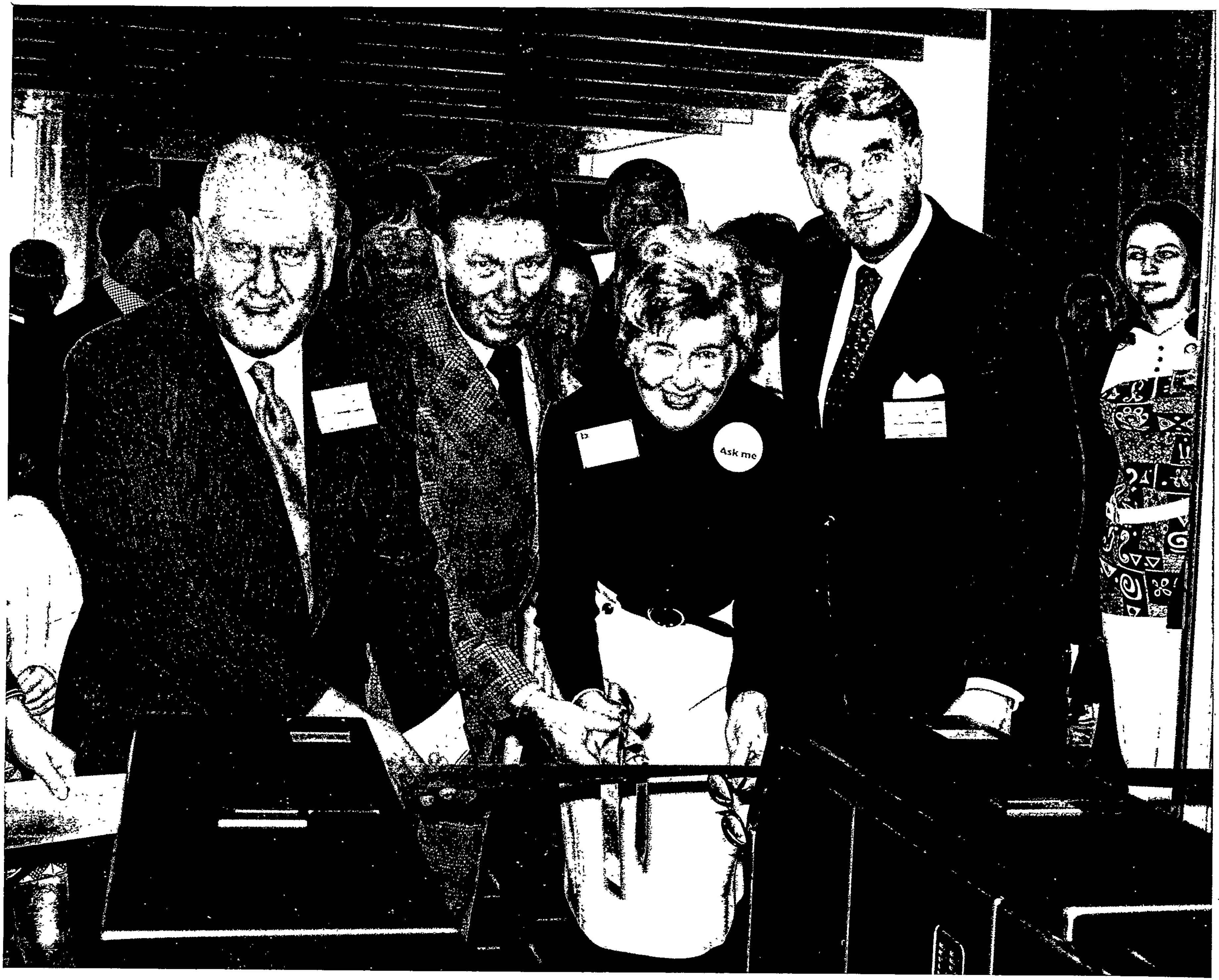
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1407 Powell Street
Emeryville, CA 94608-2009
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(415) 654-1407

FILE # 17667

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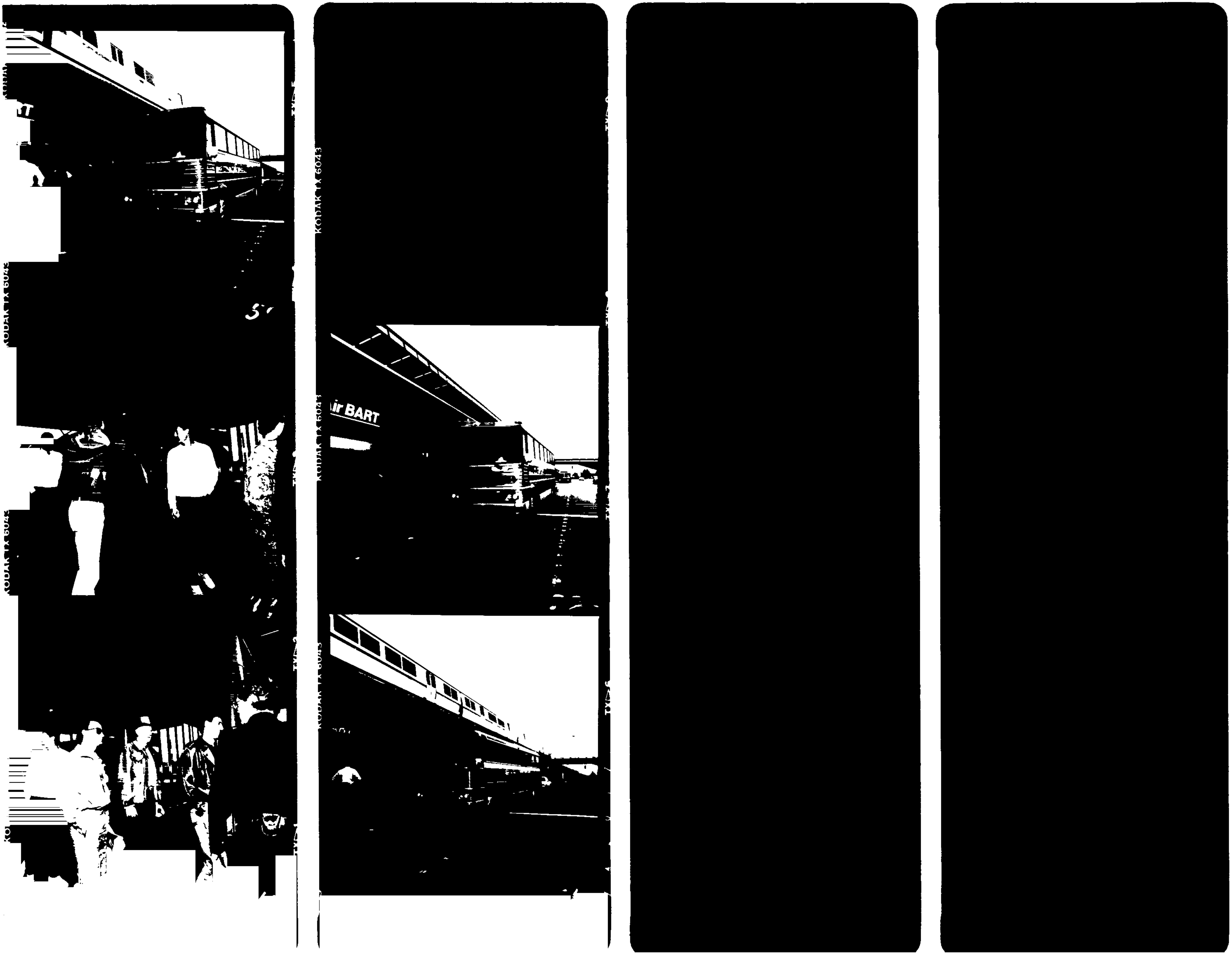

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BAY AREA RAPID TRANSIT DISTRICT

# *San Francisco - North Bay BART Connection*

*— A Conceptual Study —*

*Bechtel*

*August 1989*

# CONTENTS

# INTRODUCTION

The issue of providing a rapid transit connection between San Francisco and Marin County was the subject of four engineering studies during the 1960s. The first study was performed by BART joint venture consultants in early 1960, addressing this connection as part of the initial five-county 120-mile rapid transit plan. The study proposed the use of a new lower deck to the Golden Gate Bridge as the means of traversing the San Francisco Bay. This line to Marin County, as well as BART's extension into the Peninsula, was dropped from the plan when the Boards of Supervisors of Marin and San Mateo counties elected not to participate in the project.

In 1967, a study of transbay tube alternatives between San Francisco and Marin counties analyzed the feasibility of such a project. An alignment across the Bay between Aquatic Park and Sausalito was selected as the most suitable and economical alignment for either transit and/or auto use. Preliminary geological investigations were conducted and an order-of-magnitude cost estimate for the project developed.

About the same time, the State Department of Public Works (currently CalTrans) conducted a comprehensive study of transportation alternatives along the same San Francisco-Marin corridor, considering almost every mode of surface, water, and air transportation. By the end of that decade, another broad-based rail/bus alternatives study was performed by a consulting firm. The latter two studies evaluated the alternatives from the technical and economic viewpoints but did not recommend any particular solution.

In May of this year, BART contracted with Bechtel to undertake a conceptual study of linking downtown San Francisco with the city of Novato in Marin County by a rapid transit line (BART technology). It was directed that the Bay crossing should consider two alternatives: 1) via a sunken tube under the Bay and, 2) a new lower level of the Golden Gate Bridge. It was also stipulated that the study should examine reasonable horizontal and vertical alignment alternatives and develop a conceptual cost estimate. This study would build on the results of the four previous studies mentioned above and introduce modifications and adjustments that reflect present-day operational, environmental, and other pertinent conditions. This report summarizes the findings and conclusions of the study.

Section 1

## EXECUTIVE SUMMARY

The proposed project is to build a rapid transit line, using BART technology, between downtown San Francisco and the City of Novato in Marin County. The project is divided into three segments:

- San Francisco segment
- Transbay segment
- Marin segment

Alternative route alignments and profiles considered in this report are largely based on previous work performed on the same corridor during the decade of the 1960s. Three main differences between now and then were considered in this study:

1. The operational requirement of providing at least 2000 feet of tail track beyond all end stations. In downtown San Francisco, this tail track will have to cross Market Street underneath the existing BART structures, some 100 feet below ground. This requirement will also impact the line profile upstream from the downtown station for some distance since a maximum of a 4 percent grade has to be maintained.

2. The old studies used the Northwestern Pacific Railroad (NWP) right-of-way as the BART alignment between Sausalito and Larkspur. That right-of-way was then preferred and available for transit use. During the last 15 years, this right-of-way has been sold to private entities and public agencies and has been partly developed into bike trails, parks, parking lots, and commercial establishments.

3. Environmental regulations have been introduced in the last 15 years that place many restrictions on project developments.

Two main alternative alignments, 1 and 2, previously studied were slightly modified and analyzed in this report to reflect the above differences. Additionally, Bechtel has identified a new possible alignment through the most environmentally sensitive area of the corridor in Marin County. This is designated as Alternative 3.

Alternative 1 would start at Kearny and Market streets and follow Kearny Street and Columbus Avenue to Aquatic Park. There, the line would cross the bay in an immersed tube to the southern tip of Sausalito. The line would then generally follow the old NWP right-of-way, with slight modifications, until Larkspur. The line would then use the existing NWP rail right-of-way, again with slight modifications, until the City of Novato. Three underground stations would be provided in San Francisco and 8 stations in Marin County (1 underground, 5 aerial, and 2 at-grade). Parking would be provided at 7 of Marin's stations.

A slight deviation from this alternative has been developed and is labeled Alternative 1A. This deviation would extend the transbay tube to enter Marin County north of Sausalito, thus bypassing the City of Sausalito and eliminating its station.

Alternative 2 would start at Post Street from the foot of Market Street; it would follow Post Street, then Geary Boulevard, turning down Sixteenth Avenue through the Presidio and toward the Golden Gate Bridge. The line would cross the bay on a new second deck to the Golden Gate Bridge and penetrate the mountain at the north end of the bridge through a tunnel section to Sausalito. There, the line would follow the same alignment as Alternative 1 through Marin County. This alternative would include 6 underground stations in San Francisco and 9 stations in Marin County (1 underground, 5 aerial, and 3 at-grade). Parking would be provided at 8 of Marin's stations.

The Golden Gate Bridge District is in the process of negotiating a contract with T. Y. Lin International to evaluate the technical feasibility of utilizing a lower deck of the Bridge for rail transit uses, including BART-type technology. (Bechtel is a subconsultant for T. Y. Lin on this study.) The results of this study are anticipated to be released within one year.

Alternative 3 would be identical to any of the above alternatives except in the section between Richardson Bay and Corte Madera Creek in Marin County. This alignment would cross Richardson Bay immediately adjacent to the U.S. 101 bridge, follow U.S. 101 alignment to just south of Corte Madera Creek. There, it would join the alignment of the other alternatives.

All alternatives involve building a 2,000+ foot tail track beyond the San Francisco terminal station to conform to BART's operating requirements. This tail track would have to be built under the existing BART/MUNI structure on Market Street -- i.e., more than 100 feet below ground. A 500-foot crossover structure would also have to be included south of Market Street as part of the tail track provision. This requirement would depress the terminal stations in San Francisco (for both alternatives) to below 100 feet from the ground surface and would also influence line profiles and station locations for some distance beyond these stations.

Based on studies by others and the limited modifications introduced in this study, and pending the outcome of the Golden Gate Bridge study, all alternatives merit further technical evaluation and analysis. Environmental issues in both San Francisco and Marin will require careful and detailed analysis of alignments, profiles, and station locations for alternatives presented in this report, plus the development of other alternatives as appropriate. Mitigation measures will have to be developed to cope with these environmental issues both during construction and operation of the system.

A conceptual capital cost estimate for any of the three alternatives (1, 1A, and 2) ranges between $2.83 and $2.95 billion at mid-1989 price levels. Right-of-way acquisition, rolling stock, Owner's pre-operational testing and startup, financing and interest during construction, and utility agencies' fees and charges have been excluded from this estimate. Alternative 3 would be expected to fall within the same range as the other alternatives. Potential patronage on the system for the average weekday of the year 2005 is roughly estimated in the range of 60,000 to 85,000 passengers for Alternative 1 and 95,000 to 145,000 for Alternative 2. A summary of the alternatives' characteristics and cost by segment are given in the following tabulation.

| | *Alt 1* | *Alt 1A* | *Alt 2* |
|---|---|---|---|
| San Francisco Segment | | | |
| Length of lines (miles) | 2.18 | 2.18 | 6.29 |
| Number of stations | 3 | 3 | 6 |
| Cost ($ million) | 680 | 680 | 1,610 |
| Transbay Crossing | | | |
| Length of crossing (miles) | 4.55 | 5.97 | 1.70 |
| Cost ($ million) | 1,160 | 1,520 | 150 |
| Marin Segment | | | |
| Length of lines (miles) | 21.6 | 20.17 | 22.88 |
| Number of stations | 8 | 7 | 9 |
| Cost ($ million) | 990 | 750 | 1,100 |
| Total Length of Lines (miles) | 28.33 | 28.32 | 30.87 |
| Total Number of Stations | 11 | 10 | 15 |
| Total cost ($ million) | 2,830 | 2,950 | 2,860 |

## Section II

# DESCRIPTION OF ALTERNATIVE ALIGNMENTS

Two principal alternative alignments were considered between downtown San Francisco and the city of Novato in Marin County. Alternative 1 uses a tube to cross the San Francisco Bay to Marin County while Alternative 2 crosses the Bay via a new second deck under the existing Golden Gate Bridge. Both alignments were developed previously by other consultants. Additionally, Bechtel has identified a new possible alignment through the most environmentally sensitive portion of the corridor in Marin County and has designated it as Alternative 3. In modifying these alignments to reflect present-day conditions, the following general alignment criteria were adopted:

- Maximum allowable grade: 4 percent
- Minimum operating curve radius: 1200 feet
- Minimum non-operating curve radius = 500 feet
- Length of vertical curves = change in grade x 200
- Maximum allowable grade at station is 1 percent
- Grade at stations should be on tangent. Locate end/beginning of vertical curve at a minimum of 100 feet from station
- Grade for storage yard: 1 percent maximum, sloping away from station
- Minimum length of storage yard: 700 feet
- Spacing between tracks in storage yard: 15 feet on centers
- For storage yard in tunnel section (Third Street), use walkways on sides and middle of tracks

The alignment for all Alternatives has been broken down into three segments: San Francisco, transbay, and Marin. The following discussion highlights alignment variations from previously published reports for each of these segments. Figures A through Figure F, presented on pages 12-19 at the end of this section, follow the discussion.

## 1. SAN FRANCISCO SEGMENT

### Alternative 1 - Figure A

This route alignment in San Francisco follows Kearny Street and Columbus Avenue with a tail track extending beyond Kearny Street Station down Third Street. This alignment is consistent with a previous study titled "Golden Gate Corridor Long Range Transportation Alternatives," dated December 1970, by Kaiser Engineers for the Golden Gate Bridge District. The PBQ&D Underwater Tube Alternatives Report dated April 1967 also assumes entrance to the Bay at the extension of Columbus Avenue into Aquatic Park.

The subway profile has been modified from previous studies to incorporate a provision for 2,000+ feet of tail track, as suggested by BART's operations group. A 500-foot radius was used for the curve from Third Street to Kearny Street to maintain the Kearny Street Station as close to the existing Montgomery Street Station as possible.

Profile grades were adjusted from previous studies to allow the tail tracks to pass under the existing BART and Muni tracks in Market Street. No direct rail connections between the BART system and the Marin connection were assumed in this study. In addition to ventilation structures recommended in previous reports, a ventilation structure is recommended at the end of the line in the vicinity of Third Street at Folsom Avenue.

Station locations are consistent with past planning efforts. Stations are located at Post and Kearny Streets, Broadway and Columbus Avenue, and Bay Street at Columbus Avenue. Updated patronage origin/destination studies should be performed in subsequent studies to confirm station locations.

Top of rail at the Kearny Street Station is approximately 100 feet below ground. A pedestrian transfer facility between Montgomery Street Station and this proposed Kearny Street Station is recommended at the existing mezzanine level in Market Street. Moving sidewalks could be employed, facilitating transfer.

## Alternative 2 - Figure A1

This alternative follows Post Street from the foot of Market Street and Geary Boulevard, turning down Sixteenth Avenue towards the Golden Gate Bridge, where it is assumed to be supported on a second deck. This option also generally follows an alternative presented in the Kaiser Engineers report. This alignment was also supported by Simpson and Curtin, Urban Planning Consultants, in their October 1967 report.

Modifications to the past study include provisions for a tail track beyond the Post Street Station and elimination of the Taylor and Divisidero Street Stations. Alignments were modified to incorporate a 1,200-foot radius from Geary Boulevard to Sixteenth Avenue and profile grade changes to accommodate the tail track, which extends down Second Street. Pedestrian connections to the existing Market Street subway are also recommended for this alternative.

The Taylor Street Station has been deleted primarily for economic reasons associated with the depth of station below ground, resulting from profile modifications required to accommodate the tail track. Having a requirement of 1 percent maximum grade through a station and extending 100 feet beyond each side of the station would place the Taylor Street Station up to 150 feet below street level. In addition, Polk Street Station would be 60 feet deeper than indicated in Figure A1. Elimination of the Taylor Street Station also enhances total travel trip times with a more uniform station spacing. Entrance points between the Post and Polk Street stations would be less than nine blocks apart, which is reasonable.

The Divisidero Street Station was also eliminated because of the close proximity between Polk Street and Masonic Stations. Eliminating a station at Divisidero should be analyzed in subsequent studies to justify its inclusion based on patronage estimates in relationship to its cost. Profile grades would not have to be altered to incorporate this station on the 0.75 percent grade.

The Post Street and Presidio stations were shifted slightly from the previous study to incorporate the 500-foot and 1,200-foot radii, respectively. A ventilation structure should also be added near the end of the tail track at Howard Street, avoiding the hill up to Folsom Street along Second Street.

## 2. TRANSBAY SEGMENT

### Alternatives 1 and 1A - Figure B

These alternatives cross San Francisco Bay under water, as identified in PB's report as Line T-3 and Line T-5, respectively. Alternatives 1 and 1A exit San Francisco at the extension of Columbus Avenue in Aquatic Park. Generally following a direct connection, Alternative 1 enters downtown Sausalito in a subway while Alternative 1A avoids downtown Sausalito altogether.

Large ventilation structures are required at each end for each alternative. Immersed tube construction similar to the existing transbay tube would again be utilized for this application. Further investigation should be made of the possibility of maintaining the existing cable crossings shown on the plan view of Figure B.

### Alternative 2 - Figure B 1

As an extension of Sixteenth Avenue, this alignment crosses the Bay on a lower deck of the Golden Gate Bridge. With possible future developments in the Presidio (due to the Federal Government closing its base there), further coordination and planning with the City of San Francisco should be pursued in regard to location of a future station or two in this area.

This crossing and the approach alignments were contained in the Kaiser Engineers report. A separate analysis was made in the early 1960s on the capability of the bridge to support a train system. The study concluded that the bridge did not have the structural capacity to support a BART-type system on a lower deck. However, redecking of the Golden Gate Bridge in 1987 eliminated 11,000 tons of dead load from the structure. The Golden Gate Bridge District is currently soliciting proposals to once again determine the feasibility of putting rail transit on the Bridge, in which BART is an alternate.

## 3. MARIN SEGMENT

### Alternative 1 - Figures C Through F

The BART alignment through downtown Sausalito is entirely in subway. Previous reports utilized subway in the southern half of Sausalito, transitioning to aerial along the reverse curves just North of Napa Street. Subway construction should be considered throughout all of Sausalito to gain public acceptance if a BART-to-Marin connection is to advance further in the planning process.

The Alternative 1 Station location is at Locust Street at Bridgeway in downtown Sausalito. Having the alignment contained in a subway makes this station location feasible compared to previous studies, where it is located as depicted in Alternative 2. This location seems better suited to serve the needs of the City of Sausalito and should be confirmed in subsequent studies.

The line continues north in the ex-NWP Railroad right-of-way and transitions under Bridgeway at Harbor Drive to avoid the shopping center complex east of Bridgeway. The line transitions out from under bridgeway along the east side of Highway 101 where it emerges on an aerial structure north of Gate Road.

The alignment proceeds along the ex-NWP Railroad right-of-way, as generally shown in the Kaiser Engineers' report. However, the following deviations from the report have been incorporated in this study.

- Marin City Station was moved just north of the Highway 101 Overpass due to availability of land. Previous location of the station may not be possible due to land development activities on the site.
- Aerial structures were utilized throughout Marin City to Mill Valley Station. This is to minimize environmental disruption to the Wetland Areas that this alignment passes through. New laws concerning environmentally sensitive areas such as Wetlands make this areas a target for more in-depth analysis concerning mapping and calculation of areas of habitat type, categorization and mitigation ratios.

  Aerial structures in this area also provide unencumbered access to the shoreline along with maintaining public amenities (picnic areas, open space, bike paths, etc.) that have been developed in this region in the last fifteen years.

- In addition, housing developments north of Marin City Station would warrant further studies on noise and vibration impacts that an aerial structure would impose in this area.
- Previous reports assumed that the NWP Railroad would maintain local service throughout San Rafael from the North. Since freight service is no longer a consideration, the alignment follows the NWP Railroad in lieu of being adjacent to those tracks as considered in the KE Report.
- To avoid commercial developments at Irwin Street and Debois Street just South of downtown San Rafael, a 1,200 feet radius was adopted for the curve in this areas (Figure D) instead of the previous 3200 feet radius.
- The curvature just north of Marin Civic Center Station was improved to a 2,000 feet radius and descending directly into the NWP Railroad right-of-way.

Environmentally sensitive areas include the alignment along San Clemente Drive (Station 900 on Figure C) where existing wetlands and bird sanctuaries must be considered. There is also an ecological reserve to the west of the bridge over Corte Madera Creek and Sir Francis Drake Boulevard. Noise and vibration studies would need to be undertaken for all nearby residences and businesses sensitive to these impacts. Future environmental analyses of this alignment should also consider and deal with possible adverse public reaction to the use of parklands for transit purposes.

The alignment utilizes an existing single track tunnel south of San Rafael (Station 1000, Figure D). It is assumed that the tunnel would need complete overhaul. All other tunnels and subway sections are new.

Flood level studies would be warranted at the various creek crossings and in marshland areas to ensure safety of the transit system. These studies should take into account existing flood routing areas and avoid creating flood conditions that do not currently exist. The area south of Novato Station (Figure F) and around St. Vincent Station (Figure E) should be studied in particular.

## Alternative 1A - Figure C

Alternative 1A bypasses downtown Sausalito and has been included to avoid disruption in its downtown area during the system's construction.

Marin City Station would be the first stop after crossing San Francisco Bay under this alternative. Attempting to bypass downtown Sausalito and yet provide an accessible station location to serve the area do not lend to a compatible solution.

### Alternative 2 - Figures B1 and C

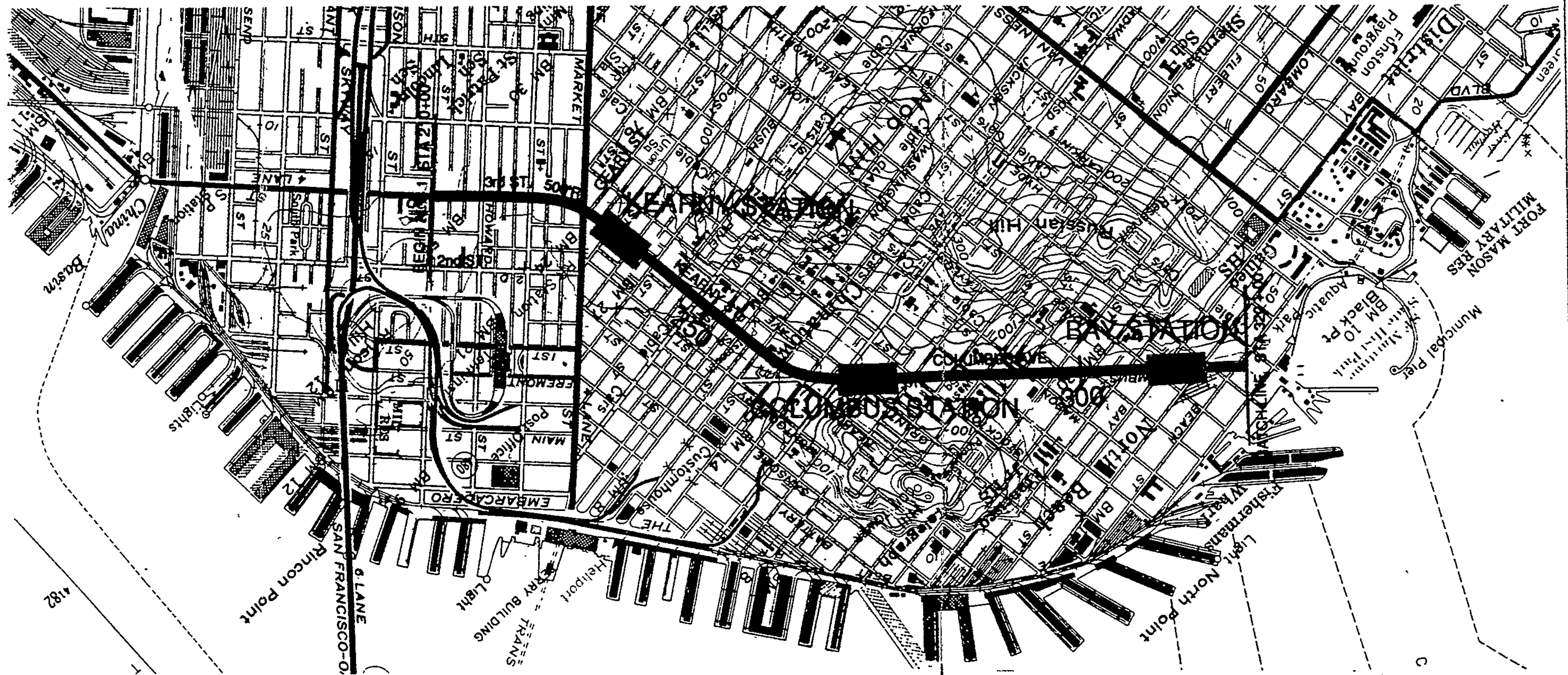
Alternative 2 in Marin is the same as Alternative 1 except that it connects downtown Sausalito with the Golden Gate Bridge. The station location in Sausalito and the horizontal alignment remain as shown in the previous Kaiser Engineers report.

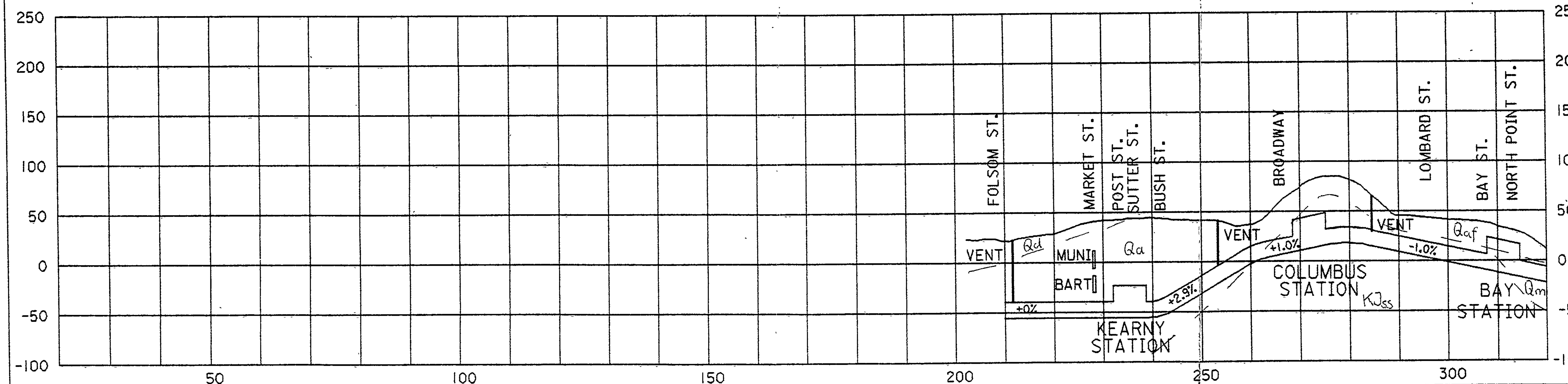
### Alternative 3 - Figures C and D

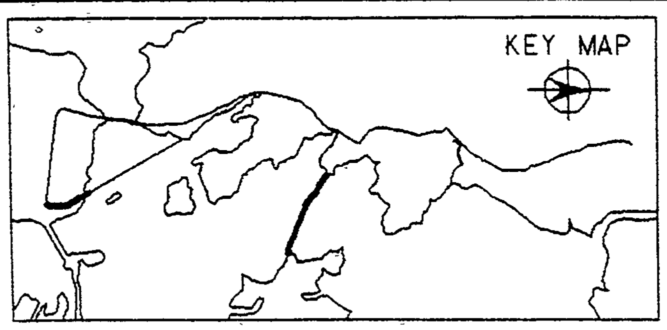
Alternative 3 between Richardson Bay and Corte Madera Creek in Marin is a new conceptual alignment not identified in previous studies. It recognizes both the heightened environmental consciousness of the public since earlier studies were made, and the changes in land use in this portion of the corridor.

This alignment crosses Richardson Bay immediately adjacent to the U.S. 101 bridge to minimize environmental impact. Once across Richardson Bay, this alternative bypasses entirely the environmentally sensitive wetlands area by following the alignment of U.S. 101 to just south of Corte Madera Creek, where it rejoins the alignment of the other alternatives.

The detail of Alternative 3 is limited by the scope of this study. Such issues as station location, vertical alignment, and possible impacts from noise or vibration require further study. However, barring unanticipated circumstances, it appears that substitution of this alignment for the wetlands alignment should not significantly change the cost of the overall project.




**ALTERNATIVE 1**

**SAN FRANCISCO CBD TO AQUATIC PARK**

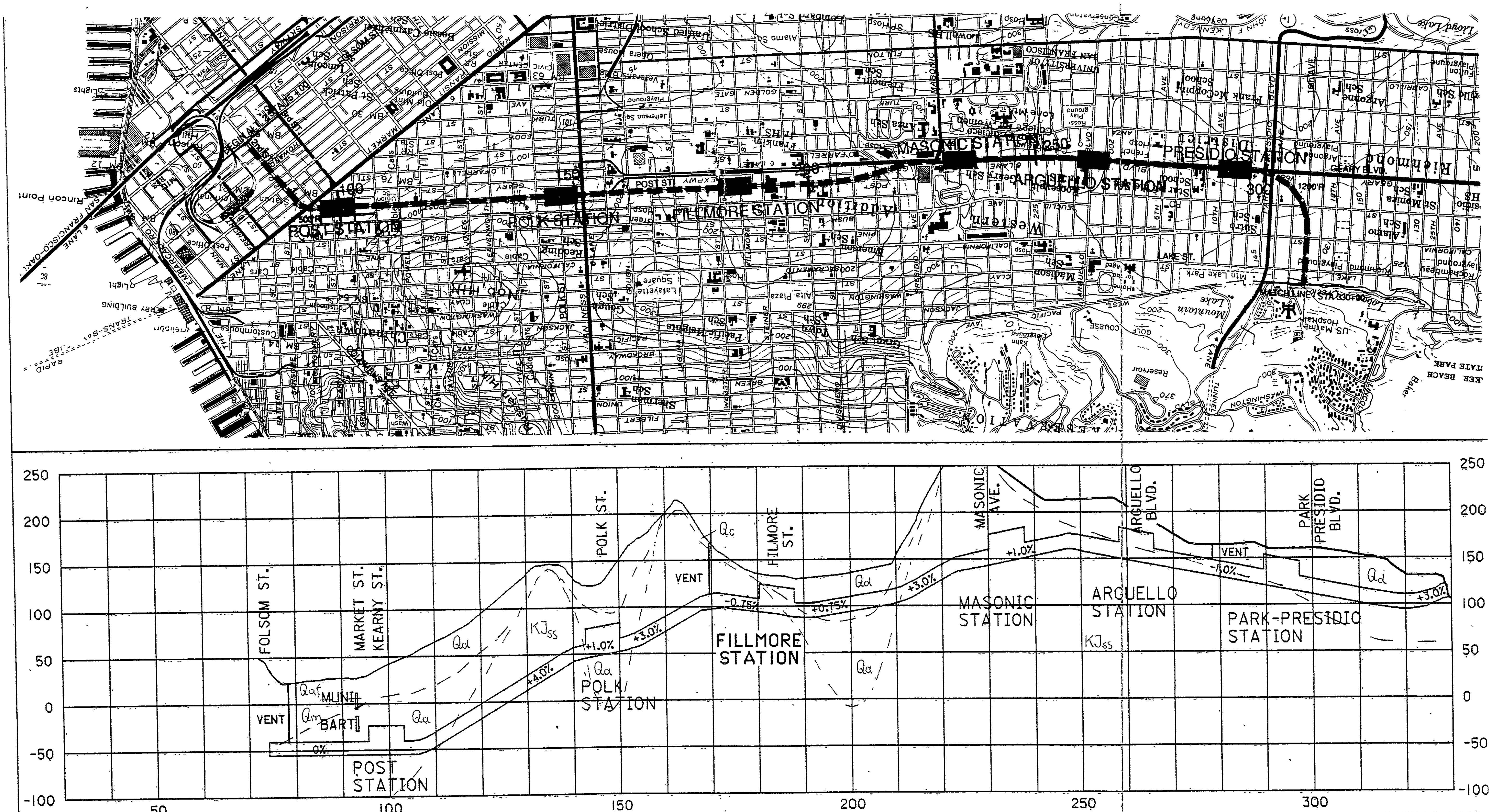
**SAN FRANCISCO-NORTH BAY BART CONNECTION**

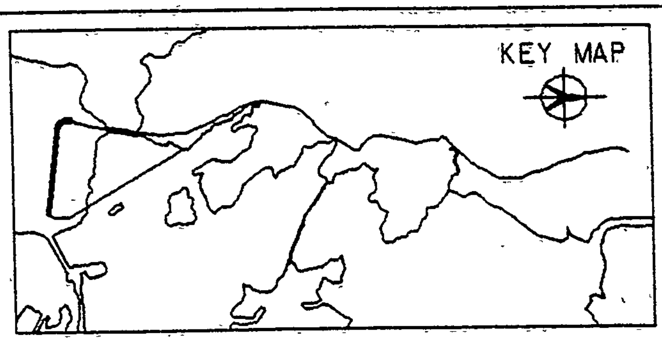
HORIZONTAL SCALE
THOUSANDS OF FEET 1 0 1 2 3 4 5

VERTICAL SCALE
FEET 50 0 50 100 150 200 250

FIGURE A

**BECHTEL CIVIL, INC**




HORIZONTAL SCALE
THOUSANDS OF FEET 1 0 1 2 3 4 5

VERTICAL SCALE
FEET 50 0 50 100 150 200 250

**ALTERNATIVE 2**

**SAN FRANCISCO CBD TO PRESIDIO**

**SAN FRANCISCO-NORTH BAY BART CONNECTION**

FIGURE A1

**BECHTEL CIVIL, INC**

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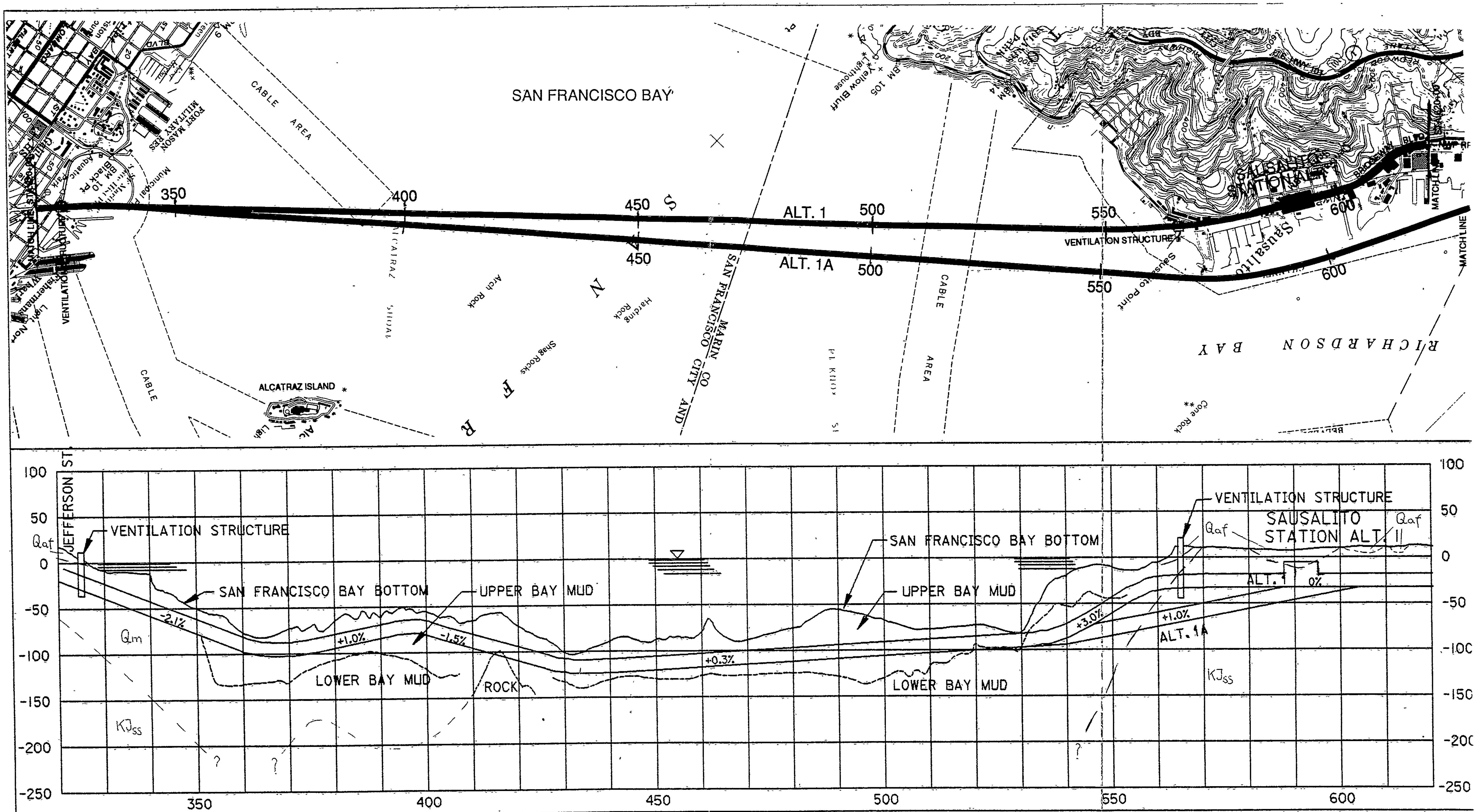


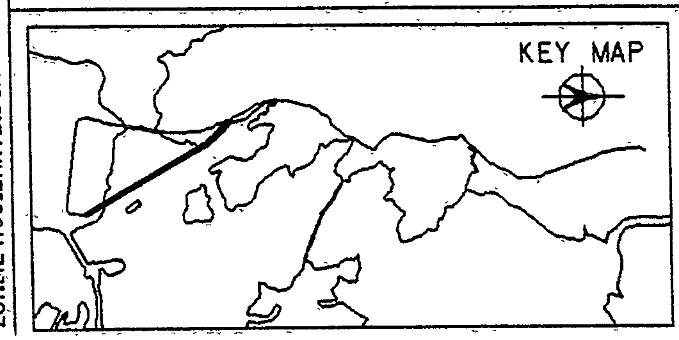


HORIZONTAL SCALE
THOUSANDS OF FEET 1 0 1 2 3 4 5

VERTICAL SCALE
FEET 50 0 50 100 150 200 250

# ALTERNATIVE 1

## AQUATIC PARK TO SAUSALITO

## SAN FRANCISCO-NORTH BAY BART CONNECTION

FIGURE B

BECHTEL CIVIL, INC

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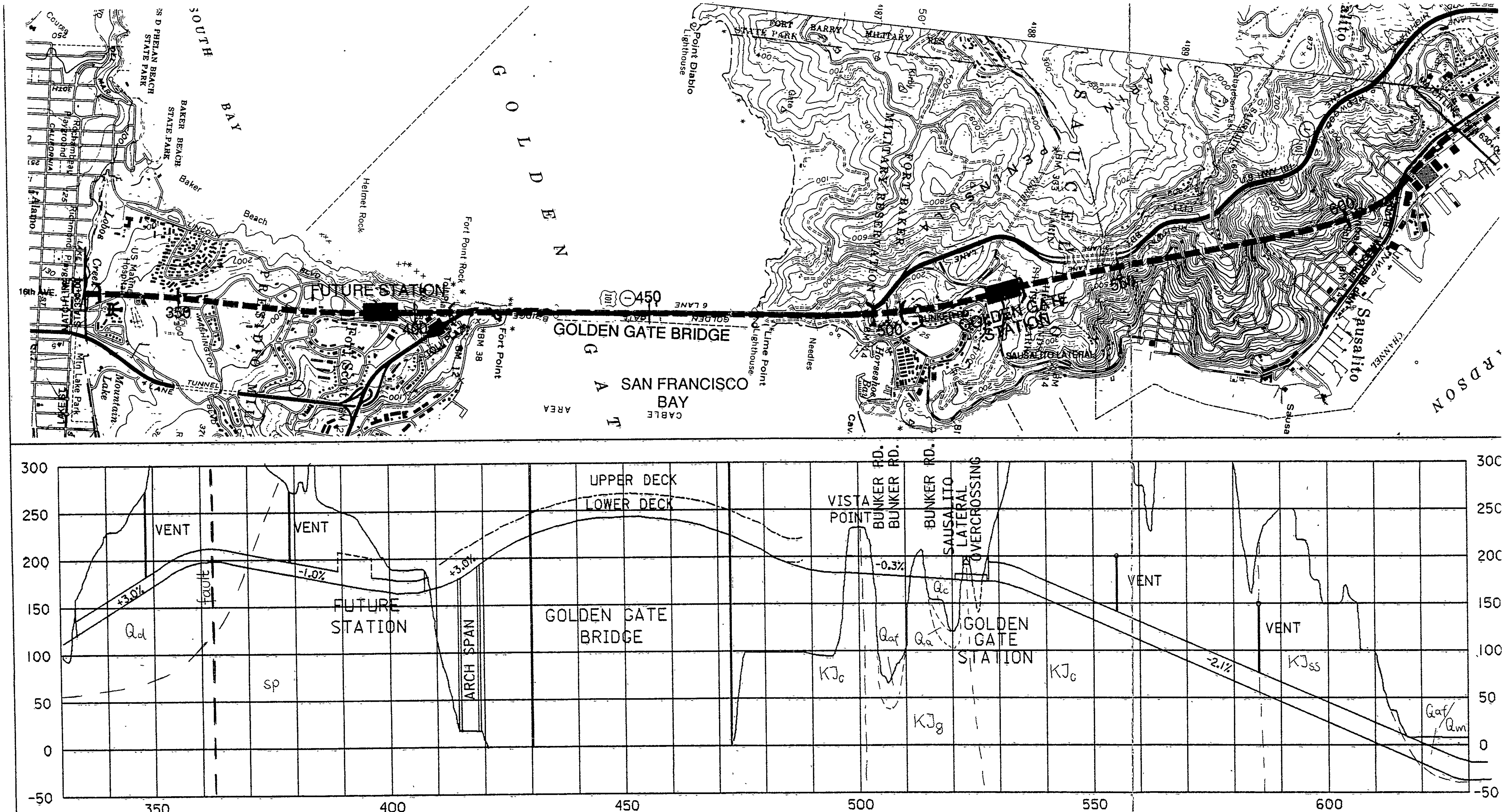


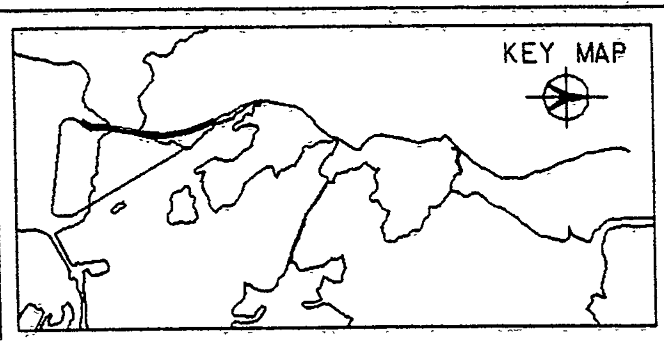


# ALTERNATIVE 2

## PRESIDIO TO SAUSALITO

## SAN FRANCISCO-NORTH BAY BART CONNECTION

HORIZONTAL SCALE
THOUSANDS OF FEET 1 0 1 2 3 4 5

VERTICAL SCALE
FEET 50 0 50 100 150 200 250

FIGURE B1

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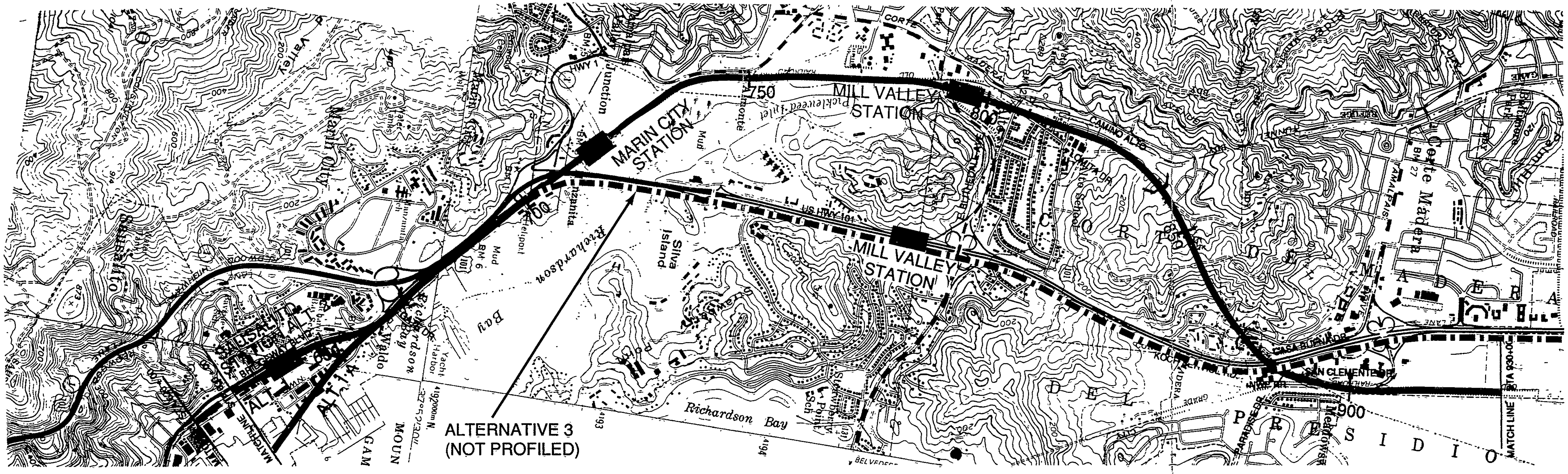


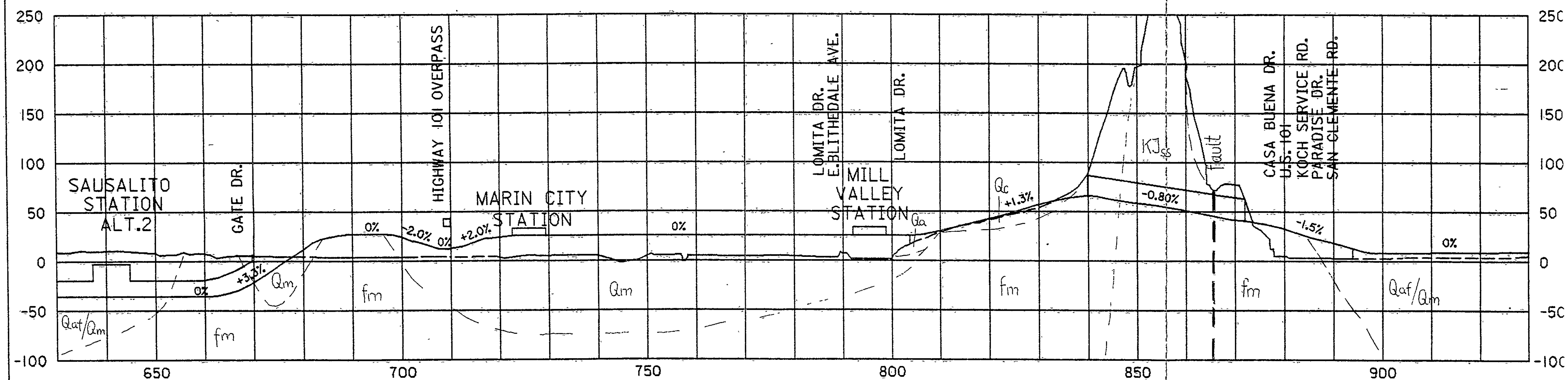



# ALTERNATIVES 1, 2, & 3

# SAUSALITO TO CORTE MADERA

# SAN FRANCISCO-NORTH BAY BART CONNECTION

HORIZONTAL SCALE
THOUSANDS OF FEET 1 0 1 2 3 4 5

VERTICAL SCALE
FEET 50 0 50 100 150 200 250

FIGURE C

BECHTEL CIVIL, INC

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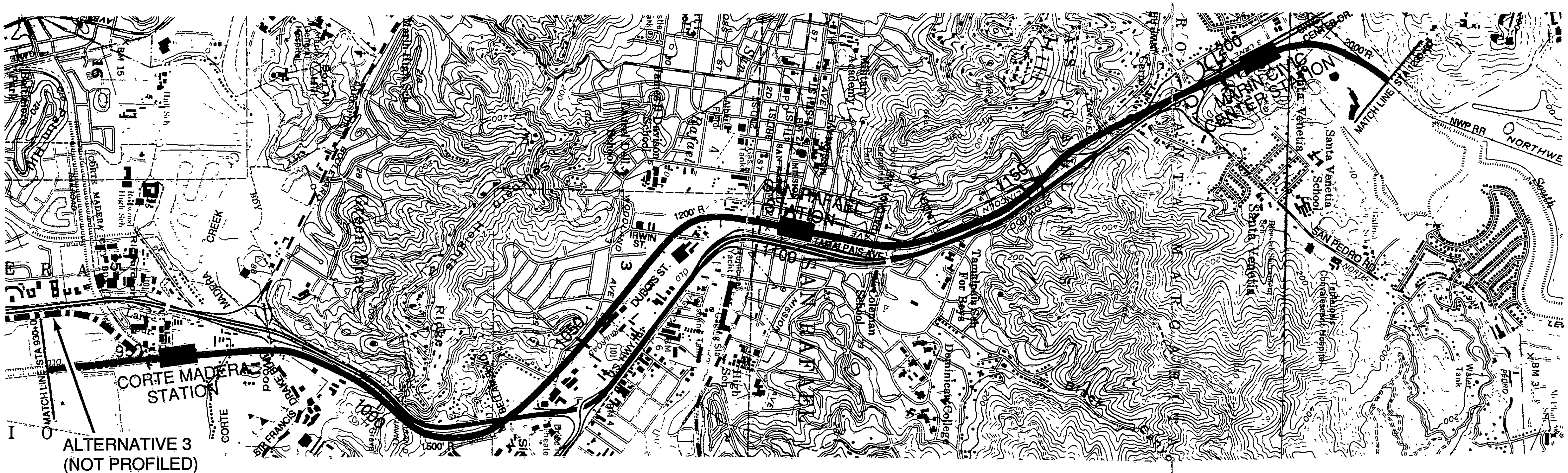


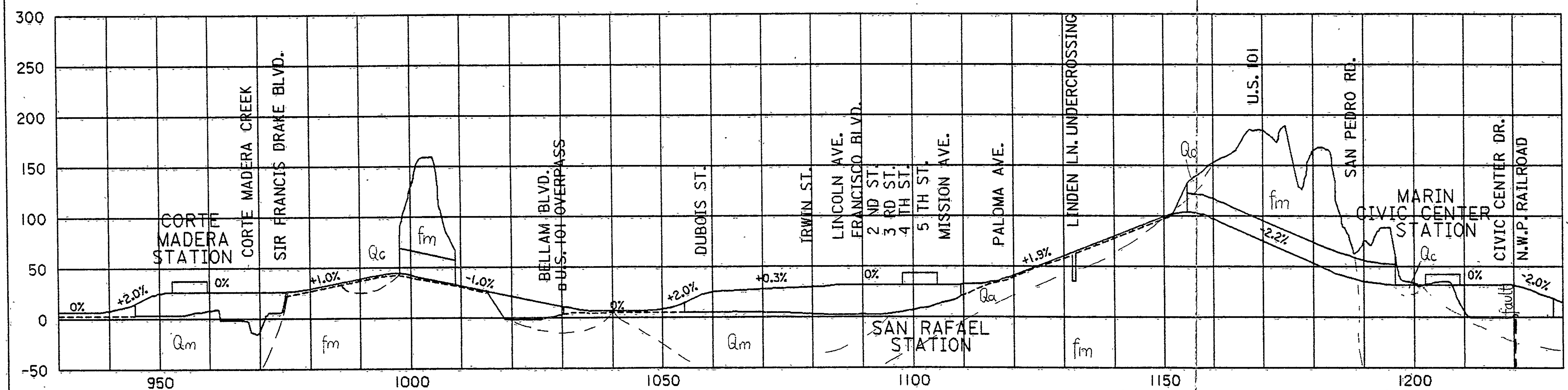


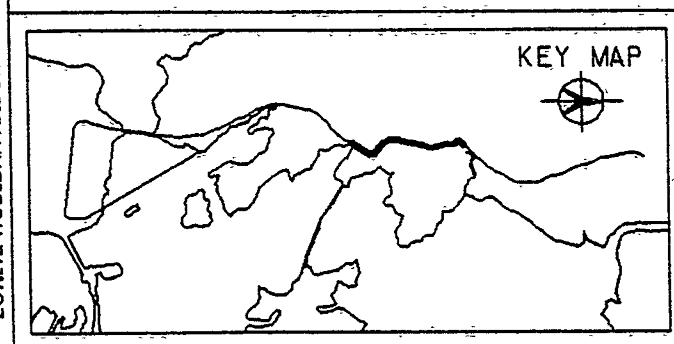


# ALTERNATIVES 1, 2, & 3

## CORTE MADERA TO MARIN CIVIC CENTER

## SAN FRANCISCO-NORTH BAY BART CONNECTION

HORIZONTAL SCALE
THOUSANDS OF FEET 1 0 1 2 3 4 5

VERTICAL SCALE
FEET 50 0 50 100 150 200 250

FIGURE D

BECHTEL CIVIL, INC

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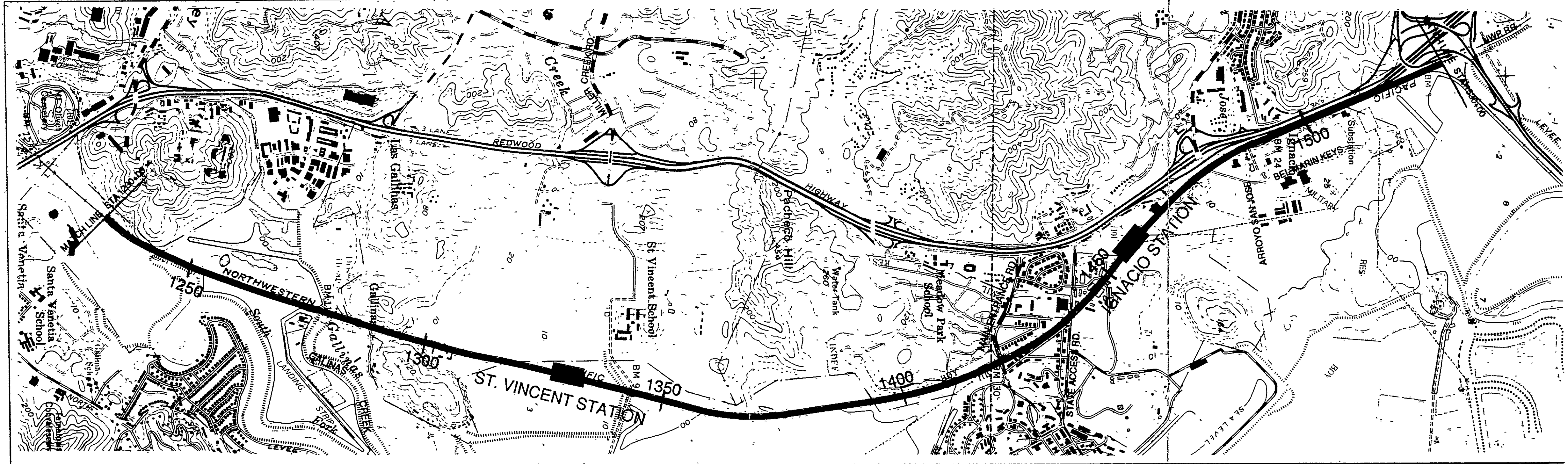


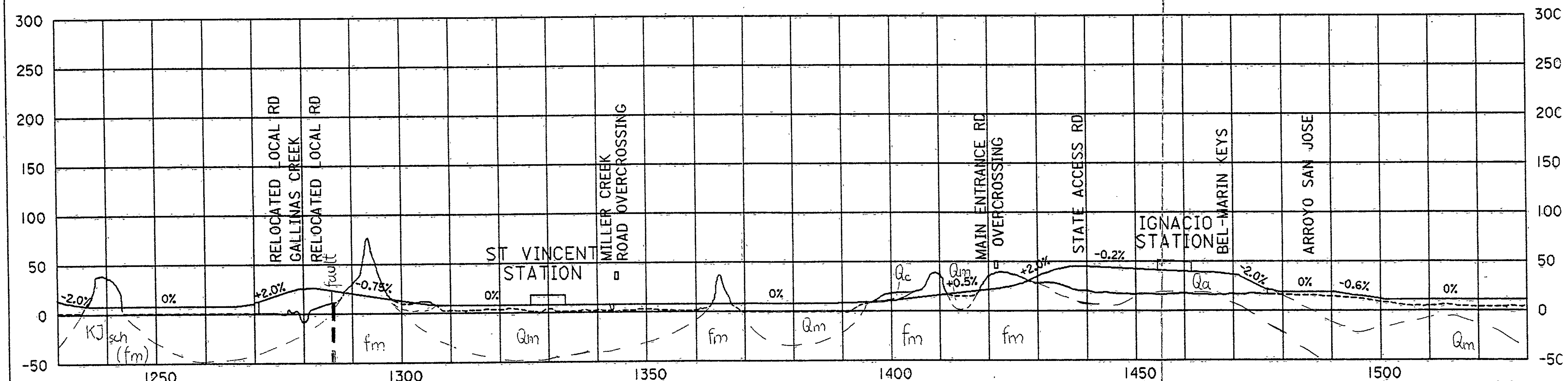


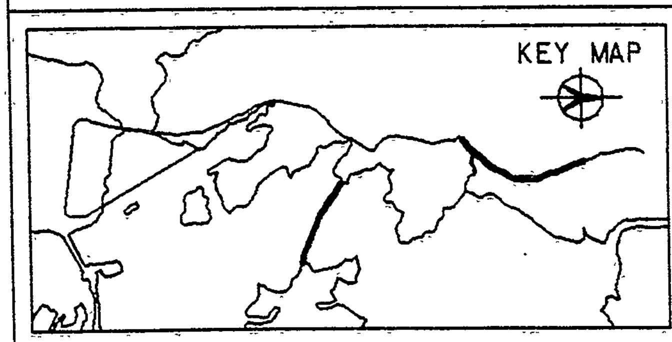


# ALTERNATIVES 1 & 2

# MARIN CIVIC CENTER TO IGNACIO

# SAN FRANCISCO-NORTH BAY BART CONNECTION

HORIZONTAL SCALE THOUSANDS OF FEET 1 0 1 2 3 4 5

VERTICAL SCALE FEET 50 0 50 100 150 200 250

FIGURE E

BECHTEL CIVIL, INC

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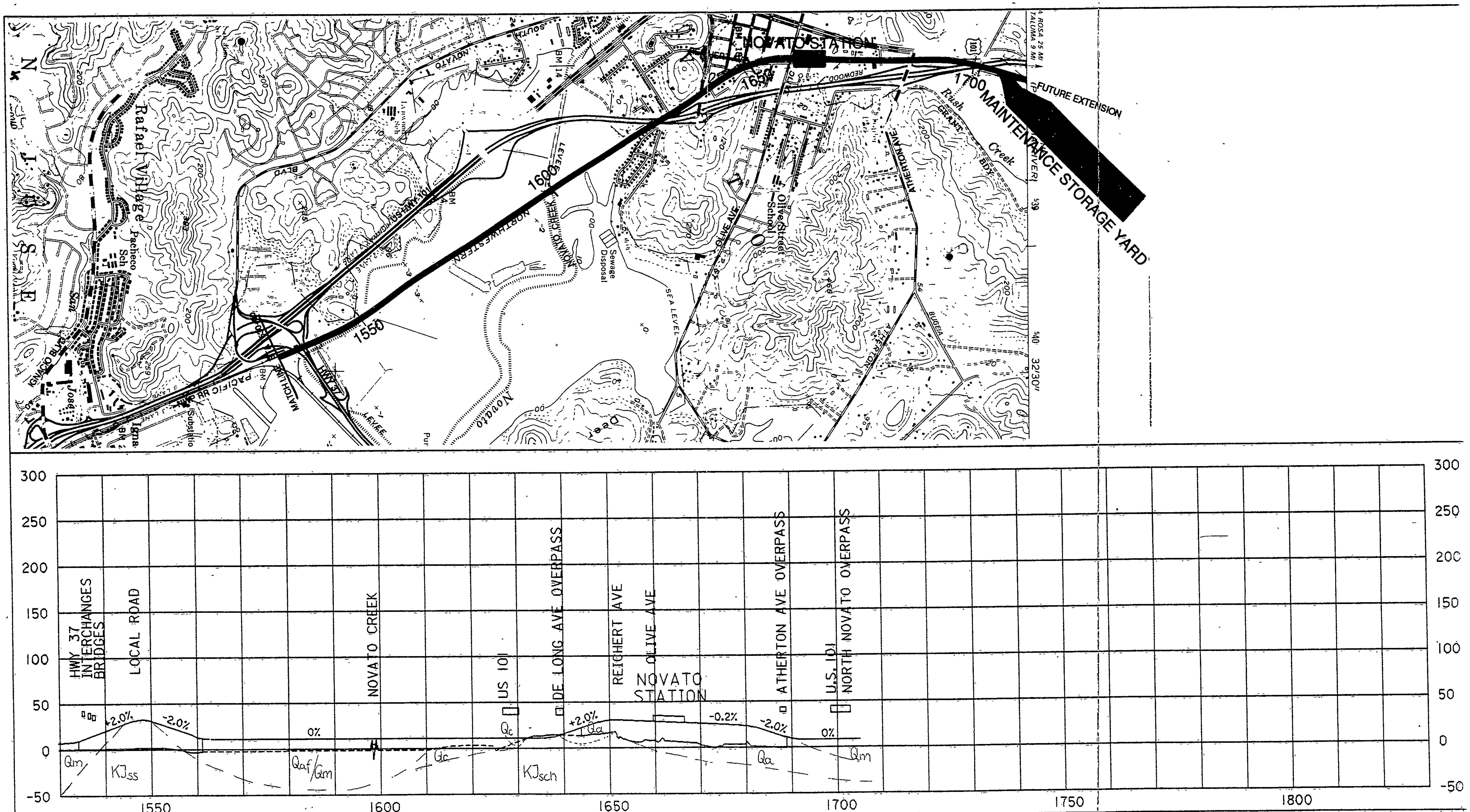


HORIZONTAL SCALE THOUSANDS OF FEET 1 0 1 2 3 4 5

VERTICAL SCALE FEET 50 0 50 100 150 200 250

# ALTERNATIVES 1 & 2

## IGNACIO TO NOVATO

## SAN FRANCISCO-NORTH BAY BART CONNECTION

FIGURE F

BECHTEL CIVIL, INC

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Section III

## CONSTRUCTION METHODS

Table 1 gives the grade profile characteristics for station and line sections for various alternatives. The table also shows the division between cut-and-cover construction and tunneling construction for the underground sections. It is proposed to build the deep stations located in rock in San Francisco by tunneling. This method would entail driving the two rapid transit tunnels through the station area, followed by the excavation of the station crown that would arch from one tunnel to the other. The station would then be completed by excavating the remaining body of the section between the two tunnels. There are enough precedents of similar construction around the world to ensure the viability of this concept. Underground stations in soft ground are assumed to be constructed by the cut-and-cover method.

Table 1

### Grade Profile Characteristics of Alternative Alignments

| | | *Tunneling (feet)* | *Cut-and-Cover (feet)* | *At Grade (feet)* | *Above Grade (feet)* | *Special Struct. (feet)* | *Total Length of Line (Incl. Stations) (feet)* |
|---|---|---|---|---|---|---|---|
| Alternative 1 | Station | – | 2,800 | 1,400 | 4,200 | — | 149,500 |
| | Line | 14,600 | 13,600 | 52,700 | 36,200 | 24,000 Transbay Tube | (28.3 miles) |
| Alternative 1A | Station | – | 2,100 | 1,400 | 4,200 | — | 150,100 |
| | Line | 14,600 | 6,400 | 52,700 | 36,200 | 32,500 Transbay Tube | (28.4 miles) |
| Alternative 2 | Station | 2,100 | 3,500 | 1,400 | 4,900 | 9,000 | 163,000 |
| | Line | 40,200 | 10,900 | 52,700 | 38,400 | G.G.B. | (30.9 miles) |

## Section IV

# POTENTIAL PATRONAGE

Resources available to this study do not permit investigating the level of patronage that a BART connection with the North Bay might draw. That would require a much more intensive effort than currently authorized. However, we have reviewed published forecasts of passenger volumes by mode of travel along the Sonoma-Marin-San Francisco corridor and made a judgmental estimate as to potential diversion to a BART system. The following considerations and methodology were used in this estimate.

The Corridor 101 study contains the most recent and most pertinent available analysis that can be tapped to arrive at a conceptual estimate of potential patronage for BART's connection to the North Bay. However, one has to be very careful in interpreting and adapting the results of this study for the following reasons:

1. The study includes a wide array of land use and projection scenarios and a multiplicity of alternatives.

2. The study did not consider the implications of the introduction of a BART-type transit system between the North Bay and San Francisco. Obviously, the mere addition of such a superior transit service will influence such factors as land use, travel patterns, employment, and population projections.

3. The study was completed before raising the Golden Gate Bridge toll to $2.00 and thus did not factor in the additional diversion to public transportation modes that has occurred since that time.

4. BART would offer travel times between the North Bay and downtown San Francisco from one-third to one-half the travel times assumed for the best transit alternative in the Corridor 101 Study. This would mean a significant diversion of traffic from auto and ferry modes to transit.

5. BART would directly link Marin and Sonoma counties with the rest of the present and future BART basic network, and vice versa. This would induce many BART trips, particularly by the carless population.

6. BART would offer fast and convenient service to downtown San Francisco, encouraging shopping, entertainment and recreational trips between the two areas.

7. BART would provide a fast and convenient connection to the local public transit system in San Francisco, allowing access to almost every part of the city.

The following tabulation gives approximate travel times between downtown San Francisco and selected destinations for each of the two main alternative alignments.

| | *Approximate Travel Time (Minutes)* | |
|---|---|---|
| *From Downtown San Francisco to* | *Alternative 1* | *Alternative 2* |
| Bay Station | 4 | -- |
| Masonic Station | -- | 6 |
| Park Presidio Station | -- | 9 |
| Sausalito Station | 10 | 17 |
| Mill Valley Station | 15 | 22 |
| San Rafael Station | 23 | 30 |
| Novato Station | 37 | 44 |

We elected in our analysis to work with the 2005 home-based work trips, estimate the portion of these trips that can be diverted to BART, double this number to account for the return trips, and use existing BART practice of peak to off-peak trip ratio as a guide to arrive at the average weekday trips. We assumed that ample parking will be provided at BART's Marin stations, that adequate feeder bus services will be provided, and that one fare structure will be used on the BART Marin line as well as on the basic BART network.

The following tabulation summarizes trip characteristics as extracted from Tables 19-2 and 19-3 (ABAG 2005, Alt. 30 Bus Hwy Case) of Technical Memorandum No. 19 of the 101 Corridor Study, and our assumed BART trip diversion:

| Origin-Destination | Home-Based Work Trips | % by Transit | 101 Corridor Transit Trips | % of Transit to BART (1) | BART Trips | % BART Trips to Total Work Trips |
|---|---|---|---|---|---|---|
| Marin-SF | 59,440 | 35 | 20,782 | 80 (2) | 16,625 | 28 |
| Sonoma-SF | 20,939 | 46 | 9,652 | 50 (3) | 4,826 | 23 |
| SF-Marin | 5,739 | 12 | 706 | 50 | 353 | 6 |
| Marin-Marin | 116,247 | 5 | 5,691 | 20 (4) | 1,138 | 1 |
| Total/Average | 202,365 | 18 | 36,831 | 62 | 22,942 | 11.3 |

1) Assume no diversion from auto trips to BART, a rather conservative assumption.

2) Assume continuation of ferry service and bus service to other than downtown SF destinations.

3) Assume continuation of bus service to downtown San Francisco as well as other SF destinations.

4) Assume continuation of intra-Marin bus service.

The above table shows about 23,000 home-based work trips on BART between San Francisco and the North Bay as well as within Marin County. Therefore, total BART work trips would be 46,000, which would take place mostly during peak periods. Assuming further that the ratio of off-peak to peak period travel on the proposed Marin line is only one-half of that currently experienced on the BART system (which is 1:1), an additional 23,000 off-peak riders would be added to arrive at a total weekday ridership between San Francisco and the North Bay and within Marin County of 69,000.

Another approach to the estimation of this potential patronage is to start with the weekday transit ridership forecast given in Table 11-18 of Technical Memorandum No. 11 of the 101 Corridor study. This forecast (Alternative 4 - HOV lanes) gives a total of 57,600 for commuter bus and basic bus ridership during a typical weekday in the year 2005 along the same corridor. The superior level of service afforded by a BART connection, particularly within San Francisco, would warrant a certain premium to account for additional ridership diverted to, and generated by, a BART link. An assumed 20 percent premium would result in 69,120 potential weekday riders on the proposed BART connection.

Given the inherent uncertainty in travel forecasts and the conceptual stage of this analysis, 55,000 to 75,000 weekday riders at the 2005 level would seem to be a prudent range for travel between San Francisco and the North Bay as well as within the County of Marin.

Local travel on the San Francisco segment would vary depending on the alternative selected. Examining present ridership levels on buses serving the Columbus-Kearny Corridor (Alternative 1) and the Geary Corridor (Alternative 2), and applying reasonable diversion factors to a BART-type service yields a local San Francisco ridership range between 5,000 to 10,000 for Alternative 1 and anywhere between 40,000 to 70,000 for Alternative 2.

Therefore, total potential weekday ridership on the BART connection at the year 2005 level would range between 60,000 and 85,000 for Alternative 1 and between 95,000 to 145,000 for Alternative 2. Again, patronage estimates should be the subject of future detailed and extensive analysis.

Section V

## CONCEPTUAL CAPITAL COST ESTIMATES

A conceptual capital cost estimate was developed for each of the three alternative alignments discussed in Section II of this report. This section presents the basis of the estimate and a summary of the conceptual estimates.

*Basis of Estimate*

***General***: The scope and quantities are based on information given in Section II of the draft final report of the study.

***Quantities:*** The following quantities have been estimated for each Alternative from the Conceptual Route Alignment Drawings included in Section II of the draft final report.

| | Alternative Route Feet/Lump Sum | | |
|---|---|---|---|
| **San Francisco:** | ---1--- | ---1A--- | ---2--- |
| • Tunnel | 5,500' | 5,500' | 22,700' |
| • Cut-and-cover | 3,400' | 3,400' | 4,300' |
| • Crossover tunnel | 1 | 1 | 1 |
| • Cut-and-cover station | 2 | 2 | 4 |
| • Tunnel station | 1 | 1 | 2 |
| • At-grade line | -- | -- | 1,500' |
| • Systemwide | 11,500' | 11,500' | 33,200' |
| **Transbay Tube:** (including systemwide) | 24,000' | 31,500' | 0 |
| **Golden Gate Bridge:** (including systemwide) | -- | -- | 9,000' |

**Marin:**

| | | | |
|---|---|---|---|
| • Cut-and-cover | 10,500' | 3,700' | 5,500' |
| • Tunnel | 8,300' | 8,300' | 17,600' |
| • Aerial | 35,300' | 35,300' | 37,100' |
| • At-grade | 49,000' | 49,000' | 49,000' |
| • Retained fill | 4,600' | 4,600' | 4,600' |
| • Cut-and-cover station | 1 | -- | 1 |
| • Aerial station | 5 | 5 | 5 |
| • At-grade station | 2 | 2 | 3 |
| • Parking (stalls) | 12,000 each | 12,000 each | 12,000 each |
| • Yard | 1 | 1 | 1 |
| • Systemwide | 114,000' | 106,500' | 120,800' |

***Estimate Pricing:*** Unit costs in the estimate represent contractors' bid prices at mid-1989 cost level.

1967 cost data with an escalation multiplier of 4.2 (in accordance with ENR cost indices for Building and Construction) were used to arrive at the following unit prices:

- Tunnels
- Cut-and-cover stations
- Aerial stations
- At-grade stations
- Yard
- Transbay tube

In addition to the escalated historical cost data, premium costs were added to the deep tunneling, deep underground stations, and crossovers in San Francisco.

Also, additional premium cost allowance was made to the Transbay Tube estimate to compensate for longer crossings, more severe excavation, backfill, and tube placement conditions than was experienced in the San Francisco-Oakland Bay crossing.

Unit prices from the "Capital Cost Methodology" submittal of the Dublin/Pleasanton Extension were used for the following structures (with some modification):

- Cut-and-cover line
- Retained fill
- At-grade line
- Aerial line
- Systemwide construction
- Trackwork
- Parking at grade

Golden Gate Bridge "retrofit" work was estimated conceptually in the following cost segments:

- Second deck construction
- Modification to existing deck beams
- Modification to towers
- Safety walk and emergency exits
- Approach structures
- Miscellaneous and other
- Traffic maintenance

Allowances were made on a route foot basis for the following:

- Utility relocations
- Traffic maintenance and control
- Landscaping

Lump sum allowances were made for underpinning costs in downtown San Francisco.

***Engineering and Management of Construction and Administration***

20 percent of the total construction cost was included in the estimate.

### *Contingencies*

Contingencies have been evaluated in following cost areas by percentage allowance:

| | *Percent* |
|---|---|
| • San Francisco construction | 25 |
| • Golden Gate Bridge construction | 30 |
| • Transbay tube construction | 30 |
| • Sausalito construction | 25 |
| • North Marin construction | 20 |
| • Systemwide | 20 |

The weighted average contingency for each alternative was calculated to be 23 percent.

### *Exclusions*

The following items have been specifically excluded from the estimate:

- Right-of-way costs
- Vehicles (rolling stock)
- Owner's pre-operational testing and revenue service startup
- Financing and interest during construction
- Utility agency fees and charges

PREPARED BY: E.J.R.
CHECKED BY:
TYPE OF ESTIMATE: CONCEPTUAL
PREPARED FOR: BART

SF-NORTH BAY BART CONNECTION
CONCEPTUAL ESTIMATE SUMMARY
(IN 1989 DOLLARS)

DATE: 8/11/89

| DESCRIPTION | ALTERNATIVES 1 LENGTH OF LINE (ROUTE FEET) | COST MILL$ | 1A LENGTH OF LINE (ROUTE FEET) | COST MILL$ | 2 LENGTH OF LINE (ROUTE FEET) | COST MILL$ |
|---|---|---|---|---|---|---|
| SAN FRANCISCO - CONSTRUCTION | 11,500 | 680 | 11,500 | 680 | 33,200 | 1610 |
| TRANSBAY - CONSTRUCTION | 24,000 | 1160 | 31,500 | 1520 | - | - |
| GOLDEN GATE BRIDGE - CONSTRUCTION | - | - | - | - | 9,000 | 150 |
| MARIN TO NOVATO - CONSTRUCTION | 114,000 | 920 | 106,500 | 680 | 120,800 | 1030 |
| MAINTENANCE YARD - CONSTRUCTION | - | 70 | - | 70 | - | 70 |
| TOTAL FOR ALTERNATIVE | 149,500 (28.3 MI) | 2,830 | 149,500 (28.3 MI) | 2,950 | 163,000 (30.9 MI) | 2,860 |
| THE ABOVE TOTALS ARE ALLOCATED TO THREE SEGMENTS AS FOLLOWS: | | | | | | |
| o SAN FRANCISCO SEGMENT | | 680 | | 680 | | 1,610 |
| o TRANSBAY CROSSING | | 1,160 | | 1,520 | | 150 |
| o MARIN SEGMENT | | 990 | | 750 | | 1,100 |

ESTISUM1

Section VI

## EVALUATION OF ALTERNATIVES

| *Evaluation Factor* | *Alternative 1* | *Alternative 2* |
|---|---|---|
| Cost | Higher cost of transbay tube compared to Golden Gate Bridge crossing. Total order-of-magnitude cost for either alternative is about the same. | Higher cost of San Francisco segment that includes 9.7 miles and 7 underground stations. |
| Potential Ridership | Higher ridership levels between North Bay and San Francisco. Lower local San Francisco ridership. Same level of ridership within Marin County for either alternative. | Lower ridership levels between North Bay and San Francisco due to longer travel time. Higher local San Francisco patronage along Geary corridor. |
| Level of Transit Service | Superior level of service between the North Bay and downtown San Francisco. Twenty two minutes between San Rafael downtown and Union Square and the financial district. Excellent service to theater/shopping district in San Francisco. | Possible speed restriction on Golden Gate Bridge, plus local service along Geary Corridor, reduces average travel time between Marin and downtown San Francisco. Excellent local service along the Geary corridor. Excellent service to theater/shopping district in San Francisco. |
| Negative Environmental Impacts | Disturbance to Bay bottom and at approaches to Aquatic Park and Sausalito. Disposal of excavated soils as a result of transbay tube and subway construction. | More net volumes of excavated soils to be disposed of due to longer subway section in San Francisco. |
| | Impacts on wetland, bird sanctuaries and parkland for both alternatives. Noise and vibration impacts during system construction and operations. Possible public opposition to the use of parkland for rapid transit. | |
| Positive Environmental Impacts | Reduction in traffic congestion levels along the Route 101 corridor. Reduction in air pollution levels along entire corridor. Net energy savings due to higher transport productivity of rail rapid transit compared to other modes. Less dependence on oil resources -- local and imported. Increase in transport capacity along the 101 corridor by the equivalent of 16 additional highway lanes. | |

Appendix I

# GEOTECHNICAL CONDITIONS

Preliminary investigation of geotechnical conditions along the proposed alternative alignments, using existing and readily available data, has been made.[1] This appendix presents a description of the various soil and rock layers along the alignments and their engineering characteristics. Reference is made to Figures A through F on pages 12-19.

## Qm (mu) - BAY MUD

### Lithologic Description

Silt, clay, and small lenses of sand; grey, structureless, soft to semi-fluid, unconsolidated with increased consolidation with depth, compressible, plastic, swelling, when diked may form a crust a few feet thick at the surface, underlain by the softer materials described above.

### Engineering Characteristics

Heavy equipment may become mired in mud, easily excavated with hand tools. Must be supported in cuts. May settle differentially under load. Sensitivity low, but the use of heavy equipment for fill placement may cause loss of strength. Shrinks and swells during drying and wetting processes occurring at the surface. Poor earthquake stability.

## Qaf - ARTIFICIAL FILL

### Lithologic Description

Fill is highly variable in composition and degree of compaction. Consists of rock, soil, debris, and trash. Artificial fill over much of the alignment has been placed over bay mud. Comprises the old railroad grade along much of the alignment.

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[1] Geo/Resource Consultants, Inc. has assisted Bechtel in this task.

### Engineering Characteristics

Workability depends on composition. Artificial fill placed over bay mud may settle differentially due to compaction of the bay mud. Fill placed over bay mud is susceptible to movement earthquakes.

## Qd - DUNE SAND

### Lithologic Description

Uniform, well-sorted, fine- to medium-grained, medium dense to dense, yellowish brown to light grey sand with high permeability.

### Engineering Characteristics

Cohesionless, when damp will stand up in excavations for a short time, when dry or saturated will run into the excavation. Relatively incompressible, moderate potential for surface subsidence during tunnelling (grouting recommended), easily excavated by hand or with power equipment.

## Qa - ALLUVIUM

### Lithologic Description

Consists of unconsolidated, gravel, sand, silt and clay deposited in valleys by streams. Generally moderate brown and mottled with red when ground water is present.

### Engineering Characteristics

Moveable by hand tools, but when clayey and wet may be heavy and sticky and heavy equipment may become mired. Depending on origin, may contain expansive clay which could cause heaving.

## Qc - COLLUVIUM, SLOPE DEBRIS AND RAVINE FILL

### Lithologic Description

Composed on unconsolidated, unsorted soil and rock materials derived from the weathering and decomposition of bedrock materials. Colluvium is defined as those materials that accumulate at the base of the slope by gravitational or slope wash processes.

### Engineering Characteristics

When clayey, colluvial soils may shrink and swell during drying and wetting processes. Excavatable with hand tools, but when clayey and wet may be heavy and sticky and heavy equipment may become mired. Depending on origin, may contain expansive clay, which could cause heaving.

## KJss - SANDSTONE AND SHALE

### Lithologic Description

Thickly bedded, fine- to coarse-grained, yellowish brown to grey sandstone with interbeds of shale. Shale interbeds often sheared.

### Engineering Characteristics

Sandstone hard, dense and strong when massive and may require blasting, in places may be excavated by power equipment. Slope stability and foundation conditions good in fresh rock, but subject to landsliding where intensely sheared.

## KJsch - SEMI-SCHIST, PHYLLITE, AND SCHIST

### Lithologic Description

Slightly- to well-foliated metamorphosed sedimentary and volcanic rocks. Dark grey when fresh but weathers to pale grey to yellowish and reddish brown. Includes metachert, which often exhibits the thin bedding characteristics of its derivative rock.

### Engineering Characteristics

With the exception of the metachert, the metamorphosed rocks are typically deeply weathered and form swelling clay-rich soils that are relatively unstable on slopes. Generally can be moved by power equipment.

## KJc - CHERT

### Lithologic Description

Aphanitic to medium-grained altered (slightly metamorphosed) igneous rock (predominantly basalt). May be massive or interbedded with chert.

### Engineering Characteristics

Greenstone generally moderately to deeply weathered at surface. Dense, hard, and generally highly fractured and will exhibit ravelling in steep cuts and in tunnel crowns. Typically can be moved with power equipment. Slope stability fair and foundation conditions good. Will generally stand in 1 1/2H:IV to 1H:IV slopes.

## sp - SERPENTINE

### Lithologic Description

Pale- to dark-green and greenish grey, fine-grained, highly sheared metamorphic rock. Primarily soft and deforms plastically but may include hard unsheared blocks.

### Engineering Characteristics

Generally can be excavated with power equipment. Slope stability and foundation characteristics fair to poor. Sheared serpentine may slide in slopes as flat as 2:1. May squeeze in tunnels.

## fm - FRANCISCAN FORMATION MELANGE

### Lithologic Description

Consists of small to large resistant rock masses in a matrix of highly sheared and crushed rock materials. Resistant rock masses are composed primarily of sandstone (greywacke), chert, greenstone, and serpentine, but may contain other exotic metamorphic rock types.

### Engineering Characteristics

Strength characteristics of the melange materials are widely variable. Melange matrix is inherently weak, are highly erodible, weather deeply to clayey expansive soils that swell and shrink with wetting and drying, and commonly exhibit slope creep and landsliding. The resistant rocks, conversely, tend to exhibit high to very high strength characteristics and, depending on placement, size, and depth of embedment, may have high slope stability characteristics.

Appendix II

## REFERENCES

*Rapid Transit for the San Francisco Bay Area.* Parsons Brinckerhoff-Tudor-Bechtel. June 1961.

*San Francisco - Marin Crossing, Underwater Tube Alternatives.* Parsons Brinckerhoff, Quade & Douglas. April 1967.

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