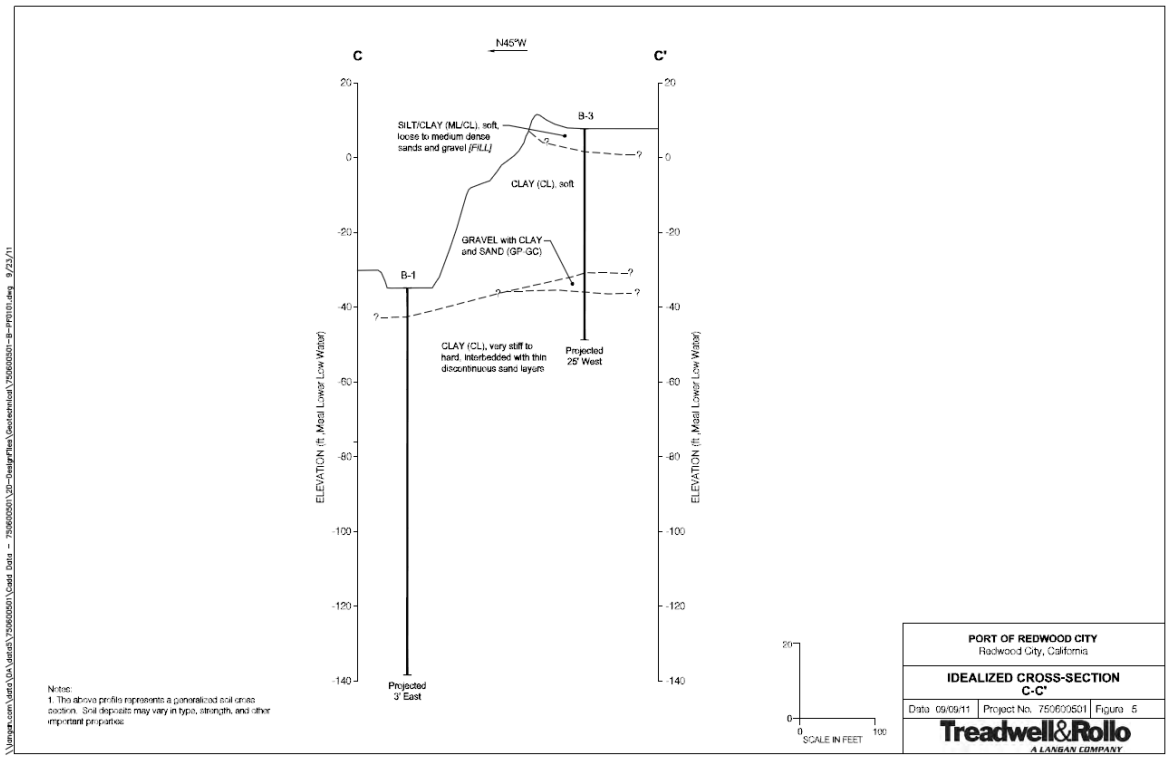

Figure 5. Typical Section in Wharf Area – Treadwell and Rollo Report

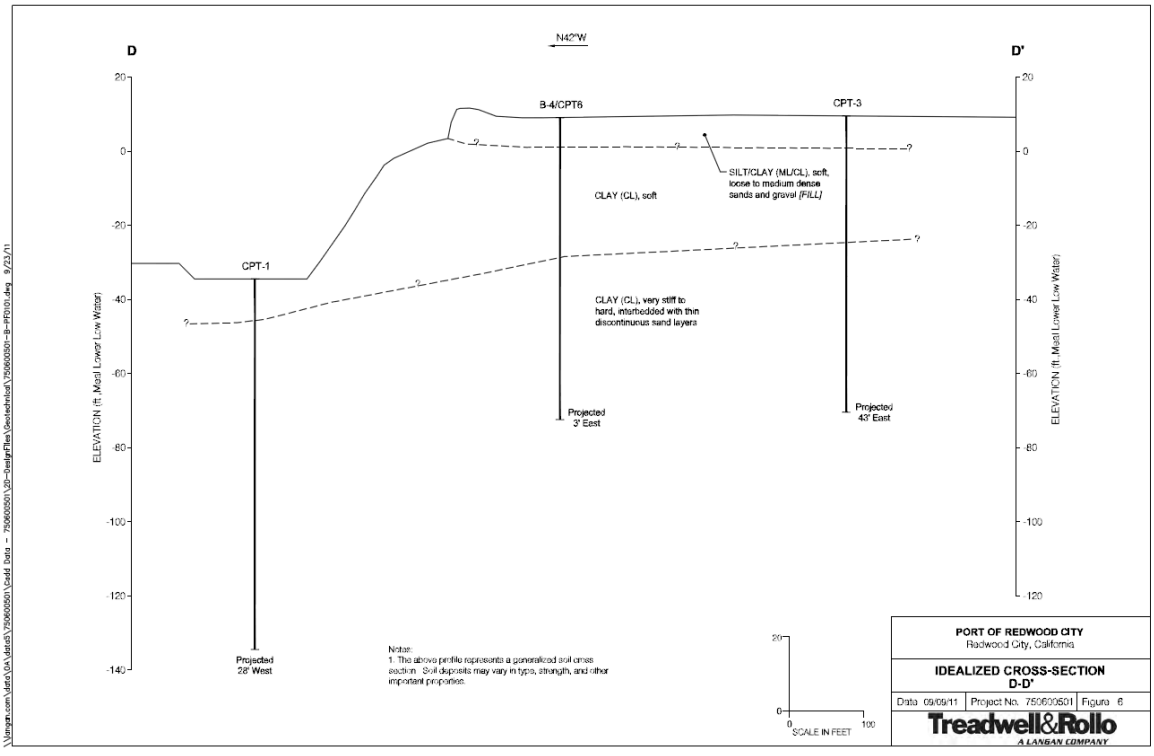

Figure 6. Typical Section in Wharf Area – Treadwell and Rollo Report

The existing and proposed slope of the deepening excavations along the alignment of the project can become unstable under seismic or static conditions. Detailed stability evaluations

of the proposed 3H: 1V excavation cut slopes were not performed for feasibility-level study. However, final slope selection will be analyzed and the future slope(s) designed and constructed in accordance with EM 1110-2-1902 (USACE 2003).

4 Operations and Maintenance Dredging

The Redwood City Harbor channels range from 300 to 900 feet wide and are about 20,800 feet long. The project area currently requires operations and maintenance (O&M) dredging to remove sediment deposition and ensure safe navigation by vessels in and out of the channel. Slopes are excavated to near 3H: 1V. The Entrance Channel, Outer Harbor Turning Basin, Connecting Channel and Inner Harbor Turning basin are dredged every 1 to 2 years and were last dredged in 2014. The San Bruno Channel is only dredged about every 10 years, and was last dredged in 2005.

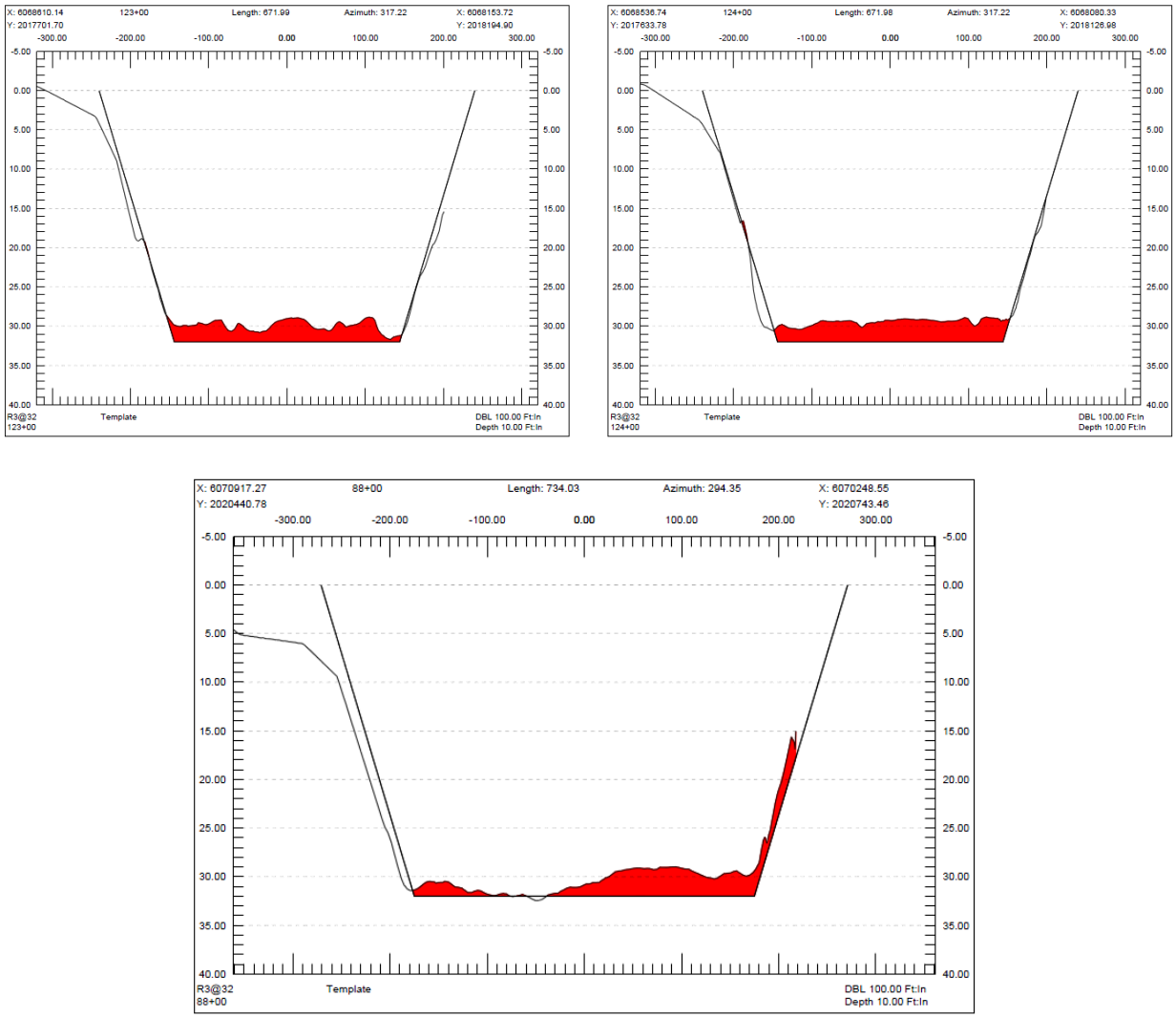

Figure 7. Typical O&M Dredging Sections – Existing Slopes (Curved Lines) Next to 3H: 1V Planned Slopes (Straight Lines) Demonstrating Acceptability of Proposed 3H: 1V Excavation Cut Slopes.

Figure 7 demonstrates typical 2014 pre-dredge existing ground surfaces along more critical areas of the project (Reaches 3 and/or 4 that are bordered by the Bair Island Wildlife Refuge). Note existing slopes are stable at the present 3H: 1V steepness. They may be stable at steeper slopes in certain areas. Represented on these sections is the 32-foot deepening alternative. Also of note is the approximately 3H: 1V existing O&M slopes have held up very well during over 50 years of project operations. No caving or loss of ground has been observed near the critical environmental habitat areas. This demonstrates the selected 3H: 1V excavation slopes are acceptable for feasibility estimating purposes.

The existing mud-line along the San Bruno Shoal Channel appears to be deepest in the center of the channel (elevations near 34 feet MLLW) in comparison to outer edges (small areas approaching elevation 28 MLLW) which has partially justified the reduced frequency of O&M dredging operations along this part of the project. Increased or decreased expected O&M frequency and/or dredging quantities for the TSP alternative depth and proposed alignment should be confirmed with additional study.

5 Avoiding Adjacent Environmentally Sensitive Areas

Refer to the Civil Design Appendix for detailed discussions concerning this issue.

6 Conclusions and Recommendations

Excavation cut slopes of 3H: 1V were determined appropriate for feasibility-level study of the TSP focused alternatives array based on the following reasoning:

(1) – Project O&M dredging episodes over the past 50 years have demonstrated adequate performance of 3H: 1V excavation cut slopes;
(2) – USACE experience on other projects in the Bay Area indicate 3H: 1V cut slopes are appropriate;
(3) – The selected 3H: 1V cut slope daylights within the existing channel so as to avoid impacts to surrounding environmentally sensitive areas located on both sides of the project leading into the wharf area; and
(4) – Review of available geotechnical reports and supporting information indicates soils to be encountered during project excavations are suitable in providing stable 3H: 1V cut slopes.

There is the possibility during future investigations and analyses to identify localized areas within the channel excavation that may not meet with bar pilot navigation desires to maintain existing channel bottom width(s), may unnecessarily encroach upon surrounding environmentally sensitive areas, and/or require adjustments to turning radius to maximize efficiency leading into the Port of Redwood city. Ship modeling studies are planned during future study to identify and evaluate potential operational constraints and possible impacts to alignment and channel location while optimizing efficiency. One option to address and minimize any potential negative impacts resulting from these studies would be to provide localized over-steepening of excavation cut slopes in the bottom of the channel.

Areas where localized over-steepening of cut slopes is selected as an option should be further investigated and evaluated from a geotechnical slope stability perspective. Borings, samples and laboratory testing are recommended in the location-specific over-steepening areas and to minimum depths of 10 feet below expected channel bottom to allow more detailed stability analyses to be done in these areas. The geotechnical investigation program should be coordinated with any environmental sampling and testing along the sides and bottom of the channel for efficiency and minimizing cost for the two programs.

Additional sampling and testing in the future, (after completion of TSP efficiency studies and for final design), along the sides and centerline of the channel should also be conducted a minimum of 10 feet below the planned maximum depth (including O&M over-excavation) of the channel bottom. Investigations should be spaced at appropriate intervals based on evaluation and determination of expected materials variability across the site during these later phases of study.

Further details for these future geotechnical investigation programs will be provided at a later date.