NPS Form 10-900
(Rev. 10-90)

OMB No. 1024-0018

United States Department of the Interior
National Park Service

NATIONAL REGISTER OF HISTORIC PLACES
REGISTRATION FORM

1. Name of Property

historic name San Francisco-Oakland Bay Bridge

other names/site number Bay Bridge

2. Location

street & number I-80 not for publication ___
city or town San Francisco and Oakland
vicinity X
state California code CA county See Continuation Sheet
zip code ___

3. State/Federal Agency Certification

As the designated authority under the National Historic Preservation Act of1986, as amended, I hereby certify that this ___ nomination ___ request for determination of eligibility meets the documentation standards for registering properties in the National Register of Historic Places and meets the procedural and professional requirements set forth in 36 CFR Part 60. In my opinion, the property ___ meets ___ does not meet the National Register Criteria. I recommend that this property be considered significant ___ nationally ___statewide ___ locally. (___ See continuation sheet.)

Signature of certifying official Date

California Office of Historic Preservation
State or Federal agency and bureau

In my opinion, the property ✓ meets ___ does not meet the National Register
criteria. (___ See continuation sheet for additional comments.)

Elsie L. Munsell 2/29/00
Signature of commenting or other official Date

Department of the Navy
State or Federal agency and bureau

NPS Form 10-900
(Rev. 10-90)

OMB No. 1024-0018

United States Department of the Interior
National Park Service

NATIONAL REGISTER OF HISTORIC PLACES
REGISTRATION FORM

1. Name of Property

historic name San Francisco-Oakland Bay Bridge

other names/site number Bay Bridge

2. Location

street & number I-80 not for publication ____
city or town San Francisco and Oakland
vicinity X
state California code CA county See Continuation Sheet
zip code ____

3. State/Federal Agency Certification

As the designated authority under the National Historic Preservation Act of1986, as amended, I hereby certify that this ___ nomination ____ request for determination of eligibility meets the documentation standards for registering properties in the National Register of Historic Places and meets the procedural and professional requirements set forth in 36 CFR Part 60. In my opinion, the property ___ meets ____ does not meet the National Register Criteria. I recommend that this property be considered significant ___ nationally ___statewide ___ locally. (___ See continuation sheet.)

Signature of certifying official Date

California Office of Historic Preservation
State or Federal agency and bureau

In my opinion, the property ____ meets ____ does not meet the National Register criteria. (___ See continuation sheet for additional comments.)

R Jarlewas USCG, CAPT 09 March 00
Signature of commenting or other official Date

US Coast Guard
State or Federal agency and bureau

00000525

NPS Form 10-900
(Rev. 10-90)

OMB No. 1024-0018

United States Department of the Interior
National Park Service

RECEIVED 2280
JUN 28
NAT. REGISTER OF HISTORIC PLACES
NATIONAL PARK SERVICE

NATIONAL REGISTER OF HISTORIC PLACES
REGISTRATION FORM

Resub

1. Name of Property

historic name San Francisco-Oakland Bay Bridge

other names/site number Bay Bridge

2. Location

street & number I-80 not for publication____
city or town San Francisco and Oakland
vicinity X
state California code CA county See Continuation Sheet
zip code ___

3. State/Federal Agency Certification

As the designated authority under the National Historic Preservation Act of1986, as amended, I hereby certify that this X nomination ____ request for determination of eligibility meets the documentation standards for registering properties in the National Register of Historic Places and meets the procedural and professional requirements set forth in 36 CFR Part 60. In my opinion, the property X meets ____ does not meet the National Register Criteria. I recommend that this property be considered significant X nationally ___statewide ___ locally. (___ See continuation sheet.)

K McEllen 6/19/01
Signature of certifying official Date

California Office of Historic Preservation
State or Federal agency and bureau

In my opinion, the property ____ meets ____ does not meet the National Register
criteria. (___ See continuation sheet for additional comments.)

Signature of commenting or other official Date

State or Federal agency and bureau

4. National Park Service Certification

I, hereby certify that this property is:

		Signature of Keeper	Date of Action
X	entered in the National Register ___ See continuation sheet.	[signature]	8/13/01
____	determined eligible for the National Register ___ See continuation sheet.		
____	determined not eligible for the National Register		
____	removed from the National Register		
____	other (explain): __________		

5. Classification

Ownership of Property (Check as many boxes as apply)

- ___ private
- ___ public-local
- X public-State
- X public-Federal

Category of Property (Check only one box)

- ___ building(s)
- ___ district
- ___ site
- X structure
- ___ object

Number of Resources within Property

Contributing	Noncontributing	
6	1	buildings
		sites
9		structures
		objects
15	1	Total

Number of contributing resources previously listed in the National Register N/A

Name of related multiple property listing (Enter "N/A" if property is not part
of a multiple property listing.)

N/A

6. Function or Use

Historic Functions (Enter categories from instructions)
Cat: Transportation: rail-related
Transportation: road-related

Current Functions (Enter categories from instructions)

Cat: Transportation: road-related

7. Description

Architectural Classification (Enter categories from instructions)
Other: Combination cantilever-truss/suspension-truss spans and tunnel

Materials (Enter categories from instructions
foundation ______
roof ______
walls ______
other concrete and steel, timber piles

Narrative Description (Describe the historic and current condition of the property on one or more continuation sheets.) See continuation sheets.

8. Statement of Significance

Applicable National Register Criteria (Mark "x" in one or more boxes for the
criteria qualifying the property for National Register listing)

X A Property is associated with events that have made a significant contribution to the broad patterns of our history.

___ B Property is associated with the lives of persons significant in our past.

X C Property embodies the distinctive characteristics of a type, period, or method of construction or represents the work of a master, or possesses high artistic values, or represents a significant and distinguishable entity whose components lack individual distinction.

____ D Property has yielded, or is likely to yield information important in prehistory or history.

Criteria Considerations (Mark "X" in all the boxes that apply.)

____ a owned by a religious institution or used for religious purposes.
____ b removed from its original location.
____ c a birthplace or a grave.
____ d a cemetery.
____ e a reconstructed building, object, or structure.
____ f a commemorative property.
____ g less than 50 years of age or achieved significance within the past 50 years.

Areas of Significance (Enter categories from instructions)
Engineering
Transportation

Period of Significance 1936
Significant Dates: 1936
Significant Person:
(Complete if Criterion B is marked above)____________
Cultural Affiliation N/A

Architect/Builder Purcell, Charles H.
Andrew, Charles E.
Woodruff, Glenn B

Narrative Statement of Significance (Explain the significance of the property on one or more continuation sheets.) See continuation sheet.

9. Major Bibliographical References

(Cite the books, articles, and other sources used in preparing this form on one
or more continuation sheets.)

Previous documentation on file (NPS)

___ preliminary determination of individual listing (36 CFR 67) has been requested.
___ previously listed in the National Register
___ previously determined eligible by the National Register
___ designated a National Historic Landmark
___ recorded by Historic American Buildings Survey # __________

_x_ recorded by Historic American Engineering Record # CA-32

Primary Location of Additional Data

___ State Historic Preservation
_X_ Other State agency
___ Federal agency
_X_ Local government
___ University
___ Other

Name of repository: See Continuation Sheet

10. Geographical Data

Acreage of Property Approximately 30 acres

UTM References (Place additional UTM references on a continuation sheet)

	Zone	Easting	Northing	Zone	Easting	Northing
1						
2						

_X_ See continuation sheet.

Verbal Boundary Description (Describe the boundaries of the property on a continuation sheet.)

Boundary Justification (Explain why the boundaries were selected on a continuation sheet.)

11. Form Prepared By

name/title John J. Mascitelli (revised by Karen Origel and Sean Riley, OHP, August, 1999)
organization ___________ date March 1, 1999
street & number P.O. Box 46 telephone (510)724-0940
city or town Pinole state CA zip code 94564

Property Owner

(Complete this item at the request of the SHPO or FPO.)
name Caltrans (California Dept. of Transportation

street & number 111 Grand Ave., P.O. Box 23660 telephone (510) 286-4444
city or town Oakland state CA zip code 94623

The following material is excerpted from: *Volume III of the Historic American Engineering Record for the Bridge (HAER No. CA-32).* The report was prepared by:

Hansen/Murakami/Eshima, Architects and Planners
John Nelson, AIA, Project Principal
JRP Historical Consulting Services
Stephen D. Mikesell, Historian
Dan Peterson, AIA and Associates, Inc.
Dan peterson, AIA HABS/HAER Consultant
OPAC Consulting Engineers
Mark Ketchum Ph.D., P.E., Structural Engineering Consultant

And from: John W. Snyder, *An Evaluation of The San Francisco-Oakland Bay Bridge in Connection with the 4-SF-1280 Transfer Concept*, California Department of Transportation, Sacramento, 1983.

And from: Andrew Hope, Primary Records for the bridge and associated features, California Department of Transportation, Oakland, 1998.

Bridge Setting

The Bay Bridge was the longest bridge in the world at the time it was built. It is also among the world's most complex bridges in that it incorporates a variety of different bridge types connected to form a single structure carrying two levels of traffic between San Francisco and Oakland, California. The Yerba Buena Island tunnel links the west spans and the east spans. The upper deck originally carried six lanes of two-way auto traffic; the lower deck originally carried three lanes of two-way truck traffic and two sets of rails for inter-urban rail vehicles (streetcars).

The Bay Bridge is formally called the San Francisco-Oakland Bay Bridge (SFOBB). As the name clearly indicates, it extends across San Francisco Bay between Oakland and San Francisco. The physical and cultural setting for the bridge is that of the most intensively urbanized parts of the San Francisco Bay Area. When it was built, the bridge began and ended in major harbor areas – the bustling San Francisco harbor and the Port of Oakland, which was then just emerging as a major harbor facility.

In San Francisco, the bridge begins on what historically was called "Rincon Hill": that hill was partially destroyed during construction of the anchorage and viaducts for the bridge. Rincon Hill is south of the Ferry Building and southwest of Union Square. The waterfront near the anchorage for the bridge was a busy harbor facility at the time the bridge was built. Since 1936, however, commercial tonnage in the port area of San Francisco has declined dramatically and the waterfront has been reused for a variety of commercial and residential purposes.

The East Bay setting for the bridge has changed dramatically since completion of the bridge in 1936. The Port of Oakland has grown into the third largest port facility on the West Coast, specializing in handling containerized cargo. The waterfront south of the bridge is lined with massive cranes and other harbor structures as well as major rail and highway connections. In addition to the port, the East Bay setting for the Bay Bridge is dominated by freeway connections that have been built and rebuilt since the 1950s. None of the original Bay Bridge approaches remain on the Oakland side. The Bay Bridge today may be accessed in the East Bay from three interstate highways: Interstate 80 from the north, Interstate 580 from the east, and interstate 880 from the south. The interchange (outside the National Register boundaries) for these three freeways, which is being rebuilt at the present time, exists just east of the tollbooth for the bridge. It includes a complex series of elevated ramps, which allow the traffic to proceed from one freeway to another or to the tollbooth for the bridge. The tollbooth is located on a spit of man-made land, which extends into the Bay and is within the city limits of Oakland. Downtown Oakland is southeast of the tollbooth. The tollbooth, which no longer retains its historic appearance, is also outside the National Register boundaries.

The San Francisco Bay and Yerba Buena Island define the setting for the Bay Bridge. Yerba Buena is a natural island situated about midway between San Francisco and Oakland. Beginning in 1900, the island was used as a station for the U.S. Navy. (It was an Army post before 1900.) While the Bay Bridge was under construction, the Army Corps of Engineers was creating a new island, called Treasure Island, on shoals north of Yerba Buena Island to serve as a site for the 1939 World's Fair. In 1940, Treasure Island was also taken over by the Navy. Treasure Island and Yerba Buena Island were used together as the Treasure Island Naval Station between 1940 and the closure of the station in 1998. The Bay Bridge passes over and through Yerba Buena Island on steel and concrete viaducts and in a tunnel. Today, Yerba Buena Island includes relatively few buildings and has a park-like feel, particularly since the Navy vacated the island.

General Description of the Bridge

The original planning and construction documents for the San Francisco-Oakland Bay Bridge describe the project as consisting of the following five distinct segments connected end-to-end across San Francisco Bay: the San Francisco Approach, the West Bay Crossing, the Island Crossing, the East Bay Crossing, and the Oakland Approach. The bridge connected to the existing roadway at each end. In Oakland, this required construction of a 'distribution structure', overpasses, and underpasses east of the Toll Plaza.

The bridges, viaducts, and tunnel total about 5 miles of which approximately 4 miles are over water. In 1936, the State of California claimed the bridge was 8 ¼ miles long, a figure that included a mass transit elevated loop in San Francisco and long approaches on the East Bay, many of which no longer exist. The San Francisco Viaduct to the anchorage is 3,707 feet. The distance from the San Francisco anchorage to the Yerba Buena Island anchorage is 9,528 feet (1.8 miles). The distance on the island is 1,663 feet, which includes a tunnel and viaducts. The distance from the island to the Oakland Toll Plaza (outside the NR boundaries) is 20,942 feet, about 4 miles, some of which is on fill.

As originally designed, the double-decked bridge carried two-way automobile traffic on the top deck and truck and interurban trolleys on the lower level. There were six lanes on the top deck, three in each direction. The lower deck carried two trolley tracks in addition to truck lanes. The complex mix of truck, trolley, and automobile traffic required a large number of different on- and off-ramps on both approaches. The on- and off-ramp structure was particularly complex in San Francisco, where the bridge approaches were made to conform to the existing street grid. On the Oakland approach, the transitions were easier because the bridge approaches were built on a broad expanse of land, made by filling in the shore of San Francisco Bay.

In the late 1950s and early 1960s, the bridge and approaches were modified to carry mixed car/truck traffic on each deck and remove the electric railway system. The upper deck was designed to carry westbound traffic and the lower deck eastbound traffic. This required strengthening the upper deck to accommodate the additional weight of trucks. The upper deck through the tunnel was lowered to accommodate the height of trucks. The lower deck required new concrete slabs where the rails were removed and the removal of a series of center columns at Yerba Buena Island. A lower roadway deck was added to the San Francisco viaducts to connect to the freeway system.

Structural Materials and Loads

All permanent structures of the bridge were built of steel and/or reinforced concrete. Reinforced concrete was used for foundations, short-span structures in the San Francisco Approach and the Island Crossing, and for roadway slabs of the long-span steel structures. Steel was used for all main superstructure components of the West Bay Crossing and East Bay Crossing. Five types of steel were used: carbon steel, silicon steel, and nickel steel for major structural components, as well as special heat-treated eye-bars for special application in the East Bay Crossing trusses, and cold-drawn wire for the cables of the West Bay Crossing. All connections of structural plate steel were made with rivets or bolts. Rivets were the norm – bolts were used only at special locations where riveting was not feasible.

The upper deck was designed for automobile traffic, with six-ton vehicles in six lanes (9'8" wide each), plus a ten-ton truck in any one lane. The lower deck was designed for three lanes (10'4" wide each) of 30 ton trucks, and two lanes (27' wide space) for 70-ton Interurban electric rail cars. Wind loads were taken at 30 pounds per square foot, typical for bridges of that era. Earthquakes were considered by designing for a load of 10 per cent of the weight of the bridge, acting laterally.

The San Francisco Approach (Bridge Structures #34-118R, #34-118L, #34-117S, #34-116F, Transbay Transit Terminal Building and Key System Electrical Substation)

The San Francisco approaches to the West Span comprise a number of separate structures. The original structures are mostly of reinforced concrete construction, with haunched concrete girders, carrying reinforced concrete slabs, supported on reinforced concrete multi-column bents, with foundations consisting of spread footings on rock or timber piles to rock. Steel girders were used at certain locations, mainly in the Terminal ramps, where the elevated roadway crosses city streets. These steel spans share concrete bents with adjacent concrete spans, and are supported at intermediate locations by steel bents.

Bridge #34-118R is comprised of continuous concrete box girders, simple span composite rolled steel stringers, and haunched concrete girders with transverse floor beams, all carried on concrete bents on spread pile footings. It originally served two-way truck traffic on the lower deck. It now serves eastbound traffic on the lower deck. It was functionally revised in 1958 following removal of interurban railroad tracks from the bridge's lower deck and conversion of the lower deck to eastbound-only traffic flow. Only a portion of bridge 34-118R is part of the original Bay Bridge construction. The original portion extends from Rincon Hill (in the area bounded by First, Second, Harrison, and Bryant Streets) to the San Francisco cable anchorage. The lower deck structure southwest of Rincon Hill was constructed in the 1950s to connect the bridge to the new freeway.

Bridge #34-118L, the Upper Deck San Francisco Approaches or Center Ramps are comprised of continuous spans with suspension span in-between, rigid frame connection between superstructure and bents. The superstructure is haunched concrete T-beams with transverse floor beams, and cellular structure at cable anchorage and abutment, carried on a substructure of reinforced concrete bents on pile and spread footings. Its 56 spans total 3,850 feet. It originally served two-way automobile traffic on the upper deck. It now serves westbound traffic on the upper deck.

Bridge #34-117S, the Upper Deck San Francisco Approaches or South Off-Ramp, is comprised of spans of two T-beam longitudinal girders with transverse floor beams on one and two column bents and open end diaphragm abutment, all on spread footings. Its 23 spans total 1035.2 feet. It was originally an upper deck on-ramp for eastbound automobile traffic. It is now an off-ramp for upper deck westbound traffic.

Bridge #34-116F, the Upper Deck San Francisco Approaches or North Connector (Westbound 80/Northbound 480), is comprised of a superstructure of T-girder and composite steel girder spans, carried on a substructure of reinforced concrete wall piers, two column bents, reinforced concrete abutment with reinforced concrete wingwalls, reinforced concrete retaining walls, all on spread footings. Its 40 spans total 1843.2 feet. It was originally a westbound off-ramp from the upper deck, and continues to serve this purpose.

Transbay Transit Terminal Building (First and Mission Streets) – This building is an 870 foot long flat slab with a 230 foot central pavilion. It is located at the San Francisco end of the bridge. The construction is reinforced concrete, faced with California granite. It is extremely simple in design and without ornament except for aluminum trim. Its most extravagant features are the seven handsome two-story windows that extend across the front of the building. In composition the building is an enframed pavilion with end bays, wings, and a base. Inside, it consists of a basement garage, street level waiting room, a mezzanine, and originally, tracks on a third level. The tracks were removed when the interurban trains were replaced with buses after 1958.

Key System Electrical Substation – San Francisco. This building, at Second and Harrison Streets in San Francisco, is adjacent to the ramp that originally carried Key System trains from the Bay Bridge west approach ramps to the Transbay Terminal. The one story building is a rectangular concrete box, approximately 87-feet long (east to west) by 41 feet wide and 26 feet high. It has doors on three sides but no windows, with small ventilation louvers comprising the only other fenestration. The exterior walls have two parallel indentations near the top, a subtle decorative feature that relates the building visually to the concrete columns of the adjacent Bay Bridge west approach. There is a smaller building of similar design on Yerba Buena Island, which also served as an electrical substation for the bridge railway. Both substations served to provide power for the Key System trains that ran on the bridge.

The integrity of the San Francisco Approach segments is moderate. Much of the forms and materials remain intact, although functional changes have been made to accommodate the removal of train tracks and traffic.

The West Span or West Bay Crossing (Bridge #34-03)

The West Span beginning at pier W-1 is comprised of two back-to-back suspension spans, one anchored at Yerba Buena Island, one in San Francisco, and each is anchored to a massive center anchor pier. Each suspension bridge is about 4700 feet long. The tandem suspension bridges extend from Transition Pier W-1 to Yerba Buena Island, with a westward extension of the cables underneath the west approach truss spans to their anchorage in San Francisco. Each of the main spans are 2,310 feet and side spans are 1,160 feet. The overall structural system consists of two parallel wire cables, 26 inches in diameter, supported on X-braced steel towers, and supporting a truss stiffened double deck roadway.

The truss system is 66 feet wide and 35 feet deep, with wind bracing in the lower plane but not in the upper plane, and with no sway bracing. The truss chords and diagonals are box-shaped, with both solid plate sides and laced sides. The vertical members are H-shaped. The floor system consists of reinforced concrete slabs, supported on steel longitudinal I-beam stringers, supported on transverse steel plate girder floor beams.

Significant Structural Components of the West Bay Crossing:

Caissons – These large cellular reinforced concrete caissons were among the largest in the world at the time of their construction, and were floated into place. They represented an incremental improvement in the open-dredging process, by maintaining domes over the cell tops to permit flotation control by compressed air during sinking.

Towers - These towers represent the first use of batter-leg towers on a major suspension bridge. The slight incline to the tower legs allows the cables to be centered over the trusses, while at truss elevation the tower legs are slightly outboard of the truss centerlines. This allows better utilization of all the space on the decks.

Tower Bases -- The connections of the steel tower shafts to the caisson caps is by bearing plates on milled concrete surfaces for compression, and by long embedded anchor bolts for tension. This detail provides the normal bearing capacity required of all suspension bridge towers, plus an additional ductile reserve in tension and bending that is required for seismic resistance.

Tower/Truss Articulation – The trusses are supported over most of their lengths by the cable system, but at the towers they are supported by a system of vertical links and lateral bearings. The vertical links, under each truss and connected to the inside legs of the cruciform-section towers, act like large rocker bearings. They provide the vertical/torsional rigidity along with large longitudinal movement capacity required for operation of trains. The lateral bearings at these locations consist of girder members with slots that engage pins in the tower system. This allows transfer of lateral wind load from the trusses to the towers in the presence of the large longitudinal movements of the trusses. These articulations resist load in three directions – vertical, transverse, and torsion – and allow movement in the other three directions – longitudinal, transverse rotation, and vertical rotation.

Rigid Suspenders – The majority of suspenders consist of pairs of wire ropes looped over cable strands and connected with sockets to the trusswork. In each of the four shorter side spans of the West Bay Crossing, the shortest suspenders that hang the truss from the cables are different. Rather than consisting of wire rope looped over the cables like all the other suspenders of the bridge, these suspenders consist of short fabricated steel shapes that can resist compression as well as tension. The compression resistance is required due to the long side spans of the bridge, which cause a stress reversal in these suspenders under unbalanced live load.

Center Anchorage – This anchorage is unique among U.S. suspension bridges, and even among world suspension bridges until construction of the back-to-back Minami Bisan-Seto and Kita Bisan-Seto bridges on the Honshu-Shikoku corridor in Japan in the 1980s. The center anchorage serves to connect the ends of the bridge cable together and to anchor both bridges. Many aspects of the unit are unusual; it is the A-frame system at its top that is unique. This fabricated and riveted steel assembly transfers balanced cable forces directly from one cable to the other, and transfers unbalanced cable forces into the concrete box pier beneath. The A-frame is post-tensioned to the pier with eyebars, providing a sturdy and constructable system.

Piers

The West Bay Crossing piers are identified as W-1 through W-6, numbered from west to east. Piers W-2, W-3, W-5 and W-6 support the suspension towers. Pier W-1 is a land pier. Pier W-4, the most unusual of the West Bay Crossing piers, supports the center anchorage. During the 1930s, it was sometimes called "Moran's Island," after the underwater construction expert, Daniel Moran, who helped conceive of how to build it and the other deepwater piers of the Bay Bridge.

Pier W-1 was built on reclaimed tidelands. This pier was sunk to bedrock by means of an open cofferdam of sheet pilings. Pier W-1 is a tall concrete structure and functions as a connector or transition pier between the suspension bridge and the cable anchorage. The cables pass over saddles atop this pier before descending to their anchors at the bottom of the San Francisco anchorage. This pier also serves as the eastern end of the continuous truss spans and western end of the deck for the suspension bridge. Like all of the concrete elements in San Francisco and on Yerba Buena Island, Pier W-1 is defined architecturally by stepped forms, which create deep reveals and shadow lines. (There are also two smaller, intermediate steel piers between the anchorage and Pier W-1. These, called Piers A and B, are original to the bridge. The steel forms of these piers mimic those of the suspension towers.)

Pier W-2 was located at the outer edge (western end) of an historic steamship dock, leading east from the Embarcadero. Construction of this pier was carried out from the steamship dock. The pier site was excavated by open trenching. A timber frame was towed to the pier site and sunk by weighting it down. Sheet piling was driven into the sides of this frame to bedrock, 80 feet below the surface. The sheet pilings then formed a steel box, or cofferdam, to the desired shape of the pier. This "box" was excavated to bedrock. Concrete was poured in the cofferdam by buckets. As the poured concrete reached to nine feet from the surface, the cofferdam was de-watered and the concrete poured in dry. The concrete pour continued to a height of 40 feet above water level, forming the base for the suspension tower. Pier W-2 supports the westernmost suspension tower.

Piers W-3, W-4, W-5, and W-6 were the most difficult piers to construct, owing to the great depth of overburden and water bedrock in the shipping channel. The piers are cellular in plan, i.e., are not solid concrete structures. The "cells" of these piers correspond with cells in the caissons, specially designed structures used in construction of these piers. Each cell is a 15-foot diameter cylinder, which served as a dredging well while the pier was being excavated and also served as a form for the concrete pour. The depth of these piers reflects the distance to bedrock, not necessarily the depth of water at the location. Pier W-3, for example, was built in a water depth of 50' but is the deepest of the piers, reach bedrock at –220'. Pier W-4 reaches bedrock at about –180'. Pier W-5 reaches bedrock at only –105', and Pier W-6 at about the same depth. The water depth is greatest at W-6, near Yerba Buena Island. Of these four, Piers W-3, W-5, and W-6 are nearly identical, differing chiefly in height (or depth to bedrock). Pier W-4 is the central anchorage and is nearly twice as wide and long as the others and is discussed separately.

The method of construction for the four cellular piers helped define their form. The construction caisson for Piers W-3 and W-6 comprised 28 steel cylinders, 15 feet in diameter, held in place in rectangular steel and wooden frames. Thus, the caisson included the cylinders (set in four rows of seven), with a series of spandrel shapes, created by the voids between the rectangular grid and the cyclinders. During construction, the cylinders were used as wells for excavation by clamshell buckets. The spandrel areas were used to pour concrete and ultimately form the structural basis for the piers. Pier 5, the smallest of the four, is built around 21 cylinders, with three rows of 15 foot diameter cylinders set in groups of seven. Pier 4, the double anchorage, is simply a much larger version of the same cellular design; it comprises 55 cylinders, 15 feet in diameter, set in five rows of eleven.

These caissons were ferried into place and sunk, using a complicated method. The caissons were sunk below the water level when the voids outside the cells were partially filled with concrete. The caissons were held in place using a block and tackle device while more concrete was poured, until the caisson reached the mud level. As the caisson was lowered, new cylinders and metal frames were welded to the top to raise the height. The mud was excavated by clamshell buckets on derricks. As the mud was removed, the caisson was forced further into the bed of the bay by the weight of new concrete. This process was continued until the steel frame, with sharp cutting edges on the outside, rested on bedrock.

When the pier reached its final elevation, the crew began construction of the base for the steel towers, which rise above the water on Piers W-2, W-3, W-5 and W-6; the central anchorage, Pier W-4, was built of concrete above the water level and supports no tower. Immediately above the water level, each pier includes a fender. The fender is a concrete arm, cantilevered from the bulk of the pier, finished in timber. The base for the steel tower is only about one-half the area of the base of the pier. Pier W-4, the center anchorage is a concrete structure, rising nearly 300' above the water level.

Towers

The towers are of two different heights: Towers W-2 and W-6 are 458 feet tall, Towers W-3 and W-5 are 502 feet tall to accommodate the vertical curve profile of the roadway. The main tower shafts are a multi-cellular cruciform cross section, made up of riveted steel plates, and bulkheads. The shafts are battered (slightly angled) to meet lateral stability and geometrical clearance requirements without wasting space on the deck of the bridge. Each steel X-brace and horizontal strut consists of multiple riveted girders, laced together to form an architectural and structural unit. The widths of the bracing members were increased beyond those required for strength, for appearance purposes. At the top of each main tower is an open gallery, also provided for aesthetic purposes. The tower foundations consist of dredged and sunken, reinforced concrete caissons at W-3 through W-6, W-1 and W-2 foundations are of reinforced concrete, cast in place in cofferdams.

The suspension bridge towers on the West Bay Crossing are built on Piers W-2, W-3, W-5, and W-6. Although there are minor variations (minor in terms of the grand scale of these structures), the four suspension towers are nearly identical. The steel bottom, or base plate, for each tower begins 40 feet above low water level for the bay. The outside towers (on Piers W-2 and W-6) are 414 feet high above their base plates. Towers on 3 and 4 (closest to the center anchorage) are 458 feet high above their base plates; the increased height relates to the fact that the center anchorage is higher than the deck level anywhere else on the bridge. The towers are distinctive in that the legs are slightly battered, representing the first use of this technology in a major suspension bridge. The slight incline of the tower legs allows the cables to be centered over the trusses, while at truss elevation the tower legs are slightly outboard of the truss centerlines. This allows for better use of the space on the decks.

The towers comprise two thick vertical members or columns, with horizontal and diagonal bracing, tying the two together. Each column supports the vertical reactions from a cable, while the bracing resists lateral loads. The central horizontal struts also support the decks. The columns are hollow, a fact that is attributable to the unusual manner in which the towers were erected. Each column is in the form of a cross with a hollow center. The columns were built of a series of steel cells, or rectangles that vary in size; the largest are 3 feet 6 inches by 4 feet. There are six cells at the top and bottom and four cells on each side, surrounding a hollow core of 7 feet by 8 feet. At the bottom, or base plate level, each column is about 30 feet by 20 feet, with the larger measurement being east-west oriented, in the direction of the cable. The two columns are about 83 feet apart. The steel that encloses these cells varies in thickness from nearly three inches to less than one inch. The hollow core of the column served as a base for an unusual crane, called a hammerhead derrick, which was built inside the lowest parts of the tower and used to hoist additional tower parts into place. As the tower rose, the derrick was raised and new parts of the tower were hoisted into place until the tower columns had been completed. As the columns were being raised and erected, the diagonal and horizontal bracing was installed as well.

At the base of the steel tower (the concrete top of the pier), the steel columns are bolted into place on plates set into the concrete. The base connection is by bearing plates on milled concrete surfaces for compression, and by long embedded anchor bolts for tension. This detail provides the normal bearing capacity required for seismic resistance.

The lowest strut is located a very short distance above the base plate, and the diagonal braces begin immediately above the horizontal member. All members other than the tower columns are latticed, i.e,. comprising numerous crossing steel members, which appear to be solid because of solid steel plates placed on the outside. As noted, there are two sets of crossing steel members between the bottom horizontal member and the deck supports. The horizontal deck struts are located a little less than half-height in the towers. Three sets of crossing members exist above the deck levels; these too are latticed members. The towers terminate in a horizontal member, with minor members above each column to accept the cable saddles.

Anchorages

There are three anchorage structures for the West Bay Crossing suspension spans, but these operate as if there were four because Pier W-4 is a double anchorage. The three anchorage structures are: the San Francisco anchorage; Pier W-4; and the Yerba Buena anchorage. The western suspension span extends from the San Francisco anchorage to Pier W-4, while the eastern suspension bridge extends from Pier W-4 to Yerba Buena Island. The San Francisco anchorage is part of a tall reinforced concrete structure, which at its top also serves as a pier for the viaduct approaches to the bridge. The double anchorages at Pier W-4 are integrated into the tall reinforced concrete structure that is the visible part of "Moran's'Island." The Yerba Buena Island anchorage is partly in tunnels.

The means of anchoring the suspension cables is much the same at each of the four anchorage points. The cables are held in place by a series of eyebars, which are embedded in the concrete at each of the four anchorage points. Each anchorage is built around three elements: inclined steel girders which hold the backs of the eyebars; the eyebars themselves; and masses of reinforced concrete, which hold the eyebars in place and serve to anchor the cables. This arrangement is most easily seen at the San Francisco anchorage, although the systems are quite similar at the other anchorages as well. The steel girders were built in an inclined position and would ultimately be encased in concrete. Each girder accepted seven eyebars. There were five sets of these girders for each cable, accommodating 35 eyebars. The opposite end of each eyebar (away from the girders and toward the bridge) was fitted with a steel spool, or strand shoe. The wire for the cables was spun around a shoe, then strung over the tops of the towers and around a shoe at the opposing anchorage. For the San Francisco anchorage, for example, the cable was also spun around shoes at the western side of Pier W-4.

The wire used in the bridge was round steel wire that measures about .19 inches in diameter (five such wires laid side by side would measure about an inch). As the wire was spun, it wrapped around the shoe, leaving one wire on either side. Ultimately, 472 wires were wrapped around each shoe, with 236 on either side of it. These 472 wires would be crimped and bound to form a strand of wire. As noted, there were 35 eyebars and shoes for each cable, meaning that there were ultimately 35 strands of wire, each with 472 wires each. As a final measure, these 35 strands were wrapped with additional wire to form a cable that is more than two feet in diameter.

As noted, the San Francisco anchorage is a gravity structure, resisting the pull of the cables by virtue of the mass of concrete. The actual anchorage occurs near the bottom of this concrete mass. The inclined steel girders are not seen; these girders were buried in the concrete. The eyebars are embedded in the concrete, with only a short length protruding. Unbound wires exist at either side of each shoe, which is attached to the eyebar. At some distance from the eyebars, the wires have been bound to form strands. At a point still further from the eyebars, the strands have been wrapped into a single cable. This final wrap occurs just before the cable leaves the anchorage building. The huge cables leave the anchorage in this form, and this is the character of the cables at every place in which they are visible to the public.

The tall concrete feature called the San Francisco anchorage is actually both a pier and an anchorage. At the top, it supports the elevated roadway as it climbs over the remnants of Rincon Hill. In its exterior, the anchorage is a battered and heavily inflected concrete mass, with huge buttresses at its base, from which the cables emerge. Architecturally the San Francisco anchorage is the largest and most successful expression of the stepped forms used in all major concrete elements on the bridge.

Pier W-4, or "Moran's Island," is a double anchorage and is arguably the most inventive single element of the Bay Bridge. The means of attaching the cables at this point are equally ingenious, although little may now be seen; most of this system is embedded in the concrete. Like the San Francisco anchorage, the W-4 system is built around five rows of inclined steel girders to hold the eyebars. The girders, in turn, are attached to one another by heavy metal beams to form a steel box, called an A-frame by its fabricator. The columns of the girders extend below the eyebars and are attached to vertical steel bars, which are embedded deep into concrete. Thus the two anchorages pull against each other, held in place by the steel box and the concrete around it. Before the A-frame was concreted into place, the bottom of it was connected to an eyebar chain (connected to the base of the anchorage), and the eyebar chain was stretched to a tension of 7.4 million pounds, essentially a post-tension procedure, effected long before post-tensioning was an acknowledged procedure in bridge construction. The chains and the rear of the A-frame were then encased in concrete and covered by a steel hood, called a shroud. Architecturally, Pier W-4 was treated in the same manner as the San Francisco anchorage; heavily inflected, stepped concrete forms which are battered, or tapered toward the top. The steelwork for the shrouds is inflected in the manner of the concrete work below.

At the Yerba Buena Island anchorage, the cables pass over an inclined bent (leaning east, toward the anchors) before reaching the anchorage structure. The cables are anchored at Yerba Buena Island in two tunnels, excavated 170 feet into the solid rock of the island, at an angle of 37 degrees from horizontal. The tunnels were tapered, their larger diameter at the rear. The steel girders to hold the eyebars were embedded at the rear of the tunnels. The cables pass over the bent and into tunnels, which were mined to reach the bedrock of Yerba Buena Island. The cable bent is carried on a concrete pier that also serves as part of the bridge abutment.

Suspension System

The cables are anchored in a gravity anchorage at the San Francisco end, in a tunnel anchorage at the Yerba Buena Island end, and in a unique cantilever box anchorage at the common center anchorage. The cables were spun in place from 0.192 in. diameter galvanized steel cold drawn wire. These wires were placed using a spinning wheel to carry wire from reels stored on the anchorage, to the final location in the saddles on the towers. The wires were bound into 37 strands consisting of 472 wires each. They were then compacted into their final round shape, coated with red lead paste, and wrapped with additional wire. A 10-foot length model cable was built to determine the final dimensions of the compacted and wrapped cable.

The course of each cable, once it leaves the San Francisco anchorage, is strung over the top of Pier W-1, a concrete pier that reaches only to the height of the deck and serves to bring the cable to deck height (as well as supporting the viaduct); rises to the top of the tower at Pier W-2; suspends in a catenary between Piers W-2 and W-3 before it rises to the top of the tower at Pier W-3; and descends to an anchorage at Pier W-4. This is effectively the end of the western suspension bridge. The cable for the eastern bridge follows that pattern in reverse; starting at the W-4 anchorage; rising to the top of the tower at Pier W-5; suspended in a catenary between the towers of Piers W-5 and W-6 before rising to the top of the tower at W-6; and descending to the anchorage at Yerba Buena Island.

The principal structural elements to hold the cables in place, other than the anchorages, are steel "saddles," atop the towers at Piers W-1, W-2, W-3, W-5, and W-6, as well s at the cable bent at the Yerba Buena Island anchorage. The saddles are heavy, three-sided cast steel pieces that hold the cable in place and transfer loads to the supporting structure. Each saddle weighs 46 tons. These were said to be the largest single-piece casts ever used in bridge construction at the time the Bay Bridge was built. The cables were spun in this saddle.

The deck is suspended from the cables by a series of suspender "ropes." These ropes are wire cables, each 2.25 inches in diameter. A rope was attached to the cables by a cable band, a metal clamp in two semi-circular parts, which was bolted together at prescribed locations.

There are 612 cable bands altogether, with four ropes from each. Collectively the ropes measure 43 miles in length. The lengths of rope differ, depending upon the location within the catenary of the suspended span. The panels of the deck stiffening truss were suspended from the suspender ropes, with the tops of the stiffening truss panels hung from the rope lengths. The exceptions to this rule are the shorter side spans of the West Bay Crossing. On these spans, the shortest suspenders in each span consist of short fabricated steel shapes that can resist compression as well as tension. The compression resistance is required due to the long side spans of the bridge, which causes a stress reversal in these suspenders under unbalanced live loads. There are eight such suspenders on the bridge.

Yerba Buena Island (Bridge #34-04, Key System Electrical Substation, Firehouse)

Yerba Buena Island is located about halfway across the Bay Bridge and more or less in line with the points of origin in San Francisco and Oakland. A bend in the viaduct on the east side of Yerba Buena Island exists because the three points are not exactly on line. The bridge crosses 2950 feet over Yerba Buena Island, or a little more than half a mile. The roadway is in a cut between the Yerba Buena Island anchorage and the Yerba Buena Island Tunnel and is in tunnel for 540 feet. There is also a short cut section at the east portal of the tunnel. The remainder of the course over Yerba Buena Island is on a steel truss viaduct, high over the east side of the island, which connects to the east span.

Yerba Buena Island Tunnel (Bridge #34-04)

The Yerba Buena Island tunnel, one of the superlatives of the Bay Bridge, represented the largest diameter tunnel in the world at the time it was built. It still remains the largest diameter tunnel in the world. Its construction introduced several new and innovative technologies, including the practice of placing the sidewalls before excavating for the arched roof.

The tunnel is in the shape of what is often called a “horseshoe” tunnel, although it is more accurately described as a segmental arch, with vertical sidewalls and an arched roof. The tunnel portals, particularly the west portal, are among the most interesting elements of the entire bridge structure from the standpoint of architectural design. The San Francisco portals include stepped concrete elements that appear as large blocks at either side of the tunnel and as three segmental arched forms at the tunnel itself. These interesting forms are now difficult to see, however, owing to the fact that traffic is unidirectional heading west on the top deck, making these elements visible only through the rear view mirror of the driver.

The original tunnel construction consisted of a 79 foot wide, 540 foot long tunnel to carry the twin decks through the rock of the island outcropping. The tunnel form itself consists of an arch founded on two retaining walls; the arch forms the ceiling of the tunnel, spans 79 feet with a rise of 21 feet, with a three to six foot thick slab rib to resist the earth pressure from above. The retaining walls, upon which the arch is supported, form the walls of the tunnel, and are 35 feet tall, supported on spread footings. The inside of the arch and walls are finished with tile. Inside this structural unit, a structural frame is supported to carry upper deck traffic. A slab on grade carries lower deck traffic. The original upper deck framing consisted of reinforced concrete beams and slabs, supported on corbels and pilasters built into the retaining walls, and by a row of columns between truck lanes and trackways at about the center of the tunnel. The tunnel was modified in the late 1950s, as described below, but still retains enough of its historic structure and appearance to be a contributing element. The original viaducts consisted of reinforced concrete slab, beam, and bent structures similar to those built for the San Francisco Approach. The upper deck was framed with reinforced concrete columns, and girders, supported on three column bents, with columns in the middle of the lower deck.

The original steel truss spans that provide a transition between the concrete viaduct and the East Bay Crossing consist of through steel truss spans, each straight but on an overall curved alignment. The basic structural system of these spans is similar to that of the through trusses of the East Bay Crossing, that are described below. Structurally speaking, it may be argued that these spans are really part of the East Bay Crossing, even though contractually they evidently were not.

Key System Electrical Substation –Yerba Buena Island. It is located east of the tunnel's east portal, between the Bay Bridge and the westbound on-ramp to the bridge. This one story building is a rectangular concrete box, approximately 50 feet long (east to west) by 36 feet wide. It has an entrance on the south side, but no fenestration on the other three walls. The exterior walls have an indentation where the roof slab meets the walls. This minor design feature relates the building visually to the concrete piers of the Bay Bridge, and was integral to the functioning of the bridge's trains.

Firehouse (Caltrans Garage) –Yerba Buena Island. The Firehouse is east of the tunnel's east portal, between the east viaduct of the Bay Bridge and the westbound on-ramp to the Bay Bridge. This one story, concrete building has a flat roof and is approximately 63 feet long (east to west) by 31 feet wide. The east façade is entirely open to provide access to the two vehicle bays. The wooden doors that originally covered this opening have been removed. The windows are multi-pane metal sash and there are two exterior doors on the south elevation. The building was made approximately 13 feet longer in the mid-1960s, with an addition to the west end. Even with these changes, however, the building retains enough of its historic appearance to make a contribution. This building once housed fire trucks that serviced the bridge; it also held a locker room and office.

The East Span (Bridge #33-25)

The East span is comprised of the series of trusses and girder spans. Four deck trusses of about 290 feet each connect the east span to the tunnel through Yerba Buena Island. The largest section of the eastern span is the massive cantilever bridge, 1400 feet long in the cantilevered and suspended segment, with flanking anchor spans of about 510 feet each. The balance of the span includes five through trusses of about 570 feet each, and fourteen deck trusses about 290 feet each. The final segment toward the Oakland toll plaza includes ten 82-foot steel girder spans and six 41-foot concrete girder spans. The curved geometry of the bridge alignment is accommodated with the 288 feet spans across the island, plus an additional curve at about E-9 that was necessary to clear the ferry terminal that was on a spit of fill in the bay at that location when the bride was built.

Despite the diversity of structural types and spans used in the East Bay Crossing, the essence of the structural system is quite similar over its entire length. Each structural span carries two decks of traffic on reinforced concrete slabs; each slab is supported on three systems of steel beams (transverse purlins, supported on longitudinal stringers, supported on transverse floor beams). The lower deck framing includes lateral bracing, the upper deck floor system does not. Sway bracing is incorporated only in the above-deck framing of the through spans; other spans incorporate no sway bracing at all. Design of the various-length longitudinal framing trusses of the crossing was largely influenced by erection requirements.

Significant Structural Components of the East Bay Crossing:

Cantilever Spans – this was the longest span and heaviest cantilever truss in the United States when it was built. Unusual aspects of its layout include the different pier types at its two ends (west: concrete, east: steel), and its longitudinal anchorage provided only at its west end.

Cantilever Spans Pier E-3 – this reinforced concrete caisson was the largest and deepest ever built. Its 225-ft deep bearing end is founded in a sand layer rather than on rock.

Cantilever Spans Joint L0 – this component connection on each side of the bridge at each of its main supports (E2 and E3) utilizes 18- and 24-inch diameter steel pins to connect five truss members to a common fabricated assembly that caps the supporting steel bent. The detail allows the required movements during cantilever construction, without undesirable secondary stresses that were blamed for collapse of previous major cantilever bridges including the Quebec Bridge.

Truss Spans – the split bents that support the trusses at major expansion joint locations allow the required thermal movements without the destabilizing forces associated with multiple rocker bearings supported on a single bent. A similar detail was later used on the Richmond – San Rafael Bridge.

Truss Spans Pier E-9 – this large box pier provides a longitudinal anchor point for the multiple approach spans of the bridge. Its configuration provides for direct transfer of forces from the lower chords of the trusses to the main members of the Pier, at a location of curvature and span length transition.

Foundations

Two basic types of foundations support the over-water East Bay Crossing. Reinforced concrete cellular caissons were used for piers near Yerba Buena Island (E-3 to E-5) and pile foundations were used from pier E-6 to the end of the bridge at the Oakland shoreline. The deepest caisson supports pier E-3, with a bottom of seal elevation about 230 feet beneath water level.

Pier E-1 and E-2 are the least complicated of the major East Bay Crossing piers because they were built on or near land. Pier E-1 is actually on Yerba Buena Island, carved from a natural knoll called "Army Hill" by the Navy. Pier E-1 is a concrete pier, built on conventional lines and taken to the bedrock of the island. Pier E-2 was built just east of the lands end and was easily taken to bedrock, which was about 45 feet below the water level. It is a solid concrete pier poured into an open cofferdam.

The most complex piers of the East Bay Crossing are Piers E-3 through E-5. Like the middle piers on the West Bay Crossing, these are cellular in plan and were built using specially designed caissons that were towed to the site and sunken. These differ a great deal from the West Bay Crossing piers in three respects. First, they do not reach bedrock. Second, the cells are built from rectangular rather than cylindrical cells. Third, a conscious effort was made to reduce the weight of the piers themselves, recognizing that they would be founded on relatively weak soil rather than bedrock.

The caissons for the three major East Bay Crossing piers were similar but of different sizes. Each was formed from a steel rectangle with rectangular chambers. Construction proceeded in much the same manner as the West Bay Crossing piers. Concrete was poured into the walls or voids outside the chambers, until the caisson reached the mud level, building new levels on top as necessary to keep the top of the caisson above water. Mud and other strata were excavated through the rectangular chambers until the caisson sunk to a previously agreed-upon level. When that level was reached, an additional 15 feet was excavated and concrete poured through the excavation chambers, creating a concrete base below the edges of the caisson.

Although not reaching bedrock, those levels below water were spectacular. Pier E-3 was the deepest of all of the piers on the Bay Bridge. It was sunk to a level of –243 feet, deeper than the –220 foot Pier W-3, the deepest on the West Bay Crossing. Pier E-3 also had the largest area of the East Bay Crossing piers. The caisson for it measured 80 feet by 134.5 feet, and included 28 rectangular chambers. The caissons for Piers E-4 and E-5 were the same size: 60 feet by 90.5 feet. Each was taken to a depth of –180 feet, in addition to the extra 15-foot scouring below the caisson.

The remaining piers, Piers E-6 through E-23, were built using a pile foundation system with multiple timber piles terminating at load-bearing sand, and clay layers at depths of about 100 feet to 125 feet below water level. All were built using a steel cofferdam that was pounded into the mud and other strata until it reached the desired depth. The area inside the cofferdam was de-watered and the concrete piers were poured on top of the piles under dry conditions. The top ends of the timber piles are beneath a surface mud layer, where they are embedded in a concrete pile cap. The pile caps provide bases for reinforced concrete piers that reach up to water level.

Towers (Bents)

The term "towers" or "bents" used here refers to the concrete or structural steel "X" braced steel supports that extend from the top of the concrete pier to the bottom chord of the trusses on each side. A shoe that provides a pin connection of the bottom chord of the truss to the tower is anchored to a plate on top of each of the legs. The towers are constructed of angles and plates riveted to together to form a cellular cross-section similar to the suspension span towers. The piers range in height according to the grade of the roadway. The towers also differ in section, according to the different roles they play in supporting this structurally complex crossing.

Pier E-1 (the piers are numbered west to east, from Yerba Buena Island to Oakland) is on Yerba Buena Island and is a poured concrete pier that extends to the bottom chord of the cantilever bridge. It serves as an anchor for the west end of the cantilever span, connecting the Yerba Buena Island Tunnel with the beginning of the over-water bridge. It also serves as the eastern support of the steel viaduct that connects the tunnel to the eastern crossing.

The tower piers E-2 and E-3 are the tallest of the East Bay Crossing piers; they support the main span of the cantilever bridge. These towers bear the weight of the cantilever bridge and thus carry the heaviest dead load of any East Bay Crossing piers. Pier E-4 tower serves as an anchor for the eastern end of the cantilever span as well as the western support for the first of the truss spans. Piers E-2 through E-4 include tall, X-braced steel towers from the concrete base to the deck level for the cantilever truss. These metal towers resemble architecturally the suspension towers of the West Bay Crossing.

Piers E-5 through E-9 support the truss spans; Pier E-9 also serves the western end of the deck truss spans. Pier E-9 is the most unusual of the East Bay Crossing piers in that it includes a rectangular tower of four columns. The through truss and deck truss elements terminate on the outside edges of this pier, requiring a 50-foot connector between the ends. This 50-foot connector failed during the 1989 Loma Prieta earthquake, the only major damage sustained in that event. The remainder of the East Bay Crossing piers support the deck truss spans. The first seven consist of steel towers on concrete bases; the remaining piers are of concrete over their full heights. These piers get shorter and shorter as the bridge descends toward the toll plaza. The deck truss piers are also very close to one another.

Cantilever Span

The cantilever bridge part of the Bay Bridge is carried on Piers E-1 through E-4. The cantilever bridge follows the essential design of all modern cantilever bridges, comprising five elements: two anchor arms; two cantilevered arms, which are built symmetrical to the end spans; and the suspended span, hung between the ends of the cantilevered arms. Because the suspended span is not supported on piers (it is, as the name suggests, suspended from the ends of the cantilevers), there are only three spans: from the anchor to the major piers on either side of the bridge, and the larger center span. By this arrangement, the center span is by far the longest of the three, including the two cantilever spans as well as the suspended span. In the Bay Bridge, this center span is 1400 feet, an impressive span and among the largest cantilever spans ever built. The anchor spans are 580 feet each.

It was erected from the main piers (E-2 and E-3) with temporary steel bents in the anchor spans but not in the main span. The main compression members at the bottom of the cantilevers are of built-up riveted steel plates, the main tension members at the top of the cantilevers are of heat treated eyebars. After completion of the anchor span steelwork and the main span steelwork to a length of 412 feet, the center 576 feet of the main span was erected with guy derricks supported from the just-completed trusses. The concrete slab was cast after all steelwork had been erected.

Distinctive elements of the cantilever span are pin-connected assemblies atop the main support members, Piers E-2 and E-3. At these piers, 18 inch and 24 inch steel pins connect five truss members to a common fabricated assembly on either side of the piers. This detail allowed the required movement during cantilever construction, without damaging secondary stresses that had been blamed for the collapse of earlier cantilever bridges during construction.

Through Truss Span

The through truss spans have both upper and lower decks within the truss framework. There are five through truss spans, located immediately to the east of the cantilever span. Each through truss span is 504 feet long, each comprising twelve 42 foot panels. The trusses are 84 feet tall. The lower deck is attached to the trusses just above the lower chord while the upper deck is attached about one-third of the height of the truss above its lower chords. The trusses are Warren trusses. These through trusses are carried on braced steel towers or bents, similar to those used on the deck truss, or incline section to the east. The split bents that support the through truss spans at major expansion joint locations allow the required thermal movement without the destabilizing forces associated with multiple rocker bearings support on a single bent.

Deck Truss Span

The deck truss spans have the lower deck inside the truss framework, and the upper deck on top of the truss framework. These truss spans extend from pier E-9 to pier E-23 comprising fourteen spans of 288' each. This series of deck trusses are often called the "incline section," denoting its ramping toward the Oakland touchdown. The deck truss spans (called "double-deck truss spans" by their fabricator) are supported on braced steel bents, except for the piers east of E-17, where the trusses are carried directly on the concrete piers. The trusses are 38 feet deep, with the top of the trusses serving as the top deck of the roadway.

Deck System

Although the bridge is carried by various structural elements (suspension bridges, cantilever, through truss and deck truss), the deck system is similar across the length of the structure. Because there are two decks, the bridge requires a truss system to support the two decks. This truss system is similar across the bridge, from the steel viaduct between the San Francisco anchorage to Pier W-1, across the suspension bridges, and across the various elements of the East Bay Crossing. The deck truss spans of the East Bay Crossing are simply the deck trusses, carried on piers. Generally, the deck system is 66' wide and 35' deep, with wind bracing in the lower but not the upper plane and no sway bracing. The floor system consists of reinforced concrete slabs supported on steel longitudinal stringers, which are in turn carried on steel transverse floor beams. Minor variations exist, particularly with respect to the manner in which the deck system was rebuilt in the late 1950s to accommodate truck traffic on the upper deck.

The deck system, of course, is different on the concrete viaducts in San Francisco and on Yerba Buena Island. The double-deck concrete viaducts have been discussed previously.

Oakland Approaches (Bay Bridge Substation , Key Pier Substation, and PG&E Substation)

The Oakland approaches as built in 1936 were at once simpler and more complex than those in San Francisco. The approaches were simpler in the sense that the bridge touched down on what had been a train yard island, or "mole" as it was called, that had been built into the Bay to provide deep water access for mass transit rail lines. This area was largely open at the time of construction and the approaches did not need to conform to the dense urban setting found in San Francisco. The approaches were more complicated, however, owing to the need to connect with a far more complex highway and rail system on the Oakland side.

Between 1936 and 1938, the California Division of Highways built a series of connectors to "distribute" traffic between the bridge and area surface streets. This included a connection with the new East Shore Highway (essentially modern Interstate 80), as well as connections with Ashby Avenue in Berkeley, and Cypress Street and 38th Street in Oakland. The East Shore Highway-Cypress Street-38th Street connection was a series of elevated ramps, similar in some respects to modern freeway-to-freeway interchanges.

Virtually all of the East Bay approaches and related distribution structures have been destroyed. The destruction occurred during the 1950s and early 1960s, when the East Shore and Cypress Street alignments were re-used for freeways, and when the bridge traffic was reconfigured for unidirectional use. The Oakland approaches were further modified in the 1990s as part of the rebuilding of the freeway system following the Loma Prieta earthquake. The National Register boundary was drawn to exclude all of the approach sections at the Oakland end of the bridge because of their loss of integrity.

Bay Bridge Substation (Caltrans substation) – Oakland. The Substation is located at the end of the narrow peninsula that extends into San Francisco Bay from the Bay Bridge toll plaza. This building is approximately 90 feet long by 42 feet wide, with a small (22' x 10') extension at the left side of the south façade, giving the building an "L" shape. The concrete walls, which are 24 feet in height, have a slightly projecting base and pilasters, with a simple cornice of vaguely classical styling. These walls are not load bearing – the flat roof is supported by steel beams on interior steel columns. There is a metal roll-up door in the center of the east façade which is ten feet wide. This door was installed in the early 1960s, replacing the original paired, side-hinged doors. The smaller door on the east façade was also installed in a new opening at that time. There is a narrow passageway extending from the west wall, connecting this building to the older Key System Substation fifteen feet to the west. Originally constructed to provide power or the bridge's trains, the building is now used primarily for storage.

Key Pier Substation – Oakland. The substation is located at the end of the narrow peninsula that extends into San Francisco Bay from the Bay Bridge toll plaza. This concrete building is approximately 42 feet wide by 32 feet deep, with a slightly projecting base and pilasters. It was constructed in 1926. The large doorway in the center of the south façade originally had paired, side-hinged doors, but now has a metal roll-up door. There re rows of small windows, each consisting of a six-pane fixed sash in a metal frame, at the top of the north and south facades. There are also narrow ventilation louvers at the tops of all four walls, just below the eaves. The hipped roof is clad in standing-seam sheet metal and is topped by a raised, central skylight which repeats the hipped roof form. The interior is a single, large room with an open mezzanine along the east and north walls. The roof is supported by steel trusses, which are supported in turn by concrete walls. A narrow passageway connects the east wall of this building to the larger electrical susbstation that was built fifteen fet to the east in the late 1930s. This electrical substation was built as part of the Key System, which provided streetcar service throughout Oakland and other East Bay communities, with connecting ferry service to San Francisco. Originally named the San Francisco, Oakland & San Jose Railway, the system was organized in 1902 by Francis M. "Borax" Smith, through the consolidation of existing streetcar lines. Smith built a long pier extending into the bay nearly to Yerba Buena Island, where streetcar passengers transferred to San Francisco-bound ferries. The railway was officially named the Key System after a reorganization in 1923, taking its name from the shape of the pier.

PG&E Substation – Oakland. This building was never used in connection with the bridge or the transportation systems linked to it. For that reason it is considered **non-contributing**. This building is approximately 42 feet by 26 feet, with a small (18' x 12') extension at the east end of the north wall, giving the building an "L" shape. The building closely resembles the larger Caltrans substation located just 70 feet to the east, with concrete walls having a slightly projecting base and pilasters, and a simple cornice of vaguely classical styling. A larger opening in the west wall is now filled in, and the building has no windows. There is a small fenced-in area on the south side of the building, containing electrical equipment.

Changes to the Bridge since Construction

The Bay Bridge has been one of the most heavily used structures in the United States, almost from the day it was completed. Not surprisingly, the bridge has been modified extensively through the years, to retain its structural integrity, to accommodate vastly different traffic patterns, and to deal with natural disasters. While it has been modified incrementally through the years, the vast majority of changes to the bridge may be attributed to major events: removal of railroad tracks and reconfiguration for two one-way mixed traffic directions between 1959 and 1963; and damage to the bridge in the Loma Prieta earthquake in 1989, leading to substantial retrofitting of all elements of the bridge and ultimately to the decision to replace the entire East Bay Crossing.

Modifications from 1959 to 1963

Between 1959 and 1963, the Bay Bridge was substantially renovated to convert it to unidirectional traffic on each deck and to remove the railroad tracks. In general, three major changes were required. First the upper deck needed to be strengthened to accept heavy truck loading; this deck was designed for automobiles only. In addition, the upper automobile deck in the Yerba Buena Tunnel was lowered to accept taller truck traffic. Second, the tracks on the lower deck were removed and the railroad and truck lanes were rebuilt to accept mixed truck, bus and automobile traffic. This required lowering the lower deck through the tunnel to allow the upper deck to be lowered as well. Third, the approaches on both ends as well as the ramps on Yerba Buena Island had to be fundamentally rebuilt to accept the unidirectional flow. The 1959-63 work coincided with freeway construction on both ends of the bridge, further complicating the process of rebuilding the approaches.

The 1959-1963 work affected all aspects of the bridge but is most evident in the approaches and on the upper deck ramping. The areas of the San Francisco and Oakland approaches have suffered a considerable loss of integrity, owing to the 1959-63 work and other construction associated with freeway connections. The upper deck of the Bay Bridge was strengthened chiefly by adding cover plates to the transverse floor beams and by adding additional rolled girders beneath the original stringers to increase their strength. The 1959-63 work, of course, also removed the transit rail lines, transforming the function as well as the appearance of the structure.

The San Francisco Approach

The remodeling consisted mostly of removing columns that supported the upper deck roadway from the Fifth Street to San Francisco anchorage viaduct. The columns would otherwise have obstructed traffic on the new eastbound lower deck. To facilitate removal of the center columns, the outer columns were reinforced with new bolsters/pilasters on the outside faces of the remaining columns at the edges of the roadway, and the floor beams/bent caps were reinforced with new concrete and post tensioning to transfer the loads that were carried by the center column out to the remaining columns.

Additional remodeling of the main-line structure consisted of adding a new lower deck west of the Terminal ramps. This new structure consists of steel plate girders carrying a concrete slab-and-stronger deck, supported on reinforced concrete columns. The terminal ramps were widened and otherwise augmented to support bus operations of the Terminal.

The remains of the viaduct in San Francisco are identified as Bridge Number 118L and 118R. The alignment of the main viaduct was not exactly that of either 118L or 118R, which is part of Highway 101. The westerly leg of the original viaduct, near its touchdown at Fifth Street, serves today as an off-ramp for U.S. 101.

The off-ramp that left the main viaduct between Rincon and First streets is largely intact and is identified as Bridge Number 34-116F. It still serves as an off-ramp. There was a smaller on-ramp for eastbound bridge travelers, again connecting with the waterfront area but on the opposing side of the bridge from what is now called Bridge Number 34-117S. This looping ramp began at Sterling, a small street just east of First Street. The on-ramp looped beneath the bridge, parallel to Bryant Street south of the bridge, and took a tight-radius curve to join the bridge viaduct at the equivalent of Essex Street, immediately opposite the off-ramp (34-116F). Most of this on-ramp still exists and is identified as Bridge Number 34-117S. This ramp is now an off-ramp for westbound traffic.

Interurban traffic was diverted to a dedicated ramp, an elevated concrete and steel structure that looped some two thirds of a mile to and from the Transbay Terminal at First and Mission Streets. That ramp and the old interurban elevated loop still exist and are used today to carry bus traffic to and from the Transbay Terminal. The loop is a 3,439 foot elevated structure of riveted steel girders on concrete and steel bents. Various bridge numbers apply to this structure; these numbers, however, refer to the bridges over surface streets and not to the bus loop as an integrated elevated bridge.

While the approaches on the San Francisco end of the bridge have been heavily modified, they still retain enough of their historic appearance to make a contribution to the overall significance of the bridge.

The West Span

The remodeling of the West Bay span consisted mainly of reinforcing the upper deck to carry heavier truck loads, and of removing the rails and widening the slab on the lower deck. Adding cover plates to the transverse floor beams strengthened the upper deck. The cover plates were pre-cut, jacked to a prescribed load, and then fastened with bolts or rivets to the existing lower flange of the floor beams.

Yerba Buena Island

The remodeling consisted mostly of work associated with removing the columns that supported the middle of the upper deck, and lowering the upper deck so that adequate headroom would be provided for tall trucks on the upper deck. Additional work was performed to bring both sides of the lower deck to a uniform grade for one-way highway use. The column removal and upper deck lowering work required replacing the upper deck floor with a new floor at a lower elevation that spanned all the way across the tunnel without intermediate support. The purpose was to provide a clear span across all of the lower deck lanes, requiring removal of the support columns for the upper deck. This was performed without closing lanes to traffic on either deck. The new floor consists of pre-tensioned concrete tees, which were installed one at a time beneath a short temporary bridge that allowed both decks to remain in service during the reconstruction.

The East Span

The remodeling of the East Bay Crossing in 1959 consisted mainly of reinforcing the upper deck to carry heavier truck loads, removing the rails and widening the structural slab on the lower deck, and re-framing the transition at the east end so that five lanes of traffic can exit the lower deck to the south. The upper deck was strengthened by adding cover plates to the transverse floor beams (similar to the procedure used on the West Bay Crossing), and by adding additional rolled girder shapes beneath the original stringers to increase their strength. These were made to act compositely under both dead and live loads by pre-bending them upward in the middle prior to connecting them. The rails were removed from the lower deck to allow for widening the reinforced concrete slab. The heavier stringers that were already in place to carry the rail car loads were left in place to support the new slab.

The major reconstruction at that time was associated with re-framing the alignment transition at the east end. At this location, where the East Bay Crossing is framed with girders in an extended abutment-like structure, the transverse framing was lengthened and strengthened to remove existing columns from the revised highway alignment.

Changes resulting from the Loma Prieta Earthquake

The East Bay Crossing suffered significant damage in the 1989 earthquake. Immediately following the earthquake, both upper and lower 50-foot spans atop Pier E-9 were replaced; these were the only elements to collapse during the quake. Significant interim strengthening has been undertaken since then, including replacement of the collapsed girders and slabs at E-9. The current appearance of Pier E-9 may be seen in photo #36. Major underpinning of the abutment area consisting of replacing columns and footings with new units that are stronger and more ductile has also been done.

Another interim measure has consisted of building tension ties along the concrete cross beams framing the upper deck, providing a more secure anchorage of the beams to the columns. The seismic strengthening of the West Bay Crossing currently being engineered and built consists principally of 1) strengthening the towers with new steel plates, 2) adding new lateral bracing to the upper plane of the trusses, 3) strengthening the truss cross section against sway with new cover plates, 4) strengthening selected truss members to provide more axial and bending load capacity, 5) strengthening anchorages and foundations, strengthening the reinforced concrete Pier W-1, and perhaps adding center-span cable to truss ties at mid-span of the 2310' spans. The seismic strengthening of the Yerba Buena Island Crossing that is currently being designed and built consists of 1) strengthening the tunnel components against the increased seismic earth pressures, 2) strengthening the reinforced concrete framing east of the West Bay Crossing anchorage, and 3) strengthening the viaduct east of the tunnel portal.

All of these changes are relatively unnoticeable considering the great size and scale of the bridge itself and its remaining historic fabric and design. The bridge clearly retains the bulk of its historic appearance, and clearly retains sufficient integrity to retain its eligibility for National Register listing. In the future, however, several major changes are slated that will call into question the bridge's continuing eligibility. The entire East Bay Crossing will be removed, as will all of the San Francisco approaches. At Yerba Buena Island the tunnel wall strengthening will consist of adding an inner shell of modern construction to increase strength and ductility, and may cover the original tile in the tunnel. The framing strengthening will utilize steel shells on the columns and additional concrete and reinforcement of beams and girders. There is some possibility that part of the Island Crossing's East Viaduct will also be removed to allow realignment associated with the East Bay Crossing replacement.

After these destructive changes, the bridge's National Register eligibility will have to be re-evaluated. That re-evaluation will be required under agreements reached during the Section 106 review process.

The San Francisco Approach section also contains two additional structures that were inadvertently omitted from the description above. These structures are:

Bridge #34-119Y consists of multiple concrete T-beam spans, with steel plate girder spans at local street overcrossings. It is 3439 feet long. It originally carried interurban trains between the lower deck of the bridge and the Transbay Terminal. It now serves the same purpose for busses rather than trains.

Bridge #34-120Y is a concrete box girder span crossing over Harrison Street. Its single span is 165 feet long. It originally carried interurban trains over Harrison Street, heading to and from the Transbay Terminal. It now serves the same purpose for busses rather than trains.

Footnote Explanation

Because this nomination is a re-submittal, footnoting is inconsistent. Section 7 originally contained footnotes numbered 1-19. That re-written section is no longer footnoted, and Section 8 begins with Footnote 20.

Statement of Significance

The San Francisco-Oakland Bay Bridge qualifies for placement on the National Register under Criterion A for its significant influence on transportation in California and directly in the Bay Area. The San Francisco-Oakland Bay Bridge's multi-modal design is a perfect example of the mindset many commuters had during the 1930s. While many Bay Area commuters enjoyed driving their automobile into the city, many still used public transportation. Though the Bay Bridge no longer directly accommodates public transit, in the form of interurban rail lines, Bay Area commuters still use automobiles and public transportation in nearly equal numbers. Today the San Francisco-Oakland Bay Bridge continues to play a significant role in transportation as it serves as a major freeway connector for many who travel to and from the Bay Area. Everyday, 274,000 automobiles utilize the bridge.[20]

The San Francisco-Oakland Bay Bridge also qualifies for placement on the National Register under Criterion C for its engineering design. The building of a 5-mile bridge over water in 1936 was a major feat in itself, but poor foundation conditions required the engineers to be creative in their plans. Because of the conditions of the underlying ground foundation and the ingenuity of the engineers, the bridge consists of three different bridges and a tunnel. This ingenuity allowed the engineers to not only design a safe structure but to also design a structure that would break world records. The suspension section of the bridge, with its six spans, is the country's longest suspension bridge. Its longest individual spans are 2310' which makes them the sixth longest in the U.S. The 1400' cantilever span was the longest in the U.S. at the time of its construction but has since been surpassed by the Commodore John Barry Bridge in Chester Pennsylvania (1644') and the Greater New Orleans Bridge (1576'). Its piers are the deepest in the world.

Narrative Statement of Significance

Criterion A: Transportation

The San Francisco-Oakland Bay Bridge stands today as one of the most important and widely used bridges in the United States and the world. Over 274,000

[20] Stephen Mikesell, John Nelson, Dan Peterson, and Mark Ketchum. Historic American Engineering Record, San Francisco-Oakland Bay Bridge (Oakland-San Francisco Bay Bridge), Addendum to: Oakland-San Francisco Bay Bridge. May 1, 1999. 238.

automobiles, trucks and buses use the Bay Bridge daily, a figure rarely matched or surpassed anywhere. The Bay Bridge connects two major population centers in one of the busiest metropolitan regions in the country. Further, the Bay Bridge serves as a major freeway connector for the region's massive transportation network, though this role has evolved over time and was not the bridge's original purpose.
The need for the Bay Bridge became apparent during the 1920s when the number of automobile registrations and population increased. California, in the 1920s, was the forerunner in the nation leading the way for automobile use.

> Its use is credited to contributing greatly to the economic prosperity of that decade and transformed virtually every aspect of transportation in California and the nation, and had profound impacts as well on settlement patterns, patterns of retail sales, and a host of other aspects of community development. Automobile sales increased nationally, automobile manufacturers regarded California as the "bottomless pit" market for their products.[21]

The Bay Area during the 1920s and the 1930s provides a perfect example of how automobiles transformed an urban environment. Population density in San Francisco had increased, with the search on for new places to live. The advantage to owning an automobile was that it granted people increased mobility. Now, Bay Area residents could move into suburban neighborhoods without the fear of losing their city-based jobs. Even though interurban rail lines remained the primary commuter mode in the Bay Area in 1930, those lines were rapidly losing their share of the market to automobiles, despite the long ferry rides and high tolls associated with transbay automobile commuting.

As Bay Area transportation patterns evolved during the 1920s, the region's transportation network had to change to meet new demands. Traffic congestion was not an uncommon phenomenon to the people of the Bay Area. State and local transportation agencies attempted to relieve this congestion by constructing new and improved highways linking both East Bay cities with Oakland and Peninsula cities with San Francisco. However, the

[21] "The crucial place of California in this regard is highlighted in James L. Flick, The Car Culture. Cambridge: MIT Press, 1975. Flick credits automobile sales for the prosperity of the 1920s and points to declining sales during the late 1920s for contributing to the depth of the Great Depression." As cited in Mikesell, et al., 239.

Bay Bridge became necessary as a link between San Francisco and Oakland, as ferries could no longer accommodate the increased traffic on the waterways. The San Francisco-Oakland Bay Bridge was in many ways like the other bridges being proposed at the time, in that seventy-five percent of its lane capacity would be designated for automobile use. However, what made the San Francisco-Oakland Bay Bridge unique among other bridge designs was that it also included lanes for mass transit use. The multi-modal design was vital to the engineers because they wanted everyone to be able to use this bridge. Further, the multi-modal design accurately reflected how Bay Area residents relied equally on automobiles and public mass transit for their commuting needs.[22]

The proposal for the San Francisco-Oakland Bay Bridge received almost universal support from both citizens and civic leaders. Most everyone recognized the importance and the necessity of having a bridge connecting these two city centers. It was no surprise then that the bridge proposal was passed and the loan of $70 million from the federal government was granted.[23]

The San Francisco-Oakland Bay Bridge was completed in three years and just a little bit ahead of schedule. Several factors led to the bridge's relatively swift construction. First, many politicians pushed for a timely completion date in order to satisfy certain political commitments that had been made. One of these commitments included the employment of thousands of people hit hard by the Great Depression. Secondly, the bridge's engineers wanted to finish early to prevent accumulation of interest onto the principal of their loan. When the San Francisco-Oakland Bay Bridge finally opened it served double and then triple the anticipated traffic. No one could have foreseen the success the San Francisco-Oakland Bay Bridge experienced.[24]

Speculations as to what sparked the success of the San Francisco-Oakland Bay Bridge are numerous. The first reason attributed to the success of the San Francisco-Oakland Bay Bridge became evident when the region hosted the World's Fair on Treasure Island in 1939-1940. Although one could access Treasure Island by water transportation, the San Francisco-Oakland

[22] Mikesell, et al., 239.
[23] Mikesell, et al., 10.
[24] Mikesell, et al., 8-9.

Bay Bridge proved to be a much more convenient and efficient method of getting to the island and the fair. Another reason for the success of the bridge was the entry of the United States into World War II in 1941. The United States' participation in the war transformed the Bay Area into a key contributor to the war effort. The San Francisco-Oakland Bay Bridge facilitated the movement of personnel and supplies from port to port. Finally, the Bay Bridge succeeded due to the significant increase in the population of the Bay Area during the post-war years.[25] The San Francisco-Oakland Bay Bridge once again served as a highly effective connector between these two metropolitan areas. One can only wonder what the Bay Area would look like if it did not have the San Francisco-Oakland Bay Bridge to accommodate the wartime and post-war growth of the area.

By 1963, the Bay Bridge had also evolved into a vital freeway connector for the Bay Area. This was not the original purpose of the Bay Bridge, as its designers assumed that most people would be traversing the bridge on interurban rail lines or buses. However, the failure of the interurban rail lines and the increased popularity of automobiles eventually led to the Bay Bridge becoming exclusively an automobile-truck bridge in 1963. Once again, the Bay Bridge reflected the changing reality of the Bay Area transportation network.

Criterion C: Engineering

In 1955 the American Society of Civil Engineers chose the San Francisco-Oakland Bay Bridge as one of the Seven Wonders in the United States. It was the only highway-related structure in the group.[26] The San Francisco-Oakland Bay Bridge broke many records when it was built, though this was not the original intention of the engineers. Nevertheless, the San Francisco-Oakland Bay Bridge excelled in its length, the depth of its piers, the total length of the suspension span, the length of its cantilever span, and in the great amounts of concrete, steel, wood, and other materials used in its construction. These remarkable feats only add to the bridge's importance.[27]

[25] Mikesell, et al., 9.
[26] Mikesell, et al., 242.
[27] Ibid.

The particular goal the engineers wanted to accomplish was to construct a double-deck, multi-modal structure between Oakland and San Francisco. They were able to accomplish this goal within a short amount of time and below their estimated budget. One aspect that contributes to the significance of the San Francisco-Oakland Bay Bridge is that "it was designed in a period of two years and built within three years."[28] One reason for the great haste in building the bridge was the desire to satisfy the promises the engineers and architects made to the governor, the legislature, and political leaders in the Bay Area. When campaigning for support of the San Francisco-Oakland Bay Bridge, C.H. Purcell, chief engineer of the bridge made promises to those who could further his cause. No doubt he wanted to make good on his promises. Another reason for the swiftness in constructing the San Francisco-Oakland Bay Bridge was to commence bringing in revenue from the tolls to cut down on the interest payments of the loan. Still another reason cited for the speed in which the San Francisco-Oakland Bay Bridge was built was the need to provide jobs. One of the promises made to politicians for their support in the bridge proposal was to provide jobs for those who were experiencing difficult times because of the Great Depression. The urgency of the approval for the plans of the bridge was in part to employ the Depression-ravaged citizens of California.[29]

The impressive length of the San Francisco-Oakland Bay Bridge also demonstrates significance in engineering. By today's standards, the San Francisco-Oakland Bay Bridge demonstrates a certain level of ingenuity from the perspective of the engineers. To fully appreciate this ingenuity, one must look at the design of the bridge through the eyes of the engineers who overcame difficulties, such as poor foundation conditions, without the benefit of modern day technology. The use of a double-suspension span would not have been necessary except for the length the bridge had to cross from Yerba Buena Island to San Francisco.[30] This double-suspension type of bridge was considered so unusual at that time that it could be considered as the first of its kind.[31]

[28] Ibid.
[29] Mikesell, et al., 242-243.
[30] Mikesell, et al., 243.
[31] "United States Steel, "San Francisco Oakland Bay Bridge," 1936, illustrates the only known predecessor to the double-suspension bridge design, an 1841 bridge in Prague, Czechoslovakia across the River Moldau; 19." As cited in Mikesell, et al., 244.

As previously noted, the engineers were not trying to build an impressive bridge; they were designing a means to cross the four-mile bay between San Francisco and Oakland. However, this is not to say that there was no desire to accomplish something daring. Some engineers advocated the use of a single-suspension span for the San Francisco-Oakland Bay Bridge for two reasons. "The first being that it would provide the best possible water way for shipping and second, it would undoubtedly create a bridge which architecturally and spectacularly would appeal to the civic pride in both cities."[32] The eventual design for the bridge was the double-suspension span because the engineers did not want to stray too far from known technologies.[33]

Why did the engineers then break world records if that was not their intention? The main reason for having to utilize the technology that they did was the poor foundation conditions of the ground that the bridge was to be built on. The depth of the piers is not attributed to the great length of the San Francisco-Oakland Bay Bridge, but actually to the seabed conditions. The length did have something to do with the piers, but only in the factors that some of them would have to be built on a poor foundation. "The deepest East Bay and West Bay piers are roughly the same depth but for different reasons. On the West Bay, the depth was defined as the depth to bedrock. The East Bay piers were sunk to a level where the hardest clay could be found. Pier E-3 reached the greatest depth by accident; the caisson continued to sink uncontrollably and gained an extra 10 feet on that basis.

"The use of multiple bridge types and the fact that the East Bay Crossing is different from the West Bay, also came from the result of the poor foundation conditions. The West Bay crossing was designed as a suspension bridge to minimize the number of piers it would have to use. When the engineers realized that the piers on the East Bay could not be taken to bedrock, they eliminated the idea of suspension bridge from that side of the island. The decision of using multiple bridge types would minimize the weight of both the substructure and superstructure.

---

[32] "Daniel Moran and Proctor to Woodruff, November 9, 1931, Board of Consulting Engineers, Moran and Proctor, 200.5, California State Archives." As cited in Mikesell, et al., 244.
[33] Mikesell, et al., 244.

National Register of Historic Places
Continuation Sheet

"In the final analysis the Bay Bridge is a very complex structure because it was also a very bold undertaking. All of the important elements of it, from the deep piers to the multiple bridge types to double-suspension bridge to the great length, were solutions to the problems posed by this daring crossing. These elements were compromises that the state engineers and consulting engineers developed as they worked to solve the problem. That the solution worked well is a testament to the talent of the people involved in that process."[34]

[34] Mikesell, et al., 245.

Bibliography

Bayol, Greg, Chief of Public Affairs, Caltrans. E-mail answers to questions about the Bay Bridge. Greg_Bayol@dot.ca.gov, June 9, 12, 25 and 29, 1998.

Dillon, Richard, Thomas Moulin and Don DeNevi. High Steel, Building Bridges Across San Francisco Bay. Millbrae, CA: Celestial Arts, 1979.

Ford, Robert S. Red Trains Remembered. Glendale, CA: Interurban Books, 1980.

Hollingsworth, J.B. and Whitehouse, P.B. American Railroads. London, England: Bison Books Limited, 1977.

Hoover-Young San Francisco Bay Bridge Commission. Report of the Hoover-Young San Francisco Bay Bridge Commission to The President of the United States and the Governor of the State of California. (Sacramento, California State Printing Office, 1930).

Hope, Andrew. Bay Bridge Oakland Substation. Primary Record. Oakland, California: California Department of Transportation, 1998.

———. Caltrans Garage. Primary Record. Oakland, California: California Department of Transportation, 1995.

———. Key Pier Substation. Primary Record. Oakland, California: California Department of Transportation, 1998.

———. P. G. & E. Oakland Substation. Primary Record. Oakland, California: California Department of Transportation, 1998.

———. Sterling Street Substation. Primary Record. Oakland, California: California Department of Transportation, 1995.

———. Y.B.I. Electrical Substation. Primary Record. Oakland, California: California Department of Transportation, 1995.

Key System Bay Bridge Trains, 1939-1958. Video. Western Railway Museum: Bartel-Thomsen Pictures, 1988.

Martin, Jim, U.S.G.S. E-mail answer about UTM references of the Bay Bridge. Jmartin@igsmn002.wr.usgs.gov, June 4, 1998.

Mensch, Ernest Cromwell. The San Francisco Oakland Bay Bridge, A Technical Description in Ordinary Language. San Francisco: (The Author), c1936.

Mikesell, Stephen D. Bay Bridge Toll Plaza. Architectural Inventory/Evaluation Form. Sacramento: California Department of Transportation, 1990.

Mikesell, Stephen, John Nelson, Dan Peterson, and Mark Ketchum. Historic American Engineering Record (HAER), San Francisco-Oakland Bay Bridge (Oakland-San Francisco Bay Bridge), Addendum to : Oakland-San Francisco Bay Bridge. n.p., 1999.

Nadeau, Bart, Western Railway Museum. E-mail answer about closures of Bay Bridge trains. BartN51729@aol.com, June 21, 1998.

San Francisco Chamber of Commerce. Research Dept. World's Two Largest Bridges, San Francisco Bay Area. San Francisco (n.d.)

Snyder, John W. An Evaluation of the San Francisco-Oakland Bay Bridge In Connection With 4-SF-I280 Transfer Concept. Sacramento: California Department of Transportation, 1983.

Snyder, John. Transbay Transit Terminal. Architectural Inventory/Evaluation Form. Sacramento: California Department of Transportation, 1983.

Southern Pacific's Interurban Electric Railway Red Train Cars of the Bay Area, Final Days of Operation, 1941. Video. Western Railway Museum: Bartel-Thomsen Pictures, 1988.

The Bridges of San Francisco Bay. Website: http://www.dot.ca.gov./dist4/calbrdgs.htm. Caltrans, February 1998.

Walker, Jim. Key System Album. Glendale, CA: Interurban Books, 1978.

Name of Repository

San Francisco Public Library
Main Library

San Francisco History Center
100 Larkin Street
San Francisco, California 94102

Western Railway Museum
5848 State Highway 12
Suisun City, California 94585

U. S. G. S.
345 Middlefield Road
M. S. 532
Menlo Park, California 94025

Caltrans District 4
Map Room
111 Grand Avenue
Oakland, California 94612

Caltrans District 4
Photography Department
111 Grand Avenue
Oakland, California 94612

Andrew Hope
Caltrans District 4
111 Grand Avenue
Oakland, California 94612

UTM references

Bay Bridge

1. Zone 10, Easting: 552900, Northing: 4181200
2. Zone 10, Easting: 555000, Northing: 4183500
3. Zone 10, Easting: 556300, Northing: 4185200
4. Zone 10, Easting: 557900, Northing: 4185800
5. Zone 10, Easting: 559400, Northing: 4186080

Boundary Description

The boundaries of the Bay Bridge consist of the named structures listed in the nomination beginning at 5th Street in San Francisco and ending just beyond where the bridge touches down on the Oakland side and becomes a roadway on grade. That easternmost point is 1100 feet from the shoreline. At various places the boundary expands to embrace the footprint of the buildings listed in the nomination, including the Transbay Terminal and the Key System Electrical Substation in San Francisco, the Key System Electrical Substation and S.F.O.B.B. Firehouse on Yerba Buena Island, and the Bay Bridge Substation, Key Pier Substation and P.G. & E. Substation in Oakland. The UTM references for these buildings are as follows:

Transbay Transit Terminal – San Francisco
Zone 10, Easting: 553260, Northing: 4182450

Key System Electrical Substation – San Francisco
Zone 10, Easting: 553490, Northing: 4181890

Key System Electrical Substation – yerba Buena island
Zone 10, Easting: 556050, Northing: 4185840

S.F.O.B.B. Firehouse (Caltrans Garage) – Yerba Buena Island
Zone 10, Easting: 556070, Northing: 4185860

Key Pier Substation – Oakland
Zone 10, Easting: 559110, Northing: 4185970

P.G. & E. Substation – Oakland
Zone 10, Easting: 559090, Northing: 4185950

Bay Bridge Substation – Oakland
Zone 10, Easting: 559130, Northing: 4185980

Boundary Justification

The boundaries encompass the historic bridge structures and appurtenant buildings. The boundaries at the eastern end of the bridge have been drawn to exclude the newer and heavily modified non-contributing buildings at and near the Oakland Toll Plaza.

All of the following photos were submitted as part of the Historic American Engineering Record work done for the bridge. One set of negatives is at the Library of Congress. Another set of negatives is on file at Caltrans District 4.

Photo #1: CA-32-54
Fred Benton, Photographer
June 20, 1997
High aerial view of entire bridge.

Photo #2: CA-32-58
Frank Deras Jr., Photographer
July 1998
Contextual view of bridge from San Francisco to Yerba Buena Island, north side. Photographed from above Alcatraz Island, facing southeast.

Photo #3: CA-32-69
Fred Benton, Photographer
August 1998
High aerial view of transbay terminal bus loop and San Francisco on and off-ramps.

Photo #4: CA-32-72
Frank Deras Jr., Photographer
May 1998
Contextual view of Transbay Terminal bus loop, facing northeast.

Photo #5: CA-32-73
Frank Deras Jr., Photographer
January 1998
Contextual view of suspension bridge from Harrison Street, north side, facing east.

Photo #6: CA-32-75
Frank Deras Jr., Photographer
July 1998
Contextual elevation view of center anchorage and tower W-5, south side, facing northwest.

Photo #7: CA-32-76
Frank Deras Jr., Photographer
June 1998
Contextual view of suspension bridge from yerba Buena Island to San Francisco, south side, facing west-southwest.

Photo #8: CA-32-77
Frank Deras Jr., Photographer
June 1998
Contextual aerial view of suspension bridge from Tower W-6 to Yerba Buena island with cantilever bridge in background, facing east-northeast.

Photo #9: CA-32-79
Frank Deras Jr., Photographer
May 1998
Contextual aerial view of Yerba Buena viaduct, east side of Yerba Buena Island, with Treasure Island in background, facing north-northwest.

Photo #10: CA-32-81
Frank Deras Jr., Photographer
July 1998
Contextual aerial view of cantilever truss from above, with Yerba Buena Island in center and San Francisco in background, facing southwest.

Photo #11: CA-32-82
Frank Deras Jr., Photographer
May 1998
Contextual aerial view of cantilever truss and through truss spans, south side, with Treasure Island and Yerba Buena Island in background, facing west.

Photo #12: CA-32-88
Frank Deras Jr., Photographer
July 1998
Contextual elevation view of cantilever truss at Pier E-2, north side, facing south.

Photo #13: CA-32-91
Frank Deras Jr., Photographer
July 1998
Contextual aerial view of east bay crossing showing through truss spans, south side, facing north-northwest.

Photo #14: CA-32-92
Frank Deras Jr., Photographer
July 1998
Contextual aerial view of upper deck roadway at deck truss spans, from Pier E-9 to Oakland, facing east.

Photo #15: CA-32-94
Frank Deras Jr., Photographer
July 1998
Contextual aerial view of Oakland approach at toll plaza with San Francisco in background, facing west-southwest.

Photo #16: CA-32-105
Frank Deras Jr., Photographer
December 1997
View of San Francisco viaduct at intersection of 1950s modification, facing east from Third Street.

Photo #17: CA-32-143
Frank Deras Jr., Photographer
April 1999
View of San Francisco viaduct (left) and upper deck off-ramp to Fremont Street (right), facing north.

Photo #18: CA-32-147
Dennis Hill, Photographer
April 1998
View of San Francisco viaduct crossing over upper deck off-ramp to Fremont Street, facing south.

Photo #19: CA-32-149
Frank Deras Jr., Photographer
April 1998
View of San Francisco anchorage, north side, facing south.

Photo #20: CA-32-181
Frank Deras Jr., Photographer
May 1998
View along upper deck of suspension bridge, facing tower, looking southwest.

Photo #21: CA-32-182
Frank Deras Jr., Photographer
May 1998
View along upper deck of suspension bridge from cable valley, facing southwest.

Photo #22: CA-32-195
Frank Deras Jr., Photographer
April 1998
View of suspension bridge from below at tower, south side, facing west.

Photo #23: CA-32-214
Frank Deras Jr., Photographer
May 1998
Detail view of strand shoes, eye bars and concrete abutment in Yerba Buena anchorage, facing southeast.

Photo #24: CA-32-220
Dennis Hill, Photographer
July 1998
Elevation view of west tunnel portal, facing northeast.

Photo #25: CA-32-238
Frank Deras Jr., Photographer
May 1998
Aerial view of deck truss at Yerba Buena Island, south side, with Treasure Island in background, facing northwest.

Photo #26: CA-32-245
Dennis Hill, Photographer
April 1998
View of underside of deck truss at Pier YB-3, facing northeast.

Photo #27: CA-32-249
Frank Deras Jr., Photographer
April 1998
View of cantilever truss and deck truss, south side, facing west.

Photo #28: CA-32-256
Frank Deras Jr., Photographer
April 1998
View of cantilever truss and deck truss at Pier E-1, south side, facing west.

Photo #29: CA-32-258
Dennis Hill, Photographer
April 1998
View of cantilever truss anchor arm at Piers E-1 and E-2, south side, facing north.

Photo #30: CA-32-263
Dennis Hill, Photographer
June 1998
View of cantilever truss from upper deck, facing southwest.

Photo #31: CA-32-264
Dennis Hill, Photographer
May 1998
Detail view of cantilever truss from upper deck between Piers E-3 and E-4, facing west.

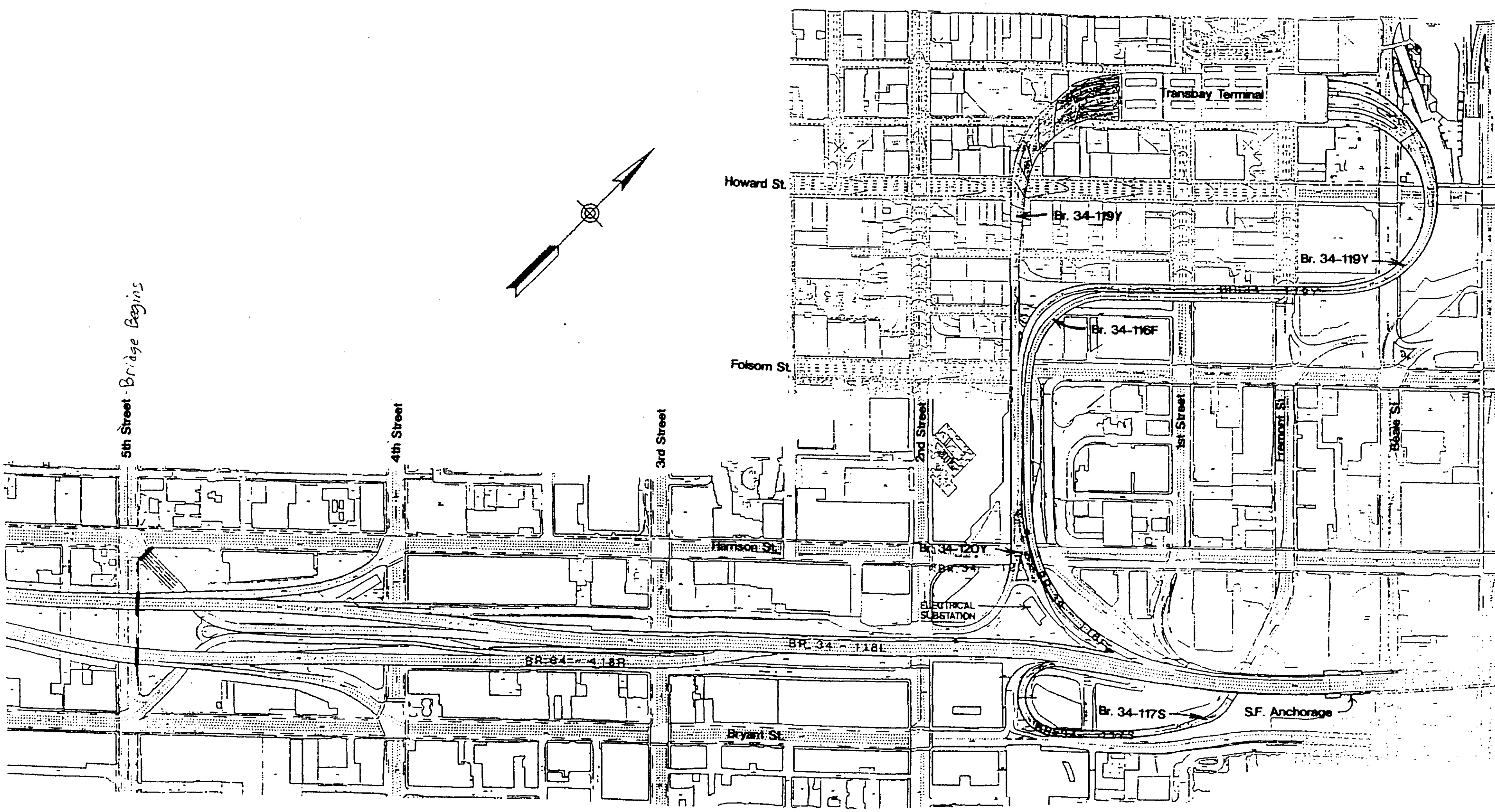
Photo #32: CA-32-269
Dennis Hill, Photographer
May 1998
View of cantilever truss portal at Pier E-4, facing west.

Photo #33: CA-32-285
Dennis Hill, Photographer
May 1998
Detail view from upper deck of through truss and service ladder at Pier E-8, facing east.

Photo #34: CA-32-293
Frank Deras Jr., Photographer
July 1998
View of base of tower at Pier E-6, facing northeast.

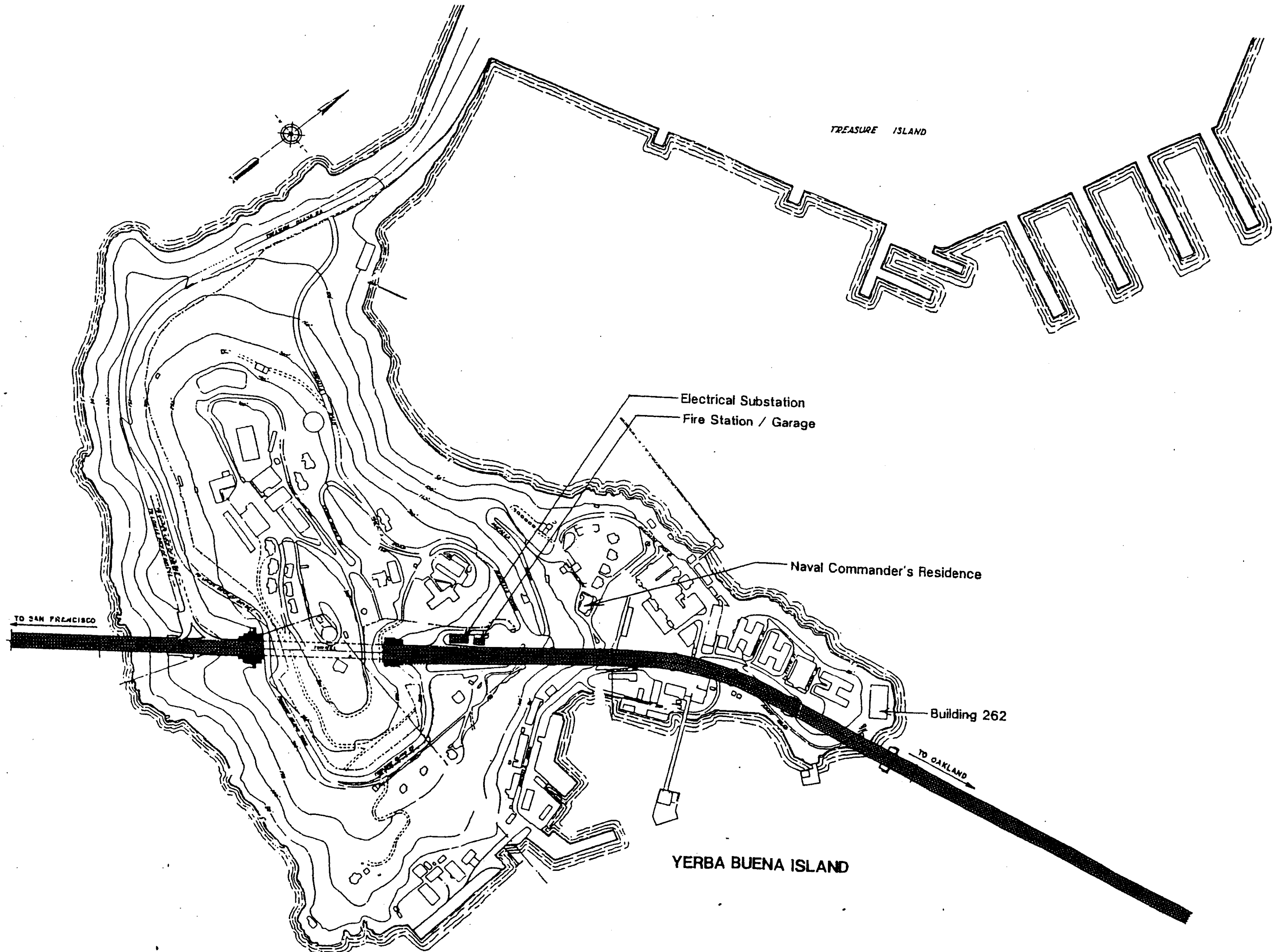
Photo #35: CA-32-294
Frank Deras Jr., Photographer
June 1998
View of deck truss and through truss spans with Yerba Buena Island in background, north side, facing southwest.

Photo #36: CA-32-296
Frank Deras jr., Photographer
July 1998
View of underside of through truss and deck truss at Pier E-9, north side, facing east-southeast.



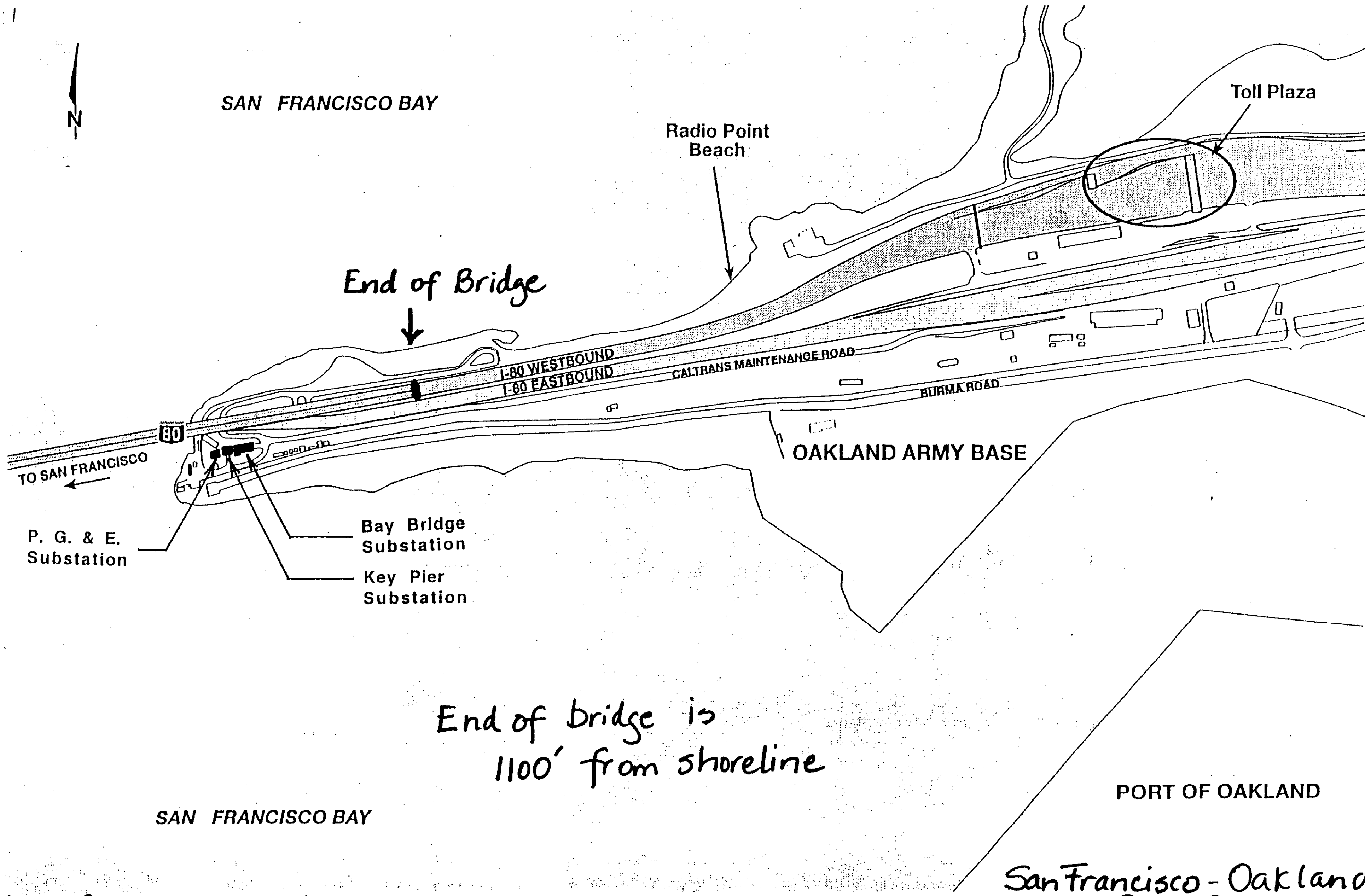
Map 1

San Francisco - Oakland Bay Bridge
San Francisco - Alameda Cos
CA



Map 2

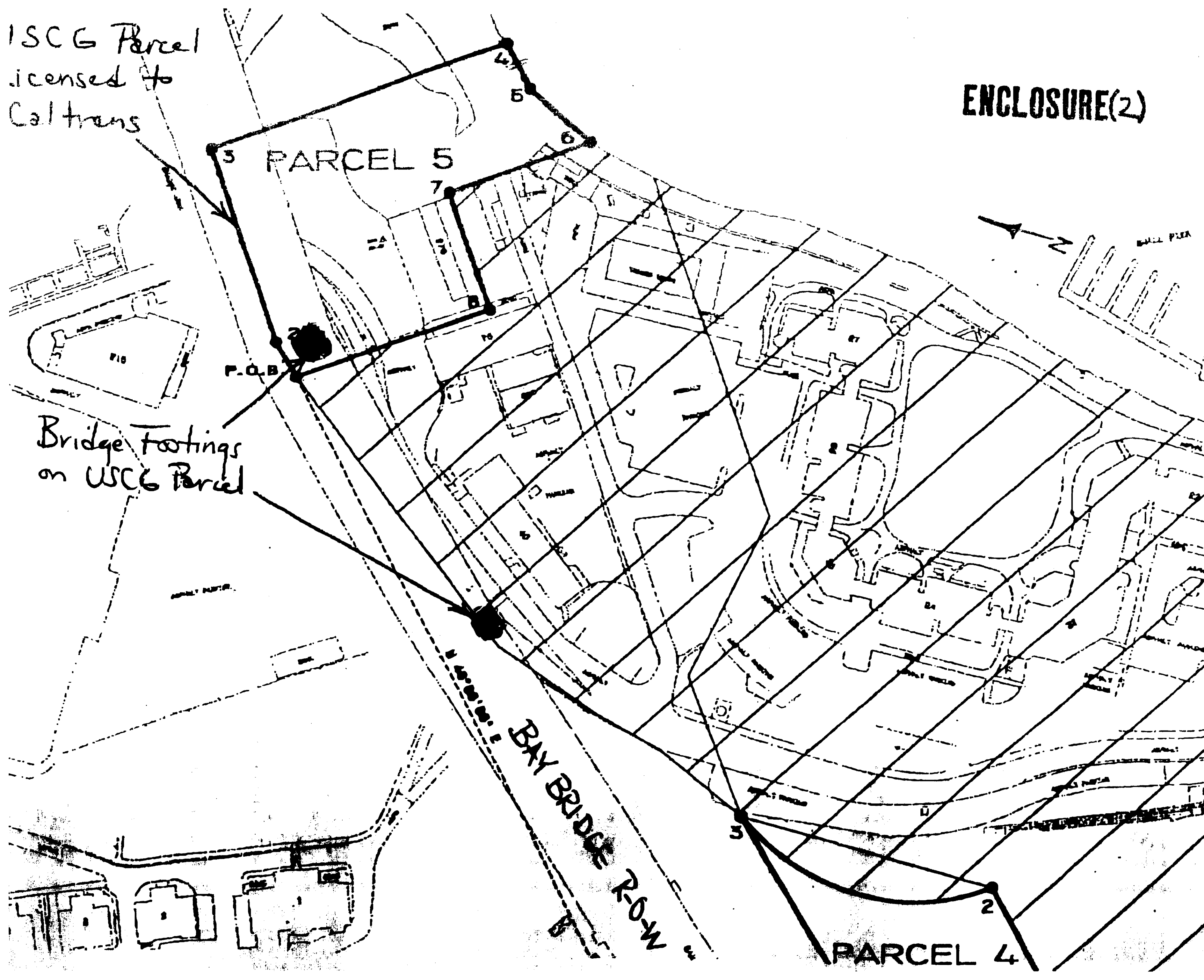
San Francisco - Oakland Bay Brid
San Francisco - Alameda Cos.
CA



Map 3

San Francisco-Oakland Bay Bridge
San Francisco-Alameda Cos.
CA

ENCLOSURE(2)



USCG Parcel
Licensed to
Caltrans
PARCEL 5
3
4
5
6
7
8
P.O.B.
Bridge Footings
on USCG Parcel
BAY BRIDGE R-O-W
N
3
2
PARCEL 4