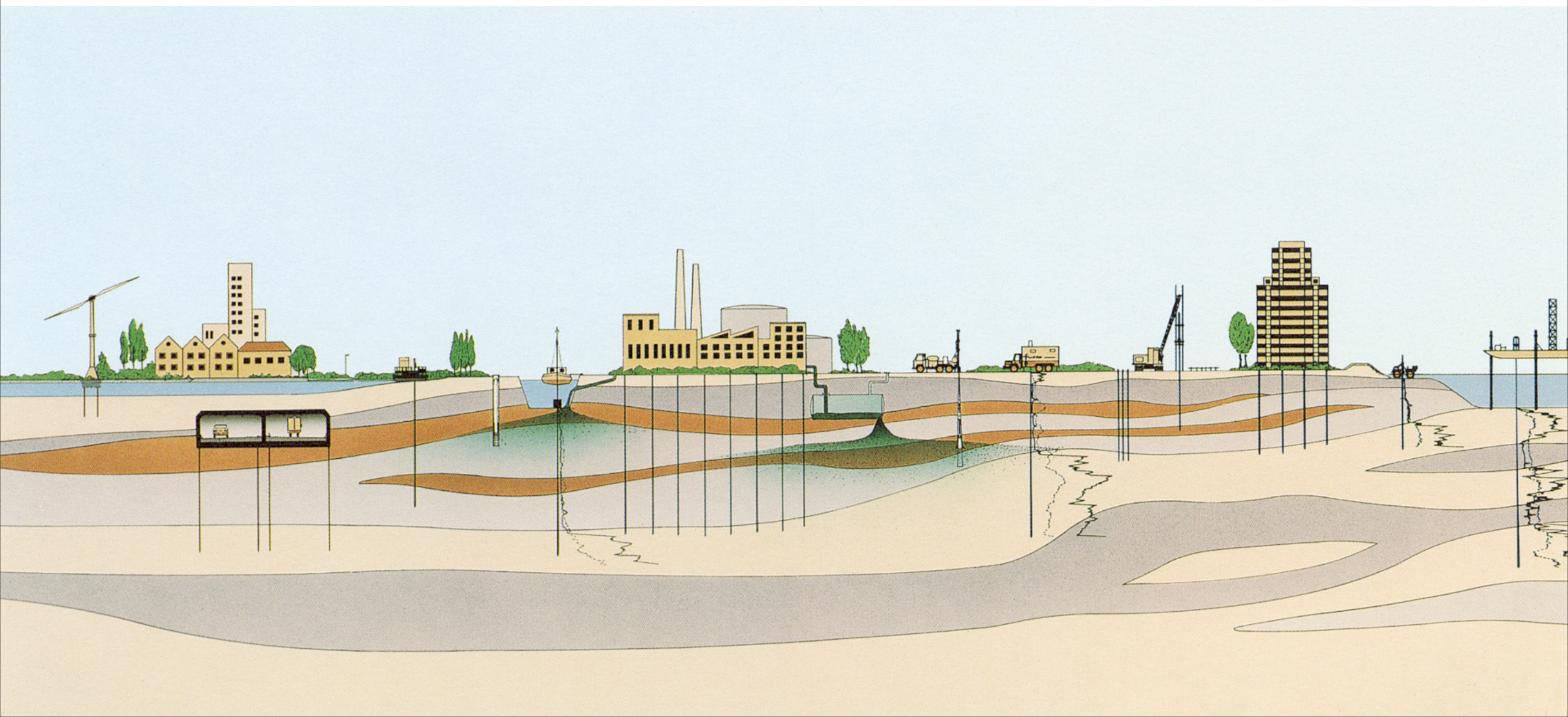
FUGRO WEST, INC.

GEOTECHNICAL EVALUATION
MAIN CHANNEL DEEPENING PROGRAM
PORT OF LOS ANGELES

VOLUME 1

Prepared for:
CITY OF LOS ANGELES HARBOR DEPARTMENT

August 1997



FUGRO WEST, INC.

5855 Olivas Park Drive
Ventura CA 93003-7672
Tel: (805) 650-7000
Fax: (805) 650-7010

August 31, 1997
Project No. 96-42-1215

City of Los Angeles Harbor Department
Harbor Department Administration Building
425 South Palos Verdes Street
San Pedro, California 90731

Attention: Mr. Richard Wittkop

Geotechnical Evaluation Report
Channel Deepening Program
Port of Los Angeles

This geotechnical evaluation report presents, discusses, and summarizes Fugro's characterization of stratigraphic conditions that underlie the various waterways of the Inner Harbor. The stratigraphic characterization and information contained within this report have been generated to support the Port of Los Angeles' proposed Channel Deepening Program and were authorized by Task IV of LAHD Agreement No. 1948.

The associated field exploration programs and preparation of this report were performed by Fugro West, Inc., in association with Kinnetic Laboratories, Inc. Fugro has provided general project management and has evaluated the geological and geotechnical aspects of the project, while Kinnetic Laboratories has evaluated environmental considerations of the Channel Deepening Program. The environmental considerations are presented in separate reports that have been prepared by Kinnetic Laboratories and ToxScan, Inc.

On behalf of the project team, we appreciate this opportunity to provide our services on this unique and interesting project, and look forward to our continued association with the Port of Los Angeles. Please contact us if you have questions or comments regarding this report and/or the Channel Deepening Program.

Sincerely,

FUGRO WEST, INC.

Gregory S. Resnick, P.E.
Project Engineer

Thomas W. McNeilan, P.E., G.E.
Vice President

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SUMMARY

Fugro West, Inc. (Fugro), has completed geological and geotechnical studies of the various waterways in the Inner Harbor of the Port of Los Angeles (POLA) to support the proposed Channel Deepening Program. The studies were conducted to document and evaluate the types and in situ physical characteristics of geologic materials present beneath the waterways. In concert with Fugro's geological and geotechnical studies, Kinnetic Laboratories, Inc. (KLI), under subcontract to Fugro, performed sampling and testing for the required environmental components of the investigations. The results of the environmental components are presented in separate reports prepared by KLI.

The first component of Fugro's study included a detailed review of existing geological and environmental data sources. Relevant data from existing data sources were used for a preliminary evaluation of shallow subsurface conditions, delineation of preliminary dredge units and environmental sampling subunits, and to develop recommended scopes of work for the field exploration programs. The field exploration programs, which were performed in two phases, included: a) cone penetration tests, b) vibrocore sampling for both environmental and geological purposes, and c) geotechnical laboratory testing. Results of those explorations and testing are included in three appendices to this report.

The new field and laboratory data, in combination with the factual information contained in various existing data sources, were used to re-evaluate and revise the interpreted shallow subsurface conditions throughout the Inner Harbor. Based on the stratigraphic interpretation and anticipated material types, eight preliminary dredge units have been established in the Inner Harbor for the Channel Deepening Program.

Four of the eight dredge units (i.e., CG-1 through CG-4) cover about 265 acres of the Inner Harbor and are underlain primarily by native coarse-grained sediments that are considered desirable, from an engineering standpoint, for use in the Pier 400 landfill. These dredge units are located in the middle two-thirds of the Main Channel, north West Basin, northeastern Turning Basin, and southwestern East Basin Channel areas of the Inner Harbor. For a dredge elevation (El.) of -52 feet, the total sediment volume in dredge units CG-1 through CG-4 is estimated to be about 1.87 million cubic yards. An additional 1.7 to 2.8 million cubic yards of desirable sediment could be mined from these dredge units between elevations of about -52 and -65 feet.

Fine-grained sediments and formation materials that are considered undesirable for use in the Pier 400 landfill predominate in the other four dredge units (i.e., FG-1 through FG-3, and FM-1). Other possible disposal options for these sediments could include ocean disposal at LA-2 or LA-3, placement in the Cabrillo Shallow Water Habitat Extension, placement into dredged borrow pits in the Inner or Outer Harbors, and/or upland disposal. Dredge units FG-1 through

FG-3 are located in the: 1) northern Main Channel and southwestern Turning Basin areas; 2) southern and eastern West Basin Channel areas; and 3) northeastern East Basin Channel, East Basin, and Cerritos Channel areas. The FG dredge units cover about 250 acres of the Inner Harbor, with a cumulative estimated dredge volume of about 1.53 million cubic yards for a target elevation of -52 feet.

Formation materials with inclusions of rock are present in the northern Glenn Anderson Ship Channel and extreme southern Main Channel areas, corresponding to dredge unit FM-1. The FM dredge unit covers about 130 acres and adds about 815,000 cubic yards of sediment.

Throughout most of the Inner Harbor, non-native harbor bottom sediments are present above the native sediments. The harbor bottom sediments are of variable composition and thickness, and are generally considered undesirable for use in the Pier 400 landfill.

Using the stratigraphic interpretation as summarized above, dredge-volume versus material-type estimates were performed for the entire Inner Harbor assuming a final dredge elevation of -52 feet and a total dredge volume of 4.2 million cubic yards. Fugro's estimates suggest that about:

- 25 to 30 percent (about 1 to 1.25 million cubic yards) are non-native harbor bottom sediments;
- 32 to 38 percent (about 1.35 to 1.6 million cubic yards) are coarse-grained sediments;
- 18 to 24 percent (about 0.75 to 1 million cubic yards) are fine-grained sediments; and
- 15 percent (about 0.65 million cubic yards) are formation materials.

The geological data and conclusions contained within this report, in combination with the environmental data and conclusions contained within KLI's reports, will form the primary basis for establishing a selective dredging and disposal plan for the Channel Deepening Program.

INTRODUCTION AND BACKGROUND

Channel Deepening Program

The Port of Los Angeles (POLA) is currently planning their Channel Deepening Program, which is directed at improving navigational conditions throughout the Inner Harbor. It is our understanding that the Channel Deepening Program will be divided into three different components:

1. Channel and basin dredging
2. Utility deepening and/or relocation
3. Berth improvements

The first component is directed at deepening the various channels and basins within the Inner Harbor (e.g., the Main Channel, Turning Basin, West Basin, East Basin Channel, and East Basin). Those areas (shown on Plate 1) will be deepened to an elevation of -50 feet relative to mean lower low water (MLLW). Including a 2-foot overdredge allowance, the deepening may extend to El. -52 feet. Localized areas may be further deepened to obtain additional coarse-grained sediments for deposition in the Pier 400 landfill or other areas in POLA. We note that a portion of the south Main Channel (i.e., a portion of dredge unit CG-1, which is discussed in a subsequent section of this report) was deepened to about El. -50 feet in May 1997 to obtain desirable borrow materials for the Pier 400 Stage 1 landfill.

Relative to use in the Pier 400 landfill, both desirable (e.g., sand and silty sand) and undesirable (e.g., silt, clay, formation) sediments are present throughout the Inner Harbor. The desirable sediments may be placed in the Pier 400 Stage 1 and/or Stage 2 landfills. For the undesirable sediments, several dredge disposal alternatives are currently being considered including: Pier 400 landfill, Cabrillo Shallow Water Habitat extension, ocean disposal at LA-2 or LA-3, upland disposal, and potential Confined Aquatic Disposal (CAD) sites.

At several locations, utility lines cross beneath the various channels and basins and are buried at various depths below the current harbor bottom (i.e., mudline). The current design burial depths were typically based on mudline elevations of about -47 feet or higher. Therefore, to deepen the Inner Harbor, some or all of the existing utility lines will have to be relocated and/or reburied at greater depths. The redesign of utility crossings reportedly will be based on a top elevation of -65 feet.

The third component of the Channel Deepening Program is directed at improvements (i.e., deepening) along specific berthlines. It is our understanding that the following berths are currently being considered for improvement:

Berths	Tenant
121-126	Yang Ming (formerly APL) Container Terminal
136-139	TransPacific Container Service Corp. Terminal
212-221	NYK Container Terminal
226-232	Evergreen Container Terminal

The discussions, summaries, and conclusions provided within this report primarily address factors associated with the first component of the Channel Deepening Program, in particular, the second phase of channel and basin deepening. The data contained herein also will be useful for the second (i.e., utility relocation) and third (i.e., berth improvement) components; however, a greater amount of site-specific evaluations will be required for those components.

Because of the dynamic and constantly changing nature of this project, recommendations for the subsequent components of the Channel Deepening Program will be provided in other reports as further details are established and additional evaluations are performed.

Completed Investigations and Reports

Field Program Assessment Reports. To initiate and facilitate the Channel Deepening Program, the Los Angeles Harbor Department (LAHD) contracted Fugro to prepare a preliminary Field Program Assessment report (Fugro, 1996a) in Spring 1996. One of the primary purposes of Fugro's preliminary (i.e., initial) report was to condense and summarize existing stratigraphic and chemistry/bioassay data that are considered relevant to the planned deepening of the Inner Harbor. The existing data provided the basis for Fugro's (1996a): a) preliminary characterization of stratigraphic and environmental conditions throughout the Inner Harbor; b) preliminary delineation of eight separate dredge units within the Inner Harbor; and c) development of a Phase 1 field exploration program. The eight preliminary dredge units (locations of which are shown on Plates 2a and 2b) generally define the limits of where significant deposits of coarse-grained (i.e., sand and silty sand) versus fine-grained (i.e., silt and clay) sediments are present within the various channels and basins of the Inner Harbor. The preliminary dredge units also were used to define environmental sampling subunits for both the Phase 1 and Phase 2 investigations.

The summaries, conclusions, and recommendations contained within Fugro's (1996a) preliminary report were the primary basis for the Phase 1 geotechnical and environmental investigations that were performed in August and September 1996. The data obtained from the Phase 1 investigations were integrated with the existing data to supplement Fugro's (1996a) preliminary stratigraphic interpretation. Furthermore, the data and conclusions from the Phase 1 investigation also were used to re-define preliminary dredge units and provide recommendations for the Phase 2 investigation, as presented in the Phase 2 Field Program Assessment report (Fugro, 1996c). Therefore, the Phase 2 Field Program Assessment report (Fugro, 1996c) superseded the preliminary Field Program Assessment report (Fugro, 1996a). In turn, the data, conclusions, and recommendations contained within this current report generally supplement and supersede those contained in Fugro's (1996a, 1996c) two Field Program Assessment reports.

Phase 1 and Phase 2 Investigations. Both geotechnical and environmental investigations are required for the channel and basin dredging component of the Channel Deepening Program. Two phases (i.e., Phase 1 and Phase 2) of geotechnical and environmental investigations were performed. Using Fugro's (1996a) preliminary stratigraphic and environmental characterization, and taking into account other factors associated with the Pier 400 Stage 1 landfill, Fugro and KLI formulated a recommended Phase 1 investigation. The recommended Phase 1 investigation, as presented by Fugro (1996a), was performed in mid to late 1996 and was primarily directed at verifying interpreted stratigraphic conditions, supplementing the existing database, redefining dredge unit boundaries, and evaluating sediment chemistry characteristics in dredge unit CG-1. Emphasis was placed on dredge unit CG-1, because additional coarse-grained material was required for fill in the Pier 400 Stage 1 landfill.

The Phase 1 investigation performed by Fugro and KLI included a detailed stratigraphic and environmental evaluation of dredge unit CG-1 (Phase 1A investigation), and a more general stratigraphic evaluation of the other areas (i.e., dredge units) within the Inner Harbor (Phase 1B investigation). Results and conclusions of the Phase 1A investigation (of dredge unit CG-1) are presented in two separate reports prepared by Fugro (1996b) and KLI/ToxScan (1996). Data from the Phase 1B investigation are presented in the Phase 2 Field Program Assessment report (Fugro, 1996c).

The Phase 2 investigation, the scope of which was recommended by Fugro (1996c), was performed in early 1997 and was primarily directed at evaluating sediment chemistry and bioassay characteristics in the seven remaining dredge units (i.e., CG-2 through CG-4, FG-1 through FG-3, and FM-1). In addition, data from the Phase 2 investigation also were used to verify or modify interpreted stratigraphic conditions as presented by Fugro (1996c). Fugro's current interpretation of stratigraphic conditions and associated sediment properties are presented within this current report. Details related to the environmental components of the Phase 2 investigation are presented in a separate report that was prepared by KLI/ToxScan (1997a), under subcontract to Fugro.

Authorization

The scope of geotechnical and environmental services for the Main Channel Deepening Program was outlined in Fugro's Revised Proposal for Geotechnical Services for the Main Channel Deepening Program, dated January 31, 1997. The work was completed as Task V of LAHD Agreement No. 1948, which was executed on March 26, 1997. The environmental sediment evaluation for the Main Channel Deepening Program, as defined by Task V of LAHD Agreement No. 1948, was completed by KLI under subcontract to Fugro.

Report Organization

Following this *Introduction and Background* section, our Volume 1 report presents and discusses the *Relevant Conditions Within the Inner Harbor*, and summarizes *Existing Stratigraphic and Environmental Data Sources.* The next sections present our *Definition of Preliminary Dredge Units* and discusses the *Field Exploration and Laboratory Testing* that were performed specifically for the Channel Deepening Program. Those sections are followed by descriptions of *Interpreted Shallow Stratigraphic Conditions* and *Sediment Properties and Characteristics*. The final sections of this report present *Estimated Dredge Volumes Versus Material Types* and *Mining Options for Coarse-Grained Sediments*. Illustrations and maps that portray site and subsurface conditions follow the report text in Volume 1. Factual field and geotechnical laboratory data are presented in Volume 2 as Appendices A through D.

Related Reports

In addition to this geotechnical report, there are several other letters and reports that relate to the scope of work completed for the Main Channel Deepening Program. These letters and reports include:

- KLI's Environmental Evaluation of Sediments for the Channel Deepening Program (KLI/ToxScan, 1997a).
- Fugro's letter describing the Side Scan Sonar Survey of Bedrock Formation Dredge Area FM (Fugro, 1997g) completed per the requirements of Item J of Task IV of LAHD Agreement 1948.
- Four Fugro letter reports presenting the In Situ "Tethered" Cone Penetration Test Results for four container wharf alignments in the Inner Harbor (Fugro, 1997c through 1997f).
- Fugro's Geotechnical Report for the Department of Water and Power (DWP) reclaimed water pipeline across the Turning Basin (Fugro, 1997b) completed per the requirements of Task V of LAHD Agreement 1948.
- Fugro's Geotechnical Report for the Department of Public Works (DPW) relocated Fries Avenue force main under the East Basin Channel (Fugro, 1997a) completed per the requirements of Change Order 1 of LAHD Agreement 1948.
- KLI's Environmental Evaluation of the Sediments to be Removed for the DWP Reclaimed Water Pipeline Crossing (KLI/ToxScan, 1997c) completed per the requirements of Task V of LAHD Agreement 1948.

Limitations

This geotechnical study has been prepared for the LAHD solely for planning, design, and other considerations associated with the Main Channel Deepening Program. The applicability of this report is specifically limited to current conditions and considerations for the proposed pipeline. Data, results, evaluations, conclusions, and recommendations contained in this report are directed at and intended to be utilized within the scope of work contained in LAHD Agreement No. 1948 and Fugro's January 31, 1997, revised work scope and fee proposal. This report is not intended to be used for any other purposes.

In performing our professional services, we have used that degree of care and skill ordinarily exercised under similar circumstances by reputable geotechnical engineers currently practicing in this or similar localities. No other warranty, express or implied, is made as to the professional advice included in this report. Fugro West, Inc., makes no claim or representation concerning any activity or conditions falling outside the specified purposes to which this report is directed.

The interpretation of general subsurface conditions is based on subsurface conditions observed at exploration locations only. The information interpreted from those explorations has been used as a basis for our interpretations. Conditions may vary at locations not investigated by our explorations. Subsurface conditions also may change with time due to either natural phenomena or people's activities. We note that any statements, or absence of statements, in this geotechnical report regarding odors, unusual or suspicious items, or conditions observed are strictly for descriptive purposes and are not intended to convey engineering judgment regarding potential hazardous/toxic assessment.

Users of this report should recognize that the construction process is an integral design component with respect to the geotechnical aspects of a project, and that geotechnical engineering is an inexact science due to the variability of natural and man-induced processes that can produce unanticipated or changed conditions. Proper geotechnical observation and testing during construction thus are imperative in allowing the geotechnical engineer the opportunity to verify assumptions made during the design process. Therefore, we recommend that Fugro be retained during construction to observe compliance with the design concepts and geotechnical recommendations, and to allow design changes in the event that subsurface conditions or methods of construction differ from those anticipated.

RELEVANT CONDITIONS WITHIN THE INNER HARBOR

Bathymetric Conditions

In late March and early April 1996, the Port of Los Angeles performed a bathymetric survey of the Inner Harbor, including all areas that may or will be dredged during the first component of the Channel Deepening Program. The bathymetric data are shown on Map 1 and have been filtered to show three ranges of elevations: 1) higher than El. -45 feet (yellow); 2) between El. -45 to -52 feet (light blue); and 3) lower than El. -52 feet (purple). The El. -45 foot level was chosen because most of the areas to be deepened during the Channel Deepening Program were dredged to about El. -45 feet in 1981 to 1983 as part of the U.S. Army Corps of Engineers (COE) Harbor Deepening Project (COE, 1980a,b), and the El. -52 foot level was specified because the Channel Deepening Program is being designed for El. -50 feet with 2-foot overdredge allowance.

As indicated on Map 1, much of the Inner Harbor bathymetry lies between El. -45 to -52 feet, with shallower areas generally limited to the edges of the channels and basins. We note a majority of the El. -45 to -52 feet area shown on Map 1 is at elevations lower than about -48 feet. There are several areas within the Inner Harbor where the current harbor bottom is at or below El. -52 feet. The larger areas are located: 1) in the middle Main Channel outboard of Berths 230 through 233; 2) in the southern and middle portions of the Turning Basin; and 3) at the north end of the West Basin. At least two of those locations were used as borrow sources for materials to fill old slips (e.g., Slip 228) within the Inner Harbor.

As previously noted, a portion of the south Main Channel was deepened to about El. -50 feet in May 1997. The area that was deepened corresponds to the eastern side of dredge unit CG-1. The Inner Harbor bathymetric survey performed by POLA (in April 1996) pre-dates the May 1997 dredging and, therefore, does not represent current harbor bottom conditions within the eastern portion of dredge unit CG-1, between POLA survey stations 72+00 and 94+00 feet.

Estimated Dredge Volumes

To support the Channel Deepening Program, the survey division of POLA established a survey control line and stationing (shown on Map 1), and performed a bathymetric survey and dredge-volume calculations. Based on the bathymetric data and preliminary dredge-cut geometries, dredge volumes were reportedly estimated to be about: 2.4 to 2.5 million cubic yards for dredging to El. -50 feet; and 1.6 to 1.7 million cubic yards for overdredge (i.e., between El. -50 and -52 feet). Thus, the total potential dredge volume is estimated to range from about 4 to 4.2 million cubic yards. That volume does not include sediments that will be removed: a) from the Cerritos Channel, b) as part of the West Basin Entrance Widening Project, and c) during the third component of the Channel Deepening Program (i.e., berth improvements). Of the total volume noted above, about 160,000 cubic yards have already been removed from the eastern portion of dredge unit CG-1 during the May 1997 dredging activities.

We note that the above-stated volumes are based on survey drawings (dated April 1, 1996) and dredge volume worksheets (dated April 5, 1996) provided by POLA. It is our understanding that revised drawings and volume calculations are being created. The changes relative to estimated volumes are reportedly minor in comparison to the overall dredge volume.

Utility Crossings

At several locations throughout the Inner Harbor, utility lines cross the channels and basins, as shown on Map 1. The utilities include oil, water, sewer, fuel, power, and telephone lines. Based on a "Channel Deepening Program, Utility Crossings" draft drawing (dated May 3, 1996) provided by POLA, and using the drawings for the COE's maintenance dredging project (COE, 1995), the following utility lines (from south to north) are reportedly present:

Type of Utility	Size/Diameter (inch)	Elevation (feet, MLLW)	Approximate Crossing Location (Berth No.)
Oil	36	-50	81 to 236
Water	20	-45	84 to 234
Sewer	2 @ 20	-55	85 to 234/235
Telephone	2 Cables	-60	85 to 234
Telephone	Cable	-50	91/92 to 229/230
Sewer	30	-54	94/95 to 226
Fuel	3 @ 18	-60	97 to 226
Sewer	30	-51	170 to 221/222
Power	2 Cables	-50	173/174 to 218
Oil	4 @ 10-24	-60	176 to 216
Water	24	-55	176 to 215/216

We note that the above summary is based on data provided by POLA. Fugro did not verify the existence, location, and elevation of the various utilities. This list is not considered all inclusive and other utilities may exist.

Outfalls

There are numerous outfalls (e.g., storm drains) that empty into the Inner Harbor of the POLA. The outfalls range in size from small, secondary drains to large, primary outlets (e.g., 14- by 12-foot boxes). POLA has compiled, on an untitled map, a summary of outfalls that are 36 inches in diameter or larger. A copy of that map was provided to Fugro and is the basis for the outfalls shown on Map 1.

As shown on Map 1, there are about 20 to 25 outfalls (measuring 36 inches in diameter or larger) that empty into the Inner Harbor. Most of those outfalls are located in three general regions: 1) Southwest Slip near Berths 109 through 115; 2) northern portions of the West Basin that correspond to Berths 127 through 142; and 3) along the southeastern edge of the East Basin, East Basin Channel, and northern Main Channel, corresponding to about Berths 206 through 232.

West Basin Entrance Widening Project

Related to the Channel Deepening Program is the West Basin Entrance Widening Project. POLA is currently widening the entrance to the West Basin by creating a new pierhead alignment that cuts diagonally from Berth 97 to Berth 101. The project includes demolition of Berths 97 to 101, removal of sediments in front and behind the current berthlines, and construction of a new pierhead alignment. Removal of the sediments was ongoing during the Phase 2 investigation for the Channel Deepening Program. The sediments from the West Basin Entrance Widening Project were reportedly placed in several locations, including: a) Pier 400 Stage 2 landfill area, b) LA-2 ocean disposal site, and/or c) upland disposal in the backland areas directly behind the new pierhead alignment.

EXISTING STRATIGRAPHIC AND ENVIRONMENTAL DATA SOURCES

Introduction

Prior to developing and executing the Phase 1 and Phase 2 investigations, Fugro performed a detailed review of relevant existing data sources, a summary of which is provided in the following paragraphs. The primary purposes of the data review were to: 1) identify and evaluate relevant existing data; 2) establish the existing level of knowledge relative to stratigraphic and environmental conditions within the project area; 3) identify areas of the Inner Harbor where additional stratigraphic and environmental data were needed; 4) delineate and define preliminary dredge units; and 5) help develop recommended scopes of work for the required stratigraphic and environmental investigations.

The existing data sources are primarily related to: 1) geotechnical studies for specific berths; 2) sediment chemistry and bioassay studies for maintenance dredging adjacent to specific berths; 3) other studies addressing large areas of the channels and basins rather than individual berths; 4) geophysical surveys; and 5) pre-development morphology maps. Those existing data sources are discussed separately in subsequent sections of this report. Emphasis is placed on those data sources that provide information in the channels and basins, as compared to information along and close to specific berthlines.

A shorthand listing of the existing data sources is provided on Plates 3a and 3b. For each data source, Plate 3 summarizes primary location/berth number, type of study, existence/nonexistence of sediment stratigraphy data, and type of explorations. If the report provides adequate data, Plate 3 also lists the number of explorations and approximate bottom elevation of the deepest exploration. Complete citations of the data sources are provided in the *References* section at the end of this report.

Geotechnical Studies

Approximately 30 geotechnical reports were identified and reviewed. Most of the geotechnical reports were for proposed engineering improvements and/or modifications along specific berthlines and did not include environmental data (e.g., sediment chemistry or bioassay testing). The subsurface exploration data from the geotechnical studies provide detailed stratigraphic information to depths generally deeper than El. -100 feet. However, because most of the explorations were performed on land and/or overwater within about 100 feet of the berthlines, the factual stratigraphic data typically do not extend into the main portions of the channels and basins. Therefore, the data contained in most of the existing geotechnical studies are only partially useful for subsurface characterization of the channels and basins (i.e., first component of the Channel Deepening Program), but should be extremely useful for the third component of the Channel Deepening Program when specific berthlines are improved.

Two geotechnical studies include extensive vibrocore explorations within the channels and basins, and provide a significant quantity of subsurface data in several areas of the Inner Harbor. CH2M Hill (1984) performed 32 vibrocores in the Turning Basin and northern portions of the Main Channel. The main objective of those vibrocores was to identify desirable sediments (i.e., sands and silty sands) for dredging and filling of old Slip 228. Most of the CH2M Hill (1984) vibrocores extended downward to elevations of about -55 to -65 feet.

The second geotechnical study that included extensive vibrocores was executed by Harding Lawson Associates (HLA, 1987). For that study, about 50 vibrocores were collected in the East Basin and Slip 5, and about 30 vibrocores were collected in the West Basin. The main objective of those vibrocores was to identify desirable sediments (i.e., sands and silty sands) for dredging and filling of several slips that existed at that time along Berths 212 through 215. The elevation data noted in the HLA (1987) report indicate that: a) the West Basin vibrocores typically extended downward to elevations of about -50 to -55 feet; and b) the East Basin vibrocores to elevations of about -60 to -65 feet.

A review of the vibrocore data in HLA (1987) suggests that the associated elevation data may be questionable and may be erroneous for some of the vibrocore locations. The elevation data for the West Basin vibrocores appear to be reasonable and correct; however, for the East Basin vibrocores, the noted elevations summarized above do not seem reasonable. Based on our evaluation, it appears that tide corrections may not have been incorporated in the elevation data for the East Basin vibrocores. Incorporating an assumed 2- to 5-foot tide correction for the East Basin vibrocores would suggest that those vibrocores typically extended downward to elevations of about -55 to -60 feet.

Sediment Chemistry and Bioassay Studies

Approximately 20 reports that specifically address chemistry and bioassay characterization of sediments within the various channels and basins were identified and reviewed. General facts relative to those reports are shown on Plate 3. A detailed review of the existing environmental studies, including summaries of sediment chemistry and bioassay results, was performed by KLI and was presented as an appendix to Fugro's (1996a, 1996c) preliminary reports.

Most of the sediment chemistry and bioassay studies listed on Plate 3 were performed for various maintenance dredging projects (along specific berthlines) that have been necessary since the completion of the 1981 to 1983 Harbor Deepening Project (COE, 1980a,b). Those maintenance-dredging studies typically address harbor bottom sediments within about 50 to 150 feet of the shoreline, often lack detailed stratigraphic data, and provide limited data relative to the middle portions of the channels and basins.

Several of the studies noted on Plate 3 provide environmental data for projects that are not related to berth-specific maintenance dredging. Included in this group are studies by MEC Analytical Systems (MEC, 1995), ToxScan (1995), and HLA (1987).

The MEC (1995) study was performed for the COE's proposed maintenance dredging throughout the Los Angeles Harbor (and at the Los Angeles River estuary). Sediment samples for chemistry/bioassay testing were collected in six large regions encompassing most of the Los Angeles Inner Harbor. The exploration locations used to collect sediment samples were generally located near the edges, and did not extend into the middle portions of the channels and basins. It is noted that MEC (1995) environmental sampling is related to the COE (1995) stratigraphic sampling.

As previously noted, POLA is currently executing the West Basin Entrance Widening Project. The project includes demolition of Berths 97 to 101 (already performed), removal of sediments located in front of and behind the current berthlines, and construction of a new pierhead alignment. As part of the West Basin Entrance Widening Project, ToxScan (1995) sampled sediments both inboard (i.e., on land) and outboard (i.e., overwater) of the existing berthlines for chemistry and bioassay characterization. In addition, McClelland Engineers, Inc. (1987), previously performed both on-land and overwater geotechnical sampling for the widening project.

The third report that provides environmental data not related to a berth-specific maintenance dredging project is HLA (1987). As previously noted, HLA (1987) performed vibrocores in the West Basin and East Basin, with the primary purpose being identification of desirable sediments for dredging and filling of several old slips along Berths 212 to 215. Bulk sediment chemistry testing was performed on three composite samples from the East Basin vibrocores (i.e., along the proposed new pierhead alignment) and ten composite samples from the West Basin vibrocores (i.e., in the proposed borrow areas). Each composite sample consisted of sediments taken from various elevations in three separate vibrocores.

Based on discussions with KLI and ToxScan, it is our understanding that several additional berth-specific chemistry/bioassay studies recently have been performed. Those studies reportedly address sediments in front of Berths 163-164, 171-173, and 233-236.

U.S. Army Corps of Engineers Dredging Projects

Two data sources related to COE dredging projects provide stratigraphic and/or limited chemistry testing data for sediments throughout the Los Angeles Inner Harbor. As part of the 1981 to 1983 Harbor Deepening Project (COE, 1980a,b), the COE performed explorations throughout the Inner Harbor in 1977 to 1979. Detailed stratigraphic data were obtained at about 100 locations down to elevations that typically ranged between about -45 to -55 feet. Limited sediment chemistry testing was performed on many discrete-depth sediment samples. Because that prior Harbor Deepening Project was primarily directed at dredging to El. -45 feet with 1.5-foot overdredge allowance, most of the chemistry testing was performed on samples from elevations typically no deeper than El. -48 feet. The stratigraphic and chemistry data were presented in a General Design Memorandum (COE, 1980a) and as project drawings (COE, 1980b).

In August 1993, the COE sampled 21 locations throughout the Inner Harbor to determine shallow stratigraphic conditions within the areas of their proposed maintenance dredging. The sediments were sampled by divers pushing tubes into the harbor bottom. Therefore, limited penetration was achieved and most samples did not extend below about El. -48 to -49 feet. To our knowledge, the stratigraphic data were only presented in the project drawings (COE, 1995).

Geophysical Surveys

Two geophysical surveys were performed in the 1990s that provide geophysical data that are useful for stratigraphic definition within the Inner Harbor. The first geophysical survey was performed in 1990 as part of the 2020 Plan Geotechnical Investigation (Fugro-McClelland, 1991, 1992). Geophysical data were acquired along two tracklines in the Main Channel, two tracklines in the East Basin Channel, and one trackline in the southern West Basin. The data consist of both shallow, analog boomer records and deeper, multi-channel, digitally processed records. We note that the 1990 geophysical records were used by Fugro for the interpretation of shallow stratigraphic conditions throughout the Inner Harbor, as discussed and presented within this report.

The California Division of Mines and Geology (CDMG) recently performed geophysical surveys in the Inner Harbor for fault identification related to Caltrans' Vincent Thomas Bridge Seismic Retrofit project. Shallow boomer data were acquired during a March 1996 survey and deeper multichannel data were reportedly acquired during a second geophysical survey performed in June 1996. Based on a preliminary trackline map provided to Fugro, the March 1996 survey included: a) four tracklines along the full length of the Main Channel extending into the Turning Basin; b) two tracklines along the East Basin Channel extending into the East Basin and Cerritos Channel; c) three tracklines in the West Basin; and d) several other shorter tracklines that extend into a few slips. The shallow boomer records acquired along those tracklines may provide useful information for further interpretation of shallow stratigraphic conditions within the areas of interest for the Channel Deepening Program. We note that digital trackline data for the March 1996 survey have not been provided to Fugro, thus limiting the usefulness of the shallow boomer data for the current stratigraphic interpretation.

Pre-Development Morphology

Two pre-development morphology maps were identified that provide useful information for interpretation of subsurface conditions beneath the POLA. Weinman and Stickel (1978) present an 11- by 17-inch version of an 1859 U.S. Coast Survey morphology map titled "Point Fermin Eastward to San Gabriel River." That map depicts unimproved conditions that existed in 1859 before the development of POLA was initiated. The current outline of POLA is overlaid on a copy of the 1859 map and is presented in this report as Map 2.

As shown on Map 2, the predominant features in 1859 included Dead Man's Island, San Pedro Creek, Rattle Snake Island, and Wilmington Lagoon (not specifically labeled on map). From Dead Man's Island, the current Main Channel generally follows the path of the old San Pedro Creek northerly towards Wilmington Lagoon. The current Turning Basin, West Basin, East Basin Channel, and East Basin occupy much of the old Wilmington Lagoon area. Several dominant channels were present in 1859 where San Pedro Creek transects Wilmington Lagoon. Most of those old channels (i.e., paleochannels) merged where the current Turning Basin is located.

The second morphology map was created by the Coast and Geodetic Survey in 1907/08 and was titled "San Pedro Harbor, California." Similar to the 1859 map, the current outline of POLA is overlaid on a copy of the 1907/08 map and is presented in this report as Map 3. As revealed by a comparison of Maps 2 and 3, many of the features that were present in 1859 still were present in 1907/08. Some of the primary differences were associated with development of the City of San Pedro and Terminal Island (a.k.a. Rattle Snake Island).

As discussed in the following sections of this report, the pre-development conditions depicted on Maps 2 and 3 provide extremely useful insights relative to interpretation of subsurface conditions. Those insights are especially important for interpretation of localized deposits that are apparently associated with paleochannels located in the northern reaches of the Inner Harbor. We note that the locations and trends of some of the paleochannels have been influenced and/or controlled by activity along the Palos Verdes fault. As discussed later, displacement along the Palos Verdes fault apparently has increased the complexity of subsurface conditions in the northern reaches of the Main Channel and southern portions of the West Basin. Reference should be made to Fugro (1994) and McNeilan et al. (1996) relative to the interpreted characteristics of the Palos Verdes fault.

Critical Evaluation of Existing Stratigraphic Data

Only a few of the previously mentioned existing data sources provide most of the useful stratigraphic information for the sediments beneath the channels and basins of the Inner Harbor. One of the primary sources is the CPT and vibrocore data acquired by Fugro during the Phase 1 and Phase 2 investigations for the Channel Deepening Program. Those data are discussed and presented in other sections of this report and, therefore, will not be re-visited herein. The other relevant existing data sources include: COE (1980a,b) vibrocores and borings; CH2M Hill (1984) vibrocores; HLA (1987) vibrocores; Fugro-McClelland (1993) vibrocores; and COE

(1995) push samples. Approximate exploration locations for each of those references are shown on Map 4. We note that the exploration locations typically were digitized from various types and sizes of maps and, therefore, the locations shown may be in error by 100 to 200 feet or more. Also shown on Map 4 are the five tracklines along which geophysical data were acquired in 1990 by Fugro-McClelland (1991, 1992).

Although there are numerous exploration locations shown on Map 4, at some of those locations the associated data are of limited depth, extent, and/or are no longer useful. Since the early 1980s, various dredging programs have removed sediments throughout the Inner Harbor and in localized areas along the channels and basins. Particularly relevant is the 1981 to 1983 COE Harbor Deepening Project (COE, 1980a,b) and dredging of borrow materials for the filling of old slips (e.g., Slip 228). Therefore, depending on when and where the explorations were performed in comparison to when and where dredging was performed, some of the existing stratigraphic data are of little use.

To evaluate the relative vertical extent of the existing exploration data (excluding the recently acquired CPT and vibrocore data), we compared the top and bottom elevations of each exploration (shown on Map 4) with the current harbor bottom bathymetry data. The comparisons were then filtered to identify exploration locations that have associated stratigraphic data extending to specific elevation ranges below the current harbor bottom.

A review of the current harbor bottom elevation data and the filtered stratigraphic data suggests that: a) about two-thirds of the stratigraphic data (excluding the recently acquired CPT and vibrocore data) extend more than about 3 to 4 feet below the existing harbor bottom; b) most of the explorations do not extend below an elevation of about -60 feet; and c) much of the deeper exploration data are associated with areas that have current harbor bottom elevations lower than about -48 to -50 feet. In certain areas of the Inner Harbor (e.g., East Basin and northern portion of the Main Channel), the existing stratigraphic data provide good coverage and information; however, in other areas of the Inner Harbor (e.g., middle portion of the West Basin and southern portion of the East Basin Channel), the existing stratigraphic data provide limited information with respect to shallow stratigraphic conditions. We note that Fugro's (1996a, 1996c) critical evaluation of the existing stratigraphic data strongly influenced the scope of the Phase 1 and Phase 2 field exploration programs.

DEFINITION OF PRELIMINARY DREDGE UNITS

Background

One of the primary objectives of the Field Program Assessment reports (Fugro, 1996a, 1996c) was to define preliminary dredge units, based on sediment type, within the Inner Harbor for the Channel Deepening Program. Delineation of the preliminary dredge units was important for the development and subsequent execution of both the Phase 1 and Phase 2 stratigraphic and environmental investigations. We note that the preliminary dredge units described within this report do not necessarily represent the specific dredge units that will be established after all the relevant data are compiled and analyzed by POLA and their consultants. Furthermore, we note that dredge spoil disposal, anticipated material types, and sediment chemistry characteristics are relevant factors that should be considered to establish specific dredge units and, thus, to define a selective dredging and placement program for the Channel Deepening Program.

As previously noted, several disposal alternatives (e.g., Pier 400 landfill, Cabrillo Shallow Water Habitat expansion) are being considered for the Inner Harbor sediments. The disposal alternatives will be strongly influenced by the material types (i.e., coarse-grained versus fine-grained sediments) and the existence and/or non-existence of environmentally challenged soils. Preliminary interpretation of the material types present throughout the Inner Harbor was initially performed (Fugro, 1996a) prior to the Phase 1 investigation, and was subsequently modified (Fugro, 1996c) based on the data acquired during the Phase 1 investigation. At the time that the preliminary stratigraphic interpretations were being performed, sediment chemistry and bioassay characteristics were not well defined and generally could not be used for disposal option evaluations and further definition of the preliminary dredge units. Therefore, Fugro defined the preliminary dredge units based on the stratigraphic interpretation that was performed subsequent to the Phase 1 investigation and was presented by Fugro (1996c) in the Phase 2 Field Program Assessment report. The preliminary dredge units are shown on Plate 2 and Map 6, and are discussed in the following paragraphs. General summary descriptions of the sediments within each preliminary dredge unit are provided in the following paragraphs; however, a more detailed discussion of the stratigraphic conditions and associated sediment properties are provided in the *Interpreted Shallow Stratigraphic Conditions* and *Sediment Properties and Characteristics* sections of this report.

We note that the preliminary dredge units discussed within this report are exactly the same as presented by Fugro (1996c). No modifications were made to the preliminary dredge units for several reasons, some of which are:

a. The final stratigraphic interpretation presented (Map 7) and discussed herein is only slightly different than the preliminary stratigraphic interpretation performed by Fugro (1996c);

b. Much of the factual environmental and stratigraphic data generated during the Phase 1 and Phase 2 investigations are directly associated to specific preliminary dredge units and dredge unit designations as defined by Fugro (1996c); and

c. To reduce the possibility of confusion when reviewing the various Channel Deepening Program reports prepared by Fugro and KLI/ToxScan.

Preliminary Dredge Units

Based on the interpreted stratigraphic conditions, Fugro (1996c) divided the Inner Harbor into eight preliminary dredge units, as shown on Plate 2 and Map 6. A summary of relevant information for each preliminary dredge unit is presented on Plate 4. The boundaries between adjacent preliminary dredge units generally correlate to the locations of interpreted stratigraphic contacts (refer to Map 7) and/or the locations of utility crossings. Because potential disposal options will partially depend on sediment types, we have created an alphanumeric dredge unit designation scheme that is based on the anticipated predominant material types within the proposed dredge depth (i.e., El. -50 feet with 2-foot overdredge allowance) of each preliminary dredge unit. The dredge unit designations are as follows:

Dredge Unit Designation	Description
CG-1, CG-2, CG-3, CG-4	Areas where **C**oarse-**G**rained sediments predominate
FG-1, FG-2, FG-3	Areas where **F**ine-**G**rained sediments predominate
FM-1	Areas where **F**ormation **M**aterials are present

Each of the abovelisted dredge units are discussed in the following sections of this report. The estimated volumes subsequently noted are based on the survey drawings (dated April 1, 1996) and dredge volume worksheets (dated April 5, 1996) provided by POLA.

CG Dredge Units

The four CG dredge units are located in the middle Main Channel (CG-1), north Main Channel (CG-2), north West Basin (CG-3), and northeast Turning Basin/southwest East Basin Channel (CG-4) areas of the Inner Harbor, as shown on Plate 2 and Map 6. In general, significant deposits of coarse-grained sediments (i.e., sand and silty sand) are present at shallow depths (i.e., above about El. -54 feet) within those four areas. We note that, because of the presence of desirable sediments, portions of dredge units CG-2 and CG-3 previously were used as borrow sources for the filling of several old slips within the Inner Harbor.

It is our understanding that POLA may be looking for coarse-grained borrow sources for use in the Pier 400 Stage 1 and/or Stage 2 landfill. The CG dredge units contain the most desirable sediments in comparison to the other dredge units. Consideration also may be given to mining the CG dredge units to obtain a greater quantity of coarse-grained sediments for use in the Pier 400 landfill or other areas of POLA. As previously noted, a portion of dredge unit CG-1 was recently (May 1997) dredged to obtain additional coarse-grained material for the Pier 400 Stage 1 landfill.

CG-1. This area correlates to an approximately 3,800-foot-long by 800-foot-wide section of the middle Main Channel that covers about 70 acres. The southern limit generally corresponds to the sediment-formation contact that crosses the Main Channel in a northwesterly trend (refer to Map 7). Based on Fugro's interpretation of the available data, in combination with the uncertainty of specifically locating the sediment-formation contact, we recommend that the southern limit of dredge unit CG-1 be located about 100 feet north of the contact between the Timms Point Silt and the Holocene sediments. The recommended southern boundary intersects the survey control line at about 68+00 feet and has a trend of about N70°W. The northern limit of dredge unit CG-1 corresponds approximately to survey station 105+00 feet and is just south of a cluster of utility lines crossing the Main Channel between about Berths 84 and 235. In the northern portion of dredge unit CG-1, a utility (i.e., 36-inch oil) line crosses approximately from Berth 81 to Berth 236.

Based on existing data, it appears that dredge unit CG-1 is underlain primarily by coarse-grained sediments; however, fine-grained deposits may be present in localized areas or as lenses interbedded with the coarse-grained sediments. Furthermore, non-native harbor bottom sediments locally overlie the native coarse-grained sediments. We note that the Phase 1A investigation was primarily directed at evaluating dredge unit CG-1. Refer to Fugro (1996b) and ToxScan (1996d) for results of the Phase 1A investigation of dredge unit CG-1.

Assuming a dredge elevation of -52 feet, about 595,000 cubic yards of sediment will be removed from dredge unit CG-1. That estimated volume includes the utility crossing area in the northern portion of the dredge unit. We note that about 160,000 cubic yards were removed from dredge unit CG-1 in May 1997 for borrow material for the Pier 400 Stage 1 landfill.

CG-2. Dredge unit CG-2 correlates to an approximately 3,000-foot-long by 900-foot-wide section of the north Main Channel and covers about 65 acres. The Evergreen Container Terminal, Los Angeles World Cruise Center, and Pasha/Honda Auto Terminal generally define the lateral limits of the area. The southern limit of dredge unit CG-2 is defined by a cluster of utilities crossing the Main Channel between about Berths 84/85 and 234/235, corresponding approximately to between survey stations 105+00 and 110+00 feet. The northern limit generally corresponds to the southern side of Slip 93, at about survey station 135+00 feet. In the northern portion of dredge unit CG-2, a utility (i.e., telephone) line crosses the Main Channel between about Berths 91/92 and 229/230.

Using the existing stratigraphic data, our interpretation suggests that primarily coarse-grained deposits are present, which is partially supported by the fact that much of dredge unit CG-2 was previously used as a borrow source for the filling of several old slips. There are some existing data, including the old morphology maps, that suggest that fine-grained deposits may be present in the middle portion of the dredge unit. Assuming a dredge elevation of -52 feet, about 300,000 cubic yards of sediment will be removed from dredge unit CG-2. That estimated volume includes the utility crossing areas in the southern and northern portions of the dredge unit.

CG-3. The north West Basin area has been designated dredge unit CG-3. This area extends from the narrow point of the West Basin near Berth 124 to the northern limit of the basin, in front of the TransPacific Container Terminal, a distance of about 2,100 feet. Relative to the survey control line and dredge limits established by the Port of Los Angeles, the area lies between about stations 354+00 and 378+00 feet and covers about 70 acres. The dredge area will extend across the full east-west width of the West Basin, which varies from about 650 feet wide near Berth 124 to about 2,300 feet wide in front of the TransPacific Container Terminal.

Stratigraphic data suggest that dredge unit CG-3 is underlain primarily by coarse-grained deposits, except for localized, interlayered deposits in the west and northwest portions of the basin. Harbor bottom sediments overlie the predominant coarse-grained deposits. Within the dredge limits, about 570,000 cubic yards of sediment will have to be removed to achieve a basin elevation of -52 feet.

CG-4. Dredge unit CG-4 includes the northeastern one-half of the Turning Basin and the southwestern 1,800 feet of the East Basin Channel. The dredge unit extends northeasterly from about Berth 224 to about Berth 218, approximately corresponding to survey stations 155+00 to 184+00 feet. The southwestern boundary, which trends northwesterly from about Berth 224 to about Berth 150, generally corresponds to our interpreted contact (refer to Map 7) between apparently significant deposits of fine- and coarse-grained sediments. The northeastern limit corresponds to a utility (i.e., power cables) line that crosses the East Basin Channel between about Berths 173 and 218.

Dredging will encompass the full width of the East Basin Channel (about 550 feet) and about 1,000 to 1,500 feet into the Turning Basin, corresponding to an area of about 60 acres. Near the intersection of the Turning Basin and the East Basin Channel, a utility (i.e., 30-inch sewer) line crosses approximately from Berth 170 to Berth 222. The materials underlying dredge unit CG-4 consist primarily of coarse-grained sediments; however, interlayered deposits also are locally present. Non-native harbor bottom sediments are present throughout dredge unit CG-4. For a dredge elevation of -52 feet, about 410,000 cubic yards of sediment will be removed from dredge unit CG-4. That estimated volume includes the utility crossing areas.

FG Dredge Units

The FG dredge units cover three relatively large regions of the Inner Harbor, as shown on Plate 2 and Map 6. Those dredge units are interpreted to contain significant deposits of fine-grained sediments (i.e., silt and clay) within the proposed dredge elevations. From an engineering standpoint, those sediments are considered undesirable for use in the Pier 400 landfill. Other possible disposal options could include ocean disposal at LA-2 or LA-3, placement in the Cabrillo Shallow Water Habitat Extension, placement into dredged borrow pits in the Inner or Outer Harbors, and/or upland disposal. Although coarse-grained sediments are present in localized areas of the FG dredge units (especially in the northwestern portion of dredge unit FG-2), fine-grained sediments generally predominate.

FG-1. Dredge unit FG-1 extends northwesterly from the north Main Channel area into the southwestern portion of the Turning Basin. Relative to the survey control line and dredge limits established by POLA, the dredge unit covers about 65 acres and corresponds to about survey stations 135+00 to 155+00 feet in the Main Channel and Turning Basin, and survey stations 310+00 to 317+00 feet in the Turning Basin. There are two utility lines that cross dredge unit FG-1. Those utility (i.e., sewer and fuel) lines cross beneath or adjacent to the Vincent Thomas Bridge, between about Berths 94/97 and 226.

Based on existing data, it appears that most of dredge unit FG-1 is underlain by fine-grained deposits with insignificant quantities of coarse-grained sediments. The predominant fine-grained sediments are related to paleochannels and other fluvial features that apparently follow the general trend of the Palos Verdes fault. About 315,000 cubic yards of sediment will have to be removed to achieve a dredge elevation of -52 feet within the dredge limits. That estimated volume includes the utility crossing areas, but does not include the sediments to be removed as part of the West Basin Entrance Widening Project.

FG-2. The West Basin Channel area, which covers about 65 acres, has been designated dredge unit FG-2. As shown on Plate 2 and Map 6, the dredge unit extends northwesterly from the West Basin entrance (at about Berths 100 and 150) to the narrow point of the West Basin near Berth 124. In relation to the survey control line, those limits correspond to about survey stations 317+00 to 354+00 feet. Our interpretation suggests that the materials to be encountered in this dredge element are variable, but consist of primarily fine-grained sediments within the dredge elevation. Because of the variability in this area, relatively significant deposits of coarse-grained sediments, however, may be locally present, especially in the western portion of dredge unit FG-2. For a dredge elevation of -52 feet, about 440,000 cubic yards of sediment will be removed from dredge unit FG-2.

FG-3. Dredge unit FG-3, which covers about 120 acres of the Inner Harbor, corresponds to the northeastern one-third of the East Basin Channel, the entire East Basin, and about 1,800 feet of the Cerritos Channel, as shown on Map 6. The southwestern limit corresponds to a utility (i.e., power cables) line that crosses the East Basin Channel between about Berth 173 and Berth 218, approximately corresponding to survey station 184+00 feet. The northeastern limit of the dredge unit correlates to the northeastern boundary of the East Basin (at about survey station 228+00 feet) and the westernmost portion of the Cerritos Channel (between about survey stations 228+00 and 246+00 feet). In the southwestern reaches of the dredge unit, several utility (i.e., oil and water) lines cross between about Berths 176 and 215/216. Within the proposed dredge depths, existing data suggest that primarily fine-grained deposits are present, with some interlayered coarse-grained sediments. We note that significant deposits of fine-grained, harbor bottom sediments are apparently present in the East Basin.

The POLA dredge volume worksheet suggests that about 775,000 cubic yards of sediment will have to be removed from dredge unit FG-3 to achieve a harbor bottom elevation of -52 feet. That estimated volume includes the utility crossing areas in the southwestern portion of the dredge unit, but does not include the sediments to be removed from the Cerritos Channel (between about survey station 228+00 and 246+00 feet).

FM Dredge Unit

Dredge unit FM-1 represents the southernmost portion of the Channel Deepening Program area and includes the extreme northern segment of the Glenn Anderson Ship Channel and the extreme southern segment of the Main Channel. From the Glenn Anderson Ship Channel segment, which corresponds to between about survey stations 10+00 to 27+00 feet, the dredge unit extends about 4,000 feet into the Main Channel. The northern limit correlates to the sediment-formation contact that crosses the Main Channel in a northwesterly trend at about survey station 68+00 feet. Existing data suggest that formation materials are present throughout dredge unit FM-1. Those materials are overlain by variable thicknesses of harbor bottom sediments.

For a dredge elevation of -52 feet, about 815,000 cubic yards of material will have to be removed. That volume includes harbor bottom sediments and rock-like layers that are most likely present in and/or on top of the formation materials. We note that, during previous and current dredging projects, the dredging contractors have reported problematic conditions while excavating the formation materials, which is attributed to the in situ characteristics of the formation materials and, in particular, the presence of the rock-like layers. Furthermore, because of the presence of the rock-like layers, POLA recently contracted Fugro to perform a full-coverage side scan sonar survey of dredge unit FM-1. The results of that survey are presented and discussed by Fugro (1997g).

Summary of Preliminary Dredge Units

Based on anticipated material types, eight preliminary dredge units were delineated within the Inner Harbor for the Channel Deepening Program. A summary of relevant information for each preliminary dredge unit is presented on Plate 4.

Four of the dredge units (i.e., CG-1 through CG-4) that cover about 265 acres of the Inner Harbor appear to be underlain primarily by coarse-grained sediments that are considered desirable, from an engineering standpoint, for use in the Pier 400 landfill. For a dredge elevation of -52 feet, the total sediment volume is estimated to be about 1.87 million cubic yards in those four dredge units. That dredge volume includes the approximately 160,000 cubic yards of sediment that was excavated from the eastern side of dredge unit CG-1 in May 1997.

Fine-grained sediments, which are considered undesirable for use in the Pier 400 landfill, predominate in the FG and FM dredge units. Other possible disposal options for these sediments could include ocean disposal at LA-2 or LA-3, placement in the Cabrillo Shallow Water Habitat Extension, placement into dredged borrow pits in the Inner or Outer Harbors, and/or upland disposal. The FG dredge units cover about 250 acres of the Inner Harbor, with a cumulative estimated dredge volume of about 1.53 million cubic yards for a target elevation of -52 feet. The FM dredge unit covers about 130 acres and adds about 0.81 million cubic yards of sediment.

FIELD EXPLORATION AND LABORATORY TESTING

Introduction

Two phases of field exploration and laboratory testing were performed to evaluate stratigraphic (and environmental) conditions within the limits of the Channel Deepening Program project area. The Phase 1 field investigation was performed in August and September 1996, and the Phase 2 field investigation was performed in April 1997. Both phases of the stratigraphic investigations included cone penetration testing, vibrocore explorations, and geotechnical laboratory testing. General summaries of those activities are provided below, while more detailed data are presented in Appendices A through C, respectively.

We note that all factual stratigraphic data generated during the Phase 1 and Phase 2 investigations are included within *Volume 2* of this current report. The Phase 1 stratigraphic data also were presented by Fugro in two other reports: 1) the Geotechnical Evaluation report of dredge unit CG-1 (Fugro, 1996b); and 2) the Phase 2 Field Program Assessment report (1996c). Furthermore, details and factual data related to the environmental components of the two investigations are presented in separate reports prepared by KLI/ToxScan (1996 and 1997a).

Tethered Cone Penetration Testing

A total of 143 tethered cone penetration tests (CPTs) were performed throughout the Inner Harbor within all the dredge units except for dredge unit FM-1, as indicated on Map 5. All testing was performed using the tethered Seascout CPT system designed and developed by Fugro.

During the Phase 1 investigation, 14 CPTs (CA-1 through CA-14) were located in dredge unit CG-1 and 38 CPTs (CB-15 through CB-52) were located throughout the remainder of the Inner Harbor, north of dredge unit CG-1. During the Phase 2 investigation, 91 CPTs were performed. As indicated on Map 5, 41 CPTs (CPT-1 through CPT-38 and CPT-90 through CPT-92) were located in the middle portions of the various waterways in the northern two-thirds of the Inner Harbor. The remaining 50 CPTs were performed within about 20 to 40 feet of existing pierhead alignments along four specific berthlines, which include the following:

- Berths 122-127 .... CPT-39 through CPT-49
- Berths 136-139 .... CPT-50 through CPT-57
- Berths 212-221 .... CPT-58 through CPT-74 (CPT-73 was not performed)
- Berths 226-232 .... CPT-75 through CPT-89

Details of the CPT system and field operations, including logs of all Phase 1 and Phase 2 CPTs, are provided in Appendix A. In addition to using the berthline-specific CPTs for the stratigraphic interpretation presented herein, Fugro also prepared four separate reports (Fugro, 1997c through 1997f) that discuss general stratigraphic conditions along the specific berthlines. The information contained within those four reports will likely be useful to the design of the future berth deepening component of the Channel Deepening Program.

Vibrocore Explorations

Vibrocore explorations were performed primarily to: a) evaluate sediment chemistry and bioassay characteristics (environmental vibrocores), and b) define stratigraphic conditions and variations (stratigraphic vibrocores). A total of 153 vibrocores were performed throughout all of the dredge units. The locations of the stratigraphic and environmental vibrocores are shown on Maps 5 and 6, respectively.

During the Phase 1 investigation, 30 vibrocores (VA-1 through VA-30) were located in and adjacent to dredge unit CG-1, and 12 vibrocores (VB-31 through VB-42) were located throughout the remainder of the Inner Harbor. Of those 42 vibrocores, 10 vibrocores (VA-1 through VA-10) were performed primarily for evaluating sediment chemistry characteristics. During the Phase 2 investigation, 111 vibrocores were performed in the seven remaining dredge units. As indicated on Map 6, 84 vibrocores (respectively designated with CG, FG or FM prefixes that correspond to each specific dredge unit) were performed primarily for evaluating sediment chemistry and bioassay characteristics. The stratigraphic vibrocores (GT-1 through GT-27) were performed throughout the northern two-thirds of the Inner Harbor, as indicated on Map 5. The vibrocores from both the Phase 1 and Phase 2 investigations are summarized below:

Phase 1 Investigation Vibrocores	
Environmental	VA-1 through VA-10
Stratigraphic: - Geotechnical - Harbor Bottom Sediment Thickness - Sediment-Formation Contact	 VA-11, VA-12, and VB-31 through VB-42 VA-13 through VA-22 VA-23 through VA-30

Phase 2 Investigation Vibrocores	
Environmental	CG2-1 through CG2-14 CG3-1 through CG3-13 CG4-1 through CG4-10 FG1-1 through FG1-10 FG2-1 through FG2-10 FG3-1 through FG3-15 FM1-1 through FM1-10
Stratigraphic: - Geotechnical - Harbor Bottom Sediment Thickness	 GT-1 through GT-15 GT-16 through GT-27

Details of the vibrocore system and field operations, including logs of all Phase 1 and Phase 2 vibrocores, are provided in Appendix B.

Geotechnical Laboratory Testing

Geotechnical tests were performed in Fugro's Ventura laboratory on sediment subsamples retrieved from most of the environmental and stratigraphic vibrocore locations. The purpose of the geotechnical testing was to define the engineering classification and properties of the sediments within and directly below the planned dredge elevation. The scope of testing (which included the appropriateness and frequency of geotechnical testing) was based on sediment descriptions noted during the subsampling process as well as the apparent distribution of the sediment characteristics.

The geotechnical testing included water content, Atterberg limits, grain size characterization, and undrained shear strength estimates, the results of which are noted on the vibrocore logs in Appendix B. The grain size distribution and plasticity data are presented in Appendix C.

Related Overwater Borings

During the Phase 2 field exploration program, overwater borings and a few additional vibrocores were performed for two separate utility crossing projects. Those projects include: a) the relocation of the Department of Public Works (DPW) Fries Avenue force main crossing between Berths 170 and 221/222; and b) the proposed Department of Water and Power (DWP) reclaimed water pipeline that will cross beneath the Turning Basin between Berths 150 and 225.

For the DPW project, Fugro (1997a) performed three overwater borings along the force main alignment. For the DWP project, Fugro (1997b) performed five overwater borings and several vibrocores along the proposed pipeline alignment. The boring locations for both projects are shown on Map 5. Furthermore, stratigraphic logs for those borings are presented by Fugro (1997a and 1997b) and also are included in Appendix D of this report.

INTERPRETED SHALLOW STRATIGRAPHIC CONDITIONS

Basis of Stratigraphic Interpretation

One of the primary objectives of the geotechnical study, as reported herein, was to interpret sediment types and stratigraphic conditions within proposed dredge depths throughout the Inner Harbor of POLA. Fugro's interpretation of shallow stratigraphic conditions, as presented in the following paragraphs, is based primarily on the recently acquired Phase 1 and Phase 2 CPT and vibrocore data, and other relevant stratigraphic data contained in the various existing data sources.

Sediments Within Dredge Depths

Using the relevant existing stratigraphic data discussed previously, the recently acquired CPT and vibrocore data, the two morphology maps (Maps 2 and 3), and the 1990 geophysical data (Fugro-McClelland, 1991 and 1992), Fugro interpreted shallow stratigraphic conditions throughout the Inner Harbor. Relative to the existing stratigraphic data, we note that emphasis was placed on the channel and basin vibrocore and CPT data, and that the stratigraphic data included in the various berthline geotechnical reports were used in only a cursory manner.

The materials that underlie the Inner Harbor generally consist of a thin surface layer of non-native harbor bottom sediments overlying disturbed and undisturbed native Holocene sediments that were naturally deposited throughout San Pedro Bay prior to the development of POLA. Specific details relative to the harbor bottom sediments, and the disturbed versus undisturbed Holocene sediments, are discussed after the general descriptions of stratigraphic conditions within each dredge unit.

Interpreted shallow stratigraphic conditions for the Inner Harbor are presented on Map 7, which is considered generally representative of stratigraphic conditions above an elevation of about -54 feet. The native materials present within the Inner Harbor have been divided into five stratigraphic units that include three Holocene sediment units and two older formation units. Those stratigraphic units are listed below:

- Unit A - Primarily coarse-grained sediments (sand, silty sand)
- Unit B - Interlayered deposits of coarse- and fine-grained sediments
- Unit C - Primarily fine-grained sediments (silt, sandy silt, clay, sandy clay)
- Unit D - Formation materials of the Timms Point Silt (silt, sandy silt, silty sand)
- Unit E - Formation materials of the Malaga Mudstone (silt)

In addition to the five native stratigraphic units presented above, non-native harbor bottom sediments are present throughout most of the Inner Harbor. The non-native harbor bottom sediments, which overly the native sediments and are of variable thickness, are discussed in further detail in a following section of this report. We note that the stratigraphic interpretation presented on Map 7 is representative of the native sediments and does not take into account the presence of the non-native harbor bottom sediments.

The locations and shapes of the interpreted contacts between different stratigraphic units (on Map 7) are approximate and were partially influenced by the shapes and general trends of paleochannels and other features depicted on the morphology maps (Maps 2 and 3). We note that several of the more prominent paleochannels that can be seen on Maps 2 and 3 were imaged on the 1990 geophysical analog boomer records (Fugro-McClelland, 1991 and 1992). Our examination of the stratigraphic data suggests that at least a few of the paleochannels, especially those in the vicinity of the Vincent Thomas Bridge, are filled with a relatively thick sequence of silts and clays.

As noted previously, delineation of the preliminary dredge units was based primarily on Fugro's stratigraphic interpretation. Therefore, in the following paragraphs, the native sediments that are present at shallow depths throughout the Inner Harbor will be discussed on a dredge unit by dredge unit basis (refer to Plate 2 and Map 6 for dredge unit locations) in the following order: CG dredge units, FG dredge units, and then the FM dredge unit. Properties and engineering characteristics of the sediments are discussed in the *Sediment Properties and Characteristics* section of this report. We note that, because the harbor bottom sediments are present in all of the dredge units, only the native sediments will be discussed in the following paragraphs.

Dredge Unit CG-1. The native sediments within dredge unit CG-1 (i.e., middle Main Channel) consist of: a) alluvial- and marine-deposited, coarse-grained (Unit A) sediments associated with a sweeping paleochannel system; and b) localized slope-wash (Unit B) sediments apparently derived from the Palos Verdes Hills. Based on the existing data, it appears that the slope-wash deposits primarily exist as 1- to 4-foot-thick interlayers within the coarse-grained paleochannel deposits. At shallow depths, the coarse-grained paleochannel deposits spatially predominate in the southern and eastern one-third of dredge unit CG-1, while the slope-wash deposits are apparently more prevalent throughout the western and northern two-thirds of the dredge unit. As indicated on Map 7, a semi-linear deposit of Unit B sediments (which is not related to the slope-wash deposits) may cross the middle portion of the dredge unit. We note that additional specific stratigraphic details for dredge unit CG-1 are provided by Fugro (1996b).

The paleochannel deposits primarily consist of light gray to gray, fine sands (SP) and fine sands with silt (SP-SM) that have a median grain size (D_{50}) between about 0.2 and 0.42 millimeter (mm). The slope-wash sediments are typically light brown to reddish brown, silty fine sands (SM) and sandy silts (ML) that contain inclusions of dissimilar sediments and yellowish-red (oxidized?) zones.

Dredge Unit CG-2. The native sediments within dredge unit CG-2 (i.e., middle and northern Main Channel) are generally the same and likely related to those present in dredge unit CG-1. The coarse-grained (Unit A) paleochannel deposits predominate throughout dredge unit CG-2, with the exception of: a) interlayered slope-wash (Unit B) deposits; b) a localized fine-grained (Unit C) deposit along the western edge of the Main Channel in the middle section of dredge unit CG-2; and c) fine-grained (Unit C) deposits in the extreme northeastern corner of the dredge unit. We note that the Unit C deposits in the northeast corner are related to a distinct U-shaped paleochannel that generally defines the limits of dredge unit FG-1, as will be discussed in a following section.

The predominant Unit A sediments within this dredge unit consist of fine sands (SP) and fine sands with silt (SP-SM) that have a median grain size (D_{50}) between about 0.18 and 0.45 mm. Those sediments were identified by CH2M Hill (1984) as "preferred" borrow sediments for the filling of old Slip 228. We note that the middle section of dredge unit CG-2 has been used as a borrow source and, as indicated on Map 1, current harbor bottom elevations are lower than El. -50 feet over much of the area. Therefore, much of the "preferred" borrow sediments have already been removed, but additional Unit A sediments are present at greater depths. The fine-grained (Unit C) deposits encountered within dredge unit CG-2 consist primarily of low to medium plasticity clays (CL).

Dredge Unit CG-3. Most of dredge unit CG-3 (i.e., West Basin) is underlain by coarse-grained (Unit A) sediments that extend well below the project dredge elevation. We note that, because of the existence of abundant coarse-grained sediments, the middle portion of dredge unit CG-3 previously has been used as a borrow source and, as indicated on Map 1, has current bottom elevations typically lower than about El. -50 feet. The Unit A sediments within dredge unit CG-3 consist of fine sands with silt (SP-SM) and silty fine sands (SM) that have a median grain size (D_{50}) between about 0.1 and 0.2 mm.

In addition to the predominant coarse-grained deposits, interlayered (Unit B) deposits are present in the northwest corner of the dredge unit, while fine-grained (Unit C) sediments are present along the southwest edge and the extreme southern portion of dredge unit CG-3. The interlayered deposits appear to consist primarily of coarse-grained sediments; however, localized layers of fine-grained sediments are present. The fine-grained layers typically consist of low to medium plasticity, normally-consolidated clays (CL).

In addition to the sediments mentioned above, an apparently localized, shallow deposit of Unit C fine-grained sediments was encountered at CPT-21 in the middle of the dredge unit along the southern portion of the existing borrow pit. That localized Unit C deposit is interpreted to be non-typical for the area and may actually be dredge spoil that was placed in the existing borrow pit.

Dredge Unit CG-4. The native sediments within dredge unit CG-4 (i.e., northeastern Turning Basin and southwestern East Basin Channel) are similar and likely related to those present within dredge unit CG-3. Consisting predominantly of fine sands with silt (SP-SM) and silty fine sands (SM), the Unit A sediments are present throughout the dredge unit, except for: a) fine-grained (Unit C) sediments at the extreme northeastern end of the dredge unit; and b) interlayered (Unit B) deposits directly adjacent to the southwestern boundary of the dredge unit. The predominant sands and silty sands within dredge unit CG-4 have a median grain size (D_{50}) between about 0.1 and 0.32 mm.

Within the predominant Unit A sediments of dredge unit CG-4, a few fine-grained layers were encountered that appear to be overconsolidated (i.e., desiccated?) and apparently consist of fat clays (CH). As will be discussed in a following paragraph, those overconsolidated layers also were encountered in dredge units FG-1 and FG-2.

Dredge Unit FG-1. This dredge unit, which covers the extreme northern Main Channel and southwestern Turning Basin areas of the Inner Harbor, is underlain almost entirely by fine-grained (Unit C) sediments that have apparently infilled at least one major paleochannel. In addition, interlayered (Unit B) deposits, which also appear to infill another paleochannel, are present along the northeastern boundary of the dredge unit. The Unit B and Unit C sediments (and the paleochannels) appear to extend northwesterly towards, and are present within, the more southern reaches of dredge unit FG-2. We note that the northwesterly extension of those deposits (and the paleochannels) generally follows the trend of, and were likely controlled by, the Palos Verdes fault within the Inner Harbor. Details relative to the Palos Verdes fault are provided by Fugro (1994) and McNeilan et al. (1996).

The fine-grained sediments within dredge unit FG-1 consist primarily of normally-consolidated, low to medium plasticity clays (CL) that extend to depths exceeding El. -70 feet or greater. Localized layers of overconsolidated (i.e., desiccated?) fat clay (CH) were encountered at a few locations within the dredge unit. The overconsolidated layers within dredge unit FG-1 are similar and likely related to the overconsolidated clay layers that are present within dredge units CG-4 and FG-2.

Dredge Unit FG-2. Dredge unit FG-2 (i.e., West Basin Channel) contains some of the most complex geologic and stratigraphic conditions encountered throughout the Inner Harbor. The complexity appears to be primarily related to movement along the Palos Verdes fault. As indicated on Map 7, Units A, B and C deposits are present within the dredge unit. The Units B and C deposits predominate, with the Unit A deposits generally limited to the southwestern portions of the dredge unit. As noted above, the Units B and C deposits within dredge unit FG-2 appear to be an extension of the same deposits present in dredge unit FG-1. We note that further evaluation of the existing stratigraphic data may allow for subdivision of the dredge unit, thus possibly permitting selective dredging of the limited Unit A deposits within the area.

The fine-grained sediments consist primarily of normally-consolidated clays (CL), with a few localized layers of overconsolidated (desiccated?) fat clays (CH). The coarse-grained sediments consist of fine sands with silt (SP-SM) and silty fine sands (SM) that are similar to the coarse-grained sediments present within dredge unit CG-4.

Dredge Unit FG-3. Within the depths of interest for the Channel Deepening Program, Unit C deposits predominate throughout dredge unit FG-3 (i.e., Cerritos Channel, East Basin and northeastern East Basin Channel). The fine-grained sediments, which extend downward to elevations of about -55 to -60 feet, consist primarily of normally-consolidated to slightly overconsolidated, low to medium plasticity silts (ML) that were likely deposited in a lagoonal or backwater environment. As indicated on Map 7, the northern corner of the East Basin contains some interlayered (Unit B) deposits at shallow depths.

In addition to the predominant fine-grained sediments, coarse-grained sediments are present at greater depths. Consisting of silty fine sands (SM), the top of those deeper coarse-grained sediments was encountered at about El. -55 to -60 feet. The existing data are insufficient to determine the thickness of the deeper coarse-grained sediments.

Dredge Unit FM-1. Dredge unit FM-1 is underlain by geologic deposits associated with two specific formations: 1) the Timms Point Silt (Unit D) member of the San Pedro Formation; and 2) the Malaga Mudstone (Unit E) member of the Monterey Formation. The Malaga Mudstone deposits consist of elastic silts (MH), while the Timms Point Silt deposits consist of silts (ML), sandy silts (ML), and some silty fine sands (SM).

The extreme northern portion of the Glenn Anderson Ship Channel contains Malaga Mudstone deposits. We note that Fugro-McClelland (1992) explored and partially mapped that portion of POLA during the 2020 Plan Geotechnical Investigation. Northerly from the Glenn Anderson Ship Channel, the Malaga Mudstone deposits extend about 3,000 feet into the extreme southern portion of the Main Channel, as indicated on Map 7. Further north, Timms Point Silt deposits are present within the Main Channel. The northern boundary of the formation materials (i.e., Timms Point Silt) crosses the Main Channel at about N55°W to N70°W, roughly corresponding to a line connecting the U.S. Coast Guard slip on Reservation Point to the San Pedro (SP) Slip. We note that additional details relative to the sediment-formation contact are presented in a following section of this report.

Furthermore, data from a recent side scan sonar survey (Fugro, 1997g) performed in dredge unit FM-1 provide additional information relative to rock inclusions within and on top of the formation materials.

Summary of Stratigraphic Conditions

Fugro has interpreted the shallow (i.e., above about El. -54 feet) stratigraphic conditions beneath the entire Inner Harbor, the results of which were discussed above and are presented on Map 7. Based on that interpretation, the existing stratigraphic conditions are summarized as follows:

1. Coarse-grained (Unit A) sediments that are considered desirable for use in the Pier 400 landfill are the predominant sediment type in the CG dredge units, which include the following portions of the Inner Harbor: middle two-thirds of the Main Channel, northeastern Turning Basin, West Basin, and southwestern East Basin Channel;

2. Interlayered (Unit B) deposits that may or may not be desirable for use in the Pier 400 landfill are present at shallow depths in localized areas of the Inner Harbor;

3. Fine-grained (Unit C) sediments that are considered undesirable for use in the Pier 400 landfill are the predominant sediment type in the FG dredge units, which include the following portions of the Inner Harbor: northern Main Channel, southwestern Turning Basin, southern and eastern West Basin Channel, northeastern East Basin Channel, East Basin, and Cerritos Channel; and

4. Formation materials (Units D and E) are present only in the northern Glenn Anderson Ship Channel and extreme southern portions of the Main Channel, and are considered undesirable for use in the Pier 400 landfill.

Non-native harbor bottom sediments overlie the native sediments throughout most of the Inner Harbor. Further details relative to the harbor bottom sediments are presented in the following paragraphs. Refer to the *Sediment Properties and Characteristics* section of this report for discussions on the characteristics and engineering properties of the materials encountered within the Channel Deepening Program project area.

Harbor Bottom Sediments

General Description. The materials that underlie the various channels and basins consist almost exclusively of sediments that were naturally deposited throughout San Pedro Bay prior to the development of POLA. A limited thickness of non-native harbor bottom sediments (that have been deposited or have accumulated subsequent to the Port development), however, overlie the native sediments throughout most of the Inner Harbor. We note that the stratigraphic interpretation presented on Map 7 is representative of native sediments and does not take into account the presence of the harbor bottom sediments.

The new CPT and vibrocore data provide abundant information relative to the harbor bottom sediments. At a majority of the new exploration locations, the harbor bottom sediments primarily consist of very soft to soft fine-grained sediments with a lesser amount of coarse-grained sediments. Based on the new laboratory data, the fine-grained sediments typically are classified as sandy clays (CL) and sandy silts (ML). In addition to the new exploration and laboratory data, several existing data sources (e.g., COE, 1980a,b; CH2M Hill, 1984; HLA, 1987; COE, 1995) also provide information relative to the occurrence and thickness of the non-native sediments (also referred to as harbor bottom sediments, surface sediments, muck, or bay mud) within the Inner Harbor. For the 1981 to 1983 Harbor Deepening Project, the COE (1980a) noted that:

> *"These sediments* [surface sediments] *extend north from about the end of Reservation Point through all the waterways in thicknesses varying from zero to 8 feet. West Basin contains a layer of these sediments generally less than 3 feet thick, since the basin is the most recent to be dredged. In general, the deposit is thicker towards the waterway borders and thinner in the middle. This is apparently caused by ocean currents and moving ships spreading it towards the borders. The material is consistently a 'soupy' and very soft muck. It consists mostly of material classifying as clay or silt with varying amounts of fine sand . . . The origin of the muck is primarily from sources in the inner waterways such as sewage or coagulation of materials in suspension following prior dredging of silts, clays and the bedrock. Surface runoff from storms drainage has provided additional material including sand..."*

Much of the "surface sediments" identified by the COE (1980a) were subsequently removed when the Inner Harbor was deepened to El. -45 feet in 1981 to 1983. Thus, the current layer of harbor bottom sediments in most of the Channel Deepening Program area has been deposited since 1981 to 1983. However, some of the harbor bottom sediments along the edges of the waterways may pre-date the 1981 to 1983 dredging program.

Both CH2M Hill (1984) and HLA (1987) performed vibrocores in several areas of the Inner Harbor (refer to Map 4) subsequent to the 1981 to 1983 Harbor Deepening Project. The associated stratigraphic data indicate that variable thicknesses of non-native harbor bottom sediments overlie the native sediments in broad and/or localized areas of the Inner Harbor. Recent maintenance dredging and dredging of borrow source materials, subsequent to both the CH2M Hill (1984) and HLA (1987) exploration programs, probably removed some of the harbor bottom sediments that were encountered in the north Main Channel and West Basin areas. It is our understanding that no dredging has been performed in the East Basin since about 1983. Therefore, the harbor bottom sediments encountered by HLA (1987) in the East Basin should still be present.

Distribution and Thickness. Based on the new CPT and vibrocore data, harbor bottom sediments are present and variable in thickness throughout the entire Inner Harbor. At the locations explored, the harbor bottom sediments range in thickness from less than 0.5 foot to greater than about 5 feet. Although the data suggest that the thickness is quite variable throughout the Inner Harbor, a few trends were identified. In general, the following trends were identified for the harbor bottom sediments:

- Thicker along the edges as compared to the middle portions of the channels and basins;
- Difference in sediment thickness between the middle portions and the edges generally appears to be greater in the "narrow" channels (e.g., Main Channel, East Basin Channel) as compared to the "wide" basins (e.g., West Basin, Turning Basin and East Basin);
- Average thickness appears to slightly increase to the north, moving up the Main Channel towards the West and East Basins; and
- Thickest accumulations generally correspond to the edges of the Turning Basin and West Basin, northern reaches of the East Basin Channel, and the edges of the East Basin.

Although the thickness is variable, we conclude that the typical range of harbor bottom sediment thickness is: a) about 0 to 1 foot thick along the middle and deepest sections of the waterways, b) generally greater than about 2.5 to 3 feet thick along the edges of the waterways, and c) about 1 to 3 feet thick between the deepest sections and the edges. Average thickness throughout the entire Inner Harbor is estimated to be about 1.5 feet.

When considered alone, the average thickness may seem insignificant; however, taking into account the size of the area being considered (about 650 acres) and the relatively shallow dredge depths (typically 3 to 4 feet), it becomes evident that the quantity of harbor bottom sediments is significant. We note that estimates of dredge volume versus material type are provided in a subsequent section of this report.

Disturbed Versus Undisturbed Native Deposits

At the harbor bottom and/or beneath a thin layer of non-native harbor bottom sediments, both disturbed and undisturbed native Holocene deposits are present within the Inner Harbor. The native sediments, which generally were deposited throughout San Pedro Bay prior to the development of POLA, consist of Holocene-age marine, alluvial, lagoonal, and localized slope-wash deposits.

Based on the new CPT and vibrocore data, the native Holocene sediments may be divided into two distinct deposits: disturbed and undisturbed. The disturbed deposits (encountered at the harbor bottom or directly beneath the harbor bottom sediments) consist of native sediments that were agitated, suspended, and/or redeposited during the dredging operations for the 1981 to 1983 Harbor Deepening Project. The disturbed deposits generally consist of the same sediment types as the underlying undisturbed deposits. Our interpretation of the available data indicates that the disturbed deposits are generally thicker and more extensive in areas underlain by coarse-grained sediments (i.e., sand) as compared to areas underlain by fine-grained sediments (i.e., silt and clay). Typical thicknesses range from about 1 to 3 feet for areas underlain by fine-grained sediments and about 2 to 4 feet for areas underlain by coarse-grained sediments.

In comparison to the underlying undisturbed deposits, the disturbed deposits typically: a) are a slightly darker color; b) have a distinctly lower cone point resistance; c) contain more shells and shell fragments; and d) where underlain by fine-grained sediments, contain intact chunks of native sediments. The interface between the disturbed and undisturbed sediments is occasionally marked by a shell hash layer and/or a significant increase in cone point resistance, and typically correlates to elevations of between about -48 and -53 feet. We note that identification of the interface generally was more obvious in the CPT data than the vibrocore data, and in areas underlain by native coarse-grained deposits as compared to areas underlain by native fine-grained deposits.

Sediment-Formation Contact

Adjacent to Reservation Point and the San Pedro (SP) Slip, the contact between older formation materials and Holocene sediments transects the southern Main Channel in a northwesterly trend. The older formation materials are present to the south-southwest of the contact and are primarily comprised of deposits associated with the Monterey and San Pedro formations. In this area, the Monterey Formation is represented by the Malaga Mudstone member, and the San Pedro Formation is represented primarily by the Timms Point Silt member. We note that while other members of the San Pedro Formation may be present and may overlie the Timms Point Silt member, the available data are inconclusive. Therefore, within this report, materials related to the San Pedro Formation are grouped together and referred to as the Timms Point Silt. Holocene-age alluvial and marine sediments are located to the north-northeast of where the Timms Point Silt approaches the harbor bottom.

There are abundant data to establish the approximate locations of the contact between the Malaga Mudstone and Timms Point Silt, and the contact between the Timms Point Silt and the Holocene sediments. The data include, but are not limited to: a) existing stratigraphic data from COE (1980a,b); b) geophysical data from Fugro-McClelland (1991, 1992); c) geophysical data from the CDMG's March 1996 survey; and d) stratigraphic data from the sediment-formation vibrocores (i.e., VA-23 through VA-30) performed during the field exploration program for the Phase 1A investigation. Stratigraphic logs for vibrocores VA-23 through VA-30 are included in Appendix B.

Based on Fugro's stratigraphic evaluation of the sediment-formation vibrocores, materials associated with the Malaga Mudstone were only recovered in vibrocore VA-23. Malaga Mudstone materials may have been slightly penetrated at another vibrocore location (e.g., VA-27); however, no samples were recovered when the core barrel was winched to the water surface. Timms Point Silt deposits (or deposits associated with other members of the San Pedro Formation) were encountered and recovered at four vibrocore locations (i.e., VA-24 through VA-27). In particular, the top of the Timms Point Silt deposits was encountered at about 3.5-foot depth in VA-24, 1.7-foot depth in VA-25, 2-foot depth in VA-26, and 2.5-foot depth in VA-27. The materials encountered in vibrocores VA-24 and VA-27 were classical Timms Point Silt (as identified in the Outer Harbor by Fugro-McClelland [1992]) and consisted of very stiff to hard silt with almost no sand fraction. We note that the materials encountered in vibrocores VA-25 and VA-26 may not be Timms Point Silt and could possibly be related to another member of the San Pedro Formation.

As shown on Map 7, Fugro's interpretation of the data indicates that both contacts cross the southern Main Channel at about N55°W to N70°W, roughly corresponding to a broad zone connecting the U.S. Coast Guard slip on Reservation Point to the SP Slip. To further describe the locations of the contacts, reference will be made to the survey control line and survey stations established by POLA for the Channel Deepening Program. Relative to the survey stations, and drawing lines perpendicular to the survey control line, the two contacts are approximately located as follows:

	Approximate Survey Stations (feet)	
	Malaga Mudstone-Timms Point Silt	**Timms Point Silt-Holocene Sediments**
Eastern Edge	55+50 to 56+00	58+50 to 59+50
Centerline	60+00 to 60+50	66+00 to 67+00
Western Edge	61+75 to 62+25	69+50 to 70+50

We note that the locations (i.e., survey stations) stated above are approximate. The location of the Malaga Mudstone-Timms Point Silt contact is relatively well defined and has an assumed error bar of about ±50 feet. However, there is more uncertainty associated with the Timms Point Silt-Holocene sediments contact and, therefore, we have assumed an error bar of about ±100 feet for that contact. The increased uncertainty is attributed to several factors, including: a) decreased resolution of the contact on the geophysical records, b) possible presence of other members of the San Pedro Formation, and c) difficulties associated with differentiating between samples of unconsolidated Holocene sediments and samples of weathered and disturbed San Pedro Formation deposits.

Adding to the uncertainty is the fact that the Timms Point Silt does not appear to be exposed on the harbor bottom and is overlain by loose sediments throughout much of the area in between the two contacts (i.e., between the Malaga Mudstone-Timms Point Silt contact and the Timms Point Silt-Holocene sediments contact). The vibrocore data suggest that the overlying, loose sediments range in thickness from about 2 to 4 feet on the west and about 3 to 8 feet on the east. We note that the survey stations summarized in the above table for the Timms Point Silt-Holocene sediments contact represent where a projection of the contact intersects the harbor bottom.

Rock Associated With Formation Materials

The location of dredge unit FM-1 represents where formation materials are present within the Channel Deepening Program project area. Although the matrix of the formation materials are predominately composed of hard clay and silt, the formation includes prevalent rock inclusions. The rock inclusions are believed to be limestone lenses and/or concretions that occur throughout the Malaga Mudstone as localized deposits and concentrated bands. Uniaxial compressive strengths for the rock-like layers in the Malaga Mudstone underlying the Outer Harbor range from about 1,150 to 6,800 pounds per square inch (psi) (Fugro-McClelland, 1992). Higher strengths, however, were measured on some rocks encountered during prior dredging.

Dredging experience in the early 1980s (when the Inner Harbor channels were deepened from El. -35 to -45 feet) and the more recent experience during the Pier 400 dredging project provide a basis for anticipation of the problematic conditions that may be encountered when dredging the Malaga Mudstone materials. That experience indicates that relatively significant quantities of the rock-like materials may be encountered within the clay matrix, especially at shallow depths in the northern Glenn Anderson Ship Channel and southern Main Channel. That experience suggests that rock may be encountered as both intact rock within the predominantly hard clay formation or as isolated rocks.

Past experience also suggests that it has been a relatively common dredging practice to overexcavate and bury rock inclusions below the project dredge depth. Thus, subsequent dredging (e.g., dredge element D6 of the Pier 400 Stage 1 project) has encountered a non-typical large quantity of rock inclusions at the top exposure of the Malaga Mudstone. This has adversely impacted dredge production.

Miscellaneous Rock and Debris

The existing stratigraphic data, in combination with experience gained from recent dredging operations within the Inner Harbor highlights the possibility that miscellaneous rock and debris may be present almost anywhere throughout the Inner Harbor. Some of the rock appears to be naturally occurring and associated with local geologic formations, while other rock appears to be non-native. Although rock or debris were not encountered in the overwater explorations conducted for the project, past dredging experience in the Los Angeles Harbor indicates that such materials may be encountered on the harbor bottom or embedded within the underlying sediments. Rock or debris could be associated with historic structures, adjacent slope protection, past construction or commerce activities, or could be redeposited material derived from sources outside the harbor area.

There are not enough data to establish typical sizes for the rock, but Fugro has been shown rocks reportedly taken from the southern Main Channel (i.e., dredge unit CG-1) that were as large as about 12 to 15 inches in rough diameter. We note that the rocks observed by Fugro were not related to the rock-like layers that are associated with the Malaga Mudstone.

Some of the debris and non-native rock are clearly remnants of old train trestles, pile foundations, wharves, breakwaters, dikes, groins, and other structures that have been built and demolished within POLA. Because much of the non-native rock and debris is likely related to old infrastructure, Fugro recommends that POLA compile and review existing data (e.g., maps, areal photos, plans, etc.) to identify locations where old structures intersect the current channels and basins. That information should be provided in the dredging bid package for the Channel Deepening Program. In addition, Fugro suggests that POLA perform a full-coverage side scan sonar survey of the entire Inner Harbor to provide data to potential dredging contractors for their evaluation of the potential presence of rock and debris.

Potential Subsurface Variability

Fugro's interpretation of general stratigraphic conditions is based on sediment conditions that were: a) observed at the new environmental and stratigraphic vibrocore locations, b) interpreted from the new CPT data, and c) depicted on the stratigraphic logs for the various existing explorations. Conditions may vary at locations not sampled by the vibrocores or probed by the CPTs. We note that, within certain areas of the Inner Harbor, Fugro relied significantly on the existing data that has been acquired over the last 15 to 20 years by various agencies and consultants.

SEDIMENT PROPERTIES AND CHARACTERISTICS

Relevant Properties and Characteristics

There are several sediment properties and conditions that are relevant to the proposed Channel Deepening Program and associated dredging. Of particular interest are defining sediment types and in situ conditions. Sediment types, which are commonly evaluated using typical geotechnical classification tests, are important for evaluating dredge spoil disposal options and dredge production rates. In situ conditions, such as relative density and undrained shear strength, also are important for determining dredge production rates and the degree of difficulty in excavating dredged materials.

Relevant sediment properties for the various geologic materials present within the Inner Harbor are discussed in the following paragraphs. The native sediments are divided into three groups: coarse-grained, fine-grained, and formation materials. In addition to discussing those three groups, the harbor bottom sediments and disturbed native sediments also are discussed separately. Prior to discussing specific sediment types and properties, background information is provided relative to the methods and correlations used to estimate typical sediment properties.

Presented on Plate 5 is a table that summarizes typical ranges of relevant properties for the sediments encountered in each dredge unit. In the table, the non-native harbor bottom sediments, disturbed native sediments, and undisturbed native sediments have been separated. In addition, the sediments have been divided into fine-grained (i.e., silt and clay) and coarse-grained (i.e., sand and silty sand) classifications. Relative to the undisturbed native sediments, data for the coarse-grained sediments are most applicable to the CG dredge units, and data for fine-grained sediments are most applicable to the FG and FM dredge units. We note that the data for the formation materials is based almost solely on data from the 2020 Plan Geotechnical Investigation.

Classification. The classification of sediments was evaluated by performing grain size analyses and plasticity determinations using the methods established by the American Society for Testing and Materials (ASTM). The following tests were performed on various samples retrieved from the vibrocores: a) sieve, hydrometer, and percent passing the No. 200 sieve (ASTM D422 and D1140); and b) Atterberg limits (ASTM D4318). Relevant data provided by those tests include percent fines, median grain size (D_{50}), liquid limit, and plasticity index. We note that the factual geotechnical laboratory data generated during the Phase 1 and Phase 2 investigations are shown on the vibrocore logs (Appendix B) and summarized in Appendix C.

Cone Point Resistance. As previously noted, CPTs were performed throughout the Inner Harbor. Details relative to the CPTs are provided in Appendix A. Particularly relevant is the measured cone point resistance (q_c). In addition to evaluating stratigraphic conditions, the cone point resistance also provides a means to estimate relative density, inferred N-values, and undrained shear strengths when direct measurement of those properties is not possible.

We note that the Seascout system uses a miniature cone (about 0.38-inch diameter) that is significantly smaller than a typical cone (about 1.4-inch diameter) used on land. The measured cone point resistances, as summarized below and presented in Appendix A, may have been influenced by the cone size. Based on Fugro's past experience and evaluation of the new CPT data, it appears that the cone point resistances measured by the miniature cone, as compared to the typical on-land cone, are or may be: a) similar in magnitude in medium dense to very dense coarse-grained deposits; b) lower in magnitude in very loose to loose coarse-grained deposits; and c) similar in magnitude in most fine-grained deposits. The possibility of lower measured cone point resistances in very loose to loose coarse-grained deposits is important to remember when considering the properties for the disturbed native coarse-grained deposits.

Relative Density. To characterize the density of the coarse-grained deposits, we used the measured cone point resistance data and published empirical correlations to estimate in situ relative density (D_r). Although multiple q_c-D_r correlations exist, we used the relationships presented by Baldi et al. (1982, 1986) to estimate relative density.

We note that overburden pressure or stress, which can be directly related to depth below mudline, is required to estimate relative density with the Baldi et al. (1982, 1986) correlations. At low values of overburden pressure and, thus, at shallow depths, the correlations have a slightly larger uncertainty than for greater values of overburden pressure (depth). The depth intervals tested by the Seascout system correlate to relatively low overburden pressures; therefore, the estimated relative densities discussed and presented subsequently may have slightly greater uncertainty than typical.

Inferred N-Values. The dredging industry commonly uses Standard Penetration Test (SPT) N-values from borings to anticipate the degree of difficulty in excavating dredged materials. No borings were conducted specifically for the Channel Deepening Program; however, a few borings were performed overwater for two utility crossing projects in the Turning Basin and extreme southwestern portion of the East Basin Channel. Only a few blow counts (i.e., N-values) within the depth interval of interest were obtained from the borings. Considering the small amount of actual blow count data and the limited area it represents, estimated N-values for the various sediments within the Inner Harbor were determined based on empirical correlations.

To estimate N-values for the coarse-grained deposits, we relied on correlations between cone point resistance (q_c) and SPT N-value presented by Robertson et al. (1983) and Kasim et al. (1986). We also used similar correlations developed during the 2020 Plan Geotechnical Investigation in the POLA Outer Harbor as another basis for estimating the N-values of the coarse-grained sediments present throughout the Inner Harbor. For the fine-grained deposits, estimated N-values are based on: a) the same correlations noted above, and b) the relationships between undrained shear strength and N-value.

Undrained Shear Strength. In addition to inferred N-values, undrained shear strengths (S_u) also can be used to anticipate the degree of difficulty in excavating (dredging) fine-grained sediments. Direct measurements of undrained shear strength could not be made on the fine-grained sediments encountered at the vibrocore locations. Therefore, general correlations between q_c and S_u were used to estimate undrained shear strengths of fine-grained sediments.

Harbor Bottom Sediments

The non-native harbor bottom sediments are composed of a mixed assemblage of materials that include sand, silt, clay, and organic matter or debris. Silt- and clay-sized particles appear to be the primary components, with varying amounts of sand-sized particles. Grain size testing indicates that the percentage of sand is typically less than about 20 to 45 percent, but occasionally is in excess of 60 to 70 percent. The typical range of gradation is presented on Plate 6. Median grain size (D_{50}) ranges from about 0.01 to 0.08 mm.

Using the grain size and plasticity data, the harbor bottom sediments are primarily classified as sandy clay (CL), clay with sand (CL), and clay (CL) throughout most of the Inner Harbor. In dredge unit FG-3, the harbor bottom sediments are classified as silt (ML) to sandy silt (ML), while in dredge unit FM-1 they are classified as elastic silt (MH).

The Atterberg data for the harbor bottom sediments, as summarized on Plate 7, plot near or typically just above the A-line on the plasticity chart. Liquid limits typically range from 38 to 50 percent and plasticity indices are between about 12 and 24 percent. Slightly lower and higher liquid limits and plasticity indices were measured on a few samples. The higher values are primarily associated with dredge unit FM-1, where the native sediments have a higher plasticity as compared to the rest of the Inner Harbor. Most of the data that plotted below the A-line represent the harbor bottom sediments within dredge unit FG-3, where the native sediments have similar plasticity characteristics. Based on this information, we conclude that the composition and properties of the underlying native sediments may have influenced the composition and properties of the overlying harbor bottom sediments. This conclusion is supported by COE (1980a), who noted that the origin of the harbor bottom sediments is partially related to "coagulation of materials in suspension following prior dredging of silts, clays and bedrock." Therefore, some of the harbor bottom sediments could be classified as and grouped with the disturbed native sediments.

The cohesive harbor bottom sediments have a very soft to soft consistency, with some of the material in a state of suspension, as noted by the COE (1995). A good indication of the soft condition is the fact that measured moisture contents are greater than the liquid limits. Measured cone point resistances generally did not exceed 2 tons per square foot (tsf) and were commonly less than 1 to 1.5 tsf. That range of cone point resistance correlates to undrained shear strengths of less than about 250 pounds per square foot (psf). Inferred N-values are estimated to be no greater than 2. The non-cohesive harbor bottom sediments generally are very loose.

Undisturbed Native Deposits

Coarse-Grained Sediments. The main deposits of coarse-grained sediments were encountered in the four CG dredge units. Based on our evaluation of the data, it appears that the coarse-grained sediments within dredge units CG-1 and CG-2 have similar properties, while the coarse-grained sediments within dredge units CG-3 and CG-4 have similar properties. We note that most of the coarse-grained sediments contain mica particles, shells, and shell fragments.

Typical ranges of gradation for the coarse-grained sediments within dredge units CG-1 through CG-4 are shown on Plates 8 through 11, respectively, and summarized on Plate 5. As indicated on those plates, the sediments within dredge units CG-1 and CG-2 have almost identical typical gradations, with about 2 to 12 percent passing the No. 200 sieve (i.e., percent fines) and median grain size (D_{50}) of between about 0.2 and 0.42 mm. Those sediments are classified as poorly-graded fine sand (SP) and fine sand with silt (SP-SM).

The coarse-grained sediments within dredge units CG-3 and CG-4, as compared to the sediments within dredge units CG-1 and CG-2, are slightly more variable, generally contain higher percent fines, and generally have a smaller median grain size. As shown on Plates 10 and 11 and summarized on Plate 5, the percent passing the No. 200 sieve typically ranges from about 5 to 35 percent and, therefore, the sediments are classified as poorly-graded fine sand with silt (SP-SM) and silty fine sand (SM). Median grain size (D_{50}) typically ranges from about 0.1 to 0.2 mm for dredge unit CG-3, and about 0.1 to 0.32 mm for dredge unit CG-4. As indicated by the grain size data, the sediments within dredge unit CG-4 are the most variable coarse-grained deposits within the CG dredge units.

The typical ranges of measured cone point resistances are similar in all four CG dredge units, with only minor differences. As indicated on Plate 5, cone point resistances range from about 200 to 300 tsf in dredge units CG-1, CG-3 and CG-4, and between about 250 and 350 tsf in dredge unit CG-2. We note that slightly lower and higher values were measured locally in all four CG dredge units. Taking into account the typical ranges of cone point resistance and the shallow depths of interest, relative densities (Dr) are estimated to be greater than 90 percent. Furthermore, inferred N-values are estimated to range from about 28 to 42 in dredge units CG-1, CG-3 and CG-4, and between about 35 to 50 in dredge unit CG-2. Those values of relative density and inferred N-values suggest that the undisturbed coarse-grained deposits may be described as dense to very dense.

In addition to the CG dredge units, coarse-grained deposits also were encountered locally in dredge units FG-2 and FG-3. The coarse-grained deposits within dredge unit FG-2 have similar properties to the coarse-grained deposits in dredge unit CG-4, as indicated on Plate 5. The typical range of gradation is shown on Plate 12. Within dredge unit FG-3, the coarse-grained deposits are present at depths that are below the project dredge elevation. As indicated on Plate 5, the coarse-grained deposits within dredge unit FG-3, as compared to all other coarse-grained deposits encountered within the Inner Harbor, generally have: a) a higher percentage of fines; b) smaller median grain size; and c) lower cone point resistances, estimated relative densities, and inferred N-values. Typical gradation for the coarse-grained deposits in dredge unit FG-3 is shown on Plate 13.

Fine-Grained Sediments. The main deposits of fine-grained sediments were encountered within the FG dredge units (the formation materials are discussed in a separate section). Based on our evaluation of the data, it appears that fine-grained sediments within dredge units FG-1 and FG-2 have similar classification properties (e.g., grain size and plasticity), and the properties for dredge unit FG-3 are slightly different. The differences between the FG-1/FG-2 and the FG-3 fine-grained deposits are primarily attributed to depositional environment. Much of the fine-grained sediments within dredge units FG-1 and FG-2 appear to be associated with paleochannels, while the FG-3 sediments were likely deposited in a low-energy, backwater or lagoonal environment.

We note that most of the fine-grained deposits appear to be normally consolidated; however, localized layers of desiccated or overconsolidated fine-grained deposits are present in dredge units FG-1, FG-2, and CG-4. The normally consolidated deposits constitute a majority of the fine-grained deposits within the Inner Harbor and, therefore, are discussed in detail in the following paragraphs, while the desiccated or overconsolidated deposits are discussed at the end of this section.

Typical ranges of data for the fine-grained sediments are summarized on Plate 5 and plotted on Plates 12 through 14. As indicated on those plates, the fine-grained deposits within dredge units FG-1 and FG-2 typically have about 65 to 95 percent passing the No. 200 sieve and median grain sizes (D_{50}) of between 0.004 and 0.025 mm. For those deposits, the Atterberg data plot near or just above the A-line on the plasticity chart, with liquid limits ranging from about 30 to 50 percent and plasticity indices between about 14 and 26 percent. Therefore, most of the fine-grained sediments within dredge units FG-1 and FG-2 are primarily classified as sandy clay (CL) to clay (CL).

In comparison to the dredge units FG-1 and FG-2, the fine-grained deposits in dredge unit FG-3 contain a smaller percentage of sand-sized particles (84 to 100 percent) and have a slightly smaller median grain size (0.003 to 0.015 mm). The Atterberg data generally plot near or just below the A-line on the plasticity chart, with liquid limits between about 38 and 55 percent and plasticity indices ranging from about 8 to 25 percent. Using the above-stated ranges of data, the fine-grained deposits within dredge unit FG-3 are primarily classified as silt with sand (ML) and silt (ML), and possibly elastic silt (MH). Most of the fine-grained deposits within the FG dredge units have measured moisture contents that are typically equivalent to or slightly lower than the liquid limits, which is indicative of normally consolidated deposits.

In the normally consolidated deposits, the cone point resistances are relatively consistent in all three FG dredge units, with only minor differences between FG-1/FG-2 and FG-3. As indicated on Plate 5, the cone point resistance typically ranges from about 6 to 15 tsf for the fine-grained deposits within dredge units FG-1 and FG-2, and between about 12 and 18 tsf in dredge unit FG-3. Based on those ranges of cone point resistance, we estimate that undrained shear strengths typically range from about 500 to 1,500 psf. In addition, inferred N-values are estimated to be about 4 to 12. Based on those ranges of data, the consistency of the fine-grained normally consolidated deposits may be described as firm to stiff.

As mentioned previously, desiccated or overconsolidated localized layers of fine-grained sediments were encountered within various sections of the Inner Harbor. A higher percentage of those layers appears to be present within dredge units FG-1, FG-2 and CG-4. The available data are insufficient to determine typical grain size properties; however, limited Atterberg limits data indicate that liquid limits typically range from about 52 to 82 percent and plasticity indices are between about 30 and 55 percent. The plasticity data are plotted on Plate 14. Taking into account the Atterberg limits data and the fact that the fine-grained layers contain a limited amount of sand-sized particles, those deposits are classified as fat clay (CH).

There are several data sources that imply that the fine-grained layers are overconsolidated and were likely desiccated in the past. First of all, the moisture contents appear to be closer to the plastic limit as compared to the liquid limit. And secondly, the measured cone point resistances typically range from about 15 to 35 tsf. That range of cone point resistance is about 1.5 to 2 times higher than the normally consolidated deposits and correlates to estimated undrained shear strengths of about 1.2 to 2.5 ksf, and possibly as high as 3 ksf. The consistency of the OC layers may be described as stiff to very stiff.

Formation Materials. The formation materials located in the northern Glenn Anderson Ship Channel and extreme southern Main Channel areas (i.e., dredge unit FM-1) appear to be the Malaga Mudstone member of the Monterey Formation, and the Timms Point Silt member of the San Pedro Formation. Both formations were extensively mapped and sampled in the Outer Harbor by Fugro-McClelland (1992) during the 2020 Plan Geotechnical Investigation. The database established during that investigation, in combination with data presented by COE (1980a,b), provides the primary basis for the following descriptions of the formation materials; however, data from the Channel Deepening Program investigations also were used. Note that the deposits we have mapped (Map 7) in the southern Main Channel as Timms Point Silt also may contain sediments associated with other members of the San Pedro Formation.

The Timms Point Silt consists predominantly of low- to medium-plasticity silt (ML to MH), with lesser deposits of low-plasticity sandy silt (ML) and non-plastic silty fine sand (SM). For the primary silt section: liquid limits are generally between 30 and 50 percent; plasticity indices typically range from 4 to 22 percent; the percent passing the No. 200 sieve is typically greater than 75 percent; and the median grain size ranges from about 0.008 to 0.04 mm. The sandy silt and silty fine sand deposits are less plastic and contain about 40 to 75 percent fines.

The Malaga Mudstone is a thick accumulation of diatomaceous, relatively uniform silt. The silt is high plasticity (MH) with liquid limits typically ranging from 55 to 85 percent and plasticity indices of between 20 and 40 percent. The percent passing the No. 200 sieve is generally greater than 92 percent and the median grain size typically ranges from about 0.006 to 0.022 mm.

Rock-like layers, believed to be limestone lenses and/or concretions, are present throughout the Malaga Mudstone as localized deposits and concentrated bands. Based on dredging data from the Pier 400 project, relatively significant quantities of the rock-like materials may be encountered, especially at shallow depths in the northern Glenn Anderson Ship Channel and southern Main Channel areas. That experience suggests that it has been relatively common dredging practice to overexcavate and bury rock inclusions below the project dredge depth. Thus, subsequent dredging has encountered a non-typical, large quantity of rock inclusions at the top exposure of the Malaga Mudstone.

Cone point resistances range from about 25 to 55 tsf in the Timms Point Silt and between about 35 and 60 tsf in the Malaga Mudstone. Measured undrained shear strengths typically exceeded 3 to 4 ksf. Blow data indicate N-values of about 10 to 30 for the Timms Point Silt and about 30 to 70 for the Malaga Mudstone. Using the above stated data, the consistency of both formation units can be described in soil engineering terminology as heavily overconsolidated, very stiff to hard soil or, in geologic terminology, as very weak rock.

Uniaxial compressive strengths for the rock-like layers in the Malaga Mudstone range from about 1,150 to 6,800 psi (Fugro-McClelland, 1992). More recent data obtained by the Pier 400 Constructors reportedly indicate that the rock-like layers may, within localized areas, have uniaxial compressive strengths that exceed 6,800 psi.

Disturbed Native Deposits

The disturbed native deposits generally consist of the same sediment types as the underlying undisturbed native deposits. The classification properties (e.g., gradation, percent fines, Atterberg limits) for the undisturbed deposits are, for the most part, applicable to the disturbed deposits. Therefore, the classification properties for the disturbed deposits will not be discussed in the following paragraphs. Reference should be made to the previous section on undisturbed native deposits.

The in situ conditions, on the other hand, are quite different for the disturbed versus undisturbed deposits. In all cases, the cone point resistance, relative density, inferred N-values, and undrained shear strengths for the disturbed deposits are significantly lower than for the undisturbed deposits. Those lower values are summarized on Plate 5 and discussed in the following text.

Coarse-Grained Sediments. The disturbed coarse-grained sediments have cone point resistances that typically range from about 5 to 20 tsf, as compared with 200 to 350 tsf in the undisturbed deposits. Relative densities are estimated to be less than 30 to 50 percent, and inferred N-values range from about 3 to 7 for the disturbed deposits. Clearly, the degree of difficulty in dredging the disturbed coarse-grained deposits should be significantly less than for the undisturbed coarse-grained deposits.

Fine-Grained Sediments. The disturbed fine-grained sediments have cone point resistances that are typically between about 2 and 7 tsf, as compared with 6 to 18 tsf in the undisturbed deposits. The upper range of the cone point resistances for the disturbed deposits likely represent intact pieces and/or chunks of fine-grained sediments that were disturbed but left in place during the 1981 to 1983 Harbor Deepening Project. Based on the CPT data, we estimate that the fine-grained disturbed deposits have undrained shear strengths of about 250 to 500 psf. Inferred N-values range from about 2 to 4. Similar to the coarse-grained sediments, the degree of difficulty in dredging the disturbed fine-grained deposits should be less than for the undisturbed fine-grained deposits.

ESTIMATED DREDGE VOLUMES VERSUS MATERIAL TYPES

Introduction

As previously noted, dredge volumes for the Channel Deepening Program were reportedly estimated to be about 2.4 to 2.5 million cubic yards for dredging to El. -50 feet, and 1.6 to 1.7 million cubic yards for overdredge (i.e., between El. -50 and -52 feet). Thus, the total potential dredge volume is estimated to range from about 4 to 4.2 million cubic yards. That volume does not include sediments that will be removed: a) from the Cerritos Channel; b) as part of the West Basin Entrance Widening Project; and c) during the third component of the Channel Deepening Program (i.e., berth improvements).

The relative volume of the different material types is an important factor relative to evaluating excavation characteristics and dredge disposal options. One of the primary disposal options being considered is the Pier 400 landfill. Desirable sediments for the landfill, from an engineering standpoint, would be coarse-grained sediments consisting of sand and silty sand. As shown on Map 7, both coarse- and fine-grained sediments are present within proposed dredge depths throughout the Inner Harbor. Therefore, to fully evaluate the Pier 400 landfill and other disposal alternatives, the approximate quantity of coarse-grained versus fine-grained sediments must be considered. In the following paragraphs, we present estimates for dredge volume versus material type.

Dredge Volumes and Material Types

Based on survey drawings (dated April 1, 1996) and dredge volume worksheets (dated April 5, 1996) provided by POLA, in combination with Map 7 and a few simplifying assumptions relative to stratigraphy, estimates of dredge volume versus material type were performed. We note that the assumptions were primarily related to the interlayered Unit B sediments. Specific percentages were assumed for the coarse- and fine-grained components of each unit. Those percentages then were multiplied by the total dredge volume for a given area to determine the volume of coarse-grained versus fine-grained sediments. In addition, Unit A was assumed to consist almost entirely of coarse-grained sediments and Units C, D, and E were assumed to consist almost entirely of fine-grained sediments.

The dredge volume versus material type estimates were performed for the entire Inner Harbor assuming a final dredge depth of El. -52 feet. For a total dredge volume of about 4.2 million cubic yards, our estimates suggest that about:

- 25 to 30 percent (about 1 to 1.25 million cubic yards) are non-native harbor bottom sediments;
- 32 to 38 percent (about 1.35 to 1.6 million cubic yards, which is inclusive of the 160,000 cubic yards already excavated from dredge unit CG-1) are coarse-grained sediments;
- 18 to 24 percent (about 0.75 to 1 million cubic yards) are fine-grained sediments; and
- 15 percent (about 0.65 million cubic yards) are formation materials.

Those ranges are considered to have an error bar of about ±5 to possibly 10 percentage points. A larger error bar may be applicable for the harbor bottom sediments. We note that the percentages listed above are based on volumes. If a weight basis is used, then the percentage of harbor bottom sediments would decrease and the percentage of native sediments would increase.

Harbor Bottom Sediments

As previously stated, non-native harbor bottom sediments overlie native sediments throughout the entire Inner Harbor. The thickness of the harbor bottom sediments is quite variable, ranging from less than 0.5 foot to greater than about 5 feet along portions of the waterway edges. Therefore, to estimate the volume of the harbor bottom sediments, we assumed an average thickness of about 1 to 1.5 feet throughout the Inner Harbor. That assumed average thickness was only applied to areas that have harbor bottom elevations at or above about El. -52 feet.

Coarse-Grained Sediments

Most of the coarse-grained sediments come from four distinct areas of the Inner Harbor where Unit A sediments are apparently present. About 75 to 85 percent of the coarse-grained sediments come from the south and middle Main Channel (dredge units CG-1 and CG-2), north West Basin (dredge unit CG-3), and the northeast Turning Basin and southwest East Basin Channel areas (dredge unit CG-4). The remainder of the coarse-grained sediments are generally associated with other areas of the Inner Harbor where Unit B deposits are present.

Fine-Grained Sediments

Most of the native fine-grained sediments are anticipated to be encountered in two distinct regions of the Inner Harbor. One region is composed of the north Main Channel, southwest Turning Basin and West Basin Channel areas, while the second region is composed of the north East Basin Channel, East Basin, and Cerritos Channel areas. Those two regions, which include dredge units FG-1 through FG-3, are estimated to contain about 80 to 90 percent of the fine-grained sediments (exclusive of the formation materials).

Formation Materials

As indicated on Map 7, the formation materials are present only in the northern Glenn Anderson Ship Channel and extreme southern Main Channel areas (dredge unit FM-1). Therefore, 100 percent of the formation materials will be encountered in those two areas.

MINING OPTIONS FOR COARSE-GRAINED SEDIMENTS

Background

It is Fugro's understanding that POLA is considering options for mining additional coarse-grained sediments that are present within the Inner Harbor below the Channel Deepening Program project elevation of -52 feet. Those additional coarse-grained sediments may be used in the Pier 400 landfill as a sand-cap layer over the Cabrillo Shallow Water Habitat Extension, and/or placed in other areas of POLA. The mining of coarse-grained sediments within the Inner Harbor also could create another dredge spoil disposal option for undesirable or environmentally challenged sediments, or sediments that are undesirable for new fill in that the borrow pits created by the mining could be used as disposal sites or even possibly as CAD sites.

The possible mining option was discussed during the development of the Phase 2 investigation. The recommended scope of the Phase 2 investigation, as presented by Fugro (1996c), was modified to include: a) deeper vibrocore sampling in areas (i.e., CG dredge units) anticipated to be underlain by coarse-grained sediments; and b) geotechnical laboratory and bulk sediment chemistry testing on samples obtained from the deeper vibrocores between elevations of -52 and -65 feet. Therefore, in addition to testing the primary dredge interval (i.e., existing harbor bottom down to El. -52 feet) during the Phase 2 investigation, sediment samples from the El. -52 to -65-foot interval also were tested for bulk sediment chemistry and to determine pertinent geotechnical properties. Results of the chemistry testing are provided by KLI/ToxScan (1997a), while the results of the geotechnical laboratory testing are presented within this report.

Interpretation of Deeper Stratigraphy

During Fugro's interpretation of shallow stratigraphic conditions, the available data also were used to evaluate deeper stratigraphic condition within the CG dredge units. Most of the available and useful data are related to the vibrocore sampling performed specifically for the Channel Deepening Program. However, some of the existing data sources (e.g., CH2M Hill, 1984; HLA, 1987) do provide useful, but limited, stratigraphic data below an elevation of -52 feet.

The deeper stratigraphic interpretation was primarily directed towards identifying significant deposits of coarse-grained sediments that exist below El. -52 feet and extend downwards to elevations of at least -65 to -70 feet. Those areas are shown on Map 8.

Evaluation of Potential Mining Areas

As shown on Map 8, Fugro has identified three general areas within the Inner Harbor that could be considered for mining of coarse-grained sediments. The three areas include:

- Middle two-thirds of the Main Channel (dredge units CG-1 and CG-2);
- Most of the northern West Basin (dredge unit CG-3); and
- A portion of the Turning Basin and East Basin Channel (dredge unit CG-4)

Each of those areas apparently contains significant deposits of coarse-grained sediments below El. -52 feet. From the standpoint of engineering characteristics, the deeper sediments within the Main Channel are more desirable than those within the West Basin, northeast Turning Basin, and southwest East Basin Channel.

The Main Channel coarse-grained sediments are classified as fine to medium sand (SP) to sand with silt (SP-SM) that have about 2 to 12 percent fines and a median grain size (D_{50}) of between about 0.2 and 0.42 mm. In comparison, the coarse-grained sediments in the other two areas are classified as fine sand with silt (SP-SM) and silty fine sand (SM) that have about 5 to 35 percent fines and median grain sizes (D_{50}) of about 0.1 to 0.2 mm for the West Basin area and about 0.1 to 0.32 mm for the Turning Basin/East Basin Channel area.

Potential Dredge Volumes

Specific dredge volumes associated with potential mining will depend on the actual lateral limits and vertical extents of the borrow pits. Because those details will be based on the information contained within this report and other related factors (e.g., results of environmental testing), precise dredge volume calculations were not performed. However, we did perform some general estimates to determine approximate minimum dredge volumes that could be taken from the three potential mining areas. Assuming bottom elevations of between El. -60 and -65 feet, those estimates suggest the following volumes:

- 1 to 1.5 million cubic yards from the Main Channel area;
- 0.4 to 0.7 million cubic yards from the West Basin area; and
- 0.3 to 0.6 million cubic yards from the Turning Basin/East Basin Channel area.

Those estimated sediment volumes are in addition to the sediment volumes estimated for the base program (i.e., dredging to El. -52 feet).

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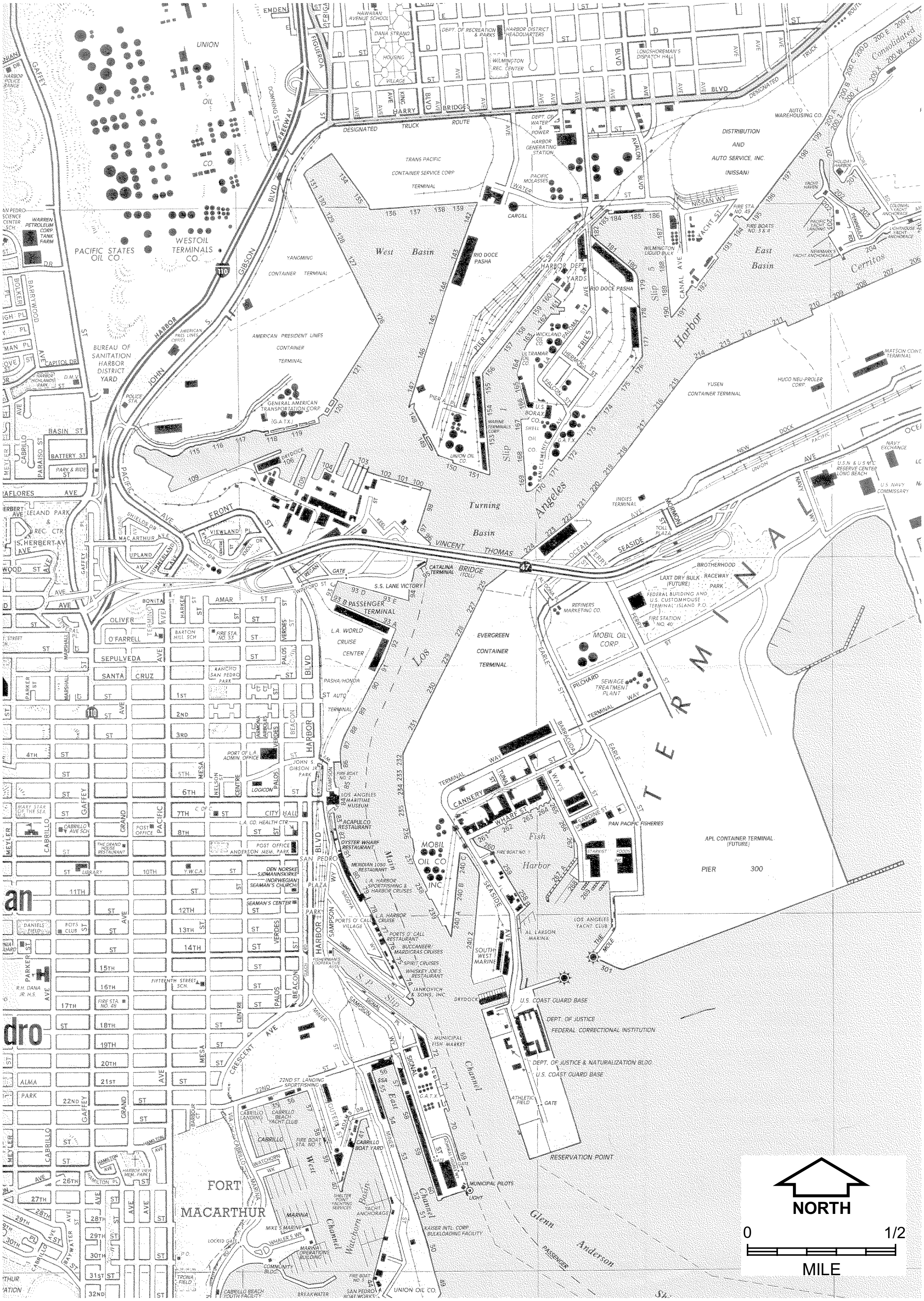
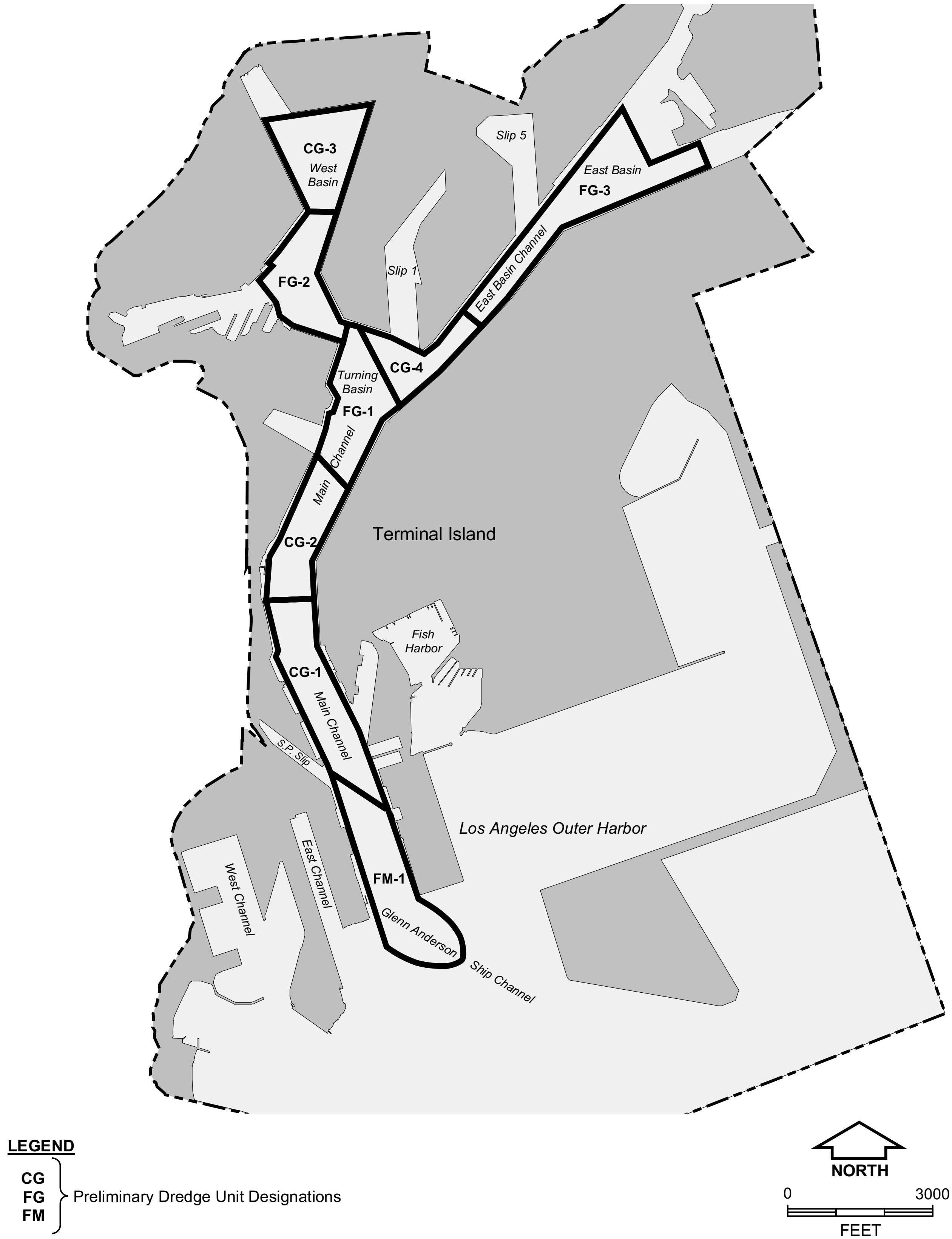
PLATES



VICINITY MAP

Channel Deepening Program
Port of Los Angeles

PLATE 1



PRELIMINARY DREDGE UNIT LOCATIONS

Channel Deepening Program
Port of Los Angeles

9642121215unit.ds4(1-3)

Reference	Primary Location/ Berth No.	Type of Study		Stratigraphic Data	Overwater Explorations				Land Explorations	
		Geology/Geotech.	Chemistry/Bioassay		Borings	Vibrocores	Grab/Push	CPTs	Borings	CPTs
LTE, 1958	93 A-E	X	- - -	X	- - -	- - -	- - -	- - -	8 (-70)	- - -
LTE, 1961	218-224	X	- - -	X	16 (-90)	- - -	- - -	- - -	9 (-5)	- - -
MH, 1964	95-96	X	- - -	X	2 (-80)	- - -	- - -	- - -	5 (-50)	- - -
LTE, 1966	93 D-E	X	- - -	X	6 (-120)	- - -	- - -	- - -	9 (-90)	- - -
MHL, 1967	125-131	X	- - -	X	3 (-130)	- - -	- - -	- - -	10 (-90)	- - -
DM, 1968	87-89	X	- - -	X	6 (-50)	- - -	- - -	- - -	1 (-30)	- - -
LTE, 1969	207-209	X	- - -	X	10 (-110)	- - -	- - -	- - -	4 (-95)	- - -
LCA, 1971a	229	X	- - -	X	3 (-85)	- - -	- - -	- - -	3 (-100)	- - -
LTE, 1971a	233-235	X	- - -	X	5 (-120)	- - -	- - -	- - -	- - -	- - -
LTE, 1971b	Slip 232	X	- - -	X	5 (-120)	- - -	- - -	- - -	6 (-80)	- - -
DM, 1971	176 to 216	X	- - -	X	5 (-60)	- - -	- - -	- - -	- - -	- - -
LCA, 1971b	Slip 230	X	- - -	X	15 (-140)	- - -	- - -	- - -	- - -	- - -
COE, 1980a,b	Inner Harbor	X	X	X	11 (-55)	~92 (-60)	- - -	- - -	- - -	- - -
HLA, 1980	216-218	X	- - -	X	3 (-165)	- - -	- - -	- - -	7 (-85)	- - -
HLA, 1981	216-218	X	- - -	X	2 (-120)	- - -	- - -	- - -	18 (-85)	- - -
DM, 1982	121-126	X	- - -	X	10 (-160)	- - -	- - -	- - -	7 (-115)*	- - -
HLA, 1982a	236	X	- - -	X	4 (-140)	- - -	- - -	- - -	2 (-75)	- - -
MBL, 1982a	Various	- - -	X	- - -	- - -	X	X	- - -	- - -	- - -
HLA, 1982b	187-190	X	- - -	X	8 (-90)	- - -	- - -	- - -	2 (0)	- - -
MBL, 1982b	233-235	- - -	X	- - -	- - -	- - -	X	- - -	- - -	- - -
ET, 1983	145-146	X	- - -	X	4 (-100)	- - -	- - -	- - -	2 (-80)	5 (-80)
HLA, 1983	218-221	X	- - -	X	1 (-100)	- - -	- - -	- - -	2 (-55)*	- - -
WCC, 1983	174-185	X	- - -	X	8 (-110)	- - -	6 (mudline)	- - -	16 (-110)	15 (-70)
DM, 1984	91, 93	X	- - -	X	- - -	- - -	- - -	- - -	7 (-100)	5 (-45)
WCC, 1984	171-173	X	- - -	X	7 (-130)	- - -	- - -	- - -	3 (-65)	3 (-45)
CH, 1984	225-229	X	- - -	X	17 (-140)	32 (-65)	- - -	- - -	5 (-190)	17 (-130)
ET, 1984	136-139	X	- - -	X	6 (-105)	- - -	- - -	- - -	1 (-25)*	24 (-105)*
MBL, 1986a	171-177	- - -	X	- - -	- - -	X	X	- - -	- - -	- - -
MBL, 1986b	Various	- - -	X	- - -	- - -	X	X	- - -	- - -	- - -
MBL, 1986c	SW Marine	- - -	X	- - -	- - -	X	X	- - -	- - -	- - -
MEI, 1987	97-101	X	- - -	X	- - -	4 (-60)	- - -	- - -	9 (-85)	- - -
HLA, 1987	212-215	X	X	X	14 (-140)	80 (-70)	- - -	- - -	9 (-120)*	- - -
TS, 1990a	118-121	- - -	X	- - -	- - -	X	- - -	- - -	- - -	- - -
TS, 1990b	229-232	- - -	X	- - -	- - -	X	- - -	- - -	- - -	- - -
TS, 1991a	84	- - -	X	- - -	- - -	X	- - -	- - -	- - -	- - -
TS, 1991b	177-179	- - -	X	- - -	- - -	X	- - -	- - -	- - -	- - -
TS, 1991c	86	- - -	X	- - -	- - -	X	- - -	- - -	- - -	- - -
TS, 1992a	167-169	- - -	X	- - -	- - -	X	- - -	- - -	- - -	- - -
TS, 1992b	79	- - -	X	- - -	- - -	X	- - -	- - -	- - -	- - -
MEC, 1992a	142	- - -	X	X (?)	- - -	X	- - -	- - -	- - -	- - -
MEC, 1992b	143-144	- - -	X	X (?)	- - -	X	- - -	- - -	- - -	- - -

SUMMARY OF EXISTING DATA SOURCES
Channel Deepening Program
Port of Los Angeles

Reference	Primary Location/ Berth No.	Type of Study		Stratigraphic Data	Overwater Explorations				Land Explorations	
		Geology/Geotech.	Chemistry/Bioassay		Borings	Vibrocores	Grab/Push	CPTs	Borings	CPTs
MEC, 1993a	142, 161	- - -	X	X (?)	- - -	X	- - -	- - -	- - -	- - -
GPI, 1993a	136	X	- - -	X	1 (-95)	- - -	- - -	- - -	- - -	1 (-90)
FM, 1993	Various	X	- - -	X	- - -	25 (-60)	- - -	- - -	- - -	- - -
GPI, 1993b	94	X	- - -	X	- - -	- - -	- - -	- - -	1 (-100)	3 (-110)
TS, 1993	Various	- - -	X	X	- - -	X	- - -	- - -	- - -	- - -
MEC, 1993b	174-176	- - -	X	X (?)	- - -	X	- - -	- - -	- - -	- - -
GPI, 1994	144	X	- - -	X	3 (-105)	- - -	- - -	- - -	2 (-95)	9 (-65)
TS, 1994a	136-139	- - -	X	X (?)	- - -	X	- - -	- - -	- - -	- - -
TS, 1994b	Various	- - -	X	X (?)	- - -	X	- - -	- - -	- - -	- - -
ET, 1994	226-232	X	- - -	X	- - -	- - -	- - -	- - -	5 (-120)	7 (-75)
MEC, 1995	Inner Harbor	- - -	X	- - -	- - -	X	- - -	- - -	- - -	- - -
ET, 1995	226-232	X	- - -	X	- - -	- - -	- - -	- - -	- - -	- - -
OE, 1995a	127-131	- - -	X	X (?)	- - -	X	- - -	- - -	- - -	- - -
OE, 1995b	187-190	- - -	X	X (?)	- - -	X	- - -	- - -	- - -	- - -
TS, 1995	97-101	- - -	X	X	- - -	X	- - -	- - -	X	- - -
COE, 1995	Inner Harbor	X	- - -	X	- - -	- - -	21 (-50)	- - -	- - -	- - -
FW, 1996b	S. Main Channel	X	- - -	X	- - -	30 (-65)	- - -	14 (-67)	- - -	- - -
FW, 1996c	Inner Harbor	X	- - -	X	- - -	12 (-66)	- - -	38 (-70)	- - -	- - -
TS, 1996a	237-239	- - -	X	X	- - -	5 (-43)	- - -	- - -	- - -	- - -
TS, 1996b	216-221	- - -	X	X	- - -	10 (-48)	- - -	- - -	- - -	- - -
TS, 1996c	51-55	- - -	X	X	- - -	8 (-39)	- - -	- - -	- - -	- - -
KLI/TS, 1996	S. Main Channel	- - -	X	X	- - -	10 (-65)	- - -	- - -	- - -	- - -
FW, 1997a	170, 221	X	- - -	X	3 (-123)	- - -	- - -	- - -	2 (-122)	- - -
FW, 1997b	Turning Basin	X	X	X	5 (-105)	7 (-57)	- - -	- - -	2 (-20)	- - -
KLI/TS, 1997b	118-120	- - -	X	X	- - -	6 (-47)	- - -	- - -	- - -	- - -

NOTES:

1) The following references are used in this table (refer to the Reference List for more detail):

CH CH2M Hill
COE U.S. Army Corps of Engineers
DM Dames & Moore
ET Earth Technology
FM Fugro-McClelland (West), Inc.
FW Fugro West, Inc.
GPI Geotechnical Professional, Inc.
HLA Harding Lawson Associates
KLI/TS Kinnetic Laboratories, Inc./ToxScan, Inc.
LCA LeRoy Crandall and Associates
LTE L.T. Evans, Inc.
MBL Marine Bioassay Laboratories
MEC MEC Analytical Systems, Inc.
MEI McClelland Engineers, Inc.
MH Maurseth and Howe
MHL Maurseth, Howe, Lockwood & Assoc.
OE Ogden Environmental
TS ToxScan, Inc.
WCC Woodward-Clyde Consultants

2) Relative to Primary Location/Berth No.:
Various Multiple berths investigated;
Inner Harbor Multiple locations throughout Inner Harbor investigated (no specific berth).

3) Stratigraphic Data represents the existence/non-existence of detailed descriptions of sediments encountered.

4) Overwater Explorations include any explorations that were performed through the water column (e.g., through wharf deck).

5) Relative to Overwater and Land Explorations:
X Explorations were performed, but limited data contained in report;
2 (-80) Number of explorations (approximate bottom elevation of deepest exploration);
***** Represents explorations within about 400-500 feet of shoreline; not all land explorations included.

SUMMARY OF EXISTING DATA SOURCES

Channel Deepening Program
Port of Los Angeles

Dredge Units	Desirable				Undesirable			
	CG-1	CG-2	CG-3	CG-4	FG-1	FG-2	FG-3	FM-1
Approximate POLA survey stations (feet)	68+00 to 105+00	105+00 to 135+00	354+00 to 378+00	155+00 to 184+00	135+00 to 155+00; 310+00 to 317+00	317+00 to 354+00	184+00 to 246+00	10+00 to 68+00
Berthlines within area	74-83, 235-240	84-92, 230-234	126-145	150-151, 170-173, 218-224	93-98, 225-229	101-103, 120-125, 146-149	174-176, 191-196, 204-217	68-72
Approximate surface area (acres)	70	65	70	60	65	65	120	130
Estimated sediment volume (yd^3)								
• To El. -50 ft	370,000	170,000	370,000	265,000	160,000	265,000	475,000	450,000
• Between El. -50 and -52 ft	225,000	130,000	200,000	145,000	155,000	175,000	300,000	365,000
TOTAL	595,000	300,000	570,000	410,000	315,000	440,000	775,000	815,000
Estimated Percentage of Coarse-Grained Sediments Above El. -52 ft	70-75	65-70	65-70	60-65	5-15	30-40	5-15	5-10

Notes:
1) Estimated volumes are based on dredge volume worksheets and survey drawings provided by the Port of Los Angeles.
2) Estimated volumes do not include sediments within about 100 feet of utility crossing areas.
3) Estimated volumes for dredge units FG-1 and FG-2 do not include sediments that will be removed as part of the West Basin Entrance Widening Project.
4) Estimated volumes for dredge unit FG-3 do not include sediments to be removed from the Cerritos Channel (between about survey stations 228+00 and 246+00 feet).

SUMMARY OF PRELIMINARY DREDGE UNITS
Channel Deepening Program
Port of Los Angeles

Preliminary Dredge Unit	Coarse-Grained Sediments: Cone Pt. Resistance (Qc, tsf)	Coarse-Grained Sediments: Relative Density (Dr, %)	Coarse-Grained Sediments: Inferred N-Value	Coarse-Grained Sediments: Median Grain Size (D50, mm)	Coarse-Grained Sediments: % Passing No. 200 Sieve	Fine-Grained Sediments: Cone Pt. Resistance (Qc, tsf)	Fine-Grained Sediments: Undrained Shear Strength (ksf)	Fine-Grained Sediments: Inferred N-Values	Fine-Grained Sediments: Median Grain Size (D50, mm)	Fine-Grained Sediments: % Passing No. 200 Sieve	Fine-Grained Sediments: Liquid Limit (LL, %)	Fine-Grained Sediments: Plasticity Index (PI, %)
	NON-NATIVE HARBOR BOTTOM SEDIMENTS											
All Dredge Units	NA	NA	NA	NA	NA	**0.5-2**	**<0.25**	**0-2**	**0.01-0.08**	**50-80**	**38-50**	**12-24**
	DISTURBED NATIVE DEPOSITS											
All Dredge Units	5-20	30-50	3-7	Similar to Undisturbed		2-7	0.25-0.5	2-4	Similar to Undisturbed			
	UNDISTURBED NATIVE DEPOSITS											
CG-1	**200-300 (350 max)**	**>90**	**28-42**	**0.2-0.42**	**2-13**	NA	NA	NA	NA	NA	NA	NA
CG-2	**250-350 (400 max)**	**>90**	**35-50**	**0.18-0.45**	**1-12**	15-30 (layers)	1.2-2 (layers)	8-15	DI	DI	Similar to NC Sediments in FG-1 and FG-2	
CG-3	**200-300 (350 max)**	**>90**	**28-42**	**0.1-0.2**	**3-30**	6-15 (layers)	0.5-1.2 (layers)	4-8	DI	DI		
CG-4	**200-300 (400 max)**	**>90**	**28-42**	**0.1-0.32**	**3-38**	15-35 (OC?) (layers)	1.2-2.5 (layers)	8-18	DI	DI	52-82	30-55
FG-1	NA	NA	NA	0.14-0.3	5-40	**6-18 (35 max)**	**0.5-1.5 (NC)**	**4-12**	**0.004-0.025**	**65-95**	**30-50 (NC) 52-82 (OC)**	**14-26 (NC) 30-55 (OC)**
FG-2	**150-250 (375 max)**	**>85**	**20-35**			**6-15 (NC) 15-35 (OC)**	**0.5-1.2 1.2-2.5**	**4-8 8-18**				
FG-3	60-120 (deeper)	65-90	10-16	0.09-0.15	18-42	**12-18 (24 max)**	**0.7-1.5**	**6-12**	**0.003-0.015**	**84-100**	**38-55**	**8-25**
FM-1 (see notes)												
Timms Point Silt	NA	NA	NA	NA	NA	**25-55**	**2-4**	**10-30**	**0.008-0.04**	**>75**	**30-50**	**4-22**
Malaga Mudstone	NA	NA	NA	NA	NA	**35-60**	**3-5**	**30-70**	**0.006-0.022**	**>92**	**55-85**	**20-40**

Dredge Desirable Undesirable

NOTES:

1) This table summarizes typical ranges of properties for the various sediments encountered within the dredge units. The sediments have been divided into several groups, including non-native harbor bottom sediments, disturbed native deposits, and undisturbed native deposits. To evaluate typical ranges of properties, the sediments were further subdivided into coarse-grained and fine-grained components. While the CG dredge units contain primarily coarse-grained sediments and the FG/FM dredge units contain primarily fine-grained sediments, both coarse- and fine-grained sediments were encountered in most of the dredge units. Therefore, we have defined typical ranges of properties (in **Bold**) for the predominant sediment type within each dredge unit. Where applicable and the data allow, ranges also are provided for the less prominent sediment types encountered within specific dredge units. Relative to the undisturbed native deposits, the properties indicated in the "Coarse-Grained Sediments" column are most representative of the CG dredge units, and the properties indicated in the "Fine-Grained Sediments" column are most representative of the FG and FM dredge units. Reference should be made to the report text for additional details and

2) Cone point resistances (Qc) based on the results of Seascout testing, except for dredge unit FM-1.

3) Relative density (Dr) values are estimates based on Qc-Dr correlations established by Baldi et al. (1982, 1986).

4) Inferred N-values (i.e., Standard Penetration Test [SPT] blow counts) are estimates based primarily on Qc-SPT N-value correlations developed for the 2020 Plan Geotechnical Investigation in the POLA Outer Harbor, except for dredge unit FM-1.

5) Undrained shear strengths are estimates based on typical correlations with Qc, except for dredge unit FM-1.

6) Data for dredge unit FM-1 are based primarily on values obtained during the 2020 Plan Geotechnical Investigation.

7) Ranges indicated in the above table are, in some instances, based on limited data.

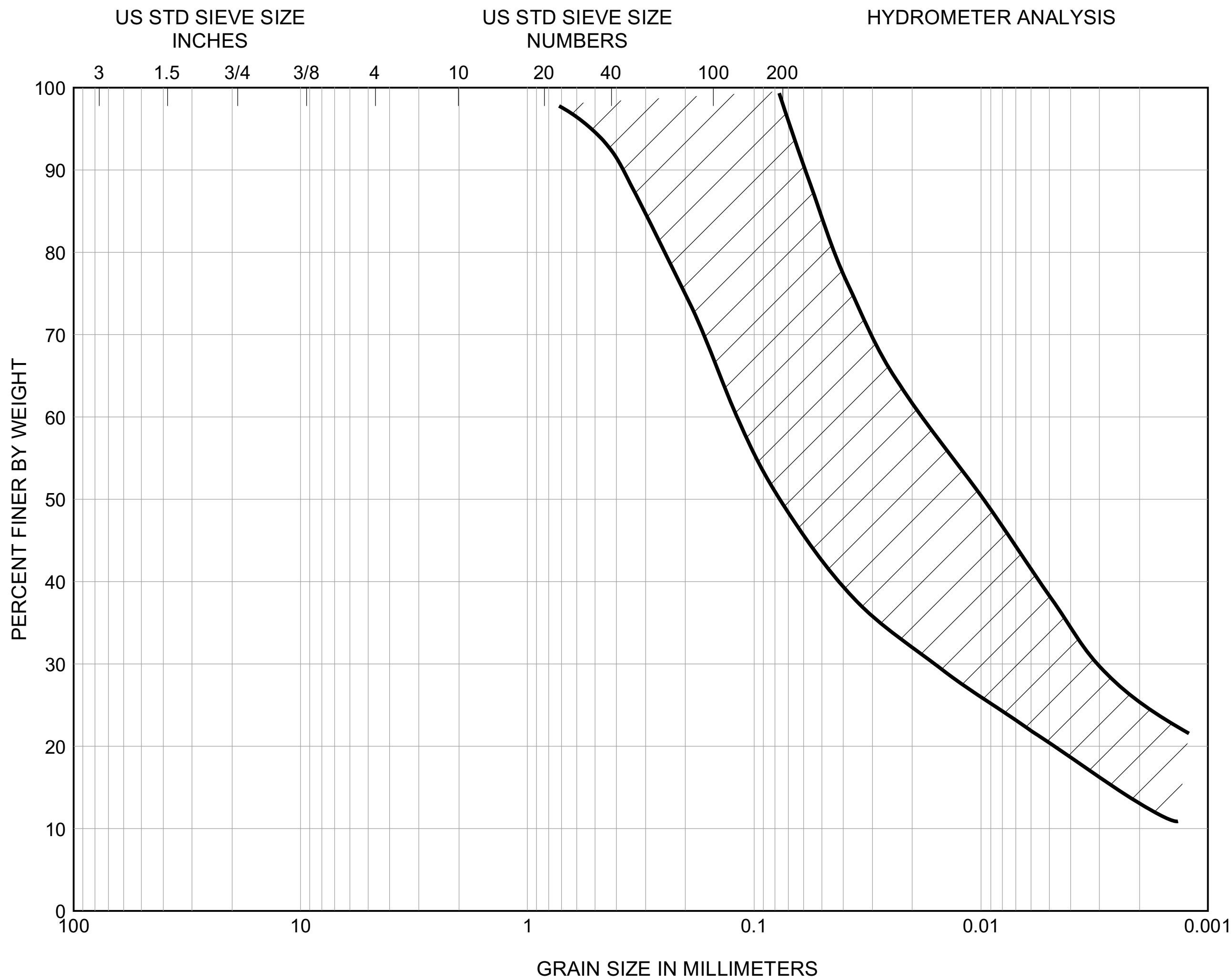
8) NA - Not Applicable; DI - Data Insufficient to determine typical range.

9) NC - Normally Consolidated; OC - Over Consolidated.

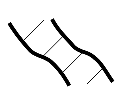
SUMMARY OF TYPICAL SEDIMENT PROPERTIES

Channel Deepening Program

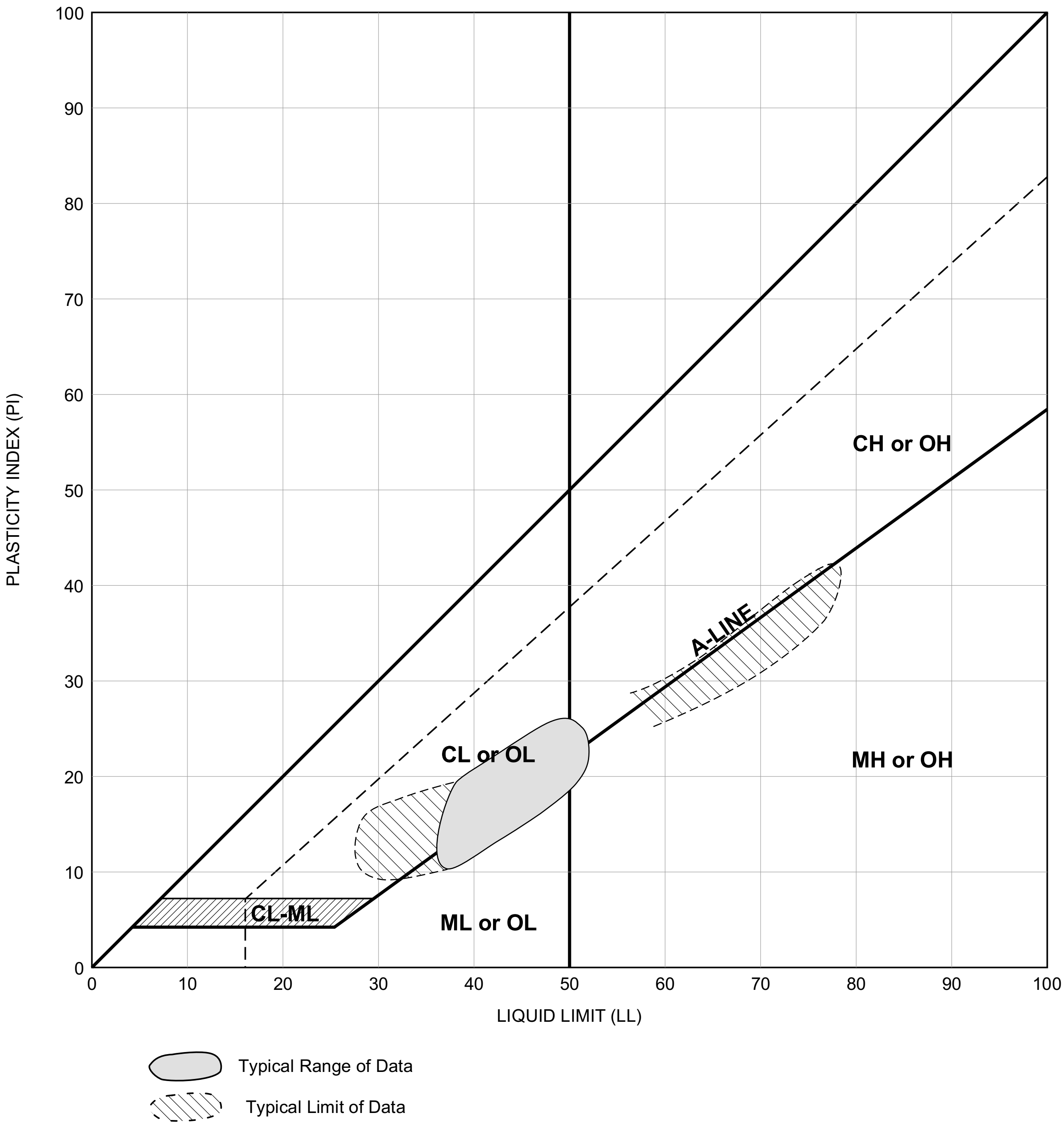
Port of Los Angeles



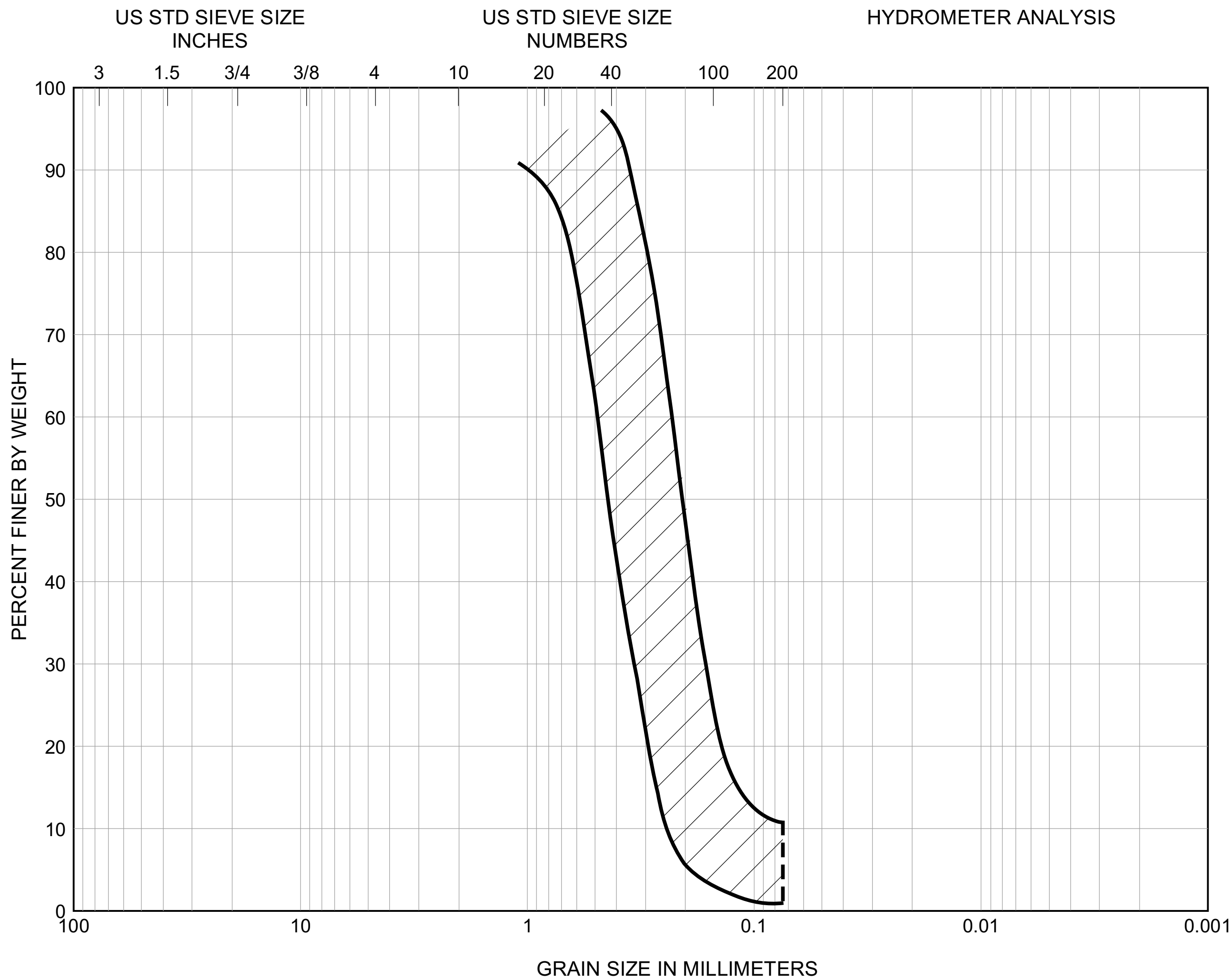
GRAVEL		SAND			SILT or CLAY
coarse	fine	coarse	medium	fine	


Typical Range of Data for Harbor Bottom Sediments

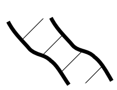
GRAIN SIZE CHARACTERISTICS
Harbor Bottom Sediments
Channel Deepening Program
Port of Los Angeles



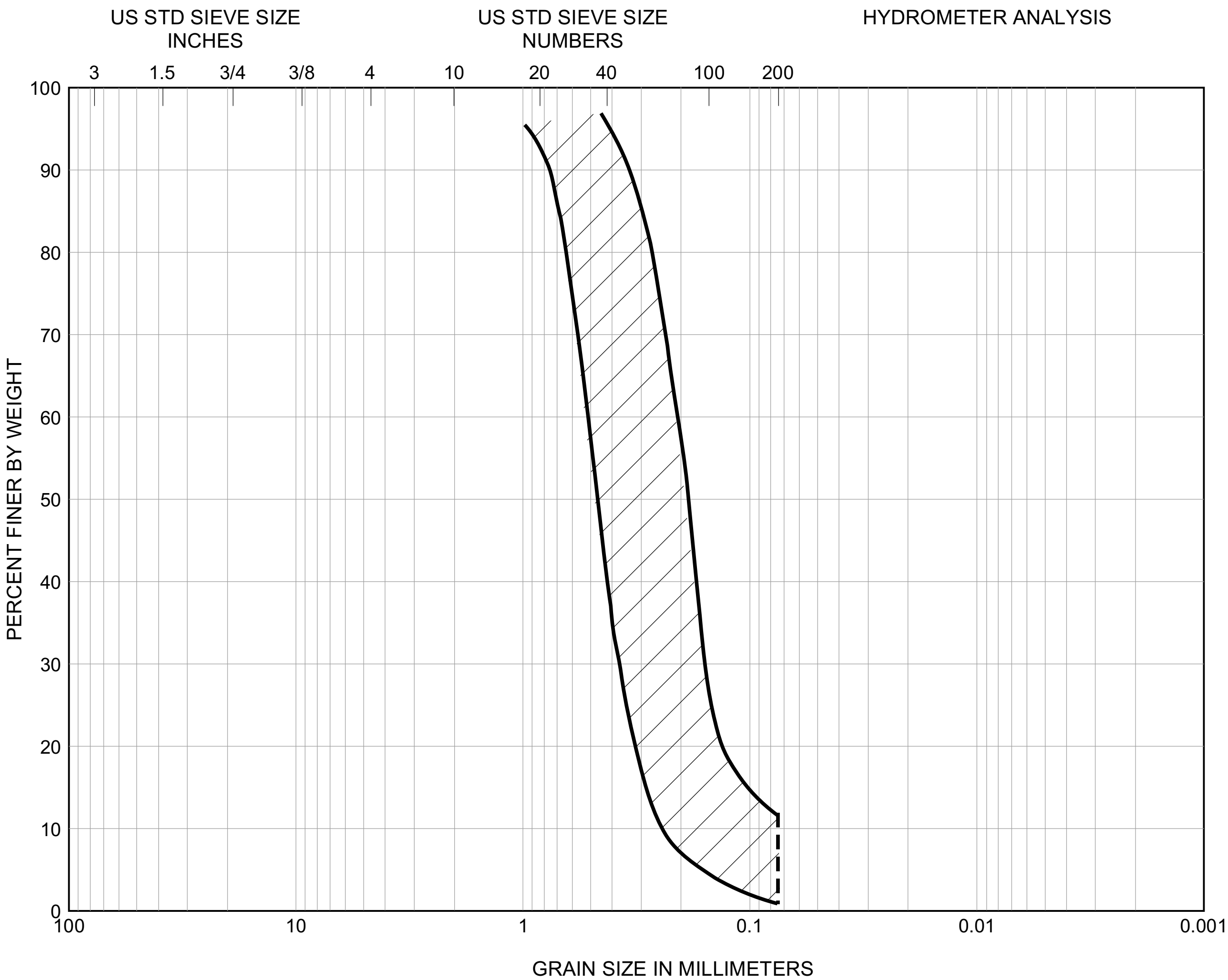
PLASTICITY CHARACTERISTICS
Harbor Bottom Sediments
Channel Deepening Program
Port of Los Angeles



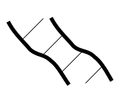
GRAVEL		SAND			SILT or CLAY
coarse	fine	coarse	medium	fine	


Typical Range of Data for Coarse-Grained Sediments in Dredge Unit CG-1

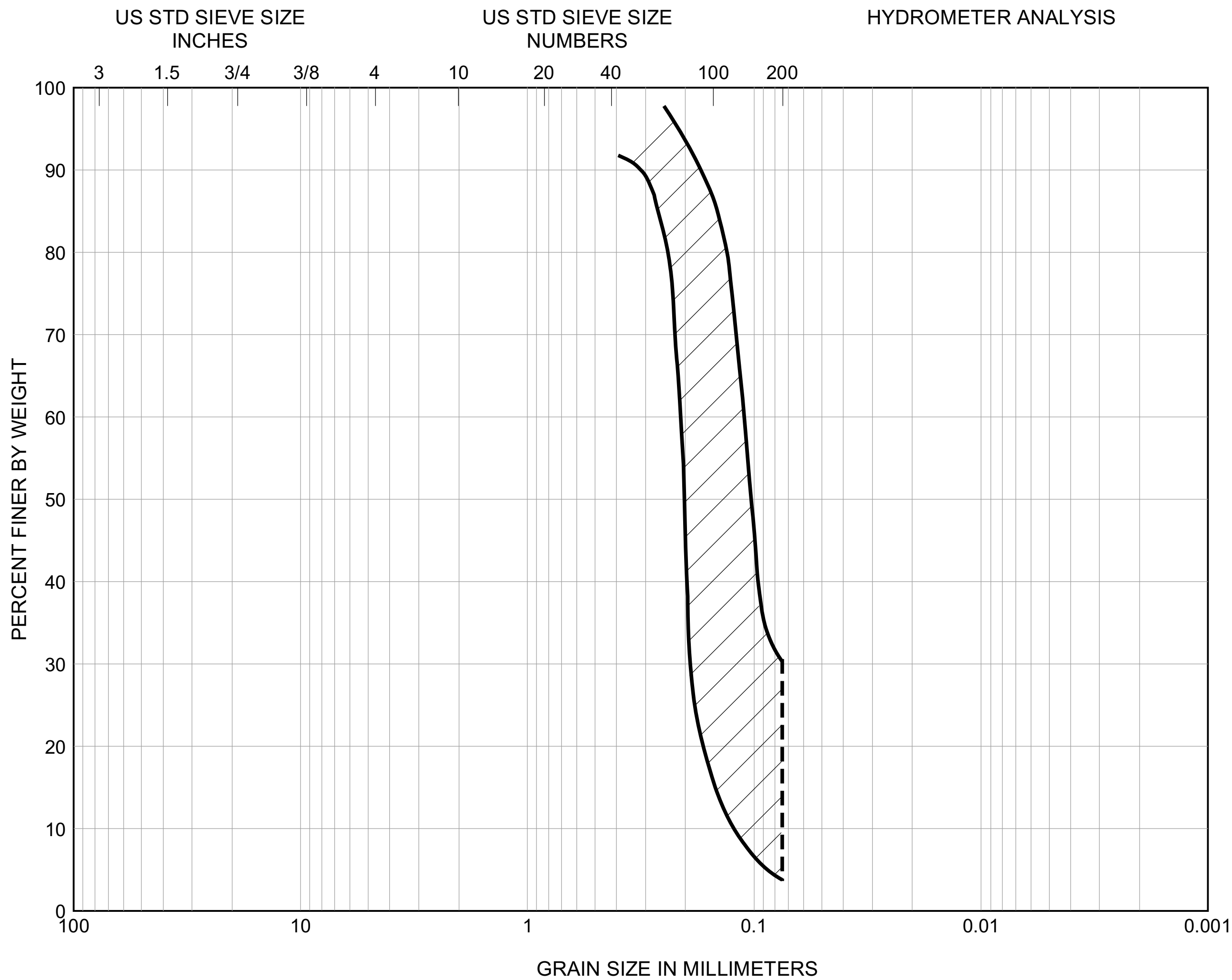
GRAIN SIZE CHARACTERISTICS
Dredge Unit CG-1
Channel Deepening Program
Port of Los Angeles



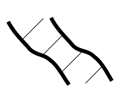
GRAVEL		SAND			SILT or CLAY
coarse	fine	coarse	medium	fine	


Typical Range of Data for Coarse-Grained Sediments in Dredge Unit CG-2

GRAIN SIZE CHARACTERISTICS
Dredge Unit CG-2
Channel Deepening Program
Port of Los Angeles



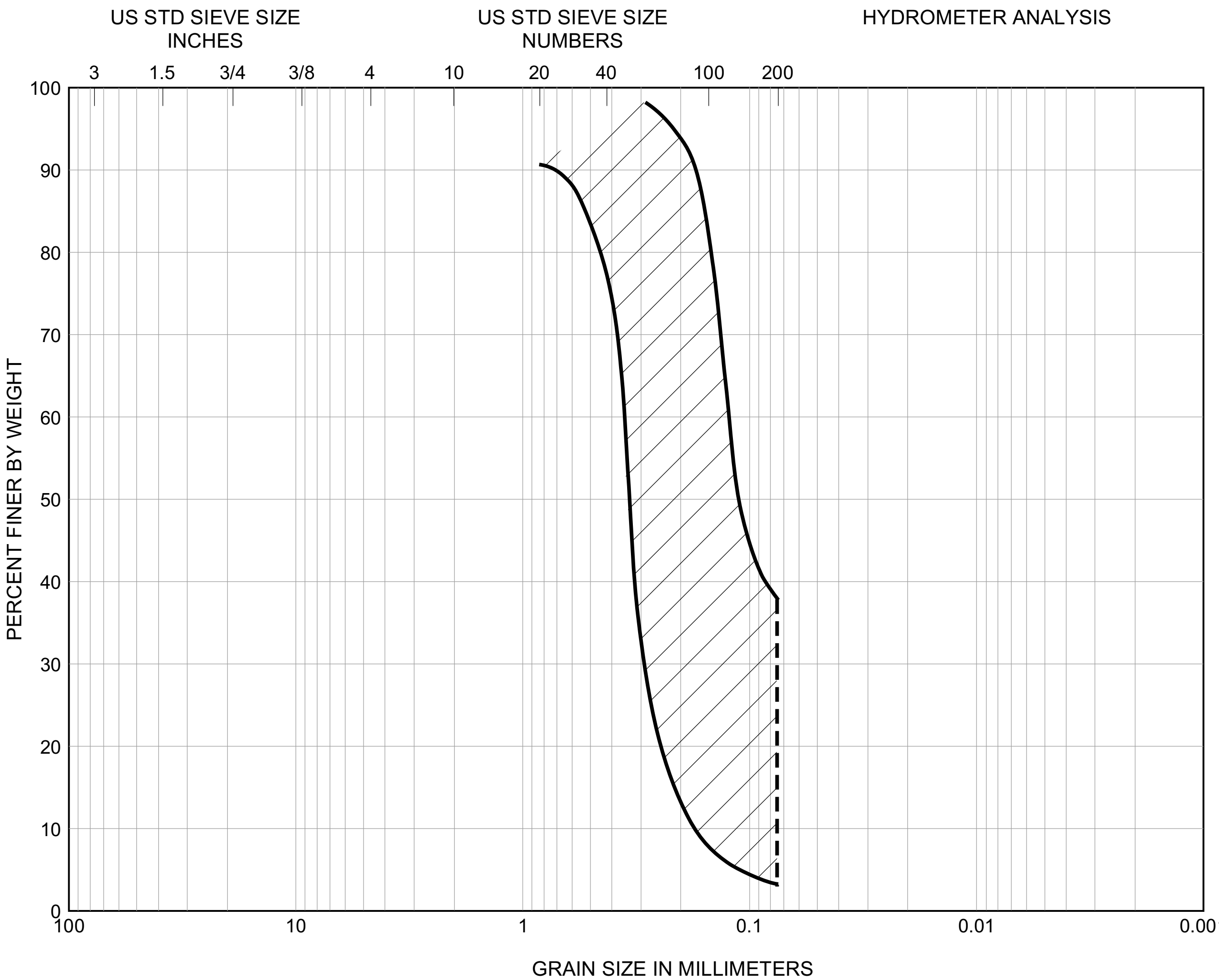
GRAVEL		SAND			SILT or CLAY
coarse	fine	coarse	medium	fine	



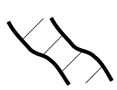
Typical Range of Data for Coarse-Grained Sediments in Dredge Unit CG-3

GRAIN SIZE CHARACTERISTICS
Dredge Unit CG-3
Channel Deepening Program
Port of Los Angeles

96421215GRN1.ds4(2,6)



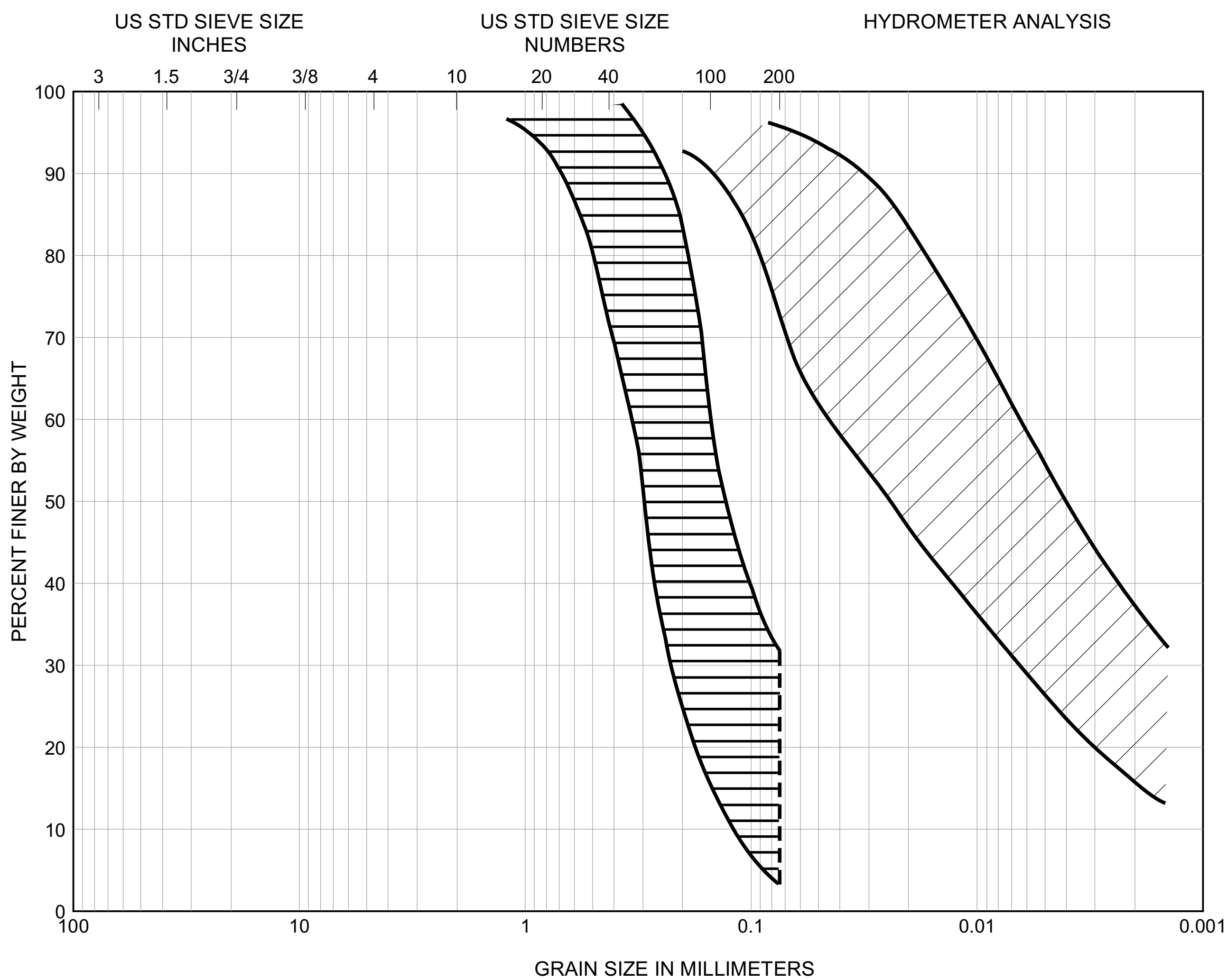
GRAVEL		SAND			SILT or CLAY
coarse	fine	coarse	medium	fine	



Typical Range of Data for Coarse-Grained Sediments in Dredge Unit CG-4

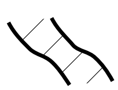
GRAIN SIZE CHARACTERISTICS
Dredge Unit CG-4
Channel Deepening Program
Port of Los Angeles

9642I215GRN1.ds4(2.7)

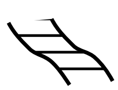


GRAVEL		SAND			SILT or CLAY
coarse	fine	coarse	medium	fine	

Typical Limits of Data



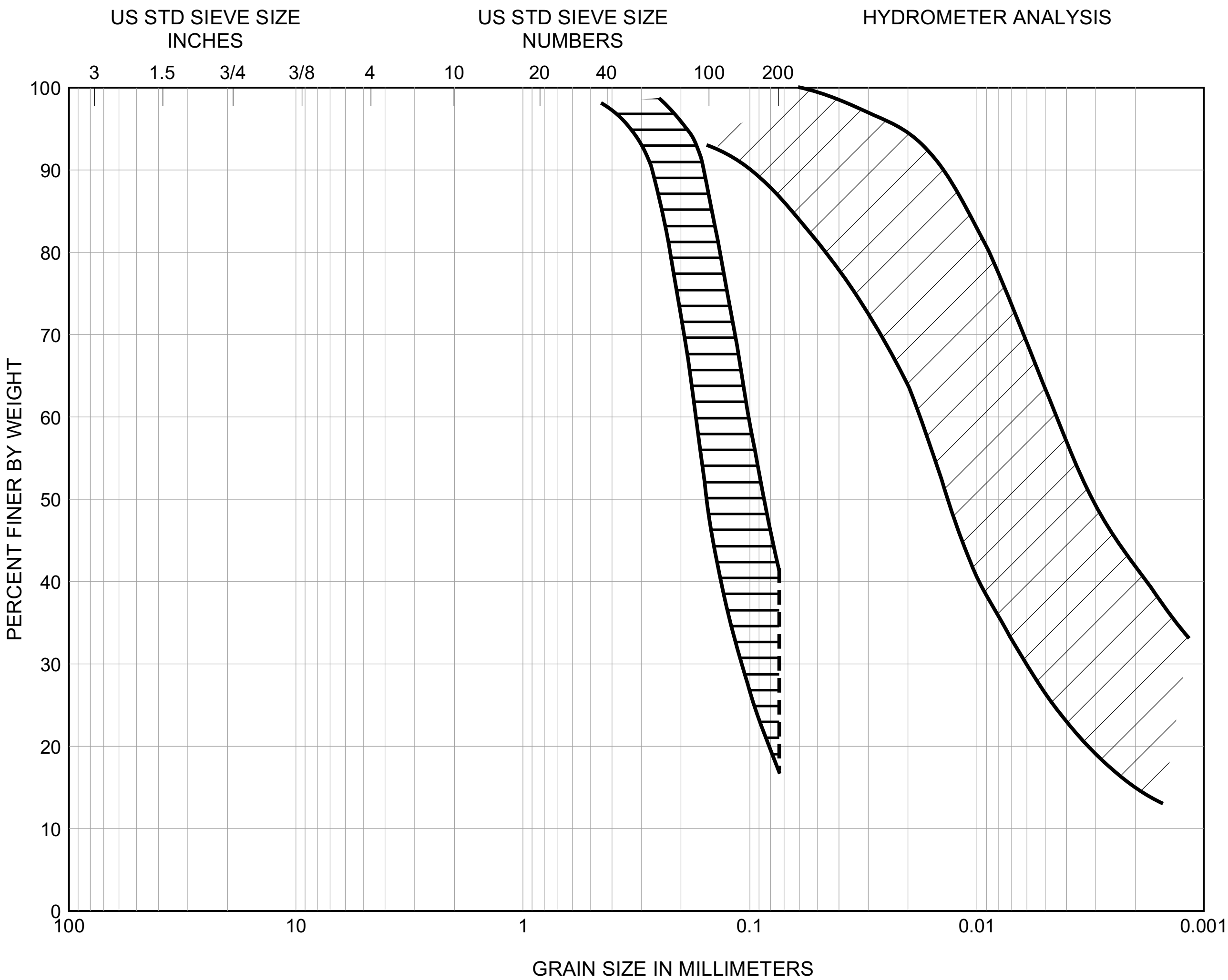
Predominant Fine-Grained Deposits in Dredge Units FG-1 and FG-2



Limited Coarse-Grained Interlayers Encountered in Dredge Units FG-1 and FG-2

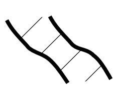
GRAIN SIZE CHARACTERISTICS
Dredge Units FG-1 and FG-2
Channel Deepening Program
Port of Los Angeles

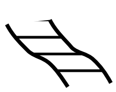
964212125GRN1.ds4(2,8)



GRAVEL		SAND			SILT or CLAY
coarse	fine	coarse	medium	fine	

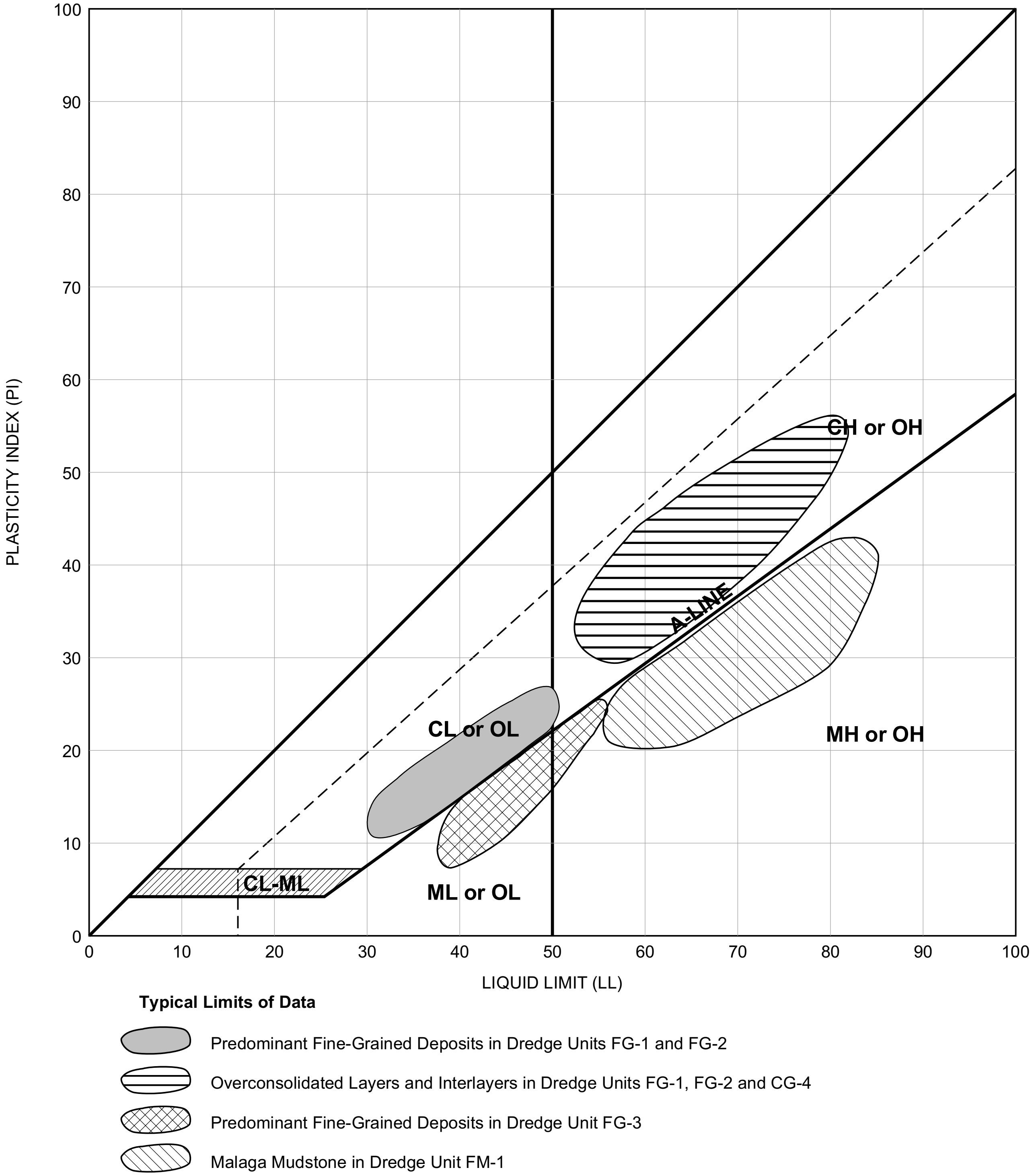
Typical Limits of Data


Predominant Fine-Grained Deposits in Dredge Unit FG-3


Deeper Coarse-Grained Layers Encountered in Dredge Unit FG-3
at or below an Elevation of about -55 to -60 feet

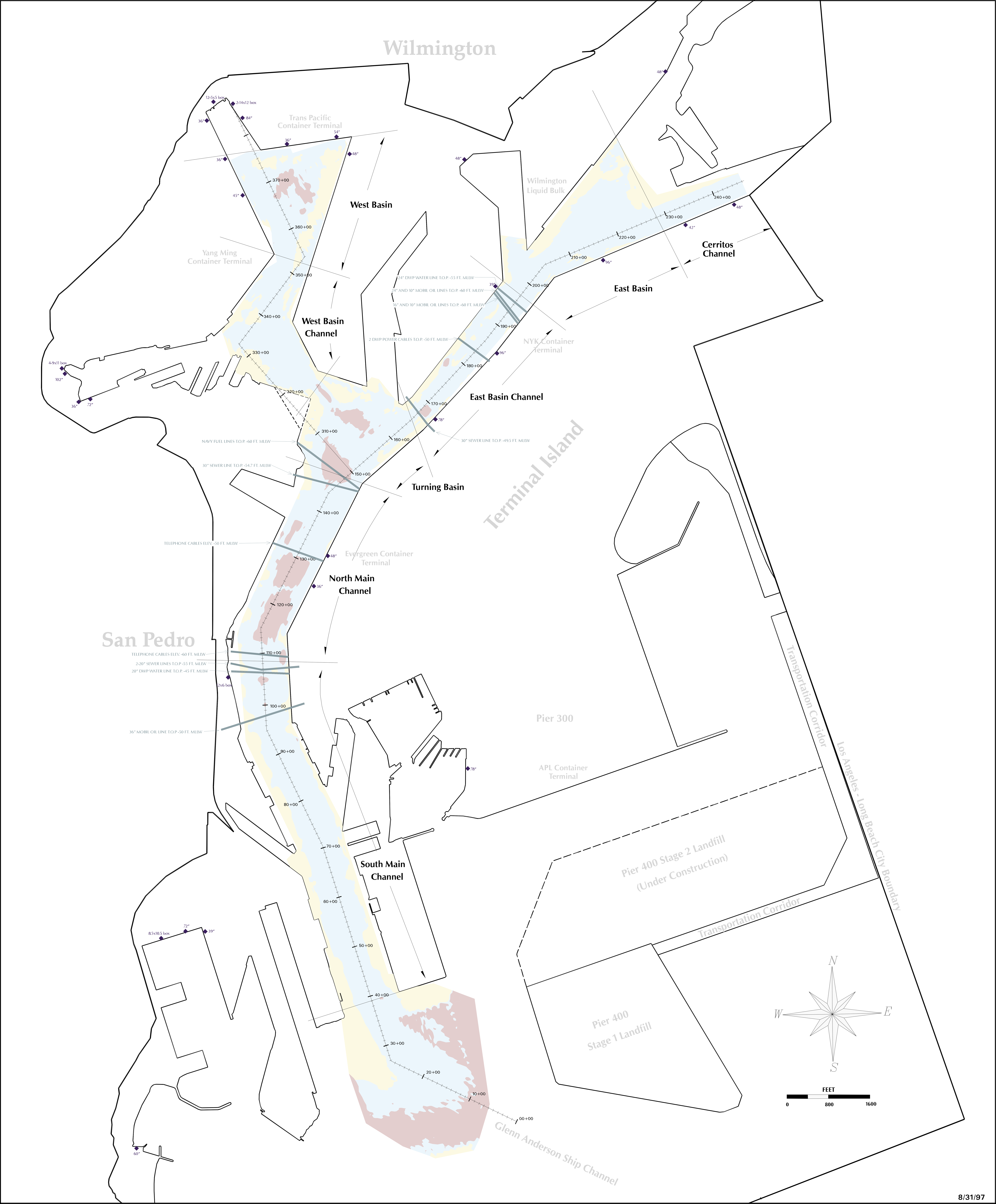
GRAIN SIZE CHARACTERISTICS
Dredge Unit FG-3
Channel Deepening Program
Port of Los Angeles

964211215GRN1.ds4(2,9)



PLASTICITY CHARACTERISTICS
Native Sediments
Channel Deepening Program
Port of Los Angeles

MAPS



Notes

1. Harbor bottom elevations are based on bathymetric survey data acquired by the Port of Los Angeles in late March and early April 1996.
2. All elevation data are in reference to mean lower low water (MLLW).
3. Utility locations are approximate and are based on: a draft drawing titled "Channel Deepening Program, Utility Crossings," dated May 3, 1996, prepared by the Survey Section of the Port of Los Angeles; and "Maintenance Dredging" drawings, dated July 1995, prepared by COE (1995). Note that Fugro did not verify the existence and locations of the utilities.
4. Outfall locations are approximate and are based on an untitled map, provided by the Port of Los Angeles, that shows the locations of outfalls that are 36-inch diameter or larger. Note that Fugro did not verify the existence and locations of the outfalls.

Harbor Bottom Bathymetry Ranges

- Areas Above Elevation -45 Feet
- Areas Between Elevations -45 and -52 Feet
- Areas Below Elevation -52 Feet

Legend

- Utility Crossing Location (refer to notes)
- 36" Outfall Location (refer to notes)
- Survey Control Line and Stationing (feet) for Channel Deepening Program (100+00)

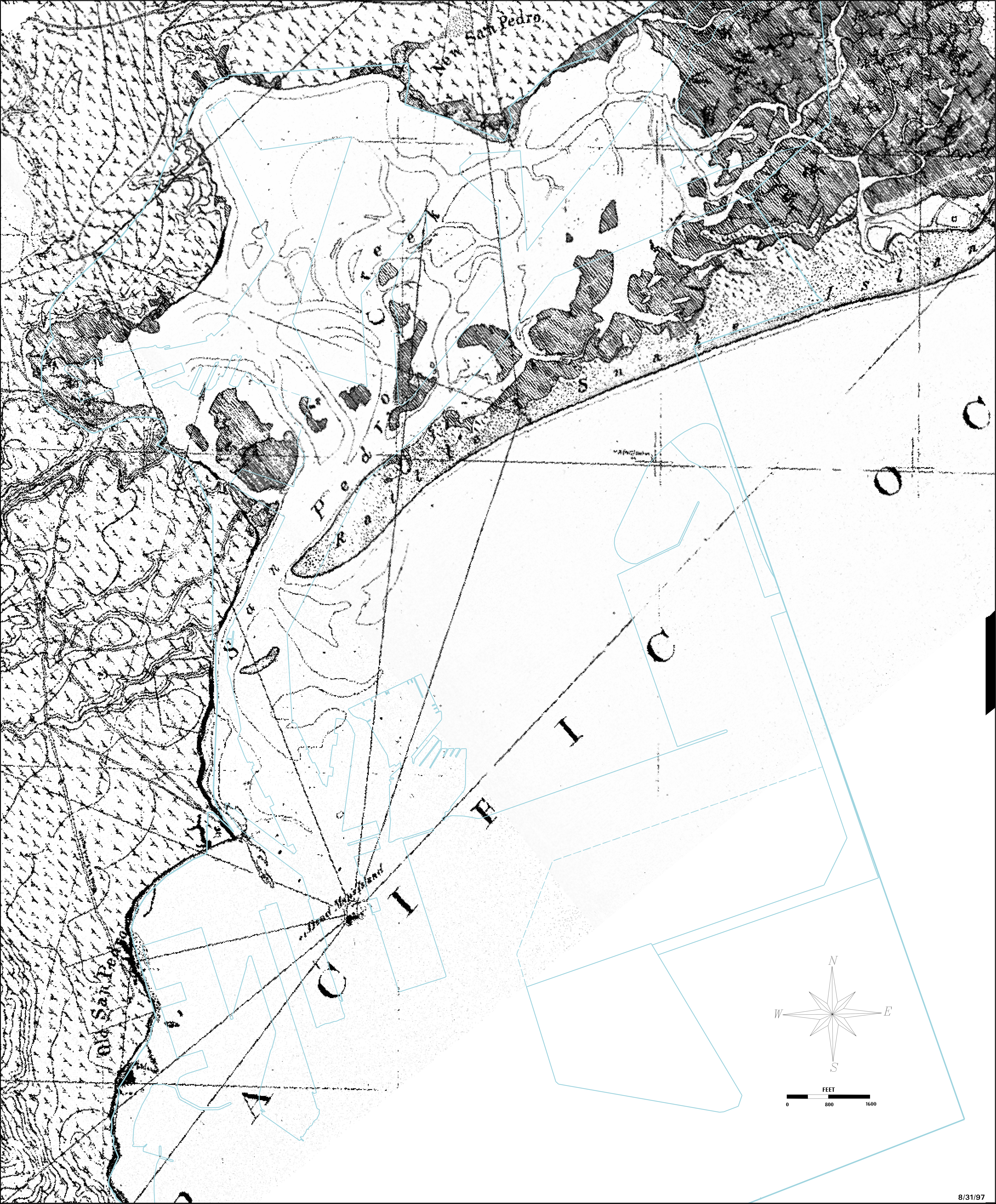
BATHYMETRY, UTILITIES AND OUTFALLS

Channel Deepening Program

Port of Los Angeles, California

Map 1

/sulu/polach/main_ch2/map1.aml, map1.map, 09/10/97 CBD



8/31/97

Notes

1. The morphology shown on this map depicts conditions as they existed in 1859. The data were computer scanned from an 11- by 17-inch version of an 1859 U.S. Coast Survey map presented by Weinman and Stickel (1978). The outline of the Port of Los Angeles and the morphology have been adjusted to an approximate common datum and most features coincide to an acceptable degree of accuracy. Additional adjustments are not justified for this project.

Legend

Approximate Outline of the Port of Los Angeles

1859 MORPHOLOGY

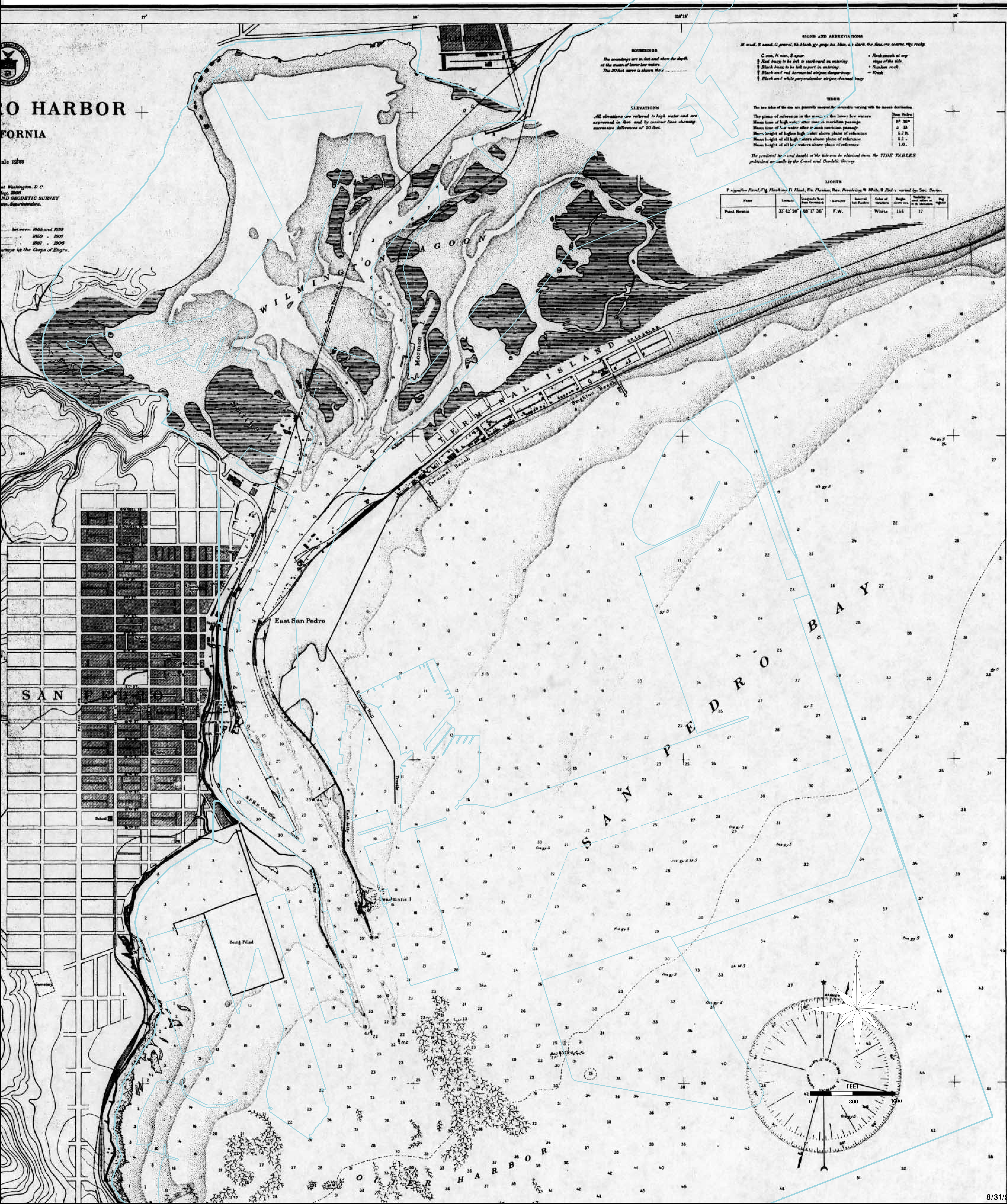
Channel Deepening Program

Port of Los Angeles, California

FUGRO

Map 2

/sulu/polach/main_ch2/map2.aml, map2.map, 09/02/97 CBD



Notes

1. The morphology shown on this map depicts conditions as they existed in about 1907/08. The data were computer scanned from a large "San Pedro Harbor" map created by the Coast and Geodetic Survey in 1907/08. The outline of the Port of Los Angeles and the morphology have been adjusted to an approximate common datum and most features coincide to an acceptable degree of accuracy. Additional adjustments are not justified for this project.

Legend

Approximate Outline of the Port of Los Angeles

1907/08 MORPHOLOGY

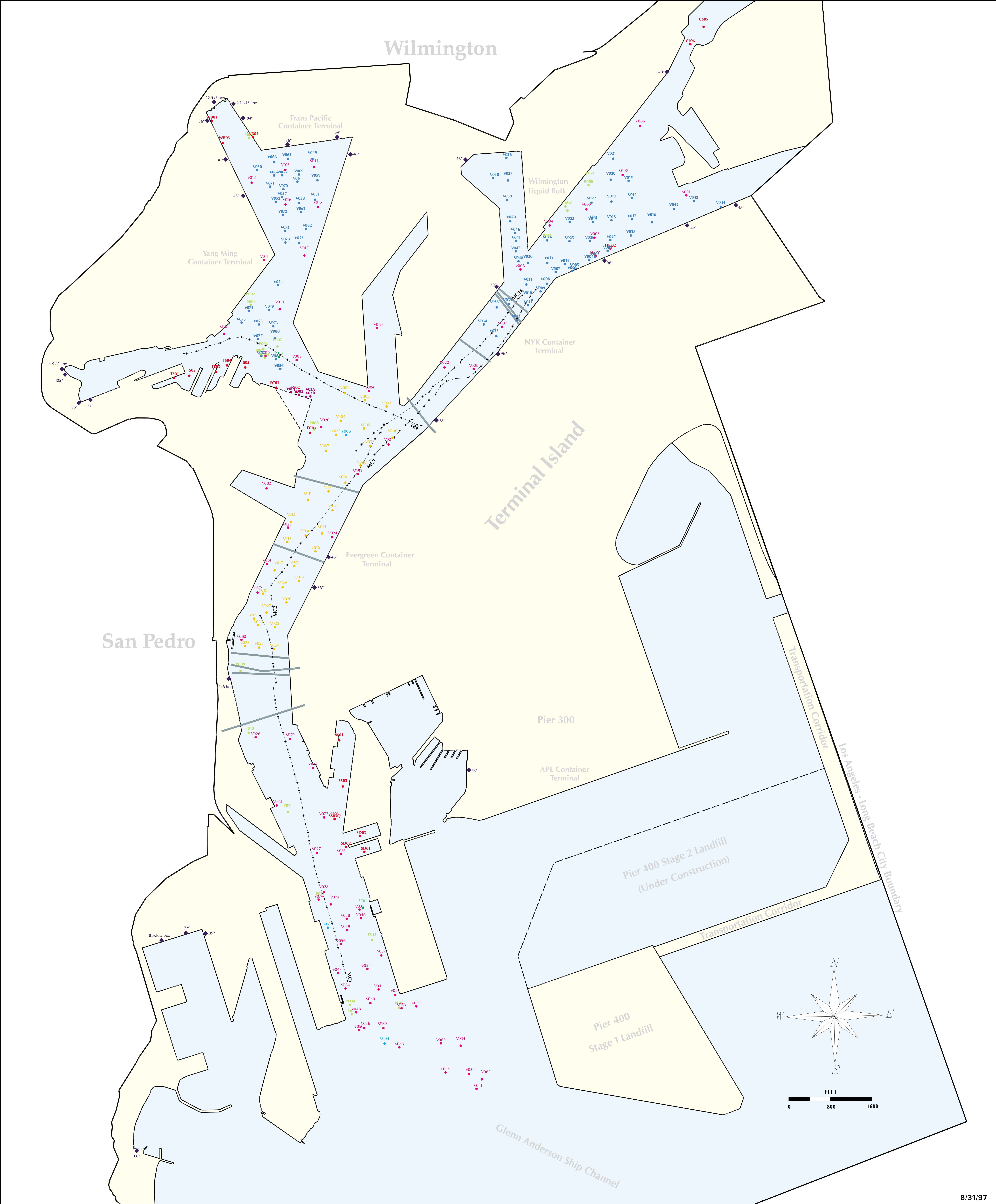
Channel Deepening Program

Port of Los Angeles, California

FUGRO

Map 3

/sulu/polach/main_ch2/map3grd.aml, map3.map, 09/02/97 CBD



8/31/97

Notes

1. Utility locations are approximate and are based on: a draft drawing titled "Channel Deepening Program, Utility Crossings," dated May 3, 1996, prepared by the Survey Section of the Port of Los Angeles; and "Maintenance Dredging" drawings, dated July 1995, prepared by COE (1995). Note that Fugro did not verify the existence and locations of the utilities.
2. Outfall locations are approximate and are based on an untitled map, provided by the Port of Los Angeles, that shows the locations of outfalls that are 36-inch diameter or larger. Note that Fugro did not verify the existence and locations of the outfalls.
3. Existing exploration locations typically were digitized from various types and sizes of maps and, therefore, are approximate and may be in error by 100 to 200 feet or more.
4. Tracklines indicated on this map represent the approximate vessel travel path where geophysical data were acquired during the 2020 Plan Geotechnical Investigation (Fugro-McClelland, 1991, 1992).

Existing Exploration Locations

- U.S. Corps of Engineers (1980) performed in 1977
- U.S. Corps of Engineers (1980) performed in 1978
- U.S. Corps of Engineers (1980) performed in 1979
- CH2M Hill (1984)
- Harding Lawson Associates (1987)
- McClelland Engineers (1987)
- Fugro-McClelland (1993)
- U.S. Corps of Engineers (1995) performed in 1993

Legend

- 36" Outfall Location (refer to notes)
- Utility Crossing Location (refer to notes)
- Trackline and Position Fix for 1990 Geophysical Data (refer to notes)

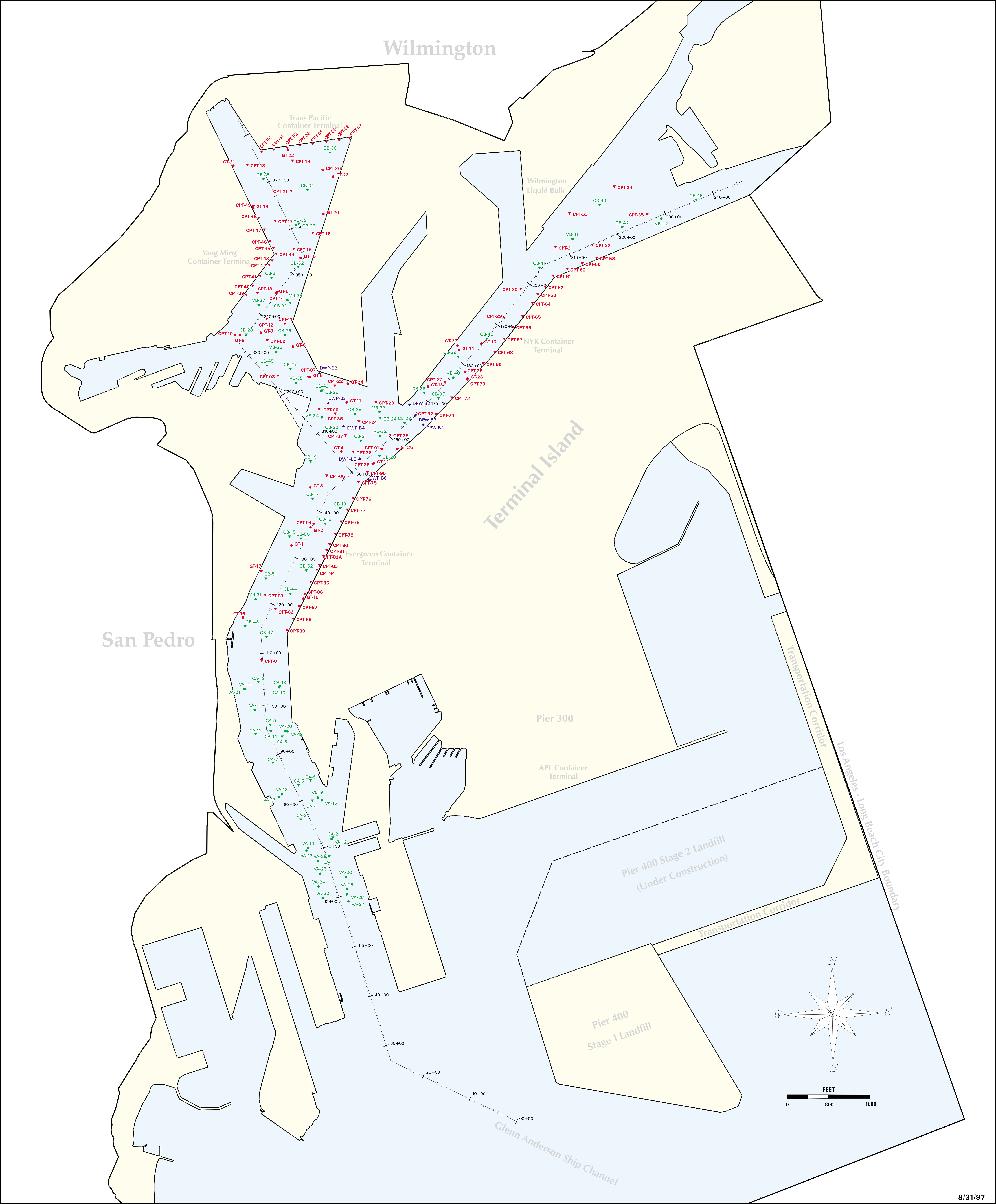
EXISTING EXPLORATION LOCATIONS

Channel Deepening Program

Port of Los Angeles, California

Map 4

/sulu/polach/main_ch2/exismap.aml, map4.map, 09/03/97 CBD, 96-42-1215



8/31/97

Notes

1. Refer to report text for additional details.
2. Fugro (1997a,b) explorations represent borings that were performed during the Phase 2 investigation for the Channel Deepening Program, but were related to utility crossing projects.

Channel Deepening Program Explorations

- Phase 1 Stratigraphic Vibrocore
- Phase 1 Cone Penetration Test
- Phase 2 Stratigraphic Vibrocore
- Phase 2 Cone Penetration Test

Utility Crossing Explorations

- Borings (Fugro, 1997a)
- Borings (Fugro, 1997b)

Legend

Survey Control Line and Stationing (feet) for Channel Deepening Program

100+00

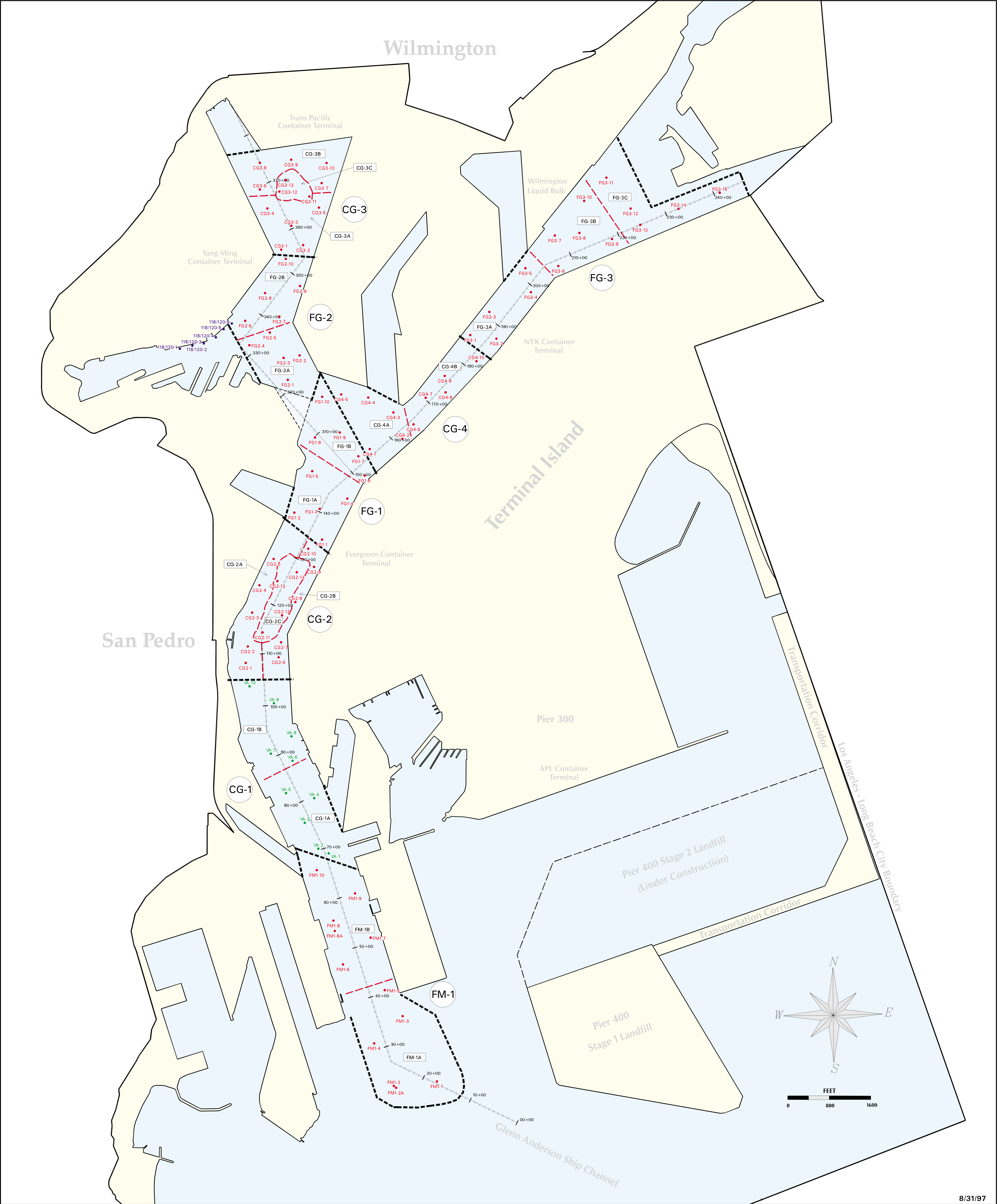
PHASES 1 AND 2 GEOTECHNICAL EXPLORATIONS

Channel Deepening Program

Port of Los Angeles, California

Map 5

/sulu/polach/main_ch2/geotmap.aml, map5.map, 09/03/97 CBD



Notes

1. Refer to report text for additional details.
2. KLI/ToxScan (1997b) explorations represent vibrocores that were performed during the Phase 2 investigation for the Channel Deepening Program, but were related to a maintenance dredging project.

Channel Deepening Program Explorations

- Phase 1 Environmental Vibrocore
- Phase 2 Environmental Vibrocore

Maintenance Dredging Explorations

- KLI/ToxScan (1997b)

Legend

- Preliminary Dredge Unit Boundary
- Environmental Sampling Subunit Boundary
- CG-1 Preliminary Dredge Unit Designation
- CG-1A Environmental Sampling Subunit Designation
- Survey Control Line and Stationing (feet) for Channel Deepening Program (100+00)

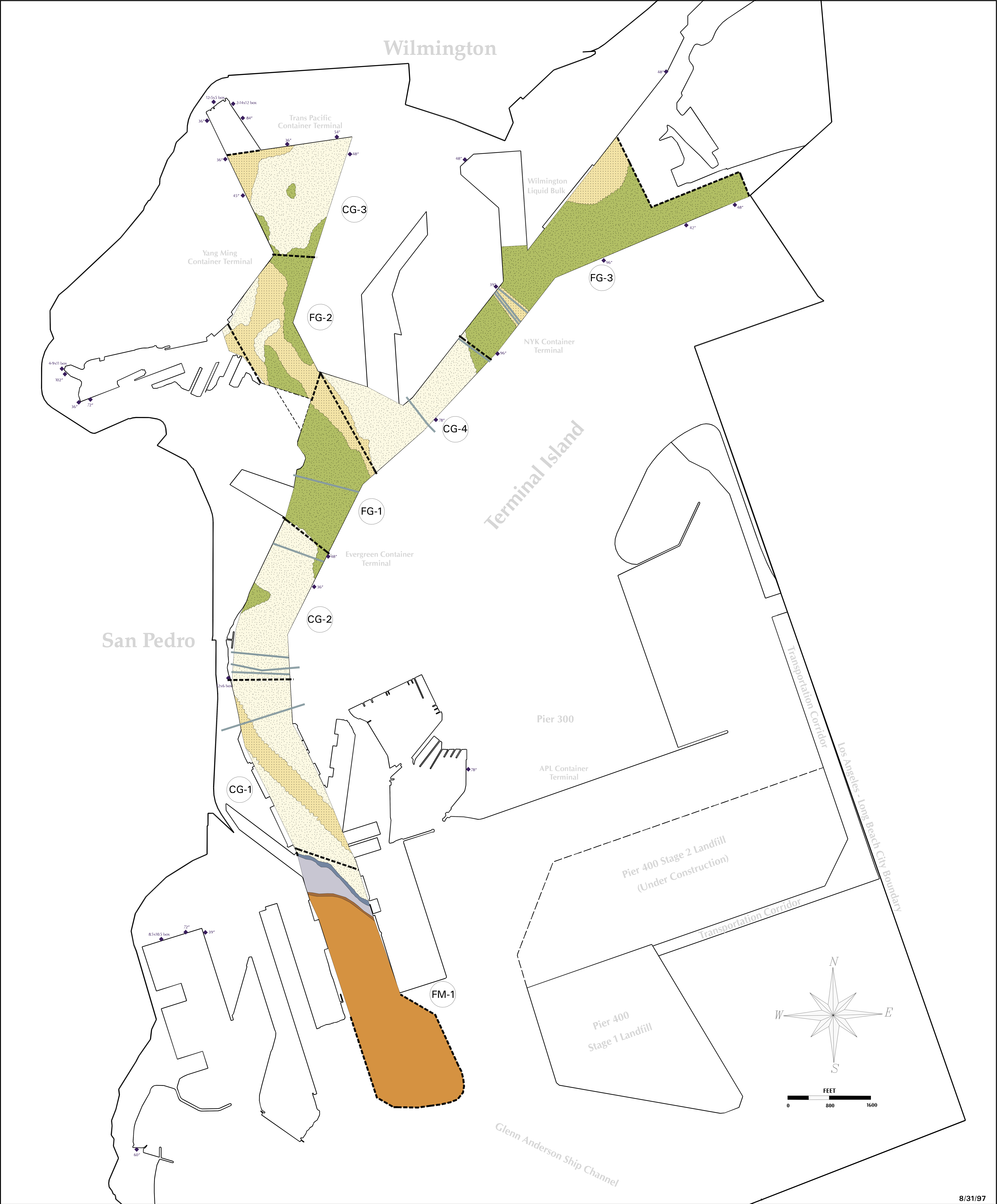
PHASES 1 AND 2 ENVIRONMENTAL VIBROCORES

Channel Deepening Program

Port of Los Angeles, California

Map 6

/sulu/polach/main_ch2/envirmap.aml, map6.map, 09/03/97 CBD



8/31/97

Notes

1. The interpreted shallow stratigraphic conditions shown on this map are generally representative of native sediments present above an elevation of about -52 to -55 feet. Non-native, harbor bottom sediments overlie the native sediments throughout much of the Inner Harbor. The presence of those harbor bottom sediments did not influence delineation of the different stratigraphic deposits. Contact locations are approximate. Refer to report text for additional details.
2. Utility locations are approximate and are based on: a draft drawing titled "Channel Deepening Program, Utility Crossings," dated May 3, 1996, prepared by the Survey Section of the Port of Los Angeles; and "Maintenance Dredging" drawings, dated July 1995, prepared by COE (1995). Note that Fugro did not verify the existence and locations of the utilities.
3. Outfall locations are approximate and are based on an untitled map, provided by the Port of Los Angeles, that shows the locations of outfalls that are 36-inch diameter or larger. Note that Fugro did not verify the existence and locations of the outfalls.

Landfill Use Desirability	Material Types
High	Primarily coarse-grained sediments (sand and silty sand).
Low-Moderate	Interlayered deposits of coarse- and fine-grained sediments.
Very Low	Primarily fine-grained sediments (silt, sandy silt, and clay).
Low-Very Low	Intact and/or weathered Timms Point Silt (silt, sandy silt, silty sand) deposits that approach the harbor bottom, but are covered by about 2 to 8 feet of loose sediments.
Very Low	Intact, disturbed, and/or weathered Malaga Mudstone (silt) deposits that are exposed on the harbor bottom or are covered by a thin veneer of harbor bottom sediments.

Legend

- Approximate location of contact between Holocene sediments and Timms Point Silt as projected upward to the harbor bottom.
- Approximate location of contact between Timms Point Silt and Malaga Mudstone as exposed on the harbor bottom.
- Preliminary Dredge Unit Boundary
- Utility Crossing Location (refer to notes)
- 36" Outfall Location (refer to notes)
- CG-1 Preliminary Dredge Unit Designation

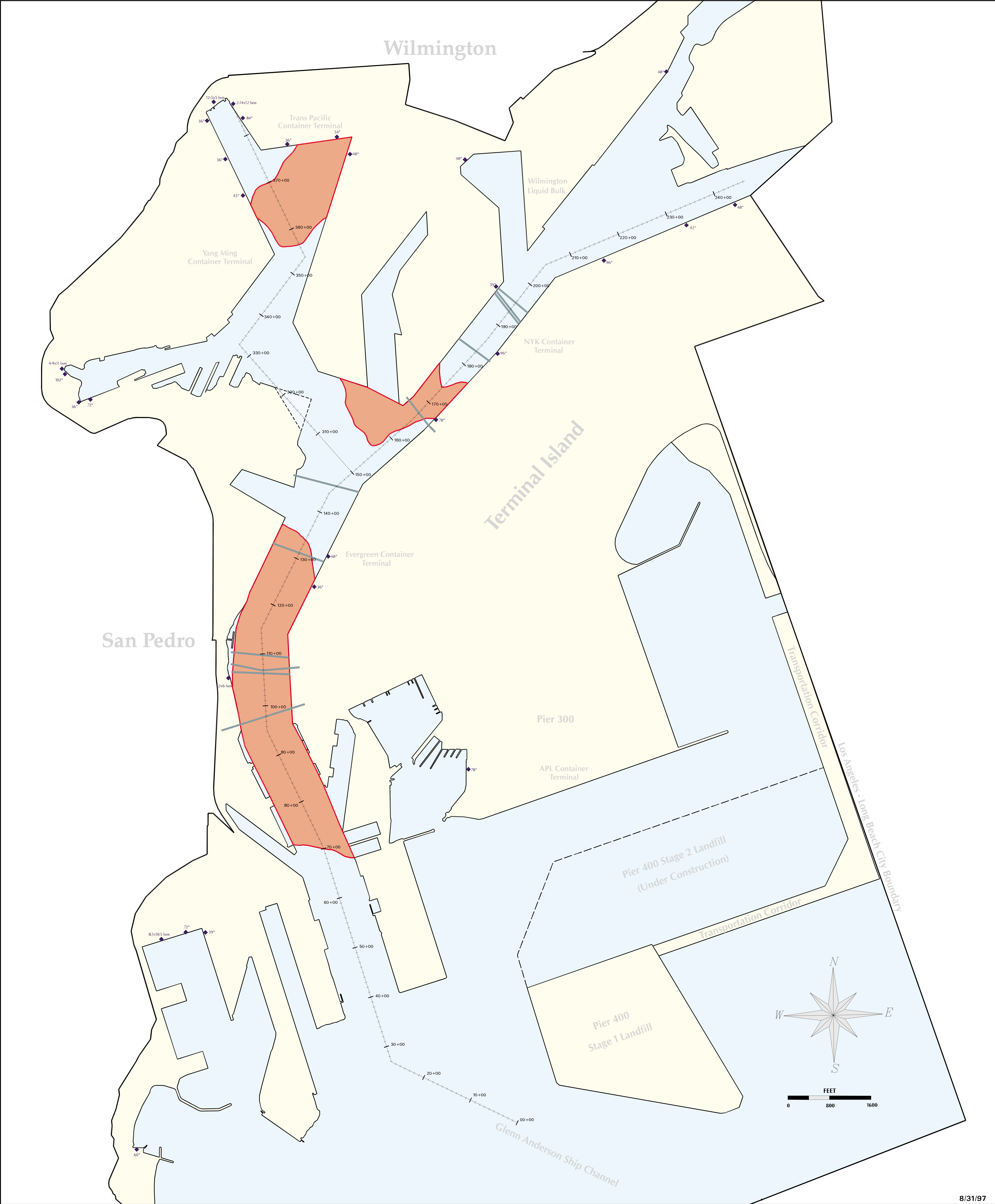
INTERPRETED SHALLOW STRATIGRAPHIC CONDITIONS

Channel Deepening Program

Port of Los Angeles, California

Map 7

/sulu/polach/main_ch2/geomap.aml, map7.map, 09/03/97 CBD, 96-42-1215



Notes

1. Recommended mining areas are based on interpretation of available stratigraphic data, which are generally limited to no deeper than about elevation -60 to -65 feet, except for explorations performed within existing borrow pits. Refer to report text for additional details.
2. Utility locations are approximate and are based on: a draft drawing titled "Channel Deepening Program, Utility Crossings," dated May 3, 1996, prepared by the Survey Section of the Port of Los Angeles; and "Maintenance Dredging" drawings, dated July 1995, prepared by COE (1995). Note that Fugro did not verify the existence and locations of the utilities.
3. Outfall locations are approximate and are based on an untitled map, provided by the Port of Los Angeles, that shows the locations of outfalls that are 36-inch diameter or larger. Note that Fugro did not verify the existence and locations of the outfalls.

Legend

Areas where appreciable deposits of coarse-grained sediments (sand and silty sand) are present below about elevation -52 feet (refer to notes).

Utility Crossing Location (refer to notes)

36" Outfall Location (refer to notes)

Survey Control Line and Stationing (feet) for Channel Deepening Program

100+00

RECOMMENDED MINING AREAS

Channel Deepening Program

Port of Los Angeles, California

Map 8

/sulu/polach/main_ch2/minemap.aml, map8.map, 09/03/97 CBD, 96-42-1215