FINAL REPORT
GEOTECHNICAL INVESTIGATION
Marina Boulevard Seawall
San Francisco, California

City and County of San Francisco
San Francisco, California

12 December, 1997
Project No. 1526.02

Treadwell&Rollo
Environmental and Geotechnical Consultants

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Mr. Harlan L. Kelly, Jr.
Deputy Director for Engineering and City Engineer
City and County of San Francisco
Department of Public Works
30 Van Ness Avenue, 5th Floor
San Francisco, California 94102

Subject: Final Report
Geotechnical Investigation
Marina Boulevard Seawall
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Dear Mr. Kelly:

We are pleased to submit 25 copies of our geotechnical investigation report, dated 12 December 1997, for the subject property. Our services were provided in accordance with the City and County of San Francisco, Department of Public Works (DPW) Order No. 169,333 (approved 20 February 1996) and our proposal dated 18 January 1996.

We appreciate the opportunity of serving you on this interesting and challenging project. If you have any questions, please call.

Sincerely yours,
TREADWELL & ROLLO, INC.

Craig S. Shields
Geotechnical Engineer

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REGISTERED PROFESSIONAL ENGINEER CRAIG S. SHIELDS GE2116 Exp. 3/31/01 GEOTECHNICAL STATE OF CALIFORNIA

Frank L. Rollo
Geotechnical Engineer

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EXECUTIVE SUMMARY

This report presents the results of the investigation performed by Treadwell & Rollo, Inc. (T&R) to evaluate the potential for liquefaction and lateral spreading to occur behind the Marina Boulevard seawall in San Francisco. The seawall is approximately 1,100 feet long and runs along the northern side of Marina Boulevard between Scott and Baker Streets as shown on Figure E-1. It is a nine-foot-high cantilever concrete wall supported on composite concrete and wood piles. The Marina Boulevard box sewer parallels the seawall near the northern curbline of Marina Boulevard. The box sewer is a buried concrete structure that collects the dry and wet weather flows from the area.

The issue of potential damage to the seawall due to liquefaction and lateral spreading was initially addressed in a report entitled "Final Report, Liquefaction Study, Marina District and Sullivan Marsh Area, San Francisco, California" dated August 1991, by Harding Lawson Associates, et. al., prepared for the City and County of San Francisco, Department of Public Works (DPW). The 1991 report concludes the Marina Boulevard seawall may move significantly toward the yacht harbor during a Richter magnitude 8.3 earthquake and the ground surface between the seawall and sewer may settle because of lateral spreading. The report recommends the seawall be strengthened and the ground improved between the box sewer to mitigate the potential for damage due to lateral spreading. A committee was subsequently appointed by the City and County of San Francisco Board of Supervisors to review the Liquefaction Study report. The committee recommended in a report dated May 1992 that the seawall be strengthened and the ground between the seawall and the box sewer be improved in accordance with the recommendations provided in the Liquefaction Study report.

We previously performed a geotechnical study in 1993-1994 to evaluate whether liquefaction and lateral spreading will occur behind the seawall and to evaluate the risk of earthquake-induced damage to the box sewer and seawall. We concluded there is potential for several feet of horizontal ground movement to occur behind the seawall during a repeat of the 1906 earthquake, and both the seawall and box sewer behind the seawall would likely experience damage from the lateral spreading. Because the conclusions were based on widely spaced borings and few laboratory test data, however, it was recommended, in a meeting with the Blue Ribbon Committee appointed by DPW, that additional field investigation be performed to confirm the conclusions and to provide recommendations for mitigation measures to reduce the potential for lateral spreading.

To better characterize the liquefiable deposit in the seawall vicinity, a field investigation was performed for the current study. The investigation included drilling test borings, performing cone penetrometer tests and measuring compression and shear wave velocities of the fill soil. During our investigation four distinct types of granular soil were encountered in the vicinity of the seawall: 1) land-tipped sand fill just below the water table, 2) hydraulic fill, 3) gravel and rock fill comprising Fair's seawall, and 4) native sand.

On the basis of our field investigation and our engineering analyses, we conclude the submerged land-tipped fill and most of the hydraulic fill will liquefy during a major earthquake. Because of the high permeability of the gravel and rock fill comprising Fair's seawall, we conclude the potential for this material to liquefy is low. The liquefaction potential of the native sand is also considered to be low except for isolated, non-continuous pockets.

For our lateral spreading analysis, we considered two earthquakes: a moment magnitude 7.9 earthquake on the San Andreas Fault, which would be a repeat of the 1906 (Richter magnitude 8.3) earthquake, and a moment magnitude 7.0 earthquake on either the San Andreas or Hayward Fault. The Working Group on California Earthquake Probabilities (U.S. Geological Survey Circular 1053, 1990) estimates the probability of occurrence by the year 2020 to be 2 and 67 percent for the magnitudes 7.9 and 7.0 events, respectively. Using an empirical relationship developed by Bartlett and Youd (1992) and taking into consideration the positive influence of various existing below-grade features (rockfill, piles, and gravel around the box sewer), we estimate the lateral movement would be about three feet for the magnitude 7.9 event and six inches for the magnitude 7.0 event. These movements would occur primarily east of Divisadero Street. Significant lateral spreading is not expected to occur west of Divisadero Street, where the soil below the water table primarily consists of medium-dense to dense natural sand (instead of fill).

There are two distinct seismic stability issues to be addressed in the analysis of the Marina Boulevard seawall. They are Local Stability and Area-wide Stability. Local Stability refers to the Marina Boulevard seawall, its foundations, the backfill immediately behind the seawall, and the sidewalk/jogging path and utilities supported by the backfill. Area-wide stability refers to both the Marina and adjacent Fair's seawall, the box sewer, Marina Boulevard, and all of the area south of Marina Boulevard that was reclaimed by hydraulic filling (see Figure E-2). Considering the large mass of ground that is susceptible to movement, and the amount of movement that is anticipated during a major earthquake, it may not be economically feasible to address Area-wide Stability. Improvements to the Marina Boulevard seawall and/or the ground between the seawall and the box sewer will not significantly reduce the amount of Area-wide lateral spreading that is expected to occur.

Local stability is governed by the adequacy of the Marina Boulevard seawall to resist earthquake forces, and the presence of potentially liquefiable material behind the wall and the resulting lateral pressures. Local stability may be addressed by:

1. strengthening the seawall to resist the lateral forces due to seismic loading (Method 1), or

1. reducing the lateral forces on the wall by improving the soil between the wall and the box sewer (Method 2), or

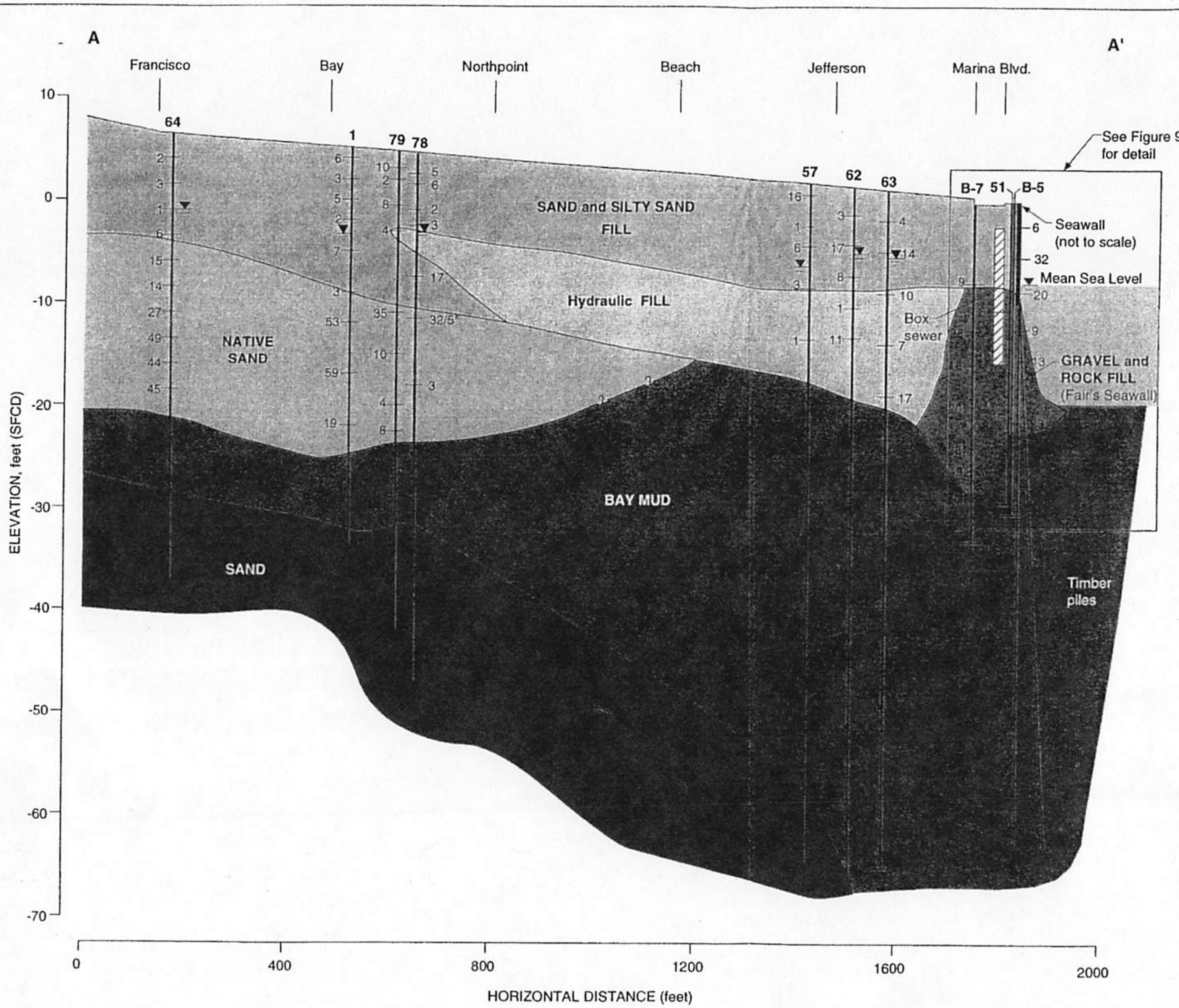
2. doing nothing and repairing the seawall, utilities, and the sidewalk/jogging path behind the seawall after an earthquake.

One solution to strengthen the seawall to resist seismic overturning forces (Method 1) would be to add new piles at the rear of the seawall. We judge prestressed, precast concrete piles would be the most economical pile type. One solution to reduce the lateral forces on the wall (Method 2) would be to strengthen the land-tipped fill behind the seawall. The fill could be strengthened by compaction grouting the submerged land-tipped fill and then installing geogrids in the backfill behind the wall.

Neither Method 1 nor 2 will protect the box sewer and the area south of the box sewer which could move 1/2 to 3 feet during a magnitude 7.0 and 7.9 earthquake, respectively. Further, even if Method 1 or 2 is implemented, the seawall could be irreparably damaged by Area-wide lateral spreading during a magnitude 7.9 earthquake.

Based on our findings, we recommend the following action be taken:

1. Be prepared to repair the box sewer and utilities along Marina Boulevard in the event of an earthquake;
2. Perform an analysis to compare the cost of the measures discussed above for reducing the potential for damage to the Marina Boulevard seawall and adjacent improvements during an earthquake to the cost of repairing the seawall and these improvements after an earthquake (cost/benefit analysis); the analysis should take into account the probabilities of earthquake occurrence.

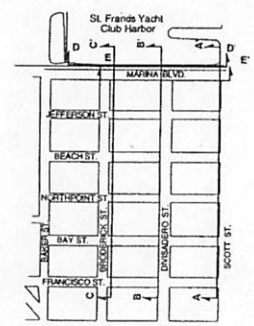


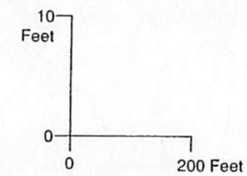
EXPLANATION

12 Indicates SPT N-values

Indicates groundwater level measured in boring

Note: The profile represents a generalized soil cross section interpreted from widely spaced borings. Soil deposits may vary in type, strength, and other important properties between points of exploration.





Approximate scale

MARINA BOULEVARD SEAWALL
San Francisco, California

IDEALIZED SUBSURFACE PROFILE SECTION A - A'

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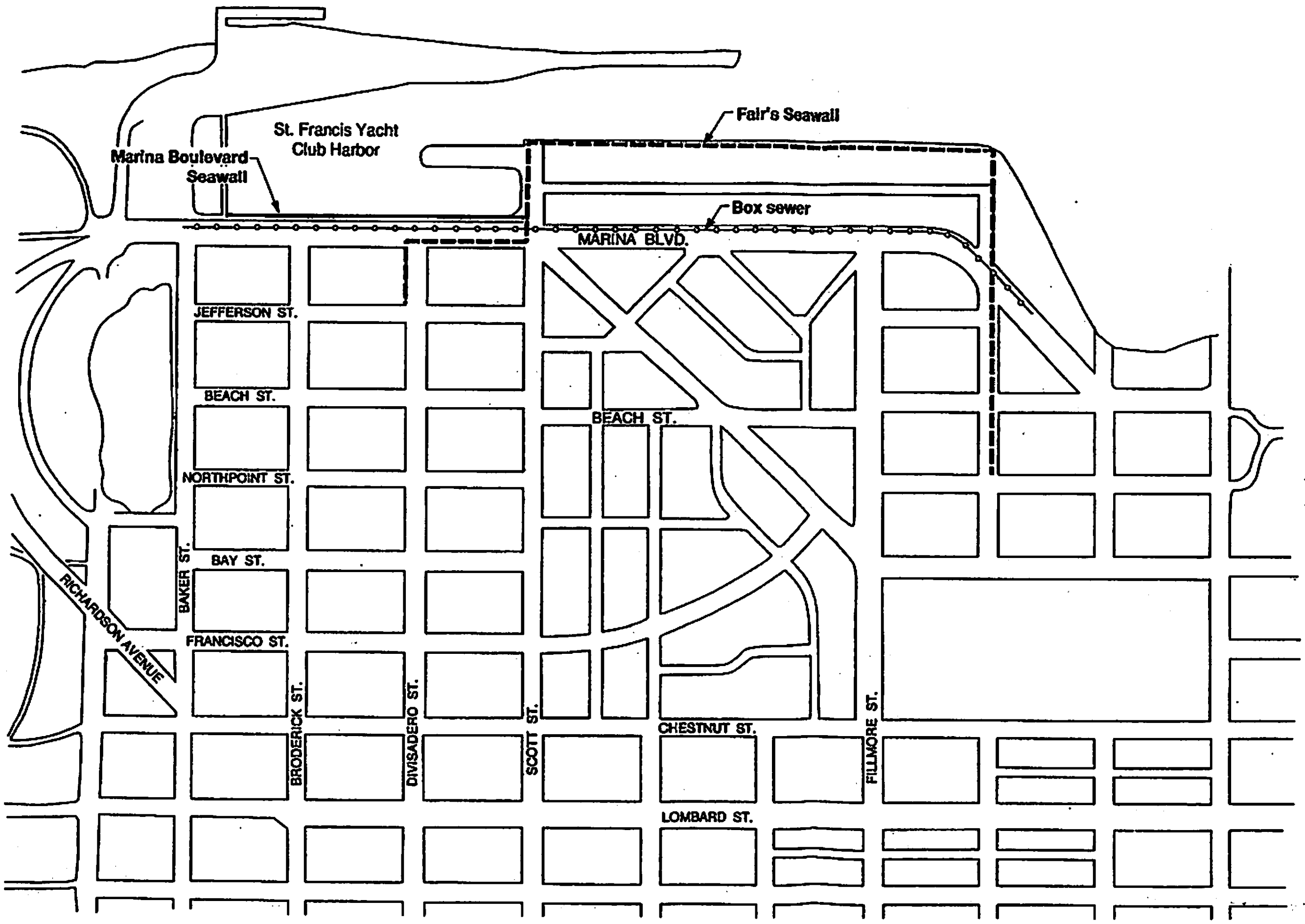

MARINA BOULEVARD SEAWALL
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GENERAL SITE PLAN

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