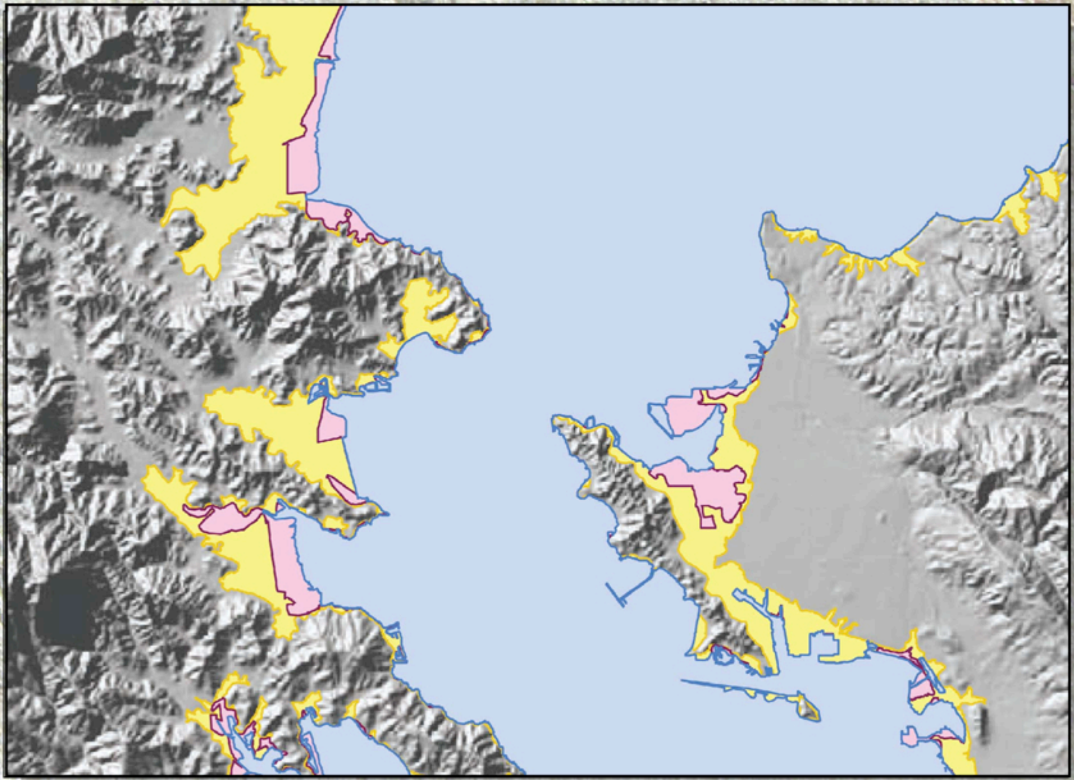
WILLIAM LETTIS & ASSOCIATES, INC.

Final Technical Report

DETAILED MAPPING OF ARTIFICIAL FILLS, SAN FRANCISCO BAY AREA, CALIFORNIA



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FINAL TECHNICAL REPORT

DETAILED MAPPING OF ARTIFICIAL FILLS, SAN FRANCISCO BAY AREA, CALIFORNIA

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ABSTRACT

Over half of all documented historical occurrences of liquefaction in the San Francisco Bay area have occurred within artificial fill placed over bay margins (Knudsen et al., 2000). During the past century, following the 1906 earthquake, tens of millions of cubic meters of fills have been placed along bay margins including infilling of the Marina District, creation of Treasure Island and Alameda Naval Air Station, and expansion of San Francisco and Oakland airports. Many of these artificial fills, emplaced prior to regulation in 1969, lack soil improvement to increase their liquefaction resistance and have yet to be shaken strongly during a major earthquake (Holzer et al, 2006). The relatively poor performance of post-1906 fills during the 1989 Loma Prieta earthquake, along with localized liquefaction-related damage in fill overlying deltaic deposits during the 1995 Kobe (Great Hanshin), 2001 Nisqually, and 2003 San Simeon earthquakes, demonstrate the unique vulnerability of artificial fills emplaced along Bay margins to strong ground shaking during future large earthquakes.

Detailed mapping was performed to: (1) map the progression of shorelines into the San Francisco Bay; (2) map the bayward emplacement of fills along the Bay margins over time (including fill ages, mechanism of fill placement, and likely composition); and; (3) provide the resultant map database to the USGS in a form that can be integrated in existing and proposed USGS map databases (e.g. Witter et al., 2006). GIS-based analyses of historic topographic and bathymetric maps, combined with examination of historical records and available compiled borehole databases (CGS), provides information on the distribution and composition of fills towards future quantitative studies of potential liquefaction-induced permanent ground deformation along the Bay margins. The final products of this study include digital map databases that depict:

- Distribution of historic Bay shorelines;
- Ages and inferred methods of emplacement of artificial fills (hydraulic fill, dumped debris, etc.); and
- Inferred composition of artificial fills from historical records.

Our maps of artificial fill addresses Element I, Products for Earthquake Loss Reduction, and Element II, Research on Earthquake Occurrence and Effects, of the National Earthquake Hazard Reduction Program.

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1.0 INTRODUCTION

Much of the urban development within the broad flatlands bordering the San Francisco Bay is underlain by Holocene sediments deposited during the last interglacial rise in sea level. These largely unconsolidated to semi-consolidated sediments are vulnerable to liquefaction and amplification of strong ground motions. However, the subsurface distribution, thickness, seismic response, and geotechnical properties of overlying artificial fill within the Bay basin are poorly characterized.

The behavior of artificial fills within reclaimed land along bay margins subject to strong ground shaking became a major source of concern following the catastrophic effects in bayfront fills during the 1995 Kobe (Great Hanshin) Japan earthquake. More recently, localized liquefaction produced by the 2001 Nisqually earthquake and 2003 San Simeon earthquake in artificial fills covering former tidal flats has confirmed the vulnerability of non-engineered, man-made fills emplaced along bay margins to failure during seismic shaking, even under relatively low ground motions (Troost et al., 2001; Holzer et al., 2005).

Past occurrences of liquefaction-related ground deformation within the San Francisco Bay area have not been randomly distributed but rather reflects the urbanization of the Bay margins. In the Bay area, liquefaction produced by the October 17, 1989 Loma Prieta earthquake resulted in significant, localized damage to bayshore areas reclaimed after the 1906 earthquake, including extensive property damage in the Marina District of San Francisco (O'Rourke and Roth, 1990; Holzer, 1993). Knudsen (2000) documented that artificial fill over Bay Mud has hosted about 50 percent of all historical liquefaction occurrences in the San Francisco Bay area. However, about 83 percent of liquefaction occurrences from the 1989 Loma Prieta earthquake occurred in artificial fill whereas only about 30 per cent of liquefaction failures in earlier earthquakes, including 1906, occurred in fill emplaced on Bay margins. Holzer et al (2006) note that laterally extensive fills emplaced along the East Bay margins since 1906 performed badly when subjected to the relatively moderate ground shaking generated by the distant 1989 Loma Prieta earthquake, and have yet to be tested by intense ground shaking generated by a large, nearby earthquake.

Most structures destroyed by the 1995 Kobe earthquake were concentrated in areas of "reclaimed land" developed since the turn of the century (Hamada et al., 1996). The worst devastation within the city of Kobe occurred in areas where fill (mostly decomposed granite from nearby hills) had been emplaced on tidal marshes along the margin of Kobe Bay. Liquefaction-induced damage was especially destructive on the man-made Kobe Port and Rokko Islands, which cover approximately 10 km^2 and 6 km^2, respectively. Both islands were constructed with fill derived from decomposed granite emplaced directly on bay mud. Along the bay margins of Kobe, artificial fills emplaced over estuarine sediment performed particularly poorly, resulting in damage even to state-of-the-art engineered structures as land surrounding pier-supported buildings and bridges settled a meter or more in some areas (Hamada et al., 1996).

Like Kobe, urbanization in the San Francisco Bay area has built outwards into the Bay by incremental emplacement of artificial fills on Bay mud and estuarine channel deposits. During a large earthquake on the nearby Hayward, Rodgers Creek, or Calaveras faults, it is likely that liquefaction-related damage within artificial fill along the Bay margins will be extensive to infrastructure and lifelines and extremely costly. It is also likely that, as was documented after the 1989 Loma Prieta earthquake, liquefaction-related ground deformation will be particularly intense in filled areas along the Bay margins (Holzer, 1993; Holzer et al., 2006), and directly correlative to the saturated thickness and type of fill present (Power et al., 1993; O'Rourke et al, 2006).

Fills emplaced since 1965 along the Bay margins have been required to be engineered. However, engineered fill and subsequent Bay margin development in many instances overlies older, potentially liquefiable uncompacted artificial fill. These older Bay fills were placed directly on top of Holocene estuarine sediments, including sand shoals, tidal mud flats, and tidal and fluvial channels. Trask and Rolston (1951) noted that historic settlement rates of fill are, in part, directly related to both the thickness of the fill, and underlying Bay Mud, and the sand content within the fill and underlying Bay Mud. Fill settlement is not uniform because permeable sand layers within the estuarine sediments (e.g., within Bay Mud) enable migration of water during loading and thus influence the behavior of the overlying fills. Fill settlement is more pronounced and rapid in sandy fill and fill overlying sand shoals or sand bodies within Bay Mud, relative to areas where the fill is either well compacted, clayey, or the underlying estuarine sediment contains no sand (Trask and Rolston, 1951). It is likely that similar, although more rapid, localized liquefaction-related fill settlement and failure will occur at these locations during earthquake loading.

Based on recognition of the above, Witter et al. (2006) reclassified San Francisco Bay mud to moderate susceptibility to liquefaction and rated the relative hazard of artificial fill based on the types of late Quaternary deposits (map units) inferred to underlie the fill. Ultimately, however, Witter et al. (2006) group artificial fill over Bay Mud and assign this unit a very high susceptibility regardless of the age, type, and composition of the overlying fill itself. In addition, all saturated artificial fills on Bay Mud, including post-1965 engineered fill, are included within California Geologic Survey liquefaction hazard zone maps. In large part this conservative generalization of liquefaction hazard reflects what isn't known. This includes the absence of information on the types and distribution of estuarine sediments within the underlying Bay Mud. However, it also reflects the absence of regionally consistent information on fill type, fill composition, and fill thickness.

Useful information on artificial fills can be derived and mapped using available historical documents, including vintage topographic maps and archival records. This information can be used to reduce the conservatism inherent in the current liquefaction hazard mapping of fills along the Bay margins. We have collected and interpreted the information required to refine the relative liquefaction susceptibility of Bay margin fills and the hazard they pose to the built environment during large earthquakes. Specifically, we provide constraints on the ages of emplaced fills, differentiating between pre- and post-1960 fills.

The historical progression of fills into the Bay has been accompanied by changes in how fill is placed (evolving from dumping to hydraulic filling using sand from the Bay to modern engineered fill) and what sources of fill have been used (ranging from local soil and quarry rock during early reclamation efforts, dumping of building debris after the 1906 earthquake, and massive reclamation efforts using sand dredged from the Bay during construction of much of Treasure Island and Alameda). The age of fills, verified against historical records and vintage aerial photographs, can be determined by analyzing progressive filling of the Bay based on shorelines derived from historic topographic maps as performed for this study.

During the 1989 Loma Prieta earthquake, there was a strong correlation between the age and type of fill (hydraulic versus dumped) and type of underlying deposit (sand shoals versus Bay Mud) with the prevalence of localized sand boils and ground failure (Holzer et al., 1993). Areas of the greatest settlement and number of sand boils coincided with hydraulically emplaced sand fills (mostly emplaced in the 1930s and 1940s). Few failures occurred in post-1965 fills suggesting that fill type, roughly correlative to fill age because of the evolution in fill emplacement practices over the past century, does have a direct correlation with potential liquefaction-induced failure.

Another significant factor that may control the likely locations and amounts of liquefaction-related effects is saturated fill thickness. Pease and O'Rourke (1998), and more recently O'Rourke et al. (2006), document a strong correlation between maximum lateral displacements during the 1906 earthquake in the south of Market area and the mapped thickness of underlying saturated fill. The total thickness of saturated, liquefiable fill material, in particular loose sands, controls the amount of settlement that may occur during liquefaction (after Tokimatsu and Seed, 1987). By mapping the thicknesses of fills, it may be possible to identify areas of greatest potential settlement and lateral spreading in future earthquakes. Fill thicknesses currently are not documented in a consistent, regional format for the Bay margins.

2.0 STUDY AREA

The study area extends from Berkeley on the northern San Francisco bay margin, to Vallejo on San Pablo Bay, and Antioch on Suisan Bay (Figure 1). The area has been mapped by William Lettis & Associates, Inc., as part of NEHRP-funded regional liquefaction susceptibility studies (Knudsen et al., 2000; Witter et al., 2006).

3.0 PURPOSE

Over half of all documented historical occurrences of liquefaction in the San Francisco Bay area have occurred within artificial fill placed over bay margins (Knudsen et al., 2000). Artificial fill over Bay Mud has hosted about 50 percent of all historical liquefaction occurrences in the San Francisco Bay area. However, about 83 percent of liquefaction occurrences from the 1989 Loma Prieta earthquake occurred in artificial fill whereas only about 30 percent of liquefaction failures in earlier earthquakes, including 1906, occurred in fill emplaced on Bay margins. Holzer et al (2006) note that laterally extensive fills emplaced along the East Bay margins since 1906 performed badly when subjected to the relatively moderate ground shaking generated by the distant 1989 Loma Prieta earthquake, and have yet to be tested by intense ground shaking generated by a large, nearby earthquake.

During the past century, following the 1906 earthquake, tens of millions of cubic meters of fills have been placed along bay margins including infilling of the Marina District, creation of Treasure Island and Alameda Naval Air Station, and expansion of San Francisco and Oakland airports. Many of these artificial fills, emplaced prior to regulation in 1969, lack soil improvement to increase their liquefaction resistance and have yet to be shaken strongly during a major earthquake (Holzer et al, 2006). The relatively poor performance of post-1906 fills during the 1989 Loma Prieta earthquake, along with localized liquefaction-related damage in fill overlying deltaic deposits during the 1995 Kobe (Great Hanshin), 2001 Nisqually, and 2003 San Simeon earthquakes, demonstrate the unique vulnerability of artificial fills emplaced along Bay margins to strong ground shaking during future large earthquakes.

S F B A Y F I L L N E H R P

Shoreline Progression

Figure 1

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Based on our research to date, the age of the fills can be used as a proxy for fill composition (based on method of emplacement and source of material). During the 1989 Loma Prieta earthquake, there was a strong correlation between the age and type of fill (hydraulic versus dumped) and type of underlying deposit (sand shoals versus Bay Mud) with the prevalence of localized sand boils and ground failure (Holzer et al., 1993). Areas of the greatest settlement and number of sand boils coincided with hydraulically emplaced sand fills (mostly emplaced in the 1930s and 1940s). For example, there is a close correspondence between the occurrence of sand boils observed in 1989 at the Alameda Naval Air Station and location of hydraulic fills. In addition, few failures occurred in post-1965 fills suggesting that fill type, roughly correlative to fill age because of the evolution in fill emplacement practices over the past century, does have a direct correlation with potential liquefaction-induced failure.

Methods of fill emplacement and types of material used over the past century are directly correlative to the progressive bayward growth of the Bay shoreline. The historical progression of fills into the Bay has been accompanied by changes in how fill is placed (evolving from dumping to hydraulic filling using sand from the Bay to modern engineered fill) and what sources of fill have been used (ranging from local soil and quarry rock during early reclamation efforts, dumping of building debris after the 1906 earthquake, and massive reclamation efforts using sand dredged from the Bay during construction of much of Treasure Island and Alameda). The age of fills, verified against historical records and vintage aerial photographs, can be determined by analyzing progressive filling of the Bay based on shorelines derived from historic topographic maps.

In 1965 the San Francisco Bay Conservation and Development Commission (BCDC) was created, in part, in response to concern about the artificial filling of the San Francisco Bay. Since 1965, engineering design and review of proposed Bay fills has been required. However, much of the artificial fill present along the Bay margins was placed prior to 1965 when the effects of strong ground motions on non-engineered fill was poorly understood and proposed fills often were not reviewed or documented. Engineered fill and subsequent Bay margin development in many instances overlies older, potentially liquefiable uncompacted artificial fill. These older

Bay fills were placed directly on top of Holocene estuarine sediments, including sand shoals, tidal mud flats, and tidal and fluvial channels.

Trask and Rolston (1951) noted that historic settlement rates of fill are, in part, directly related to both the thickness of the fill, and underlying Bay Mud, and the sand content within the fill and underlying Bay Mud. Fill settlement is not uniform because permeable sand layers within the estuarine sediments (e.g., within Bay Mud) enable migration of water during loading and thus influence the behavior of the overlying fills. Fill settlement is more pronounced and rapid in sandy fill and fill overlying sand shoals or sand bodies within Bay Mud, relative to areas where the fill is either well compacted, clayey, or the underlying estuarine sediment contains no sand (Trask and Rolston, 1951). It is likely that similar, although more rapid, localized liquefaction-related fill settlement and failure will occur at these locations during earthquake loading.

4.0 APPROACH

The possible effects of earthquakes on pre-1965, non-engineered or poorly compacted fills can be predicted in part by documenting the age, composition, and method of fill emplacement (Seed, 1969). Prior to 1965, a variety of techniques were used to emplace and compact fills, with material derived from diverse sources, along the San Francisco Bay margins. In place of new subsurface investigations, we analyzed historical topographic maps, bathymetric data, and archival records to delineate and characterize pre-1965 artificial fills emplaced along the margins of the southern San Francisco Bay after methods of O'Rourke (1990) and Bonilla (1992). We subdivided the pre-1965 fills by age using shoreline data derived from historic topographic maps (Figure 2). Archival records were examined, along with vintage aerial photography, to classify fill emplacement techniques and fill sources where possible (Figure 3).

Our mapping shows the ages, inferred thickness, and methods of emplacement of artificial fills. Seed (1969) classified pre-1965 fills in three main categories: (1) dumped fill of all types of soil, (2) hydraulic sand fills, and (3) well-compacted fills of select material. By documenting the sources and emplacement types of these pre-1965 fills using Seed's classification, important

S F B A Y F I L L N E H R P

Fill After 1960

WLA William Lettis & Associates, Inc.

Figure 2

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information on the relative exposure to failure of these fills under earthquake loading can be provided for future detailed mapping of potential liquefaction-induced ground deformation.

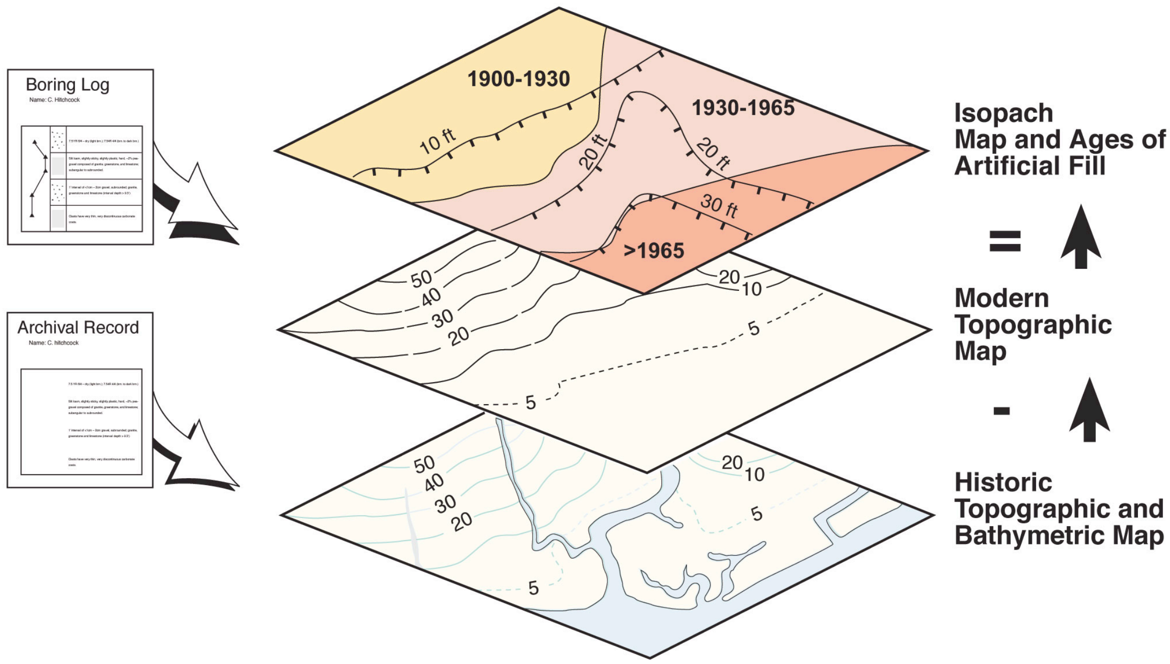

Figure 3. Conceptual diagram showing GIS-based method for mapping ages and thicknesses of artificial fill.

Our goal was to: (1) map the bayward emplacement of fills along the Bay margins over time (including fill ages, mechanism of fill placement, and likely composition). To map the bayward emplacement of fills along the Bay margins over time, modern and historic USGS topographic quadrangles of scales of 1:24,000 to 1:100,000 were obtained from historic archives. For our original 1850 shoreline, we used the SFEI database that documents the historical shoreline from 1850. For all subsequent years we used USGS topographic maps which we scanned and georeferenced for complete coverage of the San Francisco and San Pablo Bays. We defined the boundaries of our study as the Carquinez Bridge in the East and the Golden Gate Bridge in the West. We then digitized the shorelines for each of the vintages of the topographic maps into our project database.

We subdivided the shorelines derived from the topographic maps into eight different shoreline classifications; 1) The 1850 shoreline, 2) the 1900 shoreline, 3) the 1915 shoreline, 4) the 1950 shoreline, 5) the 1960 shoreline, 6) the 1970 shoreline, 7) the 1990 shoreline, and the 8) most recent shoreline from 1997. By viewing all of the shorelines on a single map, the infilling of the bay is shown over time as is the overall decreased area of the bay. The shorelines provide information about when and where the bay was filled, however for information concerning what the compositions of bayfills are, historical sources other than the topographic maps were reviewed.

To obtain information describing the composition of bayfill, we obtained information from the San Francisco Bay Conservation and Development Commission (BCDC), the California Academy of Sciences and the University of California Berkeley's Library of Water Resources. Prior to 1965, the infilling of the San Francisco Bay was relatively unregulated and thus there is spare information concerning the composition of bayfill and mechanism of fill placement, although many of these fills likely were not engineered. In 1965 the McAteer-Petris Act was passed to establish to BCDC to plan and regulate development in and around the bay. With the inception of the BCDC, unregulated bayfill was no longer legally allowed. In order to fill any portion of the bay, permits must be applied for and reviewed by the BCDC. Generally this permitting process was related to mandatory engineering of bayfill and there are thousands of permit applications in the BCDC archives from the 1960's to the present that document bayfill.

For pre-1965 bayfill information, one source that provides substantial information about fill composition is a Master's Thesis documenting the ages and distribution of bayfill for the City of San Francisco. This thesis by G.R. Dow (1973) documents the infilling of the bay throughout the city of San Francisco and has limited information on type, locations in the SF Bay, date of fill, lateral extent of fill, methods of fill emplacement, fill source, fill composition, and fill thickness (Table 1). We extracted information from Dow (1973) to tabulate some of these variables to better document changes in bayfill distribution and type overtime.

Table 1: Locations, method of emplacement, and type of fill in San Francisco.

Location in San Francisco and date of fill	Lateral Extent of Fill	Methods of Fill emplacement	Fill Sources
Yerba Buena Cove, Jackson and Montgomery Streets (1846 to 1863)	3,000 acres using more than 22 million cubic yards of fill	in 1849 with machinery	dune sand located nearby and rare amounts of "rubbish, building rubble, abandoned ships and anything else which had no immediate value"
Mission Bay (1852) -	260 acres	with machinery and manual labor	rock and sand pre 1906, debris from 1906 earthquake
North beach 1865	not reported	not reported	not reported
Fisherman's Warf 1896	not reported	not reported	earthquake debris
Aquatic Park (1920s)	not reported	not reported	not reported
Pier 45	built on a block of fill 210 feet sloping to 382 feet at the foundations bottom… and 1,000 feet into the bay	loose rock retaining wall backfilled with sand.	not reported
Fort Mason	not reported	not reported	not reported
South Beach - near Mission Bay (1867)	not reported	sand dune sand	not reported
Potrero Point (pre-1868)	not reported	unknown	not reported
Islais Creek (early 1880s)	over 1,181,452 cubic yards	increased in 1927-1928, used six power shovels and forty four five ton trucks for	clay, serpentine, and adobe
Army Street Terminal (1957 then mostly 1963-1967)	68 acres, with 4,300,000 cubic yards of land	various	removal of bay floor, then rock at the bottom, then 2 feet of bonding rock, then sand and then riprap on the rock.
India Basin (between 1929 and 1965)	not reported	concrete	not reported
Boblit Debris Dike (1962)	not reported	construction debris (mostly) and 2.5 mil yards of dredged bay mud	not reported
Hunters Point (1868-1939)	5 mil cubic yards of earth	two dry docks pre 1918 then major (275 acres) post 1942	used modern equipment
Bayview (1943 and 1947)	30 acres in between	local hillside… rock and soil?	Modern
Candlestick Point (1958 to 1965)	not reported	modern use of earth, and fill from building and redevelopment project	Modern

Outside of the City of San Francisco there is little information that describes type of fill and methods of emplacement, thus determining the age of fill is important as: (1) a proxy for fill composition, based on method of emplacement and source of material, and (2) because uncompacted, non-engineered fills may densify sufficiently with time to reduce potential liquefaction-related settlement during strong ground shaking. We used historical records to check our mapping of artificial fills emplaced along the margins of the northern San Francisco Bay after methods of O'Rourke and Roth (1990) and Bonilla (1992).

5.0 RESULTS

The results of our mapping show that as expected, there is a decrease in area of the San Francisco Bay with time until the present (see Table 2 and Figure 4). There is also a relationship that shows that post 1960, there is an overall reduction in the amount of bayfill which corresponds with the introduction of the San Francisco Bay Conservation and Development Commission (BCDC) which greatly limited unregulated bayfill emplacement.

Table 2: Showing changes in Bay fill, Area of Bay and amount of fill per period.

Shoreline Year	Total Area of Bayfill (km2)	San Francisco Bay Area (km2)	Amount of Fill Over Period
1850	0	1656.2	0
1900	276.1	1380.1	276.1
1915	282.7	1373.5	6.6
1948	503.2	1153.0	220.5
1950	555.5	1100.7	52.3
1960	605.0	1051.2	49.5
1970	639.2	1017.0	34.2

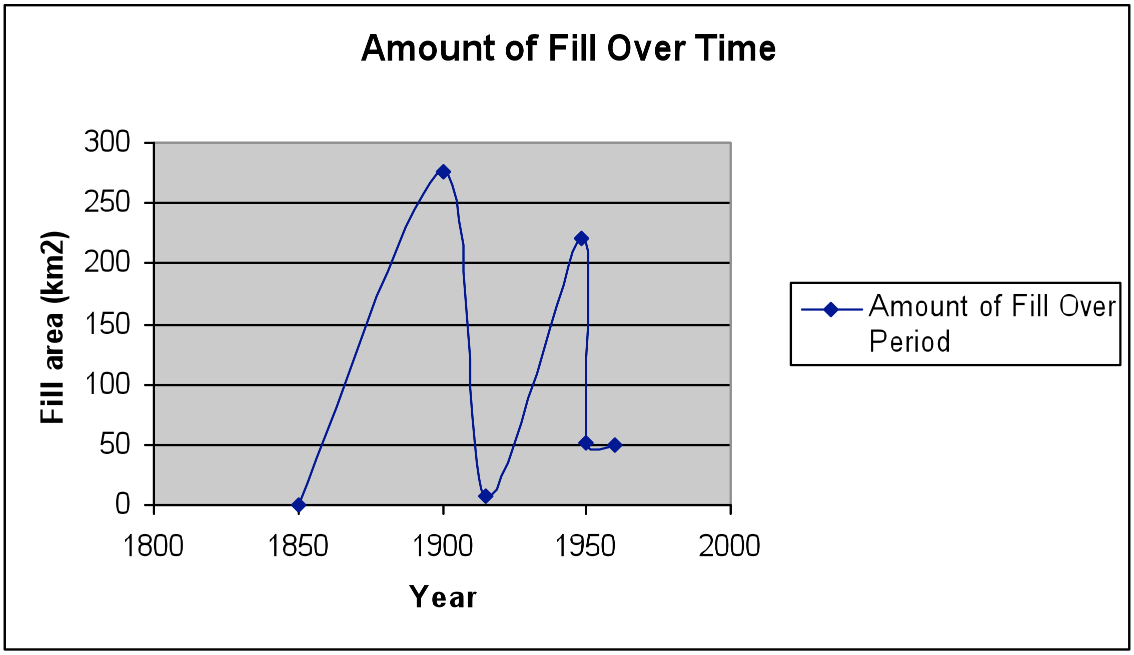

Figure 5: Chart showing the calculated surface area of infill of the bay over different periods. Notice the high amount of fill between 1850 and 1900 and then between 1915 and 1950. These two periods correspond with high periods of infilling of the Bay.

In the 1850's the San Francisco Bay was approximately 1656 km^2 and by 1960 it had decreased in size by over 40% to 1051 km^2. This infill was due to a combination of direct filling by humans and by sedimentation by the rivers and streams that flow into the bay. Hydraulic gold mining in the Sierra caused a large influx of sediment to flow into the bay that infill much of the southern areas of the bay from 1850 to 1900 (Figure 5).

The pulse of sediment associated with mining, combined with diking efforts for farming operations and infilling of bay area, lead to a 276 km^2 increase in bayfill area and corresponding decrease in size of the Bay. Between 1900 and 1915 the increase in bayfill area was very small however between 1915 and 1948 there was a increase in bayfill area of 220 km^2 due to large development projects during the years leading up to World War I and until the end of World War II. During this period between 1915 and 1948 several large bayfill projects were undertaken in the area including Hunters Point, Treasure Island and India Basin (Table 1) which infilled large areas of the bay and made this period one of the most important in regards to area of bayfill.

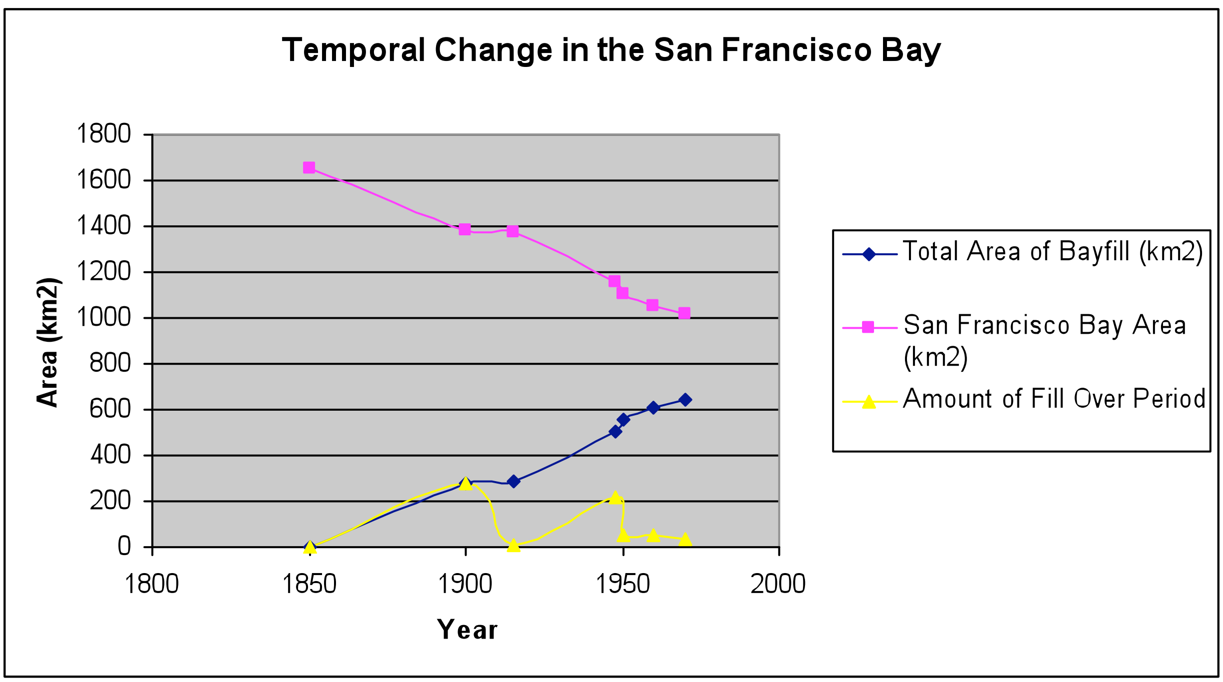

Figure 4: Chart showing change in the surface area of San Francisco Bay versus amount of fill placed over time.

We estimate that approximately 605 km^2 of the bay was filled between 1850 and 1960. Because of the lack of regulation prior to the creation of the BCDC in 1965, we assume that most bayfill prior to 1960 likely was not engineered and is thus either hydraulic fills or dumped fills. See Figure 2 for pre and post-1960 bayfill distribution. From Dow (1973) it can be seen that the composition of the bay fill materials, at least for the San Francisco region, varies greatly. These materials vary from earthquake debris from the 1906 earthquake and fire, to dredged bay mud, to local bedrock to sand from local sand dunes. In most cases, the methods used to emplace the fill varied from manual labor to dumping by machinery to hydraulic filling and based on this it is likely that most pre-1965 fill is non-engineered and thus more susceptible to liquefaction hazard.

In summary, the results of our research include compilation and preliminary interpretation of boring logs and historical maps for seventeen 7.5-minute quadrangles that cover the San Francisco Bay margins. Interpretation of data compiled has resulted in preliminary mapping of the distribution of historic artificial fills in San Francisco Bay Area. Our mapping contributes information on the geologic and geotechnical framework required to prepare three-dimensional liquefaction hazard maps in the San Francisco Bay area.

6.0 ACKNOWLEDGMENTS

We thank the agencies that provided historical records and access to borehole logs and other information on local geology. These include the 1965 the San Francisco Bay Conservation and Development Commission (BCDC), California Geological Survey (CGS), California Department of Transportation, and the Bay Area Rapid Transit District. We specifically would like to thank Steve McAdam and Tim Doherty of the BCDC for their assistance. This work was supported by the U.S. Geological Survey National Earthquake Hazards Reduction Program Grant #07-HQ-GR-0078. This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial Standards or with the North American Stratigraphic Code. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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