CAPITOL CORRIDOR®

New Carquinez Crossing Study

Suisun Bay Bridge Replacement Concepts

Phase 2 Report

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New Carquinez Crossing Study

I. Executive Summary

The Capitol Corridor Joint Powers Authority (CCJPA) has undertaken this New Carquinez Crossing Study to identify ways to maintain and provide a basis for expanded passenger and future freight rail service across the Carquinez Strait (the "Strait")[1]. A prior first phase study eliminated several representative route options, thus leaving this phase of the study to conduct additional engineering analysis for the most viable route options.

CCJPA passenger trains currently cross the Carquinez Strait on a nearly one mile-long bridge extending from Martinez to Benicia, known as the Suisun Bay bridge. This bridge does not have sufficient clearance for large ships and so the center section is configured as a "lift bridge" which can be raised to allow large vessels to pass underneath. The existing bridge "opens" several times each day to allow maritime traffic to pass, interrupting rail traffic for 20 minutes or more. These bridge openings represent the second most significant cause of delays to CCJPA trains. If CCJPA were to attempt to substantially increase train frequency, for example, to 30-minute headways each direction (as outlined in the CCJPA Vision Plan) using the current route across existing Suisun Bay bridge, the delays due to bridge openings would become difficult or impossible to mitigate, and thus too disruptive for reliable passenger and freight rail operations.

The purpose of this New Carquinez Crossing Study is to identify concepts for replacement of the existing Suisun Bay lift bridge with a new bridge constructed high enough above the water that it would not need to lift for vessels. Thus, the new bridge would always allow unobstructed passage for both marine and rail traffic. The study looked at multiple representative route options and has advanced four for additional consideration. These four representative route options are illustrated in Figure 1, below.

Two of the representative route options, the "Vallejo" and "Interstate 80" options, would create an entirely new passenger rail corridor via Vallejo, leaving the existing rail corridor near Hercules or Rodeo, traversing a new, high-level rail bridge near the existing Interstate 80 freeway bridges between Crockett and Vallejo, then passing through Vallejo on the currently lightly used Union Pacific Railroad (UPRR) corridor, and then extending onward via Jameson Canyon to Cordelia and Suisun City. These route options would have limited ability to accommodate freight trains. Cost estimates for the Vallejo and Interstate 80 representative route options range from approximately $16 Billion to $23 Billion, depending upon specific assumptions. The low end of the range representing only the first phase of work, a new bridge in the Crockett-Vallejo area with additional improvements from Vallejo to Suisun City, while the high end of the range represents once scenario for upgrades along the entire corridor from San Pablo to Suisun City (via Vallejo and Cordelia).

Two other representative route options, the "Martinez-Benicia West" and "Martinez-Benicia East" options, would remain adjacent to the existing UPRR corridor that generally follows the shoreline along the Strait, adding dedicated tracks for passenger rail service. A new, but higher bridge would be constructed near the existing rail bridge; the new bridge could be capable of accommodating freight

[1] Note that, for the purposes of this document, the Carquinez Strait includes the entire area between San Pablo Bay, at Crockett/Vallejo, to Suisun Bay, at Martinez/Benicia, even though the existing railroad bridge is often described as being at the opening of Suisun Bay.

trains. These route options would then parallel the existing UPRR corridor from Benicia to Suisun City. The Martinez-Benicia West and Martinez-Benicia East representative route options are nearly identical, with the primary difference being the specific location of the bridge over the Strait between Martinez and Benicia. Cost estimates for the Martinez-Benicia East and Martinez-Benicia West representative route options range from approximately $10 Billion to $23 Billion, depending upon specific assumptions. The low end of the range representing only the first phase of work, a new bridge in the Martinez-Benicia area, while the high end of the range represents once scenario for upgrades along the entire corridor from San Pablo to Suisun City (via the south shore of the Strait and Martinez).

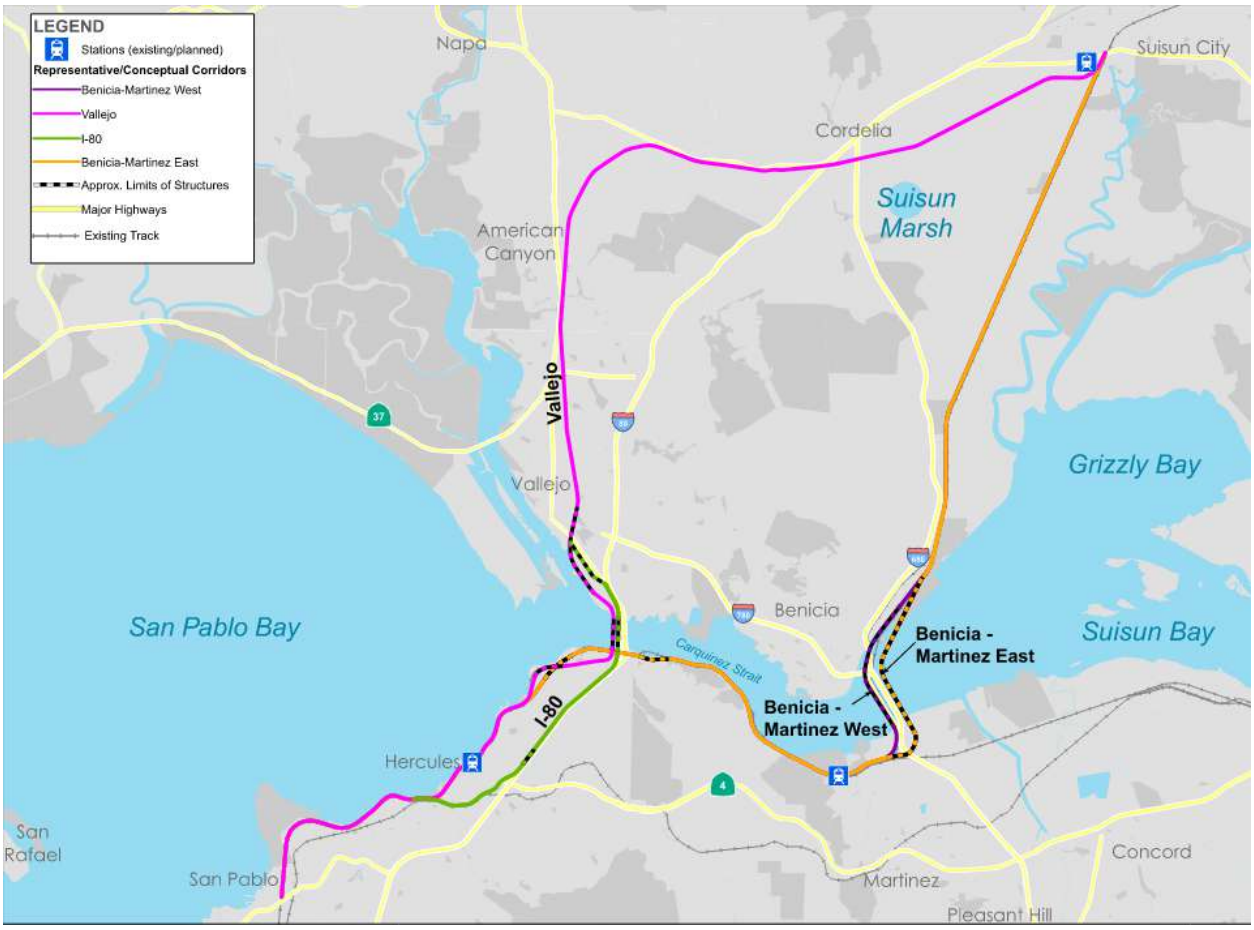

Figure 1: Four representative route options evaluated in this Phase 2 study.

Each of the representative route options has opportunities and challenges. A brief summary follows, with more detailed discussion of opportunities and challenges in the description of each representative route option. It's important to note that UPRR will need to be consulted about any changes affecting their ROW.

- Opportunities
    - The opportunities associated with the two representative route options via Vallejo, the “Vallejo” and “Interstate 80" representative routes, are chiefly related to the possibility of serving new passenger markets, specifically Vallejo, Napa, and Cordelia or connecting with other future passenger rail projects involving these communities.
    - The opportunities associated with the two representative route options via Martinez, the ”Martinez-Benicia East” and ”Martinez-Benicia West” representative routes, include direct benefits to goods movement by constructing a new bridge capable of accommodating freight trains.
- Challenges
    - The challenges associated with the two representative route options via Vallejo include:
        - The need to establish entirely new rail corridors through Crockett and Vallejo. These would be disruptive to construct and would also create new impacts on adjoining residential and commercial properties.
        - Constraints along these corridors mean it would be difficult to accommodate freight trains to directly benefit goods movement (though, by reducing passenger traffic on the existing route, goods movement would theoretically improve along the existing route, albeit without the benefit of a new bridge over the Strait). If freight trains were considered via the Vallejo options, the complexity and cost of the new bridge would increase significantly.
    - The challenges associated with the Martinez-Benicia East and Martinez-Benicia West representative route options include:
        - Impacts to industrial facilities and potentially environmentally sensitive areas, such as wetlands and open space.
        - Significant retaining walls along the bluffs on the south side of the Strait.

II. Introduction

A. Background

Today, the Capitol Corridor Joint Powers Authority (CCJPA) passenger trains operate on the Union Pacific Railroad (UPRR) route that crosses the Carquinez Strait, the waterway extending between Suisun Bay and San Pablo Bay (the Strait), on a nearly one mile-long bridge extending from Martinez to Benicia, known as the Suisun Bay bridge. This bridge, completed in 1930, spans a major maritime shipping channel, though the bottom of the bridge is not high enough above the water to clear the many large vessels using the channel. To allow marine traffic to pass, the portion of the bridge over the shipping channel is configured as a "lift bridge" which can be raised, using large cables, winches, counterweights, and two tall guide towers, to allow vessels to pass underneath.

Maritime traffic has the right of way over rail traffic. Thus, each time a large vessel transits the Strait, the existing bridge is required to "lift" or "open" to allow maritime traffic to pass, during which time rail traffic stops. Each bridge lift typically interrupts rail traffic for 20 minutes or more.

Because each bridge opening delays all train traffic, both freight and passenger, in both directions, there is a ripple effect that causes delays not only to approaching trains closest to the bridge at the time of an opening, but also to following trains. As a result, bridge openings represent the second most significant cause of delays to CCJPA trains. If CCJPA were to attempt to substantially increase train frequency using the current route across the existing Suisun Bay bridge, these delays would become difficult or impossible to mitigate and, too disruptive for reliable passenger and freight rail operations. Additionally, other track infrastructure improvements in the corridor that could ostensibly increase capacity for passenger rail service would not be practical unless the limiting factor of the existing lift bridge were first resolved by building a replacement high-level bridge that did not have to lift for maritime traffic.

A prior first phase of study examined numerous other route options for new crossings, including both bridge and tunnel options. From that effort, the CCJPA Board authorized CCJPA to pursue early conceptual engineering analysis for two of the most viable route options. The first phase of this study focused on identification of a range of potential route options and a screening process to identify which options might be infeasible. This second phase of the study focuses on very early conceptual engineering to identify technical considerations and examine the bridge crossing itself in more detail.

The purpose of this New Carquinez Crossing Study is to identify concepts for replacement of the existing Suisun Bay lift bridge with a new bridge constructed high enough above the water that it would not need to lift for vessels. Thus, the new bridge would always allow unobstructed passage for both marine and rail traffic.

While the main focus of this study is to examine options for a new bridge across the Carquinez Strait, the premise of a new bridge also presents other opportunities for improvements to CCJPA service and help CCJPA realize its Vision Plan, which calls for CCJPA service between the Bay Area and Sacramento at 30-minute headways each direction. For example, an entirely new bridge would not necessarily need to be located adjacent to the existing Suisun Bay bridge. A new bridge could be located anywhere along the Strait; as such, this study has considered entirely new route options in addition to the existing route via Martinez. While some of these new options would bypass Martinez, instead operating via Vallejo, other

options would remain on or adjacent to the existing route, making improvements to allow for the faster operating speeds and increased frequency of passenger train service contemplated in the CCJPA Vision Plan.

B. Previous Phase of the Study

The previous, first phase of this study considered bridge replacements both in the vicinity of the existing Suisun Bay railroad bridge, as well as in entirely new rail corridors. The Phase 1 study evaluated multiple representative routes within each corridor. An initial list of fourteen representative routes was developed, with potential crossing locations covering the entire length of the Strait from San Pablo Bay to Suisun Bay, and even as far east as Pittsburg, as illustrated in Figure 2.

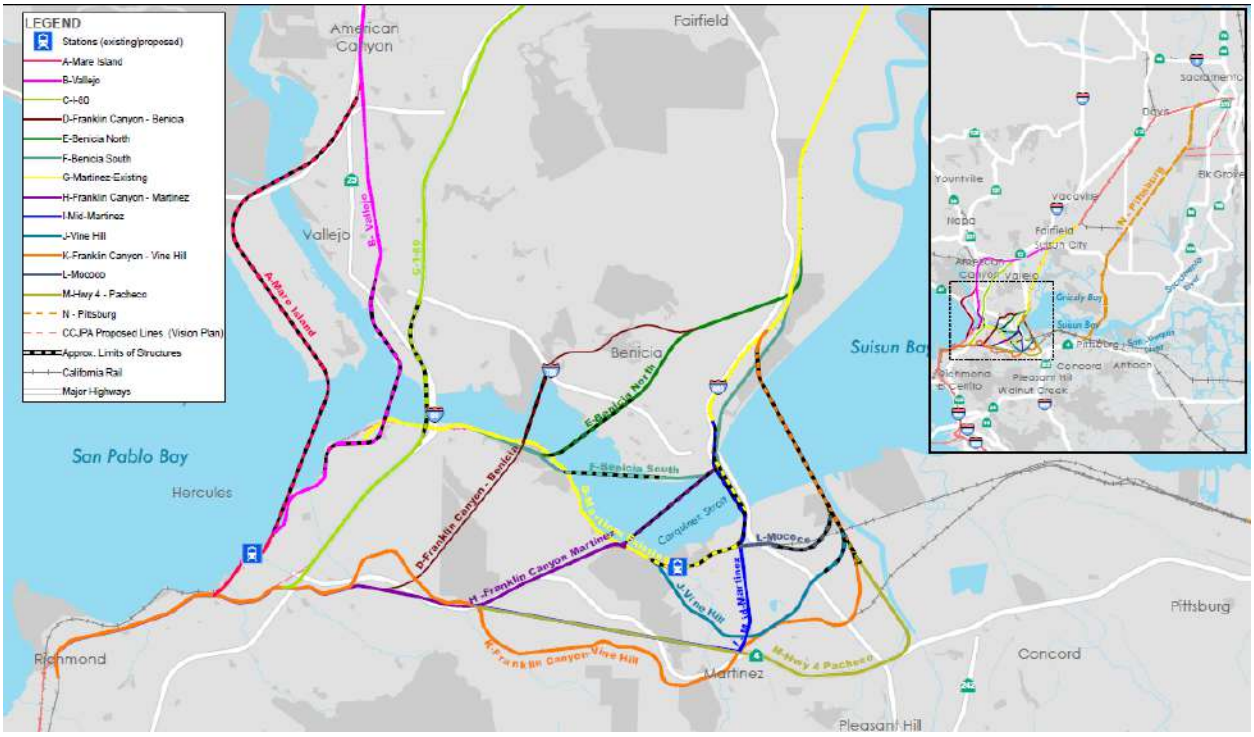

Figure 2: Initial representative routes from Phase 1 study.

Of the initial fourteen routes, several were not selected for further evaluation because, based on discussions with maritime authorities (the United States Coast Guard and San Francisco Bar Pilots), these proposed bridge locations would present significant challenges to navigation. Specifically, these authorities strongly preferred bridge locations that are close to existing highway bridges (Interstate 80 and Interstate 680) to avoid creating more obstacles for navigation.

Several other routes were not advanced because, due to topography, they would require extensive tunneling or long structures over residential and commercial areas. Underwater tunnels, which could avoid the navigational challenges, while not infeasible, typically cost several times more than a comparable bridge and present a range of geometric and technical challenges such that they were not considered further.

Of the fourteen initial route options, six representative routes were ultimately advanced for further consideration: two routes through Vallejo, a route through Benicia, a route through Franklin Canyon

(departing the existing corridor near Pinole, traversing Franklin Canyon and the southern portion of Martinez near Pacheco, then turning north), and two routes along the shoreline, one with a crossing immediately to the west of the existing Interstate 680 bridges and one to the east of the existing Interstate 680 bridges. The six representative routes are illustrating in Figure 3.

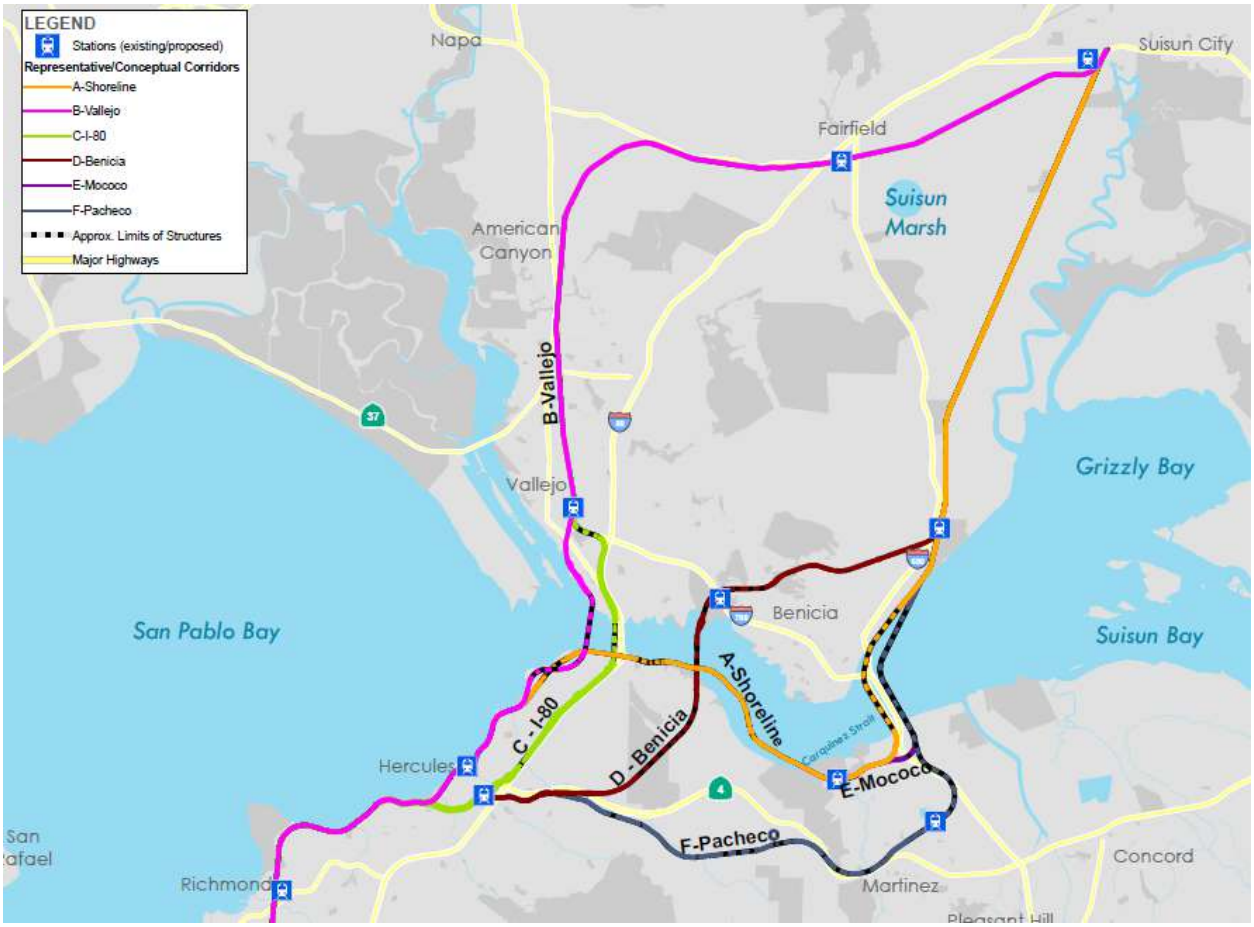

Figure 3: Six representative routes evaluated as part of Phase 1 study.

Each of the six representative routes was evaluated based on six criteria:

- *Operational Characteristics:* including travel time between Richmond and Suisun/Fairfield and the ability to accommodate freight trains.
- *Environmental Effects:* including effects on natural resources (i.e., acreage of impacts on wetlands, parks/open space, and educational facilities) and priority populations (based on census tract data).
- *Right-of-Way Effects:* effects on adjoining properties, i.e., acreage of impacts on residential, commercial, and industrial properties. At this early stage, impacts on residential properties were weighted higher than effects on commercial properties, which were weighted higher than effects on industrial properties. Impacts on industrial properties, such as refineries, also included rough order-of-magnitude (ROM) estimates of remediation costs.
- *Technical Complexity:* chiefly related to construction complexity and ROM construction costs

- *Maritime Compatibility:* impact on navigation (based on discussions with United States Coast Guard and San Francisco Bar Pilots)
- *Possibility of Phased Implementation*: possibility of constructing incremental portions of the improvements (e.g., only the high-level bridge) without constructing the remainder of the improvements while still creating benefit for CCJPA.

Ultimately, four representative route options (described below) were selected to advance to the second phase of the study.

C. Summary of Representative Route Options in this Phase 2 Study

The evaluation process in Phase 1 resulted in four representative route options being advanced for further evaluation in this, the second phase of the study. The four representative routes cross the Strait at one of two locations: the Martinez-Benicia West and Martinez-Benicia East representative routes cross the Strait near the existing Suisun Bay Bridge between Martinez and Benicia, while the Vallejo and Interstate 80 representative routes cross the Strait just west of the existing Interstate 80 highway bridges, between Crockett and Vallejo.

A brief summary of the four representative route options is presented below:

- Crossing the Strait just west of the existing Interstate 80 highway bridges, between Crockett and Vallejo, there are two representative route options:
    - The **Vallejo representative route option** would leave the current CCJPA route near Rodeo, and cross the Strait on a new bridge between Crockett and Vallejo. Upon reaching land in Vallejo, the Vallejo route would be located at-grade in a rail corridor owned by UPRR which extends from Vallejo to American Canyon, continuing eastward to Cordelia and Suisun City. The Vallejo route would have space for two passenger tracks and also space for one freight track for the portions from Rodeo through Vallejo, though the bridge over the strait would likely only accommodate two tracks without substantial additional expense and complexity.
    - The **Interstate 80 representative route option** would leave the current CCJPA route near Hercules, enter the Interstate 80 highway corridor and parallel the highway from Hercules to Crockett, cross the Strait on a new bridge between Crockett and Vallejo. Upon reaching land in Vallejo, the Interstate 80 route would be located below grade, in a trench, along a rail corridor owned by UPRR which extends from Vallejo to American Canyon and onto Cordelia and Suisun City. The Interstate 80 route would allow for two passenger tracks, but no freight tracks for the portion of the route from Hercules through Vallejo. It has been assumed that, with only a short window at night available for freight operation, freight operations would not be practical on the Interstate 80 representative route option.
    - While the Vallejo and Interstate 80 representative routes have different conceptual alignments approaching to the south side of the Strait, they both share the same corridor through Vallejo. The distinction is that, through Vallejo, the tracks for the Vallejo representative route option are at or near existing grade, while the tracks for the Interstate 80 representative route option would be depressed in a trench below grade.

- Crossing the Strait near the existing UPRR Suisun Bay bridge, between Martinez and Benicia, there are two similar representative route options:
    - The **Martinez-Benicia East representative route option** would add two passenger tracks adjacent to the existing tracks owned by UPRR between San Pablo and Suisun City, passing through Hercules, Rodeo, Crocket, Martinez, and Benicia. The Martinez-Benicia East representative route option would cross the Strait *east* the existing Suisun Bay Bridge and Interstate 680 highway bridges which extend between Martinez and Benicia.
    - **The Martinez-Benicia West representative route option** would add two passenger tracks adjacent to the existing tracks owned by UPRR between San Pablo and Suisun City, passing through Hercules, Rodeo, Crocket, Martinez, and Benicia. The Interstate 80 representative route option would cross the Strait *west* the existing Suisun Bay bridge and Interstate 680 highway bridges which extend between Martinez and Benicia.
    - Note that both the Martinez-Benicia West and Martinez-Benicia East representative routes are nearly identical, except for the specific location where they cross the Strait between Martinez and Benicia. (The Martinez-Benicia West route crosses the Strait *west* of the existing Intestate 680 highway bridges, while the Martinez-Benicia East route crosses *east* of the Interstate 680 bridges.) The minor change in crossing locations dictates significant differences in the railroad approach to the bridge crossing on both the Martinez and Benicia sides of the crossing.

III. Introduction to Representative Route Options

There are several general considerations that shape all representative route options, including the nature of the proposed rail operation, frequency of service, and right-of-way (ROW) ownership. These considerations are also part of the basis of comparison for the representative route options. It is important to note here – and this will be repeated throughout this document - that these are initial concepts, only, with the alignments described herein intended to be "representative" of possible options. No decisions have been made as to which route option to select, and no specific alignments in any segment, for any option, have been selected. Should this project advance further, additional study to verify route options, a detailed environmental evaluation process, and robust stakeholder engagement and public involvement process would occur as part of an alternatives analysis.

It is important to underscore that the alignments are conceptual in nature, and additional adjustments may be possible. The concepts illustrated in this report are for discussion only; they are not final. These concepts are based upon commercially available aerial imagery and digital terrain models. However, these concepts do offer an initial view of possible alignments and identify basic constraints.

A. Operational Considerations of Future CCJPA Service

The proposed operating plan for a railroad helps establish the nature of the infrastructure. In this case, CCJPA's Vision Plan calls for service between Sacramento and Oakland operating every 30 minutes in each direction from morning to evening. Thus, a person standing at any hypothetical point along the railroad would see four trains per hour, or, on average, one train every 15 minutes. Note that 30-minute headways are considered to be very frequent service for a railway. This level of service also places a premium on reliability (the ability of trains to maintain their assigned schedules and assigned "slots"), since any delay to one train would quickly have a cascade effect, delaying following trains - indeed,

reliability and capacity are two major motivations to replace the existing Suisun Bay lift bridge. To provide adequate capacity and reliability into the future, it has been assumed that CCJPA would require two dedicated passenger tracks, effectively one track for each direction of CCJPA traffic.

In the previous phase of this study, an operational simulation and initial travel time comparison was made for several of the route options to assess whether there were significant differences between options. The same number of stations was assumed for each simulation to provide an equal basis for comparison. The simulations showed that the travel time via the Vallejo representative route option would be approximately 50 seconds faster than the travel time via the Martinez-Benicia East representative route option. The Vallejo representative route option is also a proxy for the geometrically similar Interstate 80 representative route option, while the Martinez-Benicia East and West representative route options are also similar in travel time. Although there have been some modifications to the representative options, it is believed that the running time comparison will not change significantly.

B. Rail-Roadway Grade Crossings

This very frequent, four train per hour service also has implications for existing at-grade highway crossings. Although passenger trains are comparatively short and fast, meaning they would only occupy a grade crossing for a short time, the proposed CCJPA service would be very frequent. Grade crossings with relatively low roadway volumes, such as rural roads, may be able to remain at-grade. However, it has been assumed that significant roadways with higher volumes of roadway traffic, such as arterial roadways and many collector roadways, would be impacted by the interruptions that accompany frequent train operation across at-grade crossings and thus would require new grade separations. Grade separations also reduce the likelihood of roadway traffic driving in front of trains and being struck, which is actually a major source of delay for the current CCJPA service. Additionally, grade separations obviate the need for train horns to be sounded at grade crossings. These assumptions specific to each route option are described in more detail in the sections below.

C. Right-of-Way Ownership

The railroad ROW along the existing CCJPA route within the study area is owned by UPRR. All representative route options assume continued use of portions of UPRR's ROW already used by CCJPA. However, the Vallejo and Interstate 80 representative route options also assume use of UPRR's ROW (which currently has no passenger rail service) through Vallejo to American Canyon, and from American Canyon to Suisun City.

Note that, as this study is at an early stage, no discussions have been held with UPRR.

For all the representative routes, there are properties adjoining the existing rail corridor that would be impacted, especially in the vicinity of the new bridge crossings and along the shoreline. The impacts could range from slope easements to full acquisitions.

D. Sea Level Rise Resiliency

All options have been developed in a manner that accommodates projections for future sea level rise. Portions of representative route options along the shoreline are assumed to be raised several feet. Portions of the Martinez-Benicia East representative route option across the Suisun Marsh are assumed

to be raised on a new bridge structure. In Martinez and Vallejo, it is assumed that the proposed railroad would be incorporated into and account for local sea level rise resiliency planning.

E. Compatibility with Goods Movement

Assuming CCJPA passenger trains will operate on 30-minute headways in each direction, it has also been assumed that CCJPA would need two new tracks dedicated to passenger operations. Based on the experience of other passenger railways, this is a reasonable assumption. Freight operations would not use the passenger tracks, eliminating conflicts between passenger travel and goods movement.

Providing separate tracks for passenger service would, by itself, represent a benefit to goods movement since, today, freight and passenger trains use the same two UPRR tracks. Shifting passenger trains to dedicated tracks would allow the existing UPRR tracks to be dedicated entirely to goods movement operations.

All representative route options provide two separate passenger tracks. However, the representative route options have different abilities to accommodate new facilities for goods movement, in particular at the new high-level bridge crossing. A new high-level crossing of the Strait with sufficient track capacity to accommodate both passenger and freight service would also eliminate the potential for freight delays due to bridge openings, thereby offering resiliency benefits for goods movement activities. However, UPRR could continue freight operations on the existing bridge; at this time, no discussions with UPRR have occurred regarding any of the options.

The ability of each representative route option to accommodate goods movement is summarized below:

- **Vallejo representative route option:** The Vallejo representative route option is significantly constrained with respect to goods movement. Due to the very narrow ROW through Vallejo (generally 60 feet, but as little as 50 feet in some locations), and assuming that CCJPA would need two dedicated tracks, there would be space for only one freight track, assuming all tracks were constructed at or near the existing grade, with roadways through Vallejo elevated over the tracks. Incorporating a third freight track on the long-span bridge over the Strait would be technically challenging and result in a significant cost increase because the bridge would need to be constructed to support the extra weight of freight trains, which are much heavier than passenger trains.

  Note that the types of long-span bridges being considered for the crossing between Crockett and Vallejo do not have a history in North America for carrying heavy freight trains; more information regarding structural considerations is provided in later sections of this report.

- **Interstate 80 representative route option:** Like the Vallejo representative route option, the Interstate 80 representative route option is significantly more constrained with respect to goods movement. Due to the very narrow ROW through Vallejo (generally 60 feet, but as little as 50 feet in some locations), the Interstate 80 representative route employing a below-grade "trench" to pass through Vallejo (described later), and assuming that CCJPA would need two dedicated tracks, there would not be space for a freight track. This is because the structure and side walls of the trench would use the horizontal space that might otherwise be allotted to a third track. With no space for a freight track through Vallejo, no consideration has been made for a third, freight track across the bridge between Crockett and Vallejo. It is assumed that

goods movement would be impractical if limited only to a short nighttime window when passenger trains did not operate and when freight trains could use the passenger track. Note that the Interstate 80 representative route option is shown with a tunnel passing under Carquinez Heights to illustrate this approach. Such a tunnel would necessitate grades too steep for freight trains. Any discussion of the Interstate 80 option being viable in the context of goods movement assumes that, on the north side of the Strait, the Interstate 80 option would be combined with elements of the Vallejo representative route option in order to navigate around Carquinez Heights on a bridge with a shallower grade.

- **Martinez-Benicia East representative route option:** The Martinez-Benicia East representative route option would provide two passenger tracks in addition to the two existing freight tracks for the entire length of the study area. The bridge over the Strait between Benicia and Martinez would have space for four tracks, two dedicated to freight and two dedicated to CCJPA passenger trains. The Martinez-Benicia East representative route option assumes a portion of UPRR's ROW would be available to CCJPA, but also assumes slope easements or ROW acquisitions to provide sufficient additional space to construct the two new passenger tracks. In so doing, this would not only allow additional capacity for passenger trains, along with higher speeds (and thus improvements to travel time), but also free existing capacity for goods movement.

- **Martinez-Benicia West representative route option:** With respect to goods movement, the Martinez-Benicia West representative route option is identical to the Martinez-Benicia East route. The Martinez-Benicia West representative route option would provide two passenger tracks in addition to two freight tracks for the entire length of the study area. The bridge over the Strait between Benicia and Martinez would have space for four tracks, two dedicated to freight and two dedicated to CCJPA passenger trains. The Martinez-Benicia West representative route option assumes a portion of UPRR's ROW would be available to CCJPA, but also assumes slope easements or ROW acquisitions to provide sufficient additional space to construct the two new passenger tracks. In so doing, this would not only allow additional capacity for passenger trains, along with higher speeds (and thus improvements to travel time), but also free existing capacity for goods movement.

A further consideration for compatibility with goods movement is the steepness of the grades along any of the representative route options. The most obvious challenge would be the approach grades to the new bridge crossing. Since the proposed bridge will be at least 153 feet above the water, these approach grades must be very long in order to gain appreciable elevation. At this early, conceptual stage, it has been assumed that a 1.5% grade would be the maximum feasible for the bridge approaches. However, note that 1.5% is considered quite steep for a freight railroad and actual operating considerations would affect the maximum feasible grade.

These goods movement considerations are important from the perspective of maintaining the commercial vitality of the region, particularly the Port of Oakland and other transportation-dependent industries in the area. Options that benefit goods movement also offer additional funding opportunities,

particularly the various state and federal funding sources that are specific to goods movement and port access improvements.

IV. Discussion of Representative Route Options and Individual Segments

Concepts for the four representative route options are described below. Each description starts near San Pablo and proceeds eastward[2] towards Suisun City. For the purposes of this narrative, each route option is subdivided into shorter "segments." *Note that these are initial concepts, only, with the alignments described herein intended to be "representative" of possible options. No decisions have been made as to which route option to select, and no specific alignments in any segment, for any option, have been selected.*

One way to reduce overall travel time is to increase passenger train operating speed by adjusting the geometry of the curves since sharper curves generally require slower speeds than broader curves). Adding banking to the curves by elevating the outside rail (known as superelevation) can also promote faster speeds. Although detailed curve design has not been performed, it has been assumed that, in the future, CCJPA passenger trains could operate at a combined 10 inches of curve elevation (including superelevation and underbalance[3]); this is an increase over the current curve elevations.

Even with increased curve elevation, all options assume some amount of curve realignment in order to allow for a minimum operating speed of approximately 70 miles per hour. Curve realignments shift the tracks (or construct new tracks) on a broader, larger radius curve than currently exists. Where portions of the route options follow the shoreline, it has been assumed that the tracks will shift inland. Other than at the new bridge crossings across the Strait (where bridge piers and approach structures would, of necessity, be constructed in the Strait), this study assumes that tracks would *not* be shifted into the Strait. This is an important assumption insofar as it represents a key cost driver, particularly for the Martinez-Benicia West and Martinez-Benicia East options, since many curve shifts would be to the inland side of the existing tracks and thus, require both property acquisition and large retaining walls which add cost.

Conversely, had there been an assumption that tracks could be shifted towards the Strait, even by only 10 to 20 feet in some cases, significant ROW acquisition and other costs could have been avoided.

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[2] Note that, although portions of the Capitol Corridor are oriented in both north-south and east-west compass directions, unless otherwise noted, the following descriptions will use the directions assigned by the railroad, in which operations toward Oakland are described as "westbound" and operations toward Sacramento are described as "eastbound," regardless of actual orientation of the tracks. Accordingly, the two sides of the tracks are defined as "north" and "south." For example, at San Pablo, even though the corridor is oriented in a north-south direction, the inland side of the corridor is described as the "south" side, while the Bay side is described as the "north" side.

In some limited situations, direction will be provided relative to true north; in these situations, directions will be identified as "compass north" or "compass west."

[3] Underbalance refers to the amount of outward force a railcar can be subjected to above the amount of superelevation; like superelevation, underbalance is measured in inches.

However, to be conservative, the more expensive approach (shifting tracks inland) has been taken for this phase of the study.

The following descriptions are based on a high-level conceptual design effort employing aerial imagery and digital terrain models (DTM) from the United States Geologic Survey. The resolution of this data is somewhat limited. While appropriate for this level of conceptual analysis, features on the ground change over time and aerial imagery may not capture these changes. Similarly, some topographic features may be missing from the DTM.

A. Common Segment: Richmond to Point Pinole

All representative route options share a common initial segment, beginning at San Pablo, just north of the Richmond Parkway overpass, and extending to just west of Point Pinole. In this segment, two additional tracks dedicated to CCJPA passenger trains would be added on the inland side of the UPRR ROW. However, portions of the Bay Trail, a recreational trail that parallels the shoreline, largely adjacent to the UPRR ROW between Richmond and Rodeo, would need to be shifted to provide space for the additional tracks. In addition, some relocation of the UPRR tracks has also been assumed. Pedestrian and roadway overpasses over the railroad would be extended to allow for additional tracks underneath while maintaining access to Point Pinole Regional Shoreline.

B. Vallejo Representative Route Option

The Vallejo representative route option, as its name implies, is predicated on a route through Vallejo. The Vallejo representative route option would generally follow the existing UPRR corridor from San Pablo to the Rodeo area, where it would shift inland and ascend to a new bridge across the Strait between Crockett and Vallejo. The new bridge would be located immediately west of the westbound lanes of the existing Interstate 80 bridge. After passing through Vallejo, this representative route option would turn east at American Canyon, continuing eastward adjacent to the existing UPRR corridor through Jameson Canyon and Cordelia to Suisun City.

The Vallejo representative route option offers the opportunity for at least two, and potentially as many as three tracks from the area where it diverges from the existing UPRR corridor at Rodeo to Suisun City. Three tracks would provide for two dedicated passenger tracks and a single freight track to support goods movement. The one exception would be the length of the bridge crossing over the Strait, where design considerations associated with a long-span bridge would mean that a third freight track would make the bridge substantially more expensive. This will be discussed later, in Section V, focusing on the bridge crossings themselves.

From a conceptual operating perspective, if the bridge were not able to accommodate three tracks, the resulting two-track bridge would require freight trains to share the two passenger tracks across the bridge. This would be operationally challenging in any scenario where passenger trains operate at 30-minute intervals. Such close headways for passenger trains would mean freight trains would have little time to use the bridge and, if freight trains stopped on the steep approach grades to the bridge, may have difficulty restarting, or do so very slowly. This would significantly limit the number of freight trains to use the Vallejo corridor during the daytime hours of passenger service, though freight trains could use the corridor at night when passenger trains are assumed to be much less frequent and the two-track limitation of the bridge would present less of a constraint. Figure 4 illustrates the Vallejo representative route option.

Figure 4: Vallejo representative route option.

1. Vallejo Representative Route Option Strengths and Challenges:

- Strengths:
  - Opportunity to serve new markets in the Vallejo, American Canyon, and Cordelia areas which are not currently served by intercity passenger rail.
  - Opportunity to provide connections to proposed SMART service.
  - Dedicated passenger corridor.
- Challenges:
  - Limited ability to accommodate goods movement on the new corridor; adapting the bridge across the Strait to accommodate freight trains would substantially increase cost.
  - Significant construction impacts associated with establishing a new rail line in the narrow corridor through Vallejo.
  - Property acquisitions and impacts associated with the new rail corridor on both sides of the new bridge across the Strait .
  - Potential for visual, noise, and vibration impacts on properties adjoining the existing corridor through Vallejo, possibly dividing the community.

2. Vallejo Representative Route Option Segment Descriptions

a) Pinole to Rodeo Segment (Vallejo representative route option)

The Vallejo representative route option begins at the east end of the Common Segment (described earlier) just east of Point Pinole. The representative alignment would be constructed on the inland side of the existing tracks, and at a slightly higher elevation to provide resiliency against sea level rise. In this segment, several alignment adjustments are assumed in order to reduce the sharp curvature and allow higher speeds. These alignment adjustments would generally add the new CCJPA tracks further inland at curves. To reduce travel time and take fullest advantage of the curve reductions, it may be necessary to re-route portions of the Bay Trail. At Hercules, there is development planned along the tracks, which may be affected by the proposed concept for additional tracks (because there is no space for additional tracks without affecting the development). In this area, portions of the Bay Trail could be affected and would need to be re-routed to accommodate the additional tracks.

b) Rodeo to Crockett Segment (Vallejo representative route option)

At Rodeo, the representative alignment diverges from the existing tracks both to eliminate a sharp curve and to begin climbing toward a new, high-level bridge across the Strait at Crockett. To eliminate this sharp curve, the representative alignment would pass through several parking lots at the Phillips66 refinery, potentially affecting portions of the refinery facility itself. Although no discussions with Philips66 have occurred, based on reviews of aerial imagery, it is conceivable that no major process facilities within the refinery would be affected.[4]

After passing through the refinery, the representative alignment would head inland, turning right to traverse a low-lying area while ascending on a bridge, crossing over San Pablo Avenue west of its intersection with Cummings Skyway, then enter a tunnel while curving left to turn parallel and adjacent to Interstate 80, and at approximately the same elevation as Interstate 80 (recall, this description proceeds westward, so that a right-turn, when viewed from above, would be clockwise).

c) Crockett to Highway 29 (Vallejo representative route option)

Navigational considerations at the Strait are the overriding constraint for locating a bridge and also the railroad approaches on both the north and south sides of the Strait. Because this is one of the narrowest parts of the Strait, currents are strong, making vessel navigation a challenge. To minimize hazards to navigation, the new bridge would need to be located adjacent to the existing Interstate 80 bridges, with the piers in-line with the existing piers of the highway bridges, which would require a span length of over 1,000 feet for the railroad bridge. This is an extremely long span for a railroad bridge. The bottom of the bridge deck would be approximately 153 feet above the water. The bridge is discussed in more detail, in Section V of this study.

The baseline assumption for this bridge would be two tracks, suitable only for passenger trains, which would result in the most cost-effective bridge. A bridge with only two tracks would represent a very

[4] Refineries are complicated process facilities and it is understood that the Phillips66 facility has recently been converted to refine renewable diesel, so many of the facilities are likely new and therefore impacts could be disruptive and expensive to mitigate. An option that would avoid impacts to the refinery, but involve a long bridge to the north of the existing tracks, around the refinery, appears feasible, but is not currently included in this representative alignment.

significant capacity constraint for goods movement, given the frequent (30-minute headway) passenger service. However, a bridge able to accommodate freight trains would require a stronger, heavier design, which would increase costs above the base case.

Locating the new bridge adjacent to the existing Interstate 80 bridge at Crockett requires that the conceptual alignment be adjacent to the westbound lanes of Interstate 80 as the railroad approaches the Strait. In this area, a relocation of Vista Del Rio Street would be required in order to provide sufficient pace for the new tracks prior to the new tracks crossing over Kendall Avenue. In addition, several residences would be impacted.

As with the south side of the Strait, on the north side of the Strait route options are also limited by the location of the bridge. The Vallejo representative route option assumes construction of a long, curving bridge over the water to the west of the bluff at Carquinez Heights. This bridge would descend at an approximate 1.5% grade from the Strait crossing down to the ground elevation at Vallejo. This concept is shown in Figure 5. Note that the bridge would pass in front of developed areas at the California Maritime Academy. While not directly over structures, the bridge would be above the Academy's shoreline infrastructure.

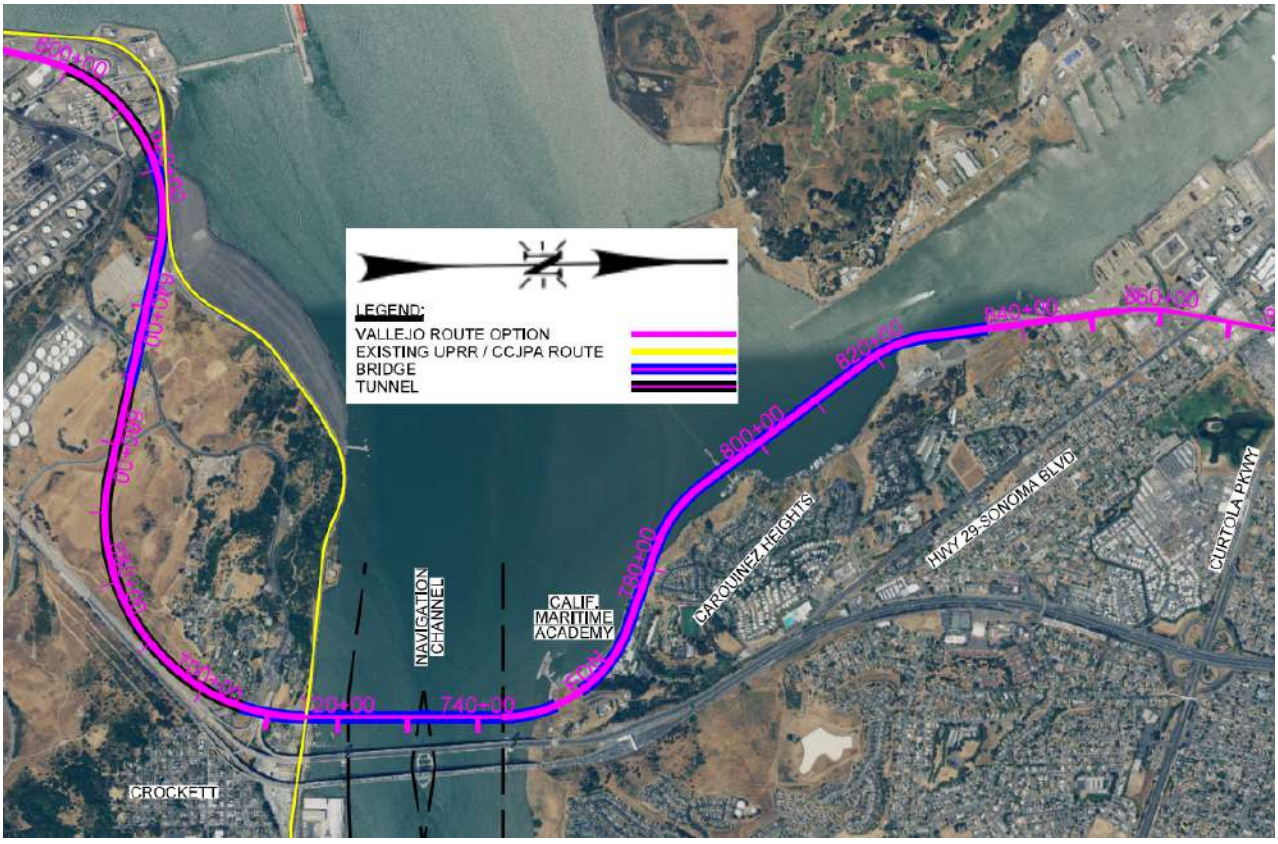

Figure 5: Magenta alignment illustrates concept for the Vallejo representative route option from Rodeo (top left), climbing through Crockett, crossing the Strait on a new bridge, passing in front of the California Maritime Academy, descending past Carquinez Heights on a bridge, reaching existing ground elevation at Highway 29 / Sonoma Boulevard (top right).

Several other options at the north side of the Strait have been considered. An option navigating around Carquinez Heights (rather than under it) has been considered for the Interstate 80 representative route

option, described in the next Section. In the prior phase of this study, additional route options paralleling Interstate 80 and entering Vallejo via Sonoma Boulevard or Curtola Parkway were considered. However, each of these would have involved significant impacts to residential and commercial areas and were not pursued further.

After traversing the bridge around Carquinez Heights, the Vallejo representative route option would pass in front of the former General Mills site and enter the existing rail corridor, descending to the existing ground level near the existing Highway 29 (also called Sonoma Boulevard) at-grade crossing.

d) Highway 29 to American Canyon Segment (Vallejo representative route option)

Between the Highway 29 at-grade crossing and American Canyon, the Vallejo representative route option assumes that the railroad would be constructed at or near existing grade in the existing, but seldom-used UPRR rail corridor through Vallejo. Based on information from publicly available Geographic Information System (GIS) data sets and examination of aerial imagery, the majority of the existing rail corridor from Highway 29 to American Canyon is only 60-feet-wide, surrounded by residential development for most of the distance. See Figure 6 for an example of the existing corridor. This 60-foot width is only just wide enough for three tracks at near-minimum side clearances, but not wide enough for four tracks. See Figure 7 for an example of three tracks in a 60-foot wide ROW.

Figure 6 (Above): Photograph of existing corridor, approximately 60-feet wide, in Vallejo.

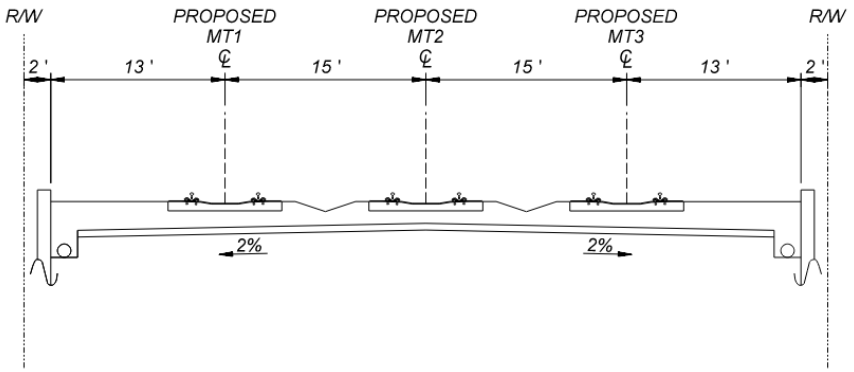

Figure 7 (Above): Concept for three tracks in 60-foot wide corridor.

i. Grade Separations in Vallejo (Vallejo representative route option, included in the Highway 29 to American Canyon Segment)

Because CCJPA's future service plan would operate trains at 30-minute headways each direction, a train would pass through Vallejo approximately every 15 minutes. The at-grade option through Vallejo assumes that the proposed railroad tracks would remain at or near the elevation of the existing tracks through Vallejo, while every roadway that crosses the rail corridor, currently at-grade crossings, would require a grade separation due to the new, frequent train service (in a corridor which, today has limited or no train service).

For the Vallejo representative route option, which maintains the full 60-foot-wide corridor available for three tracks, it has been assumed that each grade separation would involve raising the roadway on a bridge over the railroad. It is assumed that there would be 17 grade separations through Vallejo where the roadways would be elevated over the railroad, starting at and including Highway 29 and continuing northward to and including American Canyon Road. A few of the roadway crossings north of American Canyon with lower volumes of roadway traffic may be able to remain at-grade. In each case, the roadway surface would need to be elevated over the railroad tracks by approximately 28 to 30 feet in order to provide a minimum vertical clearance between the bottom of the roadway bridge and the railroad of 23.3 feet. Georgia Street and Redwood Street offer examples of the construction associated with grade separations; they are discussed below. It is assumed that other grade separations through Vallejo would be similar to these examples.

Exhibit 1 in the Appendix illustrates a concept for a representative roadway-over-rail grade separation at Georgia Street. While many residences at this location have alley access to the back of the homes, these properties would lose access to Georgia Street, and their front-window views would be impacted by retaining walls along Georgia Street.

Exhibit 2A and 2B in the Appendix illustrate concepts for a representative roadway-over-rail grade separation where Redwood Street crosses the railroad corridor. Note that at the Redwood Street location, both Redwood Street and Broadway would need to be elevated (as shown in Exhibit 2A and

Exhibit 2B, respectively) in order to maintain the intersection that allows roadway traffic to turn from Redwood to Broadway and vice versa. Elevating this intersection would add complexity and cost to the grade separation. Homes along Alameda Steet would lose access to Redwood Street. Note that there are several other intersections adjacent to the railroad tracks in the corridor that would have similar challenges.

While there would be substantial disruption associated with construction of the grade separations, it should be noted that, given the constrained ROW for both the rail corridor and roadway network, it is likely that some residential properties adjacent to the elevated portions of each of the 17 grade separations would lose some or all street access because the roadways in front of those properties would be elevated on a bridge or embankment. As a result, it may be impossible to maintain the current uses of these properties and they may need to be acquired if this option were selected. For other properties near the grade separations, while it may be possible to provide street access, they may have elevated roadways immediately in front of the structures, meaning that, in practical terms, these properties may also need to be acquired if this option were selected.

e) American Canyon to Suisun City Segment (Vallejo representative route option)

The segment of the Vallejo representative route option from American Canyon to Suisun City would parallel the existing UPRR corridor between these points. One major feature of this corridor is the grade through Jameson Canyon which, at approximately 2%, is steeper than would be acceptable for a major through freight route. This corridor is owned by UPRR, but used by short-line railroad California Northern, which operates approximately 2-4 trains per day between American Canyon and Suisun City. If compatibility with longer and more frequent through freight trains were desired (e.g., to provide goods movement capacity to the Port of Oakland), and assuming a 1.5% grade would be acceptable for freight operations, reducing the grade to a maximum of 1.5% would require lowering the crest of the grade, a new grade separation over Interstate 80, and lengthening the grade by extending the base of the grade east, past the existing Interstate 680 overpass at Cordelia. Note that the Interstate 80 representative route option, discussed later in this report, assumes maintaining the existing 2% grade through Jameson Canyon and avoids those costs.

If the railroad tracks that currently pass under Interstate 680 were raised, the overpass itself may need to be reconstructed in order to maintain sufficient vertical clearance for trains underneath. Because this portion of Interstate 680 is less than ½ mile to the freeway interchange with Interstate 80, a reconstruction at Interstate 680 may also affect the Interstate 80 interchange. If both freeways were involved in a reconstruction, the costs would be significant. Alternatives to reduce the grade to allow the possibility of freight operations were considered, such as lowering the freeway to allow the railroad to pass over it. However, such lowering would still be extremely expensive, particularly given the need to maintain the railroad in operation while the freeway was being constructed under the railroad.[5]

Other constraints in the Cordelia to Suisun City area include a tunnel, which is assumed to be "daylighted" (excavated to remove the roof and leave an open cut) to allow for up to three tracks. In addition, several new roadway-over-railroad grade separations would be needed in the Suisun City area

[5] An option that lowered the crest of the grade by an even larger amount and avoided the reconstruction of Interstate 680 in Cordelia was considered but would have necessitated significantly re-routing several streams. Desktop research during the first phase of this study identified that California Red Legged Frog (a threatened species) habitat exists in these areas. Thus, significantly re-routing these streams was considered infeasible.

in order to address the several existing at-grade crossings. Significant track reconfigurations would also be needed to address the extensive network of industrial spurs in the Suisun City area.

The segment from American Canyon to Suisun City has also been considered by the Sonoma-Marin Area Rail Transit District (SMART) for an extension of their service from Ignacio to Suisun City. Although this would offer the opportunity for cost sharing in this segment, it would also create additional demands on railroad capacity, potentially increasing costs. For example, if a CCJPA train were to operate every 30 minutes in each direction, and a SMART train were to operate between CCJPA trains, there may not be sufficient track capacity for freight trains to cross-over the passenger tracks to perform switching, and additional switching leads may be required, and even potentially "fly-overs," to allow trains to pass from one side of the passenger tracks to the other via rail-over-rail grade separations.

C. Interstate 80 Representative Route Option

The Interstate 80 representative route option, as its name implies, is predicated on a route paralleling Interstate 80 from Hercules to Crockett, and then continuing toward American Canyon through Vallejo. The Interstate 80 representative route option would generally follow the existing UPRR corridor for a short distance from San Pablo to the Pinole area, where it would shift inland and transition to an entirely new rail corridor on the compass west side of Interstate 80, paralleling Interstate 80 to a new bridge across the Strait between Crockett and Vallejo (in the same location as the bridge for the Vallejo route option). The new bridge would be located immediately west of the westbound lanes of the existing Interstate 80 bridge.

Unlike the Vallejo representative route option, the portion of the Interstate 80 representative route option through Vallejo would be located below grade, in a trench, in order to minimize operational impacts on the community. However, given constraints of the corridor, this trench would be wide enough for only two tracks. After passing through Vallejo, this route option would turn east at American Canyon and continue eastward to Suisun City, adjacent to the existing UPRR corridor through Jameson Canyon and Cordelia.

The Interstate 80 representative route option could accommodate only two tracks from the area where it diverges from the existing UPRR corridor to American Canyon. Thus it could not accommodate regular through freight trains during daytime hours and could not support goods movement, except in the few night hours when no passenger trains are scheduled. Figure 8 illustrates the Interstate 80 representative route option.

Figure 8: Interstate 80 representative route option.

1. Interstate 80 Representative Route Option Strengths and Challenges:

- Strengths:
  - Opportunity to serve new markets in the Vallejo, American Canyon, and Cordelia areas which are not currently served by intercity passenger rail.
  - Opportunity to provide connections to proposed SMART service.
  - Dedicated passenger corridor.
  - Lowering the tracks in a "trench" through Vallejo would present the opportunity to place a "lid" on top, potentially creating public open space above the railway corridor.
- Challenges:
  - Effectively no ability to accommodate goods movement on the new corridor – the only potential for goods movement would be during a brief window at night when passenger trains were less frequent; adapting the bridge across the Strait to accommodate freight trains would substantially increase cost. Steep grades on the north side of the Strait further hinder goods movement.
  - Significant construction challenges and impacts associated with connecting the existing UPRR rail corridor near Pinole to the new rail corridor adjacent to Interstate 80. This would require an entirely new corridor through Hercules, passing through both open space and developed portions of Hercules adjacent to San Pablo Avenue and Refugio Creek.

- Significant construction challenges and impacts associated with establishing a new, two-track rail corridor adjacent to Interstate 80 between Hercules and Crockett.
- Significant construction challenges and impacts associated with depressing the rail line in a new "trench" in the narrow corridor through Vallejo.
- Property acquisitions and impacts associated with the new rail corridor on both sides of the new bridge across the Strait.
- Potential for visual, noise, and vibration impacts on properties adjoining the proposed corridor through Vallejo, possibly dividing the community.

2. Interstate 80 Representative Route Option Segment Descriptions

a) Pinole to Hercules Segment (Interstate 80 representative route option)

The Interstate 80 route option begins at the east end of the Common Segment (described earlier) just east of Point Pinole. The representative alignment would be constructed on the inland side of the existing tracks, and at a slightly higher elevation to provide resiliency against sea level rise. In this segment, several alignment adjustments are assumed in order to reduce the sharp curvature and allow higher speeds. These alignment adjustments would generally add the new CCJPA tracks further inland at curves. To reduce travel time and take full advantage of the curve reductions, it may be necessary to re-route portions of the Bay Trail. At Hercules, the Interstate 80 route would leave the UPRR corridor and head inland, adjacent to the existing BNSF Railway corridor. This would require coordination and approval from BNSF Railway and likely require some ROW acquisition from adjoining residential properties.

In the vicinity of Sycamore Avenue and John Muir Avenue in Hercules, the Interstate 80 representative route option would be located on an elevated structure to cross-over this portion of Hercules, where it would join the Interstate 80 freeway corridor, adjacent to the westbound lanes of Interstate 80.

b) Hercules to Crockett Segment (Interstate 80 representative route option)

From approximately John Muir Parkway in Hercules, the Interstate 80 representative route option follows the westbound lanes of Interstate 80 towards Crockett. To accomplish this, substantial earthwork and retaining walls would be necessary at the several large cuts where Interstate 80 has already made substantial cuts and built major retaining walls to make space for the freeway. The current concept for the Interstate 80 representative route assumes the barrier between the new track and the freeway would be at least 16 feet from the existing shoulder of westbound Interstate 80. This distance is intended to provide sufficient space for a future highway travel lane, should there be a desire to expand Interstate 80.[6]

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[6] One significant design consideration would be train speed. Caltrans' Highway Design Manual states "*When a high speed rail corridor is to be constructed longitudinally to a freeway, expressway or a conventional highway with posted speeds over 40 miles per hour, the nearest fixed object or feature associated with the operation of the rail facility should be located a minimum of 52 feet horizontally from the planned ultimate edge of the traveled way.*" (Caltrans Highway Design Manual, 2023, topic 309.1 Horizontal Clearances).

Caltrans defines high speed rail as "*A type of intercity and interregional passenger rail service that operates significantly faster than conventional rail. Top operating speeds are typically 150 to 220 miles per hour. These*

The addition of a railroad corridor on the (compass) west side of Interstate 80 would necessitate reconfiguration of several existing freeway interchanges and overpasses, described below.

- The Willow Avenue interchange would be reconfigured to allow the track to pass over it. A reconfiguration would, presumably, bring that interchange up to modern geometric standards. A concept for that reconfiguration is illustrated in Figure 9.

Figure 9: Concept for adding railroad corridor to west side of Interstate 80 and reconfiguring Willow Avenue interchange. Gray shading indicates railroad bridge over Willow Avenue.

- The California Street overpass, which would pass over the railroad and travel lanes of Interstate 80, would be reconfigured to provide a longer span.
- The Cummings Skyway overpass would be reconfigured to allow the railroad to pass under the roadway. The concept provides a train box to allow the freeway overpass and the ramps to pass over the tracks. Because of the high-skew of the freeway on- and off-ramps, a conventional bridge would be impractical. A train box, essentially a cut-and-cover trench with a "lid" over the top[7], would allow the roadway to pass overhead. The conceptual modifications to the freeway to make space for the railroad include upgrades to bring the freeway to modern geometric standards, while allowing sufficient space to phase construction of the freeway overpass while maintaining the existing overpass in operation. Figure 10 illustrates the concept, including proposed freeway geometry.

trains may be powered by overhead high voltage lines or technologies such as Maglev. The tracks are grade separated within a separate controlled access right of way and may or may not be shared with freight trains."

In the event that CCJPA trains were planned to operate at speeds "significantly faster than conventional rail," presumably in the 100 MPH or higher speed range, which could be possible in this segment, a 52-foot separation would presumably be required. However, there is not sufficient space for a 52-foot separation. Caltrans qualifies this separation distance as "should," so it may be possible to use a lesser separation. Current CCJPA train speeds are limited to 79 miles per hour, and this study assumes speeds of 90 miles per hour or less along Interstate 80. Thus, the 52-foot separation has *not* been used as the base case for this study.

[7] After excavating a cut-and-cover trench or tunnel with an exposed, open top, a structural roof is added and soil or other features (such as roadways or greenways) can be added on top.

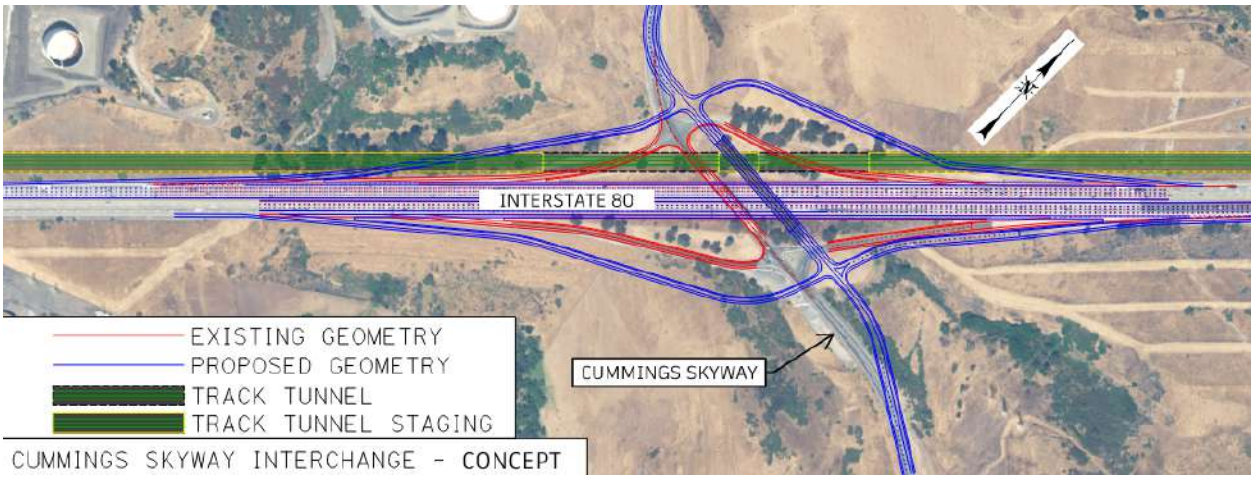


Figure10: Concept for adding railroad corridor to west side of Interstate 80 at Cummings Skyway. Roadway concept assumes existing roadway must remain operational during construction.

The segment ends at the (compass) south side of Crockett, where the highway traverses through a deep cut prior to descending toward the bridge over the Strait.

c) Crockett to Highway 29 Segment (Interstate 80 representative route option)

As with the Vallejo representative route option, navigational considerations in the Strait are the overriding constraint for locating a bridge and the railroad approaches on both the north and south sides of the Strait for the Interstate 80 representative route option. Because this is one of the narrowest parts of the Strait, currents are strong, making vessel navigation a challenge. To minimize hazards to navigation, the new bridge would need to be located adjacent to the existing Interstate 80 bridges, with the piers in-line with the existing piers of the Interstate 80 highway bridges, and the bottom of the bridge deck would be approximately 153 feet above the water. The bridge is discussed in more detail, in Section V, Structures.

As with the Vallejo representative route option, the baseline assumption for this bridge would be two tracks, suitable only for passenger trains, which would result in the most cost-effective bridge. However, a bridge able to accommodate freight trains would require a stronger, heavier design, which would increase costs above the base case.

Locating the new bridge adjacent to the existing Interstate 80 bridge at Crockett requires that the conceptual alignment be adjacent to the westbound lanes of Interstate 80 as the railroad approaches the Strait. In this area, a relocation of Vista Del Rio Street would be required in order to provide sufficient space for the new tracks prior to the new tracks crossing over Kendall Avenue. In addition, it is possible that several residences would be impacted.

As with the south side of the Strait, on the north side of the Strait, the representative route options are also limited by the location of the bridge. The Interstate 80 representative route option assumes the railroad would bridge over portions of the California Maritime Academy, then descend steeply, at approximately 3% grade, to enter a tunnel under the Carquinez Heights neighborhood. Such a steep grade would make freight operations infeasible. In this area, there may be some impact to the California Maritime Academy or residences at Carquinez Heights. After tunneling under Carquinez Heights, the

Interstate 80 representative route option would emerge above the former General Mills site, descending, reaching existing ground elevation just before Sonoma Boulevard/Highway 29.

This concept is shown in Figure 11.

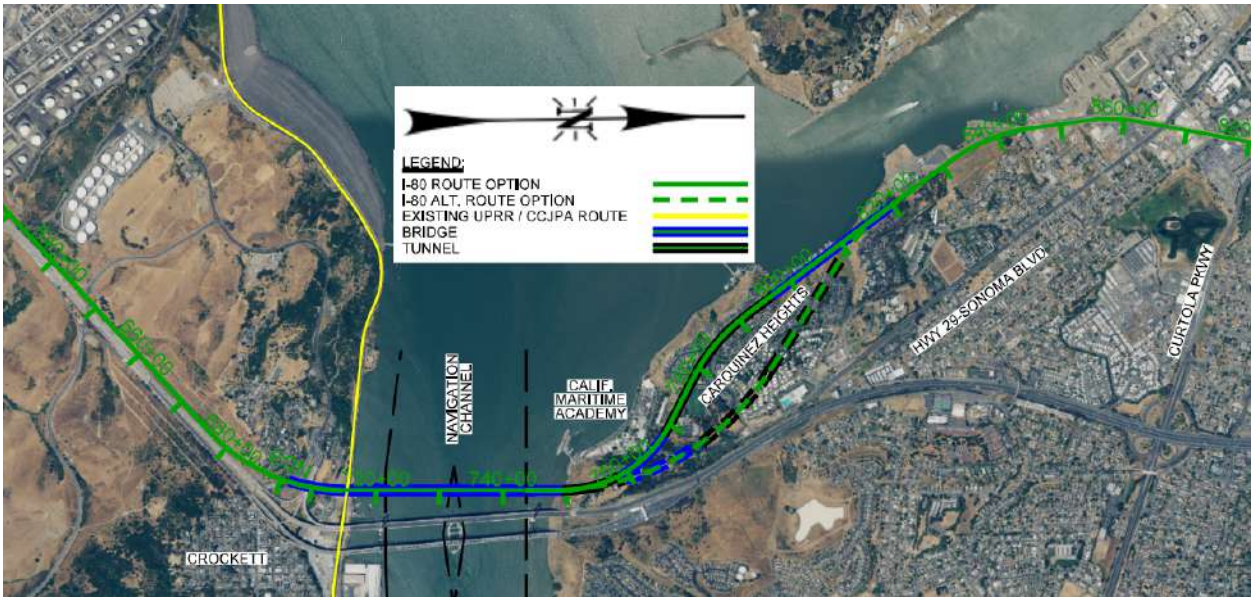


Figure 11: Green alignment illustrates concept for the Interstate 80 representative route option from Rodeo (left), parallel, to Interstate 80 through Crockett, crossing the Strait on a new bridge, passing over the California Maritime Academy, descending under Carquinez Heights in a tunnel (two options shown for the tunnel, one solid line, one dashed line), reaching existing ground elevation at Highway 29 / Sonoma Boulevard (top right).

d) Highway 29 to American Canyon Segment (Interstate 80 representative route option)

After crossing Sonoma Boulevard/Highway 29, the Interstate 80 representative route option would continue to descend into a "train box" or "trench" to approximately 30 feet below existing ground. This would allow the railroad to pass under each of the existing rail-roadway at-grade crossings in Vallejo, effectively providing a grade separation at each roadway.

As described previously, the majority of the corridor through Vallejo is approximately 60-feet-wide. For the Vallejo representative route option, this 60-foot width offered sufficient space for three railroad tracks, enough to accommodate two tracks for passenger operations and one track for goods movement. However, it is assumed that, for the Interstate 80 representative route option, the trench configuration must fit within that same 60-foot-wide corridor in order to avoid permanent impacts extending outside the existing ROW, onto adjoining properties. The trench is comparatively deep, and the retaining walls supporting each side of the trench will have thickness and will need to be waterproof. At this early stage, the wall thickness is assumed to be approximately 5 feet. Subtracting that thickness (on each side) for the overall trench width leaves only 50 feet of width, which is sufficient for two tracks, but not wide enough for three tracks (three tracks in a 50-foot-wide space would provide only 10 feet of clearance from the outermost tracks to the walls of the trench). Thus, the Interstate 80 option would not be compatible with goods movement. Further details on the trench concept are included in Section V, Structures.

i. Option for Roadway-Under Railroad Grade Separations in Vallejo (Interstate 80 representative route option, included in Carquinez Heights to American Canyon segment)

An alternate option to achieve full grade separation through Vallejo would be to lower each roadway crossing below the railroad - effectively placing each roadway in a trench – between the Highway 29 crossing and the Highway 37 crossing was evaluated, but not pursued further. To evaluate the option of lowering the roadways, an initial concept profile was developed at one crossing, which illustrates that, even with very steep grades to allow the roadway to descend under the tracks, the total length of the lowered roadway would be approximately 900 feet (measured from the point the roadway profile departs existing grade to the point it returns to existing grade) in order to provide sufficient clearance below the track. Variations on this are possible, such as raising the tracks several feet to minimize the roadway grade change, though the work would still extend hundreds of feet beyond the railroad tracks. See the concept in Figure 12.

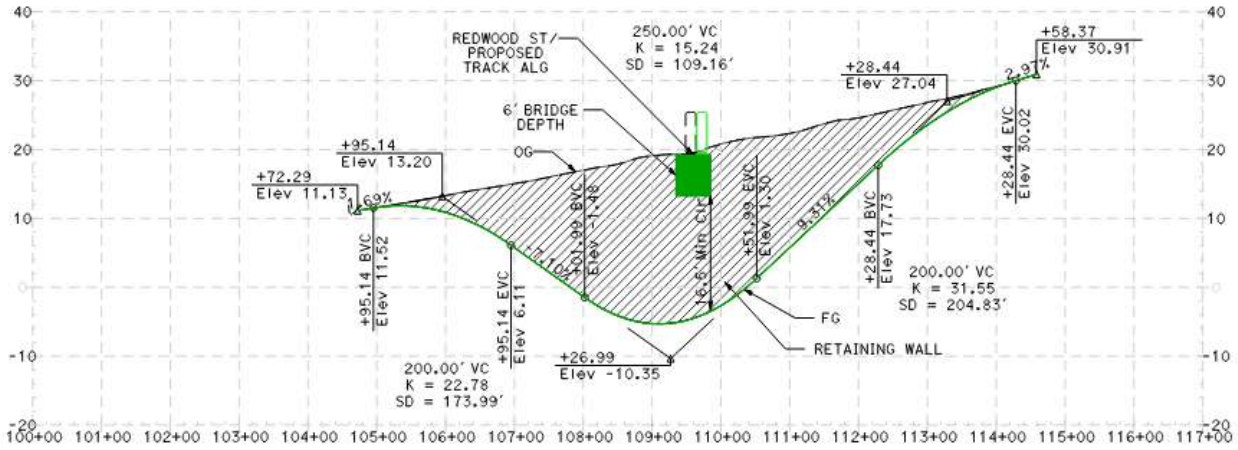


Figure 12: Concept for lowering Redwood Street roadway below railroad grade, viewed looking northward along railroad corridor. Cross section of railroad track alignment and bridge structure indicated by green box near center of profile.

When comparing the options to either a) lower each of the 17 crossings between Highway 29 and Highway 37 in Vallejo, or b) to lower the railroad over the same corridor length, the relative impacts of each approach were evaluated. The 17 existing at-grade crossings along the corridor between Highway 29 and Highway 37 are relatively closely spaced: an average spacing of 1,100 feet between crossings, based on the distance along the rail corridor between Highway 29 and Highway 37 of approximately 18,620 feet. A railroad trench would be slightly longer than this distance to allow for the approach grades: approximately 22,500 feet in total length.

For comparison, if every roadway were lowered below the track, and every lowered roadway required approximately 900 feet of excavation along the road, the total length of roadway excavation would be approximately 15,300 feet (although much of the excavation would indeed be shallow). Note that, as with the Vallejo representative route option, the properties nearest the railroad tracks would lose street access, since the new road surface road would be approximately 20 feet below grade, representing a permanent impact to these properties and necessitating full property acquisitions.

It has been assessed, at this early level, that once all the roadways were lowered and impacted property owners compensated, it would likely be less expensive and less disruptive to lower the railroad in a trench for approximately 22,500 feet, rather than attempting to lower each of the 17 roadways.

For the trench scenario, each roadway would pass over the trench at or near the roadway's existing elevation, meaning minimal disruption for the adjoining property owners once construction is complete and the project is in operation. Property owners adjacent to the trench would likely retain the same access they have today, unlike the Vallejo representative route option which would permanently impact the properties along the roadways that cross the rail corridor.

The trench would extend from Highway 29 northward to Highway 37. North of Highway 37 the tracks would begin to ascend to reach existing grade. The railroad would return to existing grade at the location of the Mini Drive at-grade crossing. Mini Drive, American Canyon Road, and Donaldson Way would each require a grade separation. However, the Interstate 80 representative route option assumes each of these three roadways would be lowered below the railroad. The railroad trench would likely not extend this far north of Highway 37; due to the long distance between grade crossings in this area, lowering the three roadways would likely be more economical than an additional 7,000-foot-long trench. Minor local roadways in this area, Holcomb Lane and South Napa Junction Road, would remain at-grade crossings.

Yet another option would be to raise the tracks through Vallejo above grade on an embankment, with a bridge at each roadway to allow the roadways to pass under the railroad. Such an embankment would likely be the least expensive way to achieve full grade separations through Vallejo. This approach was taken by Caltrain through several communities on the corridor between San Francisco and San Jose. However, this approach is not recommended at Vallejo due to the impacts on the community and has not been considered further.

e) American Canyon to Suisun City Segment (Interstate 80 representative route option)

The segment of the Interstate 80 representative route option from American Canyon to Suisun City would parallel the existing UPRR corridor between these points in a manner similar to the Vallejo representative rote option. As noted previously, a major feature of this corridor is the grade through Jameson Canyon which, at approximately 2%, is steeper than would be acceptable for a major freight route. This corridor is owned by UPRR, but used by short-line operator California Northern, which operates approximately 2-4 trains per day between American Canyon and Suisun City. Because other portions of the Interstate 80 representative route option are not likely to be compatible with through freight train operations, it has been assumed that this relatively steep grade could be retained. This would mean that, in addition to the two new passenger tracks, the freight track profile, including the existing UPRR bridge over Interstate 80, could generally be retained, as could the existing freight profile under Interstate 680 in Cordelia. However, substantial construction would remain in order to provide for the two new passenger tracks.

Other constraints in the Cordelia to Suisun City area include a tunnel, which is assumed to be "daylighted" (excavated to remove the roof and leave an open cut) to allow for up to three tracks. In addition, several new roadway-over-railroad grade separations would be needed in the Suisun City area in order to address the several existing at-grade crossings. Significant track reconfigurations would also be needed to address the extensive network of industrial spurs in the Suisun City area. These are similar to the assumptions for the Vallejo representative route option.

The segment from American Canyon to Suisun City has also been considered by SMART for an extension of their service from Ignacio to Suisun City. Although this would offer the opportunity for cost sharing in this segment, it would also create additional demands on railroad capacity, potentially increasing costs. For example, if a CCJPA train were to operate every 30 minutes in each direction, and a SMART train were to operate between CCJPA trains, there may not be sufficient track capacity for freight trains to cross-over the passenger tracks to perform switching, and additional switching leads may be required, and even potentially "fly-overs," to allow trains to pass from one side of the passenger tracks to the other via rail-over-rail grade separations.

D. Martinez-Benicia East Representative Route Option

The Martinez-Benicia East representative route option generally follows the south side of the existing UPRR corridor from San Pablo to Martinez, excavating into the hillsides (instead of encroaching slightly into the Strait) to provide sufficient space for two additional passenger tracks, separated from and elevated slightly above the existing UPRR tracks to provide resiliency against sea level rise. The Martinez-Benicia East representative route option would cross the Strait just (compass) east of the Interstate 680 northbound highway bridge, relatively close to the existing railroad bridge. At Benicia, the Martinez-Benicia East representative route option would again generally follow the existing UPRR corridor to Suisun City, crossing the Suisun Marsh between Benicia and Suisun on a new bridge, elevated to provide resiliency against sea level rise.

The Martinez-Benicia East representative route option would provide two additional tracks (for a total of four tracks) for the entire distance from San Pablo to Suisun City, thereby enhancing goods movement over the new bridge to a greater degree than the Vallejo representative route option (which could accommodate at most one additional track for freight operations).

The bridge across the Strait between Martinez and Benicia would have a much shorter main span than the potential bridge at Crockett (associated with the Vallejo and Interstate 80 representative routes) since the shipping channel is narrower in this area. The shorter main span at the Martinez-Benicia crossing location is more conducive to designs that could accommodate freight trains. This will be discussed later, in Section V, focusing on the bridge crossings themselves. Figure 13 illustrates the Martinez-Benicia East representative route option.

Figure 13: Martinez-Benicia East and Martinez-Benicia West representative route options. Note that Martinez-Benicia West is largely identical to Martinez-Benicia East, except for the bridge location between Martinez and Benicia.

1. Martinez-Benicia East Representative Route Option Strengths and Challenges:

- Strengths:
  - Established rail corridor, may make environmental documentation and permitting easier
  - Dedicated passenger tracks.
  - Most benefit to goods movement and possibly the broadest appeal to funding agencies (compared to other route options) due to ability of bridge to readily accommodate tracks for freight trains.
  - Ability to construct project in phases as funding becomes available.
  - Improvements in travel time and capacity between San Pablo and Martinez included in the Martinez-Benicia East option would benefit both CCJPA's Capitol Corridor and the San Joaquin Joint Powers Authority's San Joaquin passenger train service.
- Challenges:
  - Construction challenges and impacts to bluffs along the shoreline in order to eliminate sharp curves and provide space for additional tracks (minor encroachments into the Strait have not been considered in this study, but could result in significant cost savings).

- Depending upon limits of right-of-way, some impact may occur to portions of the Carquinez Strait Regional Shoreline that do not have public access due to very steep slopes.
- Elimination of sharp curves at Rodeo and Crockett implies cut-and-cover tunnels under both San Pablo Avenue in Rodeo and under Crockett.
- Additional impacts on communities surrounding the proposed new passenger corridor.

2. Martinez-Benicia East Representative Route Option Segment Descriptions

a) Pinole to Crockett Segment (Martinez-Benicia East representative route option)

The Martinez-Benicia East representative route option begins at the east end of the Common Segment (described earlier) just east of Point Pinole. The representative alignment would be constructed on the inland (south) side of the existing tracks, and at a slightly higher elevation to provide resiliency against sea level rise. In this segment, several alignment adjustments are assumed in order to reduce the sharp curvature and allow higher speeds and reduced travel times. These alignment adjustments would generally add the new CCJPA tracks further inland at curves. In this area, portions of the Bay Trail could be affected and would need to be re-routed to accommodate the additional tracks, especially in areas of the curve reductions noted earlier.

At Rodeo, the representative alignment diverges from the existing tracks to eliminate a sharp curve through the existing Rodeo tunnel. In this area, the Martinez-Benicia East representative route option alignment is similar, but not identical, to the concept for the Vallejo representative route option. To eliminate this sharp curve, the Martinez-Benicia East representative route option would diverge from the UPRR tracks, generally parallel San Pablo Avenue, pass through several parking lots at the Phillips66 refinery, potentially affecting portions of the refinery office and refinery facility itself. As noted for the Vallejo representative route option, though the refinery has not been engaged, it is conceivable that no major process facilities within the refinery would be affected. For the Martinez-Benicia East representative route option, the alignment may be able to extend along and underneath San Pablo Avenue in a cut-and-cover tunnel with a "lid" to support San Pablo Avenue above, thereby using the footprint of San Pablo Avenue to minimize effects on the refinery. In this case, San Pablo Avenue would be reconstructed above the tunnel.[8]

The two tracks of the Martinez-Benicia East representative route option would continue past Selby on the inside of the existing UPRR tracks. This would require excavation into the hillside which, in turn, would require extensive retaining walls with tiebacks to support the soil above.

The existing alignment includes a sharp curve at Crockett where the railroad weaves between the C&H Sugar refinery and the hillside. In this area, it may be possible to straighten that curve and reduce travel time by constructing a cut-and-cover tunnel immediately north of Loring Avenue in Crockett. Such an alignment would affect several tanks near Rolph Street used by C&H, an office building associated with C&H, possibly a fire station, and possibly the Crockett Community Foundation building, though each of these structures could be potentially be historic, and could be relocated. Ground support would be

[8] As noted previously, refineries are complicated process facilities and it is understood that the Phillips66 facility has recently been converted to refine renewable diesel, so many of the facilities are likely new and therefore impacts, if any, could be expensive to mitigate. An option that would avoid impacts to the refinery but involve a long bridge to the north of the existing tracks, around the refinery and over water, appears feasible, but is not currently included in this representative alignment.

needed to support the C&H storage silos. The remainder of the area over the proposed cut-and-cover tunnel appears to consist mostly of vacant property. A detailed route analysis may reveal other alignments in this area that create less disruption, though possibly also employing a cut-and-cover approach to retain usable space on top of the tracks. An initial concept for the alignment of a cut-and-cover tunnel through Crockett is shown in Figure 14.

Figure 14: Concept for cut-and-cover tunnel through Crockett, north of Loring Avenue. Orange line indicates centerline of proposed tracks.

b) Crockett to Martinez Segment (Martinez-Benicia East representative route option)

The Martinez-Benicia East representative route option continues eastward from Crockett along the shoreline, located inland and above the existing tracks on a short bench in the hillside, as shown in Figure 15. A system of retaining walls, potentially with sculpted rock fascia would support the hillside, above. There are slopes above the track evidencing geologic instability along the shoreline; based on previous projects and preliminary reconnaissance and desktop research, it appears feasible to support these slopes with tieback retaining wall systems. Additional information on these tall retaining wall systems is provided in Section V. Note that, in consideration of the uncertainty of environmental impacts and potential for effects on Delta Smelt, no consideration has been made to even slight encroachments into the Strait, such as short bridges or bulkheads (short retaining walls) in the water. However, such an approach could result in significant cost savings were it pursued.

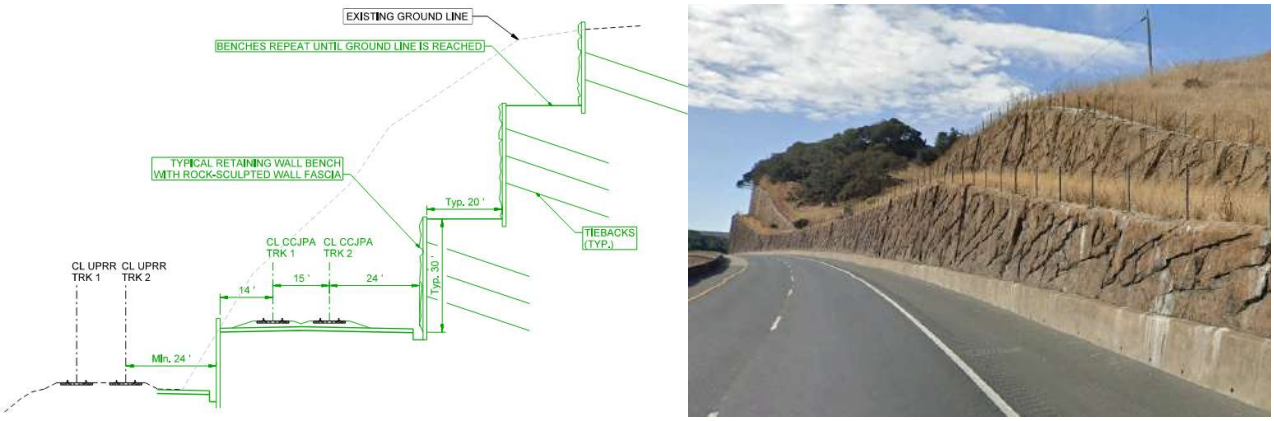


Figure 15:
Left: Concept for adding track on benches above existing UPRR track between Crockett and Martinez. Note that this concept does not involve any encroachment into the Strait (on the left side of this typical section, to the left of the UPRR tracks). Additional detail is presented in Section V.
Right: Photo of similar retaining walls above a roadway, along similar terrain to the south shoreline of the Strait.

In the area between Crockett and Martinez, there are several ridge lines that extend down from the hillside; the existing railroad turns around these. The proposed railroad would cut through several of these ridges with short tunnels in order to reduce curvature and reduce travel time.

This type of construction – raising the tracks on a short bench inland from the existing tracks – would continue from Crockett to UPRR's Ozol Yard, located just west of the Berrellessa Street at-grade crossing.

Based on GIS information, the width of UPRR's right-of-way varies significantly in this segment. The area at the top of the tall bluffs, inland from the UPRR right of way, is part of the Carquinez Strait Regional Shoreline Park. It is possible that acquisitions from the Carquinez Strait Regional Shoreline may be necessary to provide sufficient space for curve widening. However, such acquisitions would be at the base of the bluffs, where there is no public access.

c) Martinez to Benicia Segment (Martinez-Benicia East representative route option)

This segment will be described in two parts:

- Martinez Station Area, and
- Bridge Options and Approach Grades.

i. Martinez to Benicia Segment - Martinez Station Area (Martinez-Benicia East representative route option)

The Martinez-Benicia East representative route option continues through Martinez. Today there are four tracks in the area of the Martinez passenger station; it is assumed that in the future condition there would also be four tracks. In this way, the railroad footprint through downtown Martinez would not be expanded.

The at-grade crossings at Berrellesa Street and Ferry Street would be grade separated.

It appears feasible to re-route the Berrellesa Street crossing further west, as a roadway-over-rail grade separation, with an elevated "T" intersection on Embarcadero Street, supported by retaining walls or bridge structures, on the north side of the tracks, though the parking lot of a private business along Foster Street may be impacted, and additional roadway traffic would traverse Foster Street to Embarcadero using the new grade separation. See Exhibits 3A and 3B in the Appendix for the concept for the Berrelessa Street grade separation.

At Ferry Street, a slight track raise – on the order of 2 feet – appears to provide sufficient vertical clearance to route the roadway under the tracks, though the passenger platforms would need to be raised accordingly. The access road to the station, south of the platform between Estudillo Street and Ferry Street would need to be closed or lowered to meet the new (lower) elevation of Ferry Street. The slopes on Ferry Street, while steep, would meet City criteria for local roads. See Exhibit 4 in the Appendix for the concept for the Ferry Street grade separation.

An additional benefit of grade separating both crossings would be the reduction in train horn noise at these locations. Note that both grade separations are at relatively low-volume roadways, meaning the approach grades could be relatively steep. Similarly, the parcels near the tracks do not require frontage access (or have alternate frontage access), so impacts to adjoining properties would be minimal, though at Berrellesa Street, a business parking lot would be impacted

The passenger station building at Martinez would be unaffected, though the tracks in front of the station may need to be raised several feet to accommodate the Ferry Street grade separation. Raising the tracks would also necessitate raising the passenger platforms several feet. Today, the passenger platform surface is approximately 2 feet below the finished floor of the station building (there are steps and a ramp down from the station to the platform). There appears to be sufficient space to raise the platforms 2 to 3 feet (making the platform surface level, or slightly above the station floor), if needed, while retaining pedestrian connectivity between the platforms and the station. Alternately, there also appears to be sufficient ROW width to reconfigure the platforms to provide a center island platform with grade separated access, though that would reduce the number of platform tracks from three to only two.

ii. Martinez to Benicia Segment - Bridge Options and Effects on Approach Grades (Martinez-Benicia East representative route option)

Two distinct structure types have been investigated for the bridge over the Strait between Martinez and Benicia: steel truss bridges and cast-in-place concrete segmental bridges. The two key constraints at this location are the 153-foot air draft (the required clearance above the water to allow ships to pass unobstructed) and the maritime channel width. At Martinez, the shipping channel width is only approximately 500 feet wide (compared with two channels, each over 1,000 feet wide at Crockett), thereby allowing for several possible structure types. The two structure types are described below:

- **A steel truss bridge:** The advantage of a steel truss bridge is that the deck structure is quite thin, meaning that the tracks would need to be only approximately 10 feet above the bottom of the deck. As a result, to provide sufficient air draft (clearance) above the water, the tracks would be about 10 feet higher than the minimum air draft elevation. Thus, the top of rail elevation would be approximately 163 feet above the water.
    - The most cost-effective concept appears to be a double-deck truss, where the passenger tracks are stacked above the freight tracks. The resulting bridge would look similar to the existing steel truss bridge carrying the eastbound lanes of the existing Interstate 80 roadway between Crockett and Vallejo.
    - A concept with all four tracks at the same elevation on two adjacent bridges (two tracks per bridge, with the superstructures sharing the same piers) would also be possible, and would present a less massive appearance, but also be more expensive. The resulting truss bridges would look similar to the fixed steel truss spans of the existing UPRR bridge.
- **A concrete segmental bridge:** A concrete segmental bridge would look like the northbound Interstate 680 bridge, completed in 2007, which was also a concrete segmental bridge. This type of structure has a very thick deck; the thickest portion would be nearly 30-feet-deep. As a result, to provide sufficient air draft (clearance) above the water, the tracks would be about 30 feet higher than the minimum air draft - approximately 183 feet above the water.

Additional details of the structural considerations and illustrations of the respective bridge types are included later, in Section V.

Note that, despite the different structural types (steel versus concrete), when considering the entire scope of construction between Martinez and Benicia (including different approach configurations for the respective bridge types), there was minimal cost difference between the structure types. This cost

difference is likely to change depending upon the relative costs of steel and concrete building materials at any given time.

A plan and profile extending from Martinez to Benicia illustrating a concept for the concrete segmental bridge is included in the Appendix as Exhibit 5. The concrete segmental bridge, having a higher track elevation, has the more restrictive profile.

The bridge type affects the length of the approach grades based on the minimum top of rail elevation. This study has assumed a maximum grade of 1.5% for freight operations; as noted, this is a preliminary assumption, subject to detailed operational analysis which would need to be conducted in conjunction with UPRR. Since the minimum top of rail elevation in order to clear the shipping channel is fixed for both the steel truss and concrete segmental bridge types (about 163 feet and 183 feet, respectively), the maximum 1.5% grade dictates how long the approach grades would need to be, and how far those approach grades would extend into Martinez and Benicia. It has been assumed that passenger operations could accommodate a 3% grade.

On the Martinez side of the channel, there are several key points that could geometrically constrain the approach grades to the new bridge:

- The Martinez passenger station platforms
- The Ferry Street grade crossing
- The crossing of the railroad over Interstate 680
- The crossing of the ship channel, where top of rail would need to be at least 163 feet above water level

As noted, the Berrellesa and Ferry Street at-grade crossings are assumed to be upgraded to grade separations, mitigating these potential constraints. Similarly, it appears that the Martinez passenger station platforms could be raised several feet, mitigating this potential constraint.

For a steel truss bridge, the 1.5% approach grades would need to start in the vicinity of the Shell Dock private grade separation (an existing private roadway structure over the tracks, owned by the refinery, approximately 2,800 feet east of Ferry Street, connecting the two sides of the refinery across the tracks). This would allow for relatively simple phasing of construction, since much of the existing railroad embankment that climbs toward the existing UPRR bridge could remain in place. The addition of two separate passenger tracks would require rearrangement of switching leads for the refinery and the adjacent main line track leading to Port Chicago and Pittsburg.

Although the passenger platforms at the Amtrak station would not be directly affected by the approach grades for a steel truss bridge, the tracks in front of the station may still need to be raised by approximately 2 feet to accommodate a roadway-under-railroad grade separation at Ferry Street.

For a concrete segmental bridge, which requires a higher track elevation at the navigation channel, the 1.5% approach grade would need to be longer and thus start farther west, in the vicinity of Berrellesa Creek, just west of the Amtrak platforms. This would require raising the Amtrak platforms. The elevation gain in front of the station would be more significant than with the steel truss bridge option; the platform surface may be several feet above the floor of the station (currently a passenger leaving the station steps down to the platforms, in this scenario a passenger would step up), though the elevation gain at the Ferry Street crossing would be more significant. Some impacts would likely occur on the

north side of the tracks to the access road to Joe DiMaggio field and to the Shell refinery. As with the steel truss bridge option, the addition of two separate passenger tracks would require rearrangement of switching leads for the refinery and the adjacent main line track leading to Port Chicago and Pittsburg.

Other aspects of the Martinez approach include a new bridge over a portion of the refinery near Mococo Road, as well as a bridge over Interstate 680. At the refinery, an office building may be impacted, though is it assumed that the building could be removed and replaced with a new building at another location. At Interstate 680, the representative route option would cross over the southbound and northbound freeway lanes with the only intermediate piers being in the median between the southbound and northbound lanes.

East of Interstate 680, the representative route option would be constructed on a tall bridge, curving toward the crossing of the Strait. Several of the piers of this bridge would be located in a wetland area compass east of Interstate 680.

The structural options for the main span bridge are described in more detail in SectionV.

At Benicia, there is more physical space for the approach grades and associated structures. Mimicking the current arrangement, two freight tracks would be located on a “low grade” line, routing inland to parallel the existing single track railroad viaduct (which itself parallels Interstate 680) that crosses over Bayshore Road and Industrial Way as they descend to match the existing railroad grade. The passenger tracks could descend more steeply, matching existing grade near the private road that accesses the automobile loading yard off Industrial Way. The approach grades would cross over the automobile loading yards, meaning some reconfiguration of those yards would be necessary to accommodate the bridge piers. In addition, some reconfiguration of the industrial tracks would also be necessary.

d) Benicia to Suisun City Segment (Martinez-Benicia East representative route option)

The corridor from Benicia to Suisun City extends across the Suisun Marsh and is relatively flat. However, this area is also susceptible to sea level rise. To mitigate the effects of sea level rise, the representative route option would be constructed on a new bridge, several feet higher than the existing railroad, and up to 8-miles-long. It may be possible to refine this concept, possibly eliminating portions of the bridge and instead using lightweight fill, with potentially significant cost reduction. However, additional geotechnical analysis would be required to better understand conditions in the area to determine the feasibility of such a concept.

For the sea level rise analysis, this study has considered parameters similar to those used for the Link21 project. The analysis years considered are 2040 and 2090. The risk aversion scenario is “Intermediate-High.” Based on this analysis, the anticipated sea level elevations in the vicinity of the Suisun marsh are indicated in Table 1.

Time horizon and storm scenario	Sea level elevation above NAVD88
2040 with no storm	6.6 feet
2040 with 100-yr storm	9.7 feet
2090 with no storm	9.2 feet
2090 with 100-yr storm	12.3 feet

Table 1: Projected sea level rise elevations, intermediate-high scenario.

It is important to note that the information in the table above does not represent the amount of increase in sea level elevation. The information above represents absolute elevations, with respect to the North American Vertical Datum of 1988 (NAVD88). The lowest point of the current railroad in the marsh area is at approximately elevation 7.0 feet in NAVD88, though much, if not most, of the railroad in the marsh is located above the lowest point, at elevations ranging from 8.0 to 10.0 feet in NAVD88.

As shown in Table 1, the projected sea level elevation in the year 2090 with storm surge is projected to be 12.3 feet in NAVD88, which is 5.3 feet above the lowest parts of the existing railroad embankment, although only 2.3 feet above the higher portions of the existing embankment.

E. Martinez-Benicia West Representative Route Option

The Martinez-Benicia West representative route option is identical in nearly all respects to the Martinez-Benicia East representative route option. However, between Martinez and Benicia, the Martinez-Benicia West representative route option remains closer to the shoreline and crosses the Strait *west* of the southbound Interstate 680 bridge. Due to constraints at this crossing location, this option was deemed to be extremely complex and expensive and has not received further consideration in this study. Only the segment of this route option between Martinez and Benicia and the associated challenges are described below and illustrated in Figure 16.

Martinez to Benicia Segment (Martinez-Benicia West representative route option)
An option for a bridge on the west side of the existing Interstate 680 bridges was evaluated. However, several major constraints were apparent:

- The Martinez-Benicia West representative route option would be located on the water side of the existing tracks. To make space for the additional tracks, the route would affect large areas of the refinery located on the water (north) side of the existing tracks.
- In addition to the main navigation channel, there are two vessel docks, one close to the Martinez shoreline, and one close to the Benicia shoreline that the Martinez-Benicia West representative route must pass over.
    - The geometry of a new bridge in this area would place it relatively close to the vessel dock on the south, Martinez shore of the Strait. To provide clearance in the event an errant vessel shifted upriver while mooring, the bridge would need to provide the full 153 feet air draft. It appears to be infeasible to obtain this air draft while also maintaining the maximum 1.5% grade and avoiding impacts to the Martinez passenger station (a steeper grade could be employed, though the ability to accommodate goods movement would be lost).
    - The geometry of a new bridge in this area would place it directly over the vessel dock located on the north, Benicia shore of the Strait. As a result, the bridge would need to maintain the full 153 feet vertical clearance for its entire length.
    - The Transbay Cable also runs through this area and may pose a conflict with preferred pier locations and adjustments may be necessary.
- At the north landing, the tracks would need to pass over the Interstate 780/Interstate 680 freeway interchange, meaning the bridge would continue at a very high elevation. Alternately, the bridge could attempt to descend at a steep grade to tunnel under this interchange.

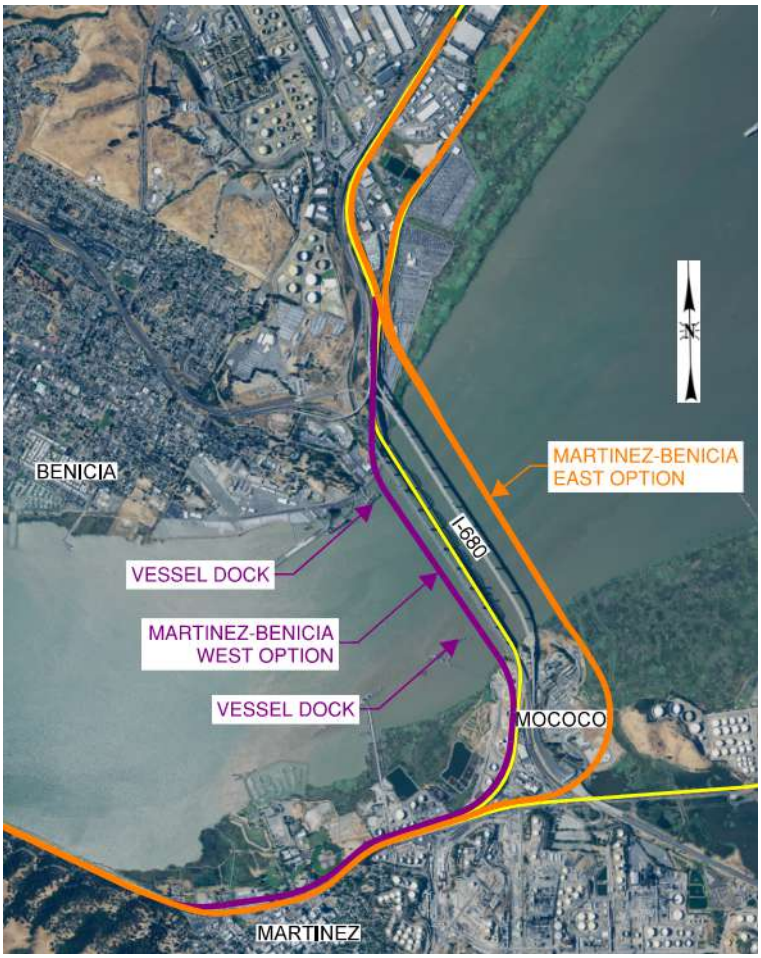


Figure 16:
Constraints for Martinez-Benicia West representative route option (purple line) on west side of Interstate 680 bridges.

For reference, the Martinez-Benicia East representative route option on east side of Interstate 680 bridges is shown in orange.

Existing UPRR line via the lift bridge is shown in yellow

These constraints make a bridge on the west side of Interstate 680 significantly more complex and expensive than a bridge on the east side of the freeway. Conversely, the Martinez-Benicia East representative route option does not have any of these constraints, though it is identical for the entire distance from San Pablo to Suisun City (except for the bridge location at Martinez). As a result of the aforementioned complexities and costs, the Martinez-Benicia West representative route was not considered further.

V. Structures

A. General Considerations for Long Span Structures Across the Carquinez Strait

1. Navigation and Maritime Requirements

The Carquinez Strait is a major shipping channel and large ships transit this waterway on a daily basis. Thus, the ability for any bridge to provide unimpeded vessel navigation through and within the Strait is a primary consideration for the type, clear span length, bridge arrangement and low chord elevation for any proposed structure. Today, there are several high-level, fixed highway bridges in addition to the UPRR vertical lift railroad bridge across the Strait and the shipping channel that provides vessel access to ports along Suisun Bay and to the Port of Stockton.

The existing bridge spans that control navigational clearances over the Strait are:

- The eastbound lanes of the Interstate 80 bridge between Crockett and Vallejo, which is a large steel through truss constructed in the 1950s and strengthened/seismic retrofitted in the 1990s. It provides approximately 1,000 feet of clear channel width.
- The northbound lanes of the Interstate 680 bridge between Martinez and Benicia are supported on a newer (2007) segmental concrete post-tensioned box bridge. This bridge provides approximately 640 feet of clear channel width.
- The southbound lanes of the Interstate 680 bridge between Martinez and Benicia are supported on a steel truss bridge constructed in 1962. This bridge provides approximately 450 feet of clear channel width. Given the age of this bridge, were it ever to be replaced, the new span would likely provide the same clear span over the navigation channel as that afforded by the concrete bridge supporting the northbound lanes, 640 feet.
- The existing UPRR vertical lift bridge sits about 150 feet northeast of the Interstate 680 westbound bridge and only accommodates navigation through a 320-foot-long vertical lift span opening.

Other waterway navigation considerations that affect bridge design include water draft (depth); air draft (clearance above the water); currents and ebb and flow velocities; channel geometry (bends); active dock and mooring facilities; and meets and passes with other vessels in the channel.

Based on the above constraints as well as discussions with the United States Coast Guard and San Francisco Bar Pilots, this study uses the following geometric criteria:

- At the Crockett-Vallejo crossing location, controlling minimum horizontal navigation channel width of 1,000-feet and height of 153 feet above mean lower low water elevation.
- At the Martinez-Benicia crossing location, controlling minimum horizontal navigation channel width of 550-feet and height of 153 feet above mean lower low water elevation.

2. Railroad Loading

The American Railway Engineering and Maintenance of Way Association (AREMA), an independent industry association, has adopted a standardized system to describe the loads (demands) placed on railroad structures known as the Cooper Equivalent load. These are expressed as “E loads” to represent the demands placed on a structure, and “E ratings” to represent the capacity of a structure.[9]

Most freight railroads require E-80 live loading for design of new bridges in accordance with the AREMA Manual for Railway Engineering. Other live loading effects must be considered for fatigue, deflection, and strength of steel bridges as well, termed “Alternative 100 kip axle loading” and/or “F-80 fatigue loading.” This large loading combined with impact loads due to dynamic effects creates the need for larger and stiffer bridges to support railroad tracks.

These high railroad loads ultimately require bridges to incorporate large structural members which are relatively heavy, adding to the weight of the structure itself (known as “dead load”). Because the demands placed on railroad bridges are much higher than those placed on highway bridges, railroad bridges must be stronger, requiring larger structural members, and thus generally have higher dead loads when compared with highway bridges of similar span length. The longer the span length of a

[9] Information on the Cooper Equivalent load system is readily available via the internet and is not repeated here.

railroad bridge, the more dead loads dominate the design, forcing the bridge to work even harder just to hold itself up while maintaining small enough deflections and movements to be serviceable for trains.

By comparison to freight trains, passenger trains tend to be lighter and shorter, so passenger-only lines are sometimes designed for lesser live loading. For example, current CCJPA train consists may produce about E-60 live load effects on shorter spans and much less on long spans, perhaps down to the E-30 range depending on train length. In contrast, freight trains will produce live load effects very close to E-80 on shorter spans and trend downward to around E-50 or E-60 on much longer spans. This means that, effectively, bridges designed only for passenger trains can be lighter and span longer distances than bridges designed to accommodate freight trains.

Together, these are important considerations as bridge span lengths get longer. Figure 17 illustrates the concept with an approximation of the loads: as bridge span lengths increase, the dead loads increase exponentially, forcing bridges with long spans to work much harder just to hold themselves up, compared to bridges spanning shorter distances.

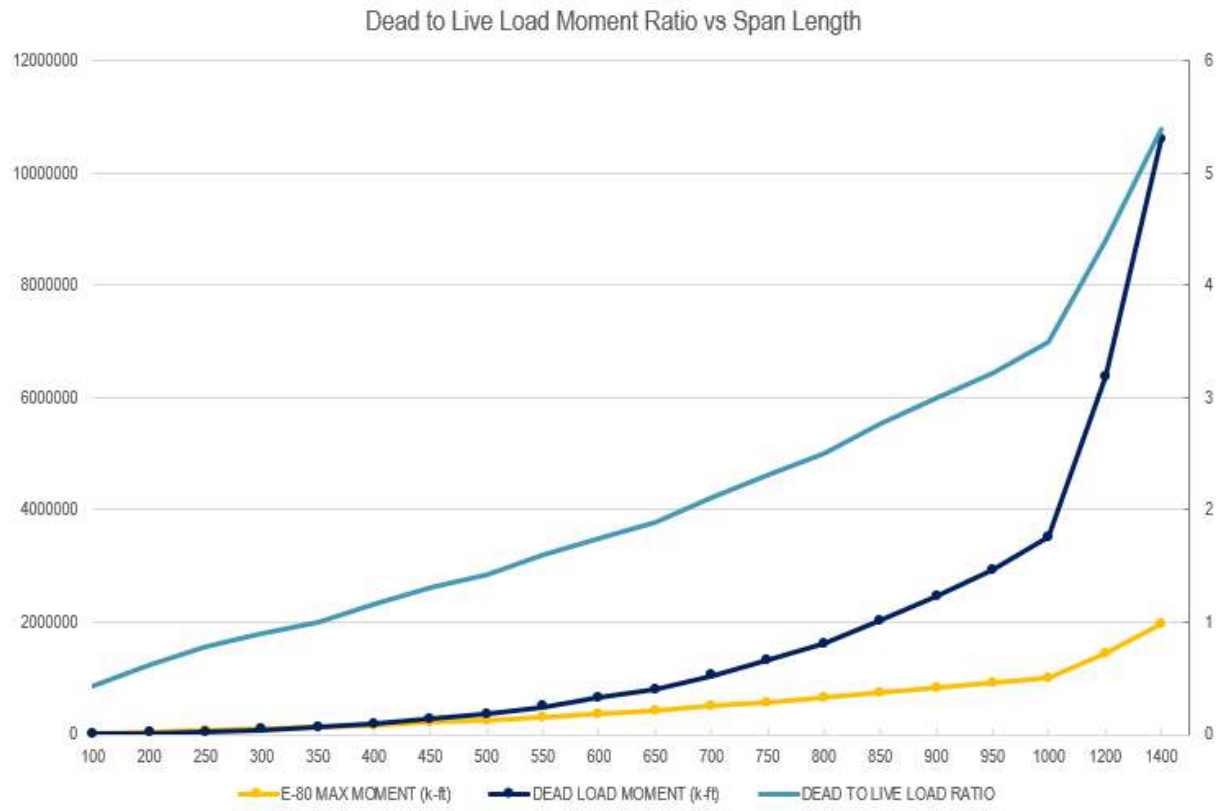


Figure 17: Conceptual comparison of dead load moments (flexural loads, left hand side), live load moments (left hand side), and ratio of dead load to live load (right hand side) resulting from different span lengths (bottom axis), resulting from E-80 rail loading.

3. Stiffness, Deflections, and Thermal Movements

Key factors for the performance of long span railroad bridges are much more critical than typical shorter span bridge designs. Adequate stiffness to maintain track geometry within governing tolerances is critical for safe train operations. As span lengths increase, deflections become even more important to consider since they are directly related to span length raised to the power of 4 (in other words, doubling the span length for a given bridge member would increase the deflection by a factor of 16), and trains, particularly relatively high-speed passenger trains, cannot accommodate a significant deflection (i.e., rise and fall) in a structure. Thermal movements can also be quite large for longer spans. As a result, balancing the required allowances for thermal expansion and contraction versus stiffening against deflections become very challenging. Differential thermal movements between the railroad running rails and the supporting structure must also be considered. Due to the high level of analytical complexity involved, these factors have been considered using engineering judgment to develop preliminary bridge concepts in this high-level study. Additional design effort would be needed to confirm adequate performance for operating and environmental conditions encountered at the candidate bridge sites.

4. Dynamic Effects Including Rolling Stock, Wind, and Seismic Forces

Long span bridges in general require special consideration of dynamic effects due to wind and seismic forces that are beyond the scope of this study. However, wind studies and dampers can limit those effects. Additionally, railroad bridges tend to be stiffer than similar span length highway bridges thus, reducing the potential for these effects to control the design. Seismic design would carefully consider isolation and damping to reduce the bridge response to ground motions and place emphasis on adequate detailing for large displacements, structural ductility and redundancy wherever possible. Long span railroad bridges must be studied for behavior under the effects of a range of potential rolling stock (train types, weights, and axle spacings) beyond the notional loading represented by the Cooper E loading. Understanding the envelope of dynamic behavior from train loading is key to developing adequate floor system strength and fatigue resistance as well as adequate structure stiffness.

5. Long Span Bridges

As shown in Figure 17, long span bridges are controlled more by dead load (weight of bridge and attachments) than by live loading from vehicles. This becomes more pronounced for railroad bridges because the larger axle weights and tight tolerances on track deflection under load push the floor system to be stiffer and heavier. Some bridge types considered for lighter live loading may not be feasible or may not be able to achieve the same span lengths for railroad loading. Further studies are warranted to select the appropriate live load for design of long span bridges carrying freight and passenger trains. For the purpose of this study, E-80 live load was assumed when load conditions would include freight trains and E-50 live load was assumed when load conditions would be limited to passenger trains only.

B. Martinez-Benicia East Representative Route Option: Martinez-Benicia Crossing

The following sections describe the various structural options for a bridge across the Strait between Martinez and Benicia. The water crossing itself would be over 1-mile-long, with the main span across the shipping channel providing an air draft of 153 feet. The approach structures over soft ground and wetland areas, would also be on the order of 1-mile-long, though the approaches would also make use of portions of the existing railroad approach embankments.

1. Martinez-Benicia Bridge Main Crossing Structures

a) Martinez-Benicia Study Option 1: Double-Deck Steel Through Truss

The first option for the Martinez-Benicia East representative route's conceptual alignment across the Strait between Martinez and Benicia would be a steel truss bridge. This bridge would be located just east of the existing Interstate 680 northbound highway bridge. This concept would require 6,600 feet total length of through truss units with 400 feet simple span double deck structural steel trusses on the approaches. This concept would take advantage of continuous span behavior over two units of primary through truss with about 150 feet maximum depth over the piers and a continuous span length arrangement of 445 feet-620 feet-620 feet-445 feet.

The trusses of this bridge type would be generally similar in appearance and size to the existing eastbound Interstate 80 roadway bridge between Crockett and Vallejo. Another example of this bridge type is shown in Figure 18.

Figure 18: Photograph of steel truss bridge, generally similar in size to conceptual design for Martinez-Benicia East crossing steel truss option. This example is the Huey Long combined railroad and roadway bridge over the Mississippi River. Photo courtesy creative commons, "070305-N-7427G-002" by mashleymorgan is licensed under CC BY-SA 2.0.

Because passenger trains can climb steeper grades (for this study, assumed to be 3.0%) than freight trains (for this study, assumed to be 1.5%), some efficiency is expected by placing the two passenger tracks on a higher deck level with a separate floor system, located above the two freight tracks. This would take advantage of the depth of the truss structure (which would be required, regardless of whether there was a separate set of passenger tracks). This would make the floor system much more

efficient than would be possible if all four tracks were placed on the same level, which would result in longer transverse floorbeam spans with more spread between the primary trusses.

Seismic design considerations will be important at this location because the Concord Fault, believed to be active, is approximately one mile from the proposed crossing of the Strait.[10]

Preliminary analysis has been conducted for the continuous through truss railroad structure to identify conceptual member sizing and conceptual structure depth. See Figure 19 for an example of one output from this analysis, a truss chord force diagram.

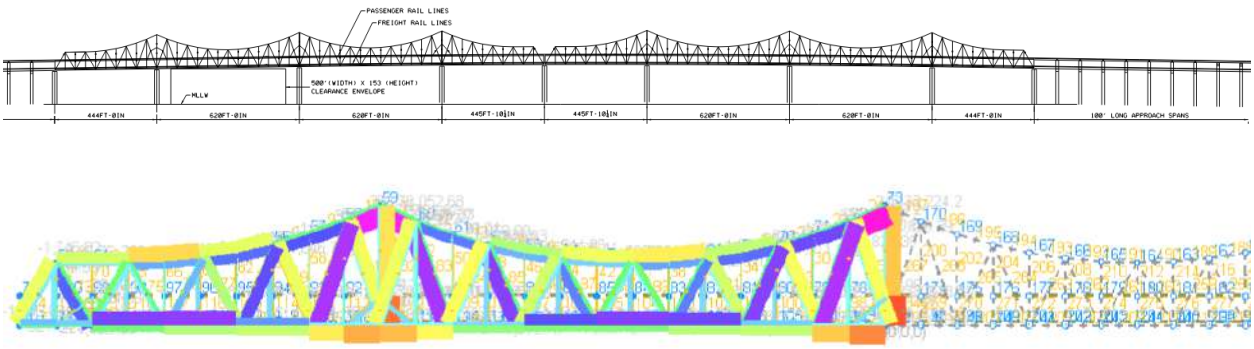


Figure 19:
(Above) Conceptual elevation view of steel truss bridge with two tracks of E-80 freight loads on bottom deck and two tracks of E-50 passenger loads on top deck.
(Below) Conceptual truss chord force diagram for steel truss bridge.

Key assumptions for this bridge include:

- Lower freight deck and floor system designed for two tracks of E-80 live load and upper passenger deck and floor system designed for two tracks of E-50 live load.
- Ballasted deck tracks with standard rail, ties, and rock ballast on all tracks. Further consideration of traditional open deck track system is suggested for future studies to determine whether an open-deck approach would provide greater efficiency with equivalent access and future maintenance (particularly for the passenger tracks, above).
- Steel floor systems consisting of steel stringers and steel floorbeams with cast-in-place concrete deck. Both strength and fatigue resistance are key factors influencing the floor system member sizes.
- Large welded or bolted steel box sections for most truss members.
- Reinforced concrete substructures supported on pile caps at water level with deep foundations.
- Deep foundations assume large diameter steel casings with drilled shafts in rock below bay mud and other overburden.
- Large dolphins and fenders around pile caps to protect the bridge from vessel impacts.

[10] Based on USGS "Preliminary Geologic Map of the Napa and Bodega Bay 30'x60' Quadrangles, California", compiled by Wagner and Gutierrez, 2017

i. Opportunities:

- Widely accepted bridge type for long span freight railroad bridges across North America.
- Long history of proven performance.
- Certainty of adequate strength and stiffness to meet serviceability requirements.
- Ballast deck is widely preferred for quality and maintainability of tracks on modern bridges.
- Can be designed with internal member and connection redundancy.

ii. Challenges:

- Steel structure in this chloride and moisture-rich environment requires special coatings for long lifespan.
- Requires careful design and detailing to avoid fatigue-shortened life or risks of damage causing instability or progressive collapse.
- Large mass of steel truss results in larger seismic demands on substructures and foundations.
- More significant visual impact compared to a segmental cast-in-place concrete structure.

b) Martinez-Benicia Study Option 2: Segmental Cast-In-Place Concrete Post-Tensioned Box

The second option for the Martinez-Benicia East representative route's Martinez-Benicia crossing would be a segmental cast-in-place concrete post-tensioned girder bridge. Unlike the first option, this option would have two freight tracks and two passenger tracks adjacent to each other, at the same elevation, over the Strait. The bridge would have a maximum span of 620 feet and the structure depth would vary from 50 feet at the piers to 25 feet at mid-span. The cross section would have three internal open cells with a concrete web roughly centered under each track to provide the most efficient cross section.

This type of bridge would be nearly identical in appearance to the existing northbound Interstate 680 highway bridge, although the railroad bridge would have deeper sections and thus, be somewhat higher in order to provide the same navigational clearance. A photograph if the Interstate 680 northbound bridge is shown in Figure 20.

Figure 20: Photograph of existing Intestate 680 northbound highway bridge. The proposed segmental cast-in-place concrete railroad bridge would be in front of (relative to the camera in this view) and generally similar in appearance to the Interstate 680 bridge. However a railroad bridge would have a thicker deck structure than the Interstate 680 highway bridge. Photo courtesy of creative commons, "Benicia-Martinez Bridge 1 (cropped)" by User:Downtowngal is licensed under CC BY-SA 3.0.

Preliminary analysis has been conducted for the segmental cast-in-place concrete, post-tensioned railroad structure to identify conceptual member sizing and conceptual structure depth. See Figures 21 and 22 for examples of the output from this analysis.

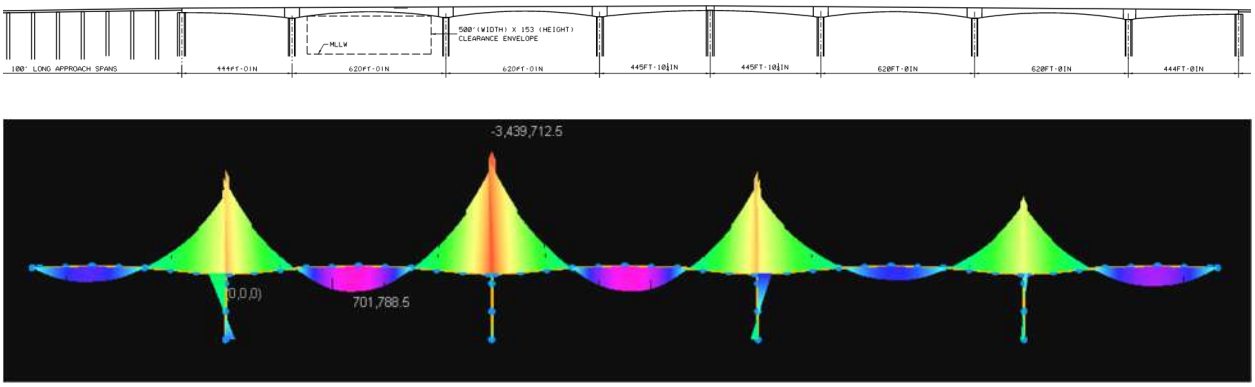


Figure 21 (Above):
Conceptual elevation view of segmental cast-in-place concrete post-tensioned box bridge (above) and conceptual moment diagram for selected spans for segmental cast-in-place concrete post-tensioned box structure (below).

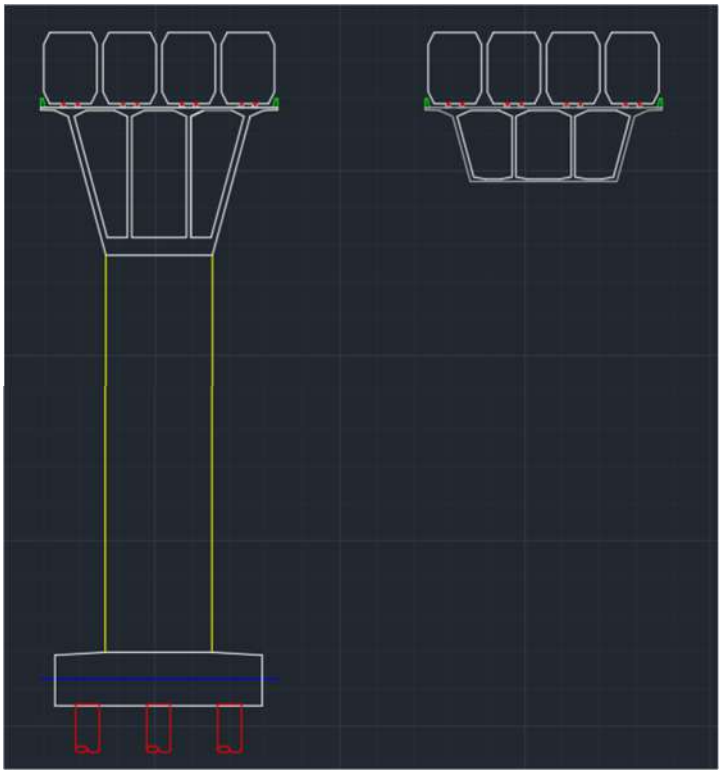


Figure 22 (Left):

Conceptual cross section of three-cell of segmental cast-in-place concrete, post-tensioned box structure used for conceptual structural analysis. Cross section at left is at a pier, cross section at right is mid-span.

It is assumed that a cast-in-place concrete bridge would be built using the balanced cantilever method, similar to how the existing northbound Interstate 680 bridge was built. The concrete box would need to be heavily prestressed in the longitudinal direction for cantilever, mid-span flexure and continuity to counteract a range of potential train positions and lengths. It would need to be prestressed transversely in the top deck and, most likely, also prestressed in the vertical direction at each web.

Key assumptions for this bridge include:

- All four tracks would be on the same vertical alignment above the post-tensioned box top slab.
- Direct fixation track with rail supported on raised concrete plinths slightly above the deck level.
- Two tracks of E-80 live load for freight and two tracks of E-50 live load for passenger, where loads from any type of train could be accommodated on any of the four tracks.
- Reinforced concrete substructures supported on pile caps at water level with deep foundations.
- Deep foundations assume large diameter steel casings with drilled shafts in rock below bay mud and other overburden.
- Large dolphins and fenders around pile caps to protect bridge from vessel impacts.

i. Opportunities:

- Similar construction technique as used for the existing Interstate 680 eastbound bridge; could reduce construction costs compared to large steel trusses.
- Increased seismic resistance through internal redundancy and ductility.
- Less visual impact and potentially less risk of changing or blocking views than large steel trusses.

ii. Challenges:

- Freight railroads in North America do not have significant experience with direct fixation track and the feasibility of this bridge type would be reduced if ballasted deck were required.
- Increased depth required for railroad loading could make this bridge look bigger and heavier than the nearby existing Interstate 680 eastbound bridge.
- Increased depth under the deck level also requires a raised profile for freight as compared to the double deck truss option, which pushes elevated tracks higher and further into Martinez, likely resulting in a slight raise through the existing passenger station downtown.
- While the construction methods and longevity of this type of post-tensioned box construction have proven viable for similar span lengths, experience with this type of bridge on North American railroads is minimal so acceptance by railroads may be complicated and not assured.
- Large mass of post-tensioned box construction results in large seismic demands on substructures and foundations.

c) Other Steel Through Truss Options

In addition to the two options studied here, other potential options include different arrangements of simple and continuous trusses for support of a new Carquinez Strait bridge with similar span lengths. These other options could be just as viable as the steel truss option considered here and with total costs in a similar range.

Another potential option would be adjacent, side-by-side trusses. This option would be more expensive but would not be as tall as a double-deck steel truss bridge. A bridge constructed in this manner would look similar to the spans of the existing railroad bridge (which are approximately 530-feet-long), but the

span over the shipping channel would be mounted higher above the water to provide the necessary vertical clearance (such a bridge would be similar in height to the UPRR lift bridge in its raised position).

2. Martinez-Benicia Bridge Approaches (Martinez-Benicia East Representative Route Option)

The Martinez-Benicia bridge would be the high point of the railroad between Oakland and Sacramento. To gain sufficient elevation, the tracks would need to climb gradually from an elevation of approximately 12 feet to 15 feet at Martinez and Benicia to at least 163 feet at the crossing of the shipping channel. To accomplish this, long approaches would be necessary (such approaches existing today for the UPRR lift bridge though, because the rail elevation is much lower at the lift bridge, they have shallower grades and are not as long).

Where the new approaches are more than approximately 50-feet-tall, or where the approaches cross over obstacles (such as Interstate 680) it is assumed that bridges would be required and be more cost-effective than retained fill embankments. Where the approaches are less than approximately 50-feet-tall, is has been assumed that lightweight cellular concrete retaining structures would be feasible and cost-effective.

a) Bridge Portion of Martinez-Benicia Approaches

i. Bridge Approach Option 1: Double-Deck Steel Transition Structures

Beyond the main Strait crossing on both ends, long viaducts would be needed to transition back to existing grades. The first option for these bridges would be steel deck plate girders with reinforced concrete decks with varying span lengths between 120 feet to 220 feet. With the higher passenger deck level of the main bridge, transition structures would be needed to spread out the track alignments horizontally and then gradually bring the upper deck level down to meet the lower freight tracks. Long straddle caps composed of welded steel box beams are necessary to support these spans through the transition zones and over other track and roadway crossings.

Key assumptions for the double-deck approach bridge include:

- Ballasted deck tracks with standard rail, ties and rock ballast on all tracks.
- Welded steel girders and cast-in-place concrete deck all placed below the tracks.
- Reinforced concrete substructures with deep foundations.

(a) Opportunities:

- Widely accepted bridge type for freight railroad bridges across North America.
- Long history of proven performance.
- Certainty of adequate strength and stiffness to meet serviceability requirements.
- Ballast deck is widely preferred for quality and maintainability of tracks on modern bridges.
- Opportunity to reduce structure cost if only passenger service were accommodated, since the bridge would need to carry fewer tracks and approach grades could be shorter.

(b) Challenges:

- Steel structure in this chloride and moisture-rich environment requires special coatings for long lifespan.
- Long span straddle caps to support spans in transition zones add complexity to design and detailing and add cost.

- If the railroad were electrified with overhead catenary, vertical clearances on a steel truss bridge would need to be increased slightly, though this would not result in substantially increased costs.

A sample of this configuration, transitioning to the double-deck steel through truss, is illustrated in Figure 23.

Figure 23: Typical sections illustrating the steel plate girder approach sections associated with the double-deck steel truss concept. Approaches transition from side-by-side tracks near the bottom of the approaches (left) to stacked tracks near the mid-point of the approaches (center) to a full double-deck configuration at the approaches before and after the main truss span, as well as the main truss span itself (right).

ii. Bridge Approach Option 2: Segmental Cast-In-Place Concrete or Precast/Prestressed Concrete Post-Tensioned Box Bridges

Similar to Option 2 for the main straight crossing, post-tensioned box spans could also be used for bridge approaches. This type of approach bridge would only be used in a single-level scenario, so these would not be compatible with a double deck steel through truss, were that bridge type selected for the main span across the Strait. Span lengths for these approach bridges would vary from about 150 feet to 250 feet, and could be constructed using the balanced cantilever method with cast-in-place or precast concrete box segments or in a span-by-span approach with better overland access than the main crossing. Because of the significantly shorter span lengths, the span depths could be reduced (compared

to the 600-foot-long main span discussed earlier). The configuration could be one wide girder with three open cells and webs roughly placed at each track (similar to the main span) or the approach bridge segments could use a split arrangement with two single cell concrete box girders supporting two tracks each.

Key assumptions for the concrete approach structures include:

- All tracks placed above the post-tensioned box top slab.
- Ballasted deck tracks with standard rail, ties and rock ballast on all tracks.
- Reinforced concrete substructures with deep foundations.

(a) Opportunities:

- Similar construction technique as used for the existing Interstate 680 Eastbound bridge and the new San Francisco Oakland Bay Bridge could reduce construction costs compared to steel spans.
- Proven bridge type and construction methods used throughout California.
- Need for large steel straddle caps is reduced or completely avoided since all tracks are on a similar vertical alignment.
- Increased seismic resistance through internal redundancy and ductility.
- Opportunity to reduce structure cost if only passenger service were accommodated, since the bridge would need to carry fewer tracks and approach grades could be shorter.

(b) Challenges:

- While the construction methods and longevity of this type of post-tensioned box construction have proven viable for similar span lengths, North American railroads have minimal experience with this structure type, so acceptance may be complex and not assured.

iii. Other Steel Bridge Approach Span Options

In addition to welded steel deck plate girders with cast-in-place concrete deck, other steel bridge arrangements may be possible or preferred in some situations. Steel plate decks, steel through plate girders, and steel rolled beam spans are also potential options for the main crossing approaches.

b) Retained Earth Portion of Martinez-Benicia Approaches

i. Retained Earth Approach Option 1: Lightweight Cellular Concrete Fill (LCCF) Retaining Structures

Soils in the area of the approach fill are expected to have low bearing capacity: much of the soil in this area is a formation known as “Young Bay Mud” which cannot support heavy loads and resulting bearing pressures. In order to reduce bearing pressures and minimize the footprint beneath the raised tracks on bridge approaches for the Martinez-Benicia crossing, lightweight fill is proposed to minimize both settlement and the construction footprint through developed areas. One proven approach to this is using cellular concrete, which is simply Portland cement grout mixed with foam to create tiny air bubbles throughout the fluid mix, resulting in a matrix of spherical air voids within a solid concrete mass. This cellular concrete is stronger than soil, but much weaker than typical concrete and thus must be retained and supported by utilizing external walls and/or internal reinforcing. Mechanically Stabilized Earth (MSE) wall systems consisting of precast concrete wall panels and galvanized steel reinforcing elements have been used successfully to retain LCCF and are proposed here as well. See Figure 24.

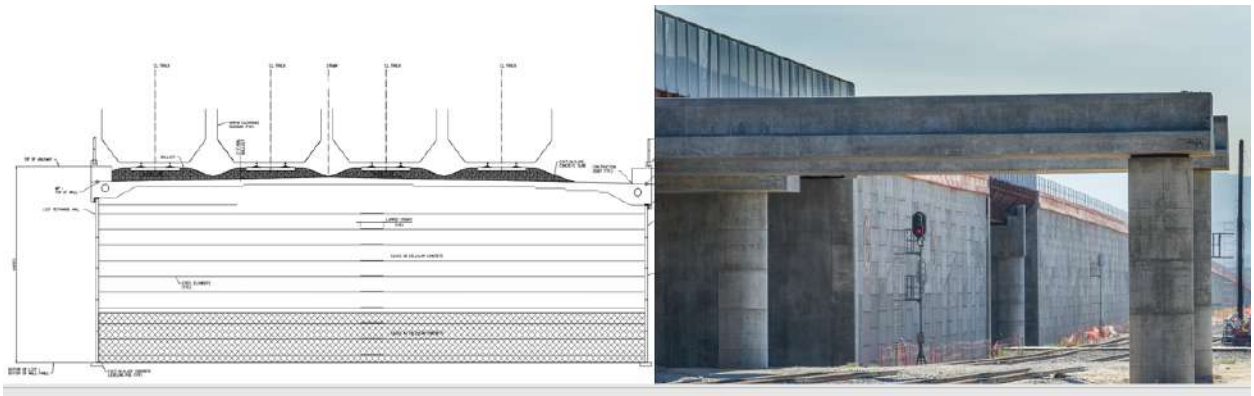


Figure 24: Typical section and photograph of typical lightweight cellular concrete approach structure.

Key assumptions for LCCF approaches include:

- Precast concrete wall panel system with steel reinforcing elements, typically a proprietary MSE-wall product for exterior walls, which can have a range of aesthetic finishes applied.
- LCCF provides the mass and creates a solid block structure to support the tracks above.
- Drainage, waterproofing, and potentially a concrete slab to support tracks.
- Minimal foundations, typically small concrete leveling pads beneath the wall facing and ground improvement techniques beneath the fill.

(a) Opportunities:

- LCCF retaining structures greatly reduce bearing pressure and settlement and usually can be implemented without deep foundations.
- Reduced mass and large block structure increase seismic stability and reduce seismic demands on the foundation.
- Construction methods require only small equipment and can reduce space needed, truck trips generated, and potential air quality concerns compared to earthen fills.
- Potential for greatly reduced costs compared to traditional retaining walls.

(b) Challenges:

- Relatively new structure type for support of railroad tracks; may be challenging to gain acceptance by freight railroad stakeholders (though railroads in California have used this structure type previously, albeit in areas with simple geotechnical conditions).
- High seismic and poor subsurface conditions may dictate ground improvements or even deep foundations in order to implement this structure type.

c) Other Retaining Wall Types

Other retaining wall types may be feasible for the Martinez-Benicia bridge approaches as well, such as cast-in-place concrete walls, precast concrete modular walls (often proprietary in nature, such as T-walls and MSE walls, for example) and anchored cast-in-place U-walls. However, based on the underlying Young Bay Mud soil formation, ground improvement or deep foundations are expected to be required to support such wall types. As a result, these have not been considered for this study. In addition, some

of these potential wall types have not gained wide acceptance with freight railroads and could pose challenges to achieve that acceptance.

C. Vallejo and Interstate 80 Representative Route Options: Crockett-Vallejo Crossing

The following sections describe the options for the Strait crossing between Crockett and Vallejo associated with the Vallejo and Interstate 80 representative route options. This crossing location requires a main span that provides a clear width of over 1,000 feet over both shipping channels, which limits the feasible structure types. On the south side of the Strait, the existing high ground provides a simple approach because it is at nearly the same elevation as the bridge. On the north side of the Strait, while the topography is relatively high, there is substantial development along the possible routes for a rail line, including residential areas and the California Maritime Academy (as described earlier, in Section IV).

In order to achieve the long clear span openings for navigation at the Crockett-Vallejo crossing, different bridge types have been considered in order to be both structurally efficient and visually appealing. Very large and heavy cantilever and continuous truss types are not expected to obtain public acceptance at this location based on appearance, and such massive steel trusses come with extremely high cost.[11] Instead, cable-stayed and suspension bridges with two tracks have been assumed as the baseline for this bridge location. Likewise, passenger rail E-50 live loading (as opposed to E-80 live loads for freight trains) has been considered as the baseline for this crossing. These constraints have been incorporated because this location requires an extremely long span to clear the shipping channel and because these representative route options have limited ability to accommodate freight trains.

However, further consideration could be given to incorporating freight E-80 live loading into the design, as well the possibility of a third, dedicated freight track. These additional constraints would significantly increase the cost of any bridge at the Crockett-Vallejo crossing location. Although conceptual designs have not been developed, adding the capability to accommodate freight service would approximately double the cost of a bridge at this location. Moreover, it is important to note that cable-stayed and suspension bridges have not been used anywhere in North America for freight loading (though there are overseas examples). It is not certain that these bridge types could provide sufficient stiffness and serviceability for heavy freight live loading conditions in a cost-effective manner.

1. Crockett-Vallejo Bridge Main Crossing Structures

a) Crockett-Vallejo Study Option 1: Cable-Stayed Bridge

The bridge would consist of two main cable-supported spans of 1,100 to 1,200 feet between three post-tension concrete pylons with back spans of 500 to 600 feet for a total bridge length of about 3,400 feet. The middle pylon would be aligned with the existing middle pier of the 1950s continuous truss for the Interstate 80 eastbound bridge and splits the middle of the Interstate 80 westbound suspension span. The deck would be lightweight concrete.

Key assumptions for a cable-stayed bridge:

[11] To obtain the required navigational clearances, a steel truss bridge would have the size and appearance of the Quebec Bridge in Quebec, or the Firth of Forth bridge in Scotland. Photographs and descriptions of these massive structures are readily available on the internet.

- The analysis assumes two tracks of E-50 live load, accommodation only passenger rail operations. However, an allowance has been made in the cost estimate for an additional freight track associated the Vallejo representative route option.
- Direct fixation track on raised concrete plinths.
- Steel girder main longitudinal members with composite cast-in-place lightweight concrete deck.
- Steel cable tendons spanning diagonally down from each pylon to support the longitudinal girders.
- Steel cables likely cross/overlap at midspan of the long main spans to improve stiffness.
- Anchor cables of back spans may need to be grouped with added uplift anchorage piers within the shorter back spans to provide adequate stiffness for the heavy train loading.
- Large reinforced concrete pylon towers rising approximately 350 feet above deck level.

i. Opportunities:

- Obtaining adequate stiffness for the deck and cable-supported longitudinal members should be more easily accomplished with a cable-stayed bridge than a longer suspension span.
- Cable-stayed bridges are generally considered aesthetically pleasing.

ii. Challenges:

- Very large combined compression and bending in composite longitudinal girders and deck section at the pylons.
- Large cable tendons will be required for strength and stiffness.
- Obtaining adequate stiffness and fatigue resistance for the cables and longitudinal girders may be challenging for rail loading when considering dynamic effects. This would be exacerbated by heavy freight trains and as a result this structure type may not be able to accommodate freight operations (additional analysis would be required).
- The middle pylon of the cable stayed bridge would change view of existing westbound Interstate 80 suspension span (which has no middle pylon) and may elicit objections from the public.
- Direct fixation track is required to reduce dead load. However, direct fixation track does not have proven performance on freight operations in the United States.

Preliminary conceptual analysis of a cable stayed bridge has been performed, illustrated in Figure 25.

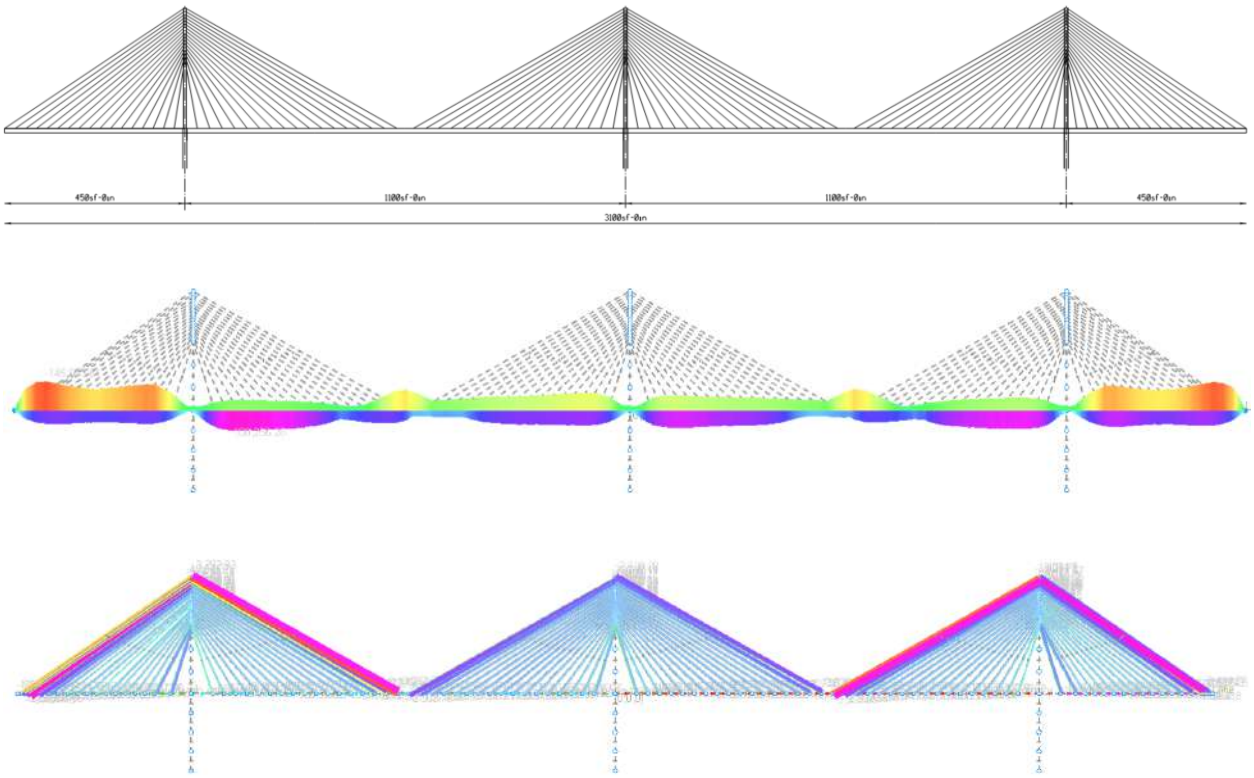


Figure 25:
Top: Conceptual elevation view of cable-stayed structure.
Middle: Conceptual longitudinal girder moment diagram.
Bottom: Cable stay tension forces.

b) Crockett-Vallejo Study Option 2: Suspension bridge

The bridge consists of a cable-supported span of 2,400 to 2,600 feet suspended between two tall towers with rather short anchor spans of 400 to 500 feet for a total bridge length of about 3,400 feet. This bridge would visually be similar to the existing westbound Interstate-80 suspension span.

Key assumptions for a suspension bridge:

- Two tracks of E-50 live load assume passenger rail only operations on this crossing.
- Direct fixation track on raised concrete plinths.
- Steel truss main longitudinal members with a steel girder floor beam and stringer floor system and cast-in-place lightweight concrete composite deck.
- Steel cable hangers suspending the longitudinal trusses from the main suspension cable supports.
- Post-tensioned rock anchors would be needed to support the anchor span reactions from the main suspension cables in order to provide adequate capacity and stiffness for the heavy train loading.
- Large reinforced concrete towers rising about 500 feet above deck level.

i. Opportunities:

- Suspension bridges are generally considered aesthetically pleasing.
- Matching the existing westbound Interstate 80 bridge could reduce viewshed concerns from the public.

ii. Challenges:

- Very large suspension cables, towers and anchorages are required to support railroad loading.
- Obtaining adequate stiffness for the deck and cable-supported longitudinal members requires a heavier and stiffer longitudinal structure than a cable-stayed bridge.
- Dynamic effects must be carefully considered for such a long span supporting heavy axle load trains. May not be able to accommodate freight operations.
- Direct fixation track is required to reduce dead load. However, direct fixation track does not have proven performance on freight operations in the United States. May not be able to accommodate freight operations.
- Large thermal and seismic movements may be difficult to accommodate with direct fixation track and could require very specialized track components to implement.

2. Crockett-Vallejo Carquinez Heights Approach Span Viaduct (Vallejo Representative Route Option)

a) Study Option 1: Segmental cast-in-place concrete post-tensioned box

Beyond the main Strait crossing on both ends, additional bridge spans are needed to transition to tunnels or existing grades. On the south side of the Strait, at Crockett, these spans would be relatively short. However, on the north side of the Strait, at Vallejo, these spans would be much longer, particularly for the Vallejo representative route option that includes a long bridge around and in front of the bluff at Carquinez Heights. A series of segmental cast-in-place concrete post-tensioned box spans would be similar to the options available for the Martinez-Benicia bridge approaches. Span lengths would be approximately 250 feet and could be constructed using the balanced cantilever method with cast-in-place or precast concrete box segments or in a span-by-span approach with a traveling gantry crane. The bridge segments would use a single cell concrete box girder to support two tracks from the north end of the main spans to the touchdown into Vallejo.

Key assumptions for the concrete approach span option:

- All tracks placed above the post-tensioned box top slab.
- Ballasted deck tracks with standard rail, ties and rock ballast on all tracks.
- Reinforced concrete substructures with deep foundations.

i. Opportunities:

- Improved aesthetics compared to typical steel girder bridge can be achieved.
- Durability of post-tensioned concrete in high moisture and chloride environment can be better and less expensive than steel spans.
- Similar construction technique as used for the existing Interstate 680 eastbound bridge and the new San Francisco Oakland Bay Bridge could reduce construction costs compared to steel spans.
- Proven bridge type and construction methods used throughout California.
- Increased seismic resistance through internal redundancy and ductility.

ii. Challenges:

- While the construction methods and longevity of this type of post-tensioned box construction have proven viable for similar span lengths, experience with this for North American railroads is minimal so acceptance may not be a simple matter.

b) Study Option 2: Steel Deck Plate Girders

Although a post-tensioned concrete structure is the baseline assumption for the Carquinez Heights approach span, a more conventional steel deck plate girder would also be an option. A steel deck plate girder structure with reinforced concrete decks would have varying span lengths between 150 to 220 feet. This type of approach span would be similar to the Martinez-Benicia bridge approach Option 1.

Key assumptions for the steel deck plate approach span option:

- Ballasted deck tracks with standard rail, ties and rock ballast on all tracks.
- Welded steel girders and cast-in-place concrete deck all placed below the tracks.
- Reinforced concrete substructures with deep foundations.

i. Opportunities:

- Widely accepted bridge type for freight railroad bridges across North America.
- Long history of proven performance.
- Certainty of adequate strength and stiffness to meet serviceability requirements.
- Ballast deck is widely preferred for quality and maintainability of tracks on modern bridges.

ii. Challenges:

- Steel structure in this chloride and moisture-rich environment requires special coatings for long lifespan.
- Potential aesthetic concerns for this bridge type compared to Option 1.

D. Vallejo Trench

One way to reduce community impacts would be to lower the tracks beneath existing grade through the entire area. In the case of Vallejo, it may be preferred to convert the existing UPRR-owned corridor to a depressed trench to allow for continued access and site lines within the community above.

For construction and ongoing use of depressed trenches in low-lying areas, exclusion of groundwater and control of drainage are very important considerations. Top-down construction of retaining walls on both sides is necessary to provide temporary excavation support and control groundwater. Ideally, the walls for temporary excavation support would also be incorporated into the final structure. Working in the wet bottom of excavation often requires a working surface called a "mud slab" and temporary pumping to handle groundwater intrusion and storm water during construction.

The permanent structure would be designed to handle future use and development adjacent to the railroad corridor while providing drainage, inspection and maintenance access within the trench. It would be designed and detailed to exclude or permanently drain groundwater and storm water (via pumping stations) and to counteract any effect of buoyancy. For example, the trench may need piling at the bottom to hold the trench down, rather than support it. The top of a trench is generally left open, which improves ventilation and emergency access and egress. However, at roadways and other crossing locations, bridges spanning over the trench will be necessary for continued at-grade accessibility. It

would also be possible to add a “lid” to provide open space over portions of the trench, making the trench resemble the cut and cover tunnels (described in the next section).

See Figure 26 for a conceptual representation of a trench.

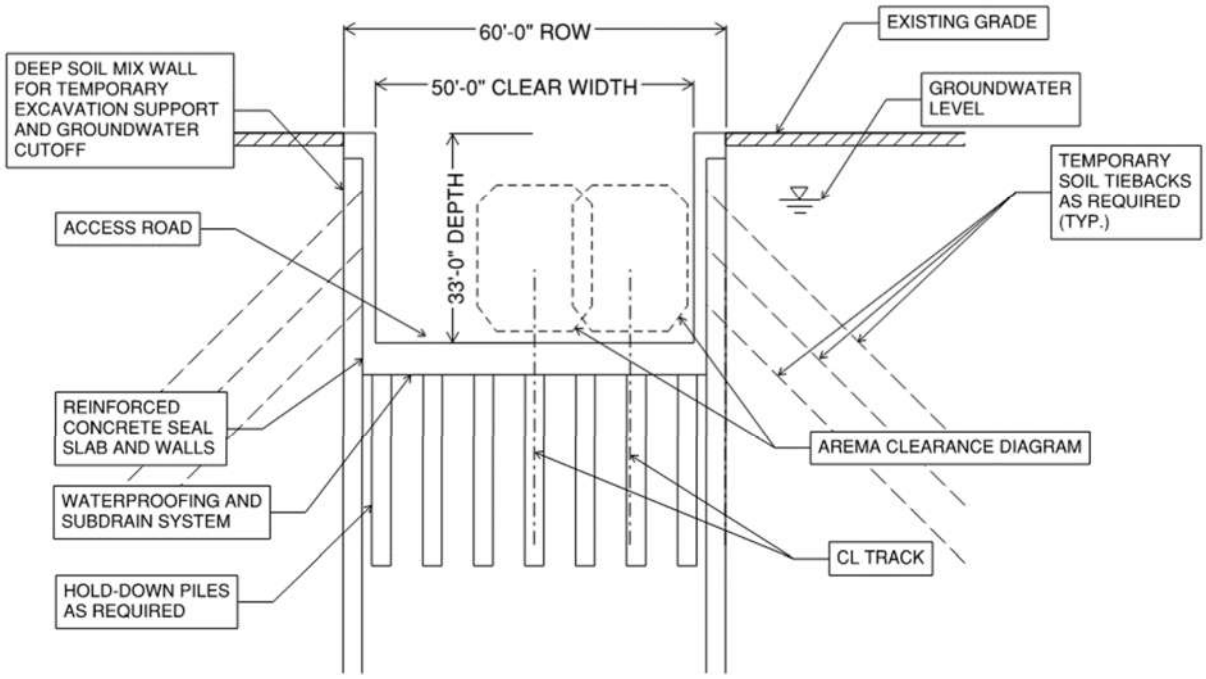


Figure 26: Conceptual typical section for open trench through Vallejo

Key assumptions for the Vallejo trench:

- Walls comprised of deep soil mix groundwater cutoff and temporary excavation support walls with soil tiebacks
- Mud slab working surface with sandwich membrane waterproofing
- Soil-cement hold-down piles
- Vertical membrane waterproofing, drainage gallery, and sub drainage system
- Reinforced concrete seal slab
- Reinforced concrete composite walls
- Storm drain system and signal ducts

1. Opportunities:

- Less community impact with fewer elevated crossings, less visible retaining wall, and more continuity compared to the “Vallejo” route option approach (which contemplated raised roadways at each grade crossing).
- Generally considered more favorable aesthetically

2. Challenges:

- Significant underground utility impacts are anticipated, especially gravity storm and sanitary sewers that must be pumped or completely rerouted

- Potential for large volumes of contaminated subsurface soil and water that must be disturbed, treated and disposed to allow for excavation.
- Significant community disruption during a multi-year construction period.
- Despite attempts to develop this concept in a way that minimizes impacts on neighboring properties, there will likely be some construction impacts.

E. Cut and Cover Tunnels at Crockett and Rodeo

Where adjacent development or terrain limits space, but a corridor is necessary for additional tracks, "cut and cover" tunnels may provide a solution. In this case, retaining walls, constructed top-down, on both sides would provide temporary excavation support and control groundwater. Ideally, the walls for temporary excavation support would also be incorporated into the walls for the final structure. The permanent structure would be able to handle future use and development above and adjacent to the railroad corridor while protecting rail service within the tunnel with provisions for drainage, inspection, and maintenance access. The top cover "lid" of the cut and cover tunnel is effectively a single span bridge and would be designed for roadway traffic, construction surcharges, soil fill, and superimposed construction or development, as appropriate. See Figure 27 for a conceptual representation of a cut-and-cover tunnel.

Key assumptions for cut and cover tunnels:

- Secant pile walls alternating lean concrete shafts with reinforced concrete shafts with soil tiebacks or rock anchors as required
- Vertical membrane waterproofing, drainage gallery and sub drainage system
- Reinforced concrete composite walls
- Precast/prestressed concrete beam bridge stringers (such as boxes or bulb tees)
- Cast-in-place concrete top slab
- Membrane waterproofing and soil or roadway pavement section cover
- Storm drain system

1. Opportunities:

- Less community impact
- Considered more favorable aesthetically compared to an open-trench scenario
- Possibility of community open space or development on top of tunnel at Crockett

2. Challenges:

- Potential for significant underground utility impacts
- Potential for contaminated subsurface soil and water that must be disturbed, treated, and disposed to allow for excavation
- Community disruption during construction
- Impacts to property owners along and adjacent to the cut-and-cover tunnel alignment

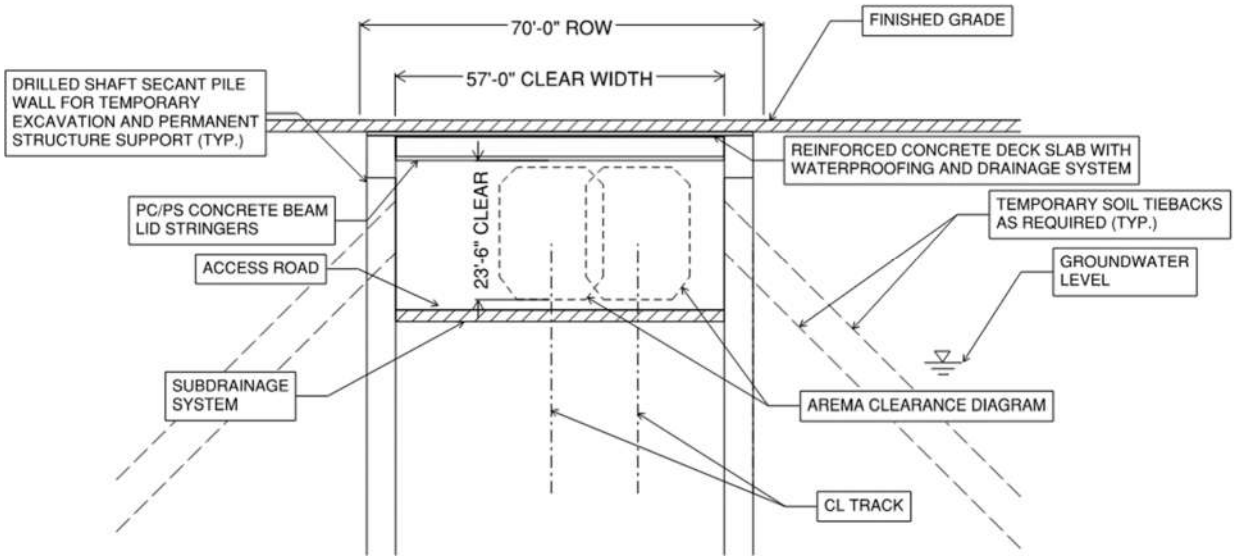


Figure 27: Conceptual typical section for cut-and-cover tunnel with "lid" to allow open space, roadways, or development on top.

F. Mococo Shoreline Retaining Walls

In areas of sloping terrain along the existing shoreline along the south side of the Strait, retaining walls will be needed to enable the excavations and/or fills needed to add tracks adjacent to the existing railroad corridors. These existing slopes have marginal existing stability in many locations and there is evidence of past landslides. Therefore, retaining walls would need to incorporate specific measures, accounting for local conditions, to provide stability and strength.

For this study, conceptual design for tiered and anchored retaining walls was developed to provide this space and support. Aesthetic and natural viewscapes, as well as access for inspection and maintenance will be key considerations. See Figure 28 for an example (repeated from Section IV, for convenience).

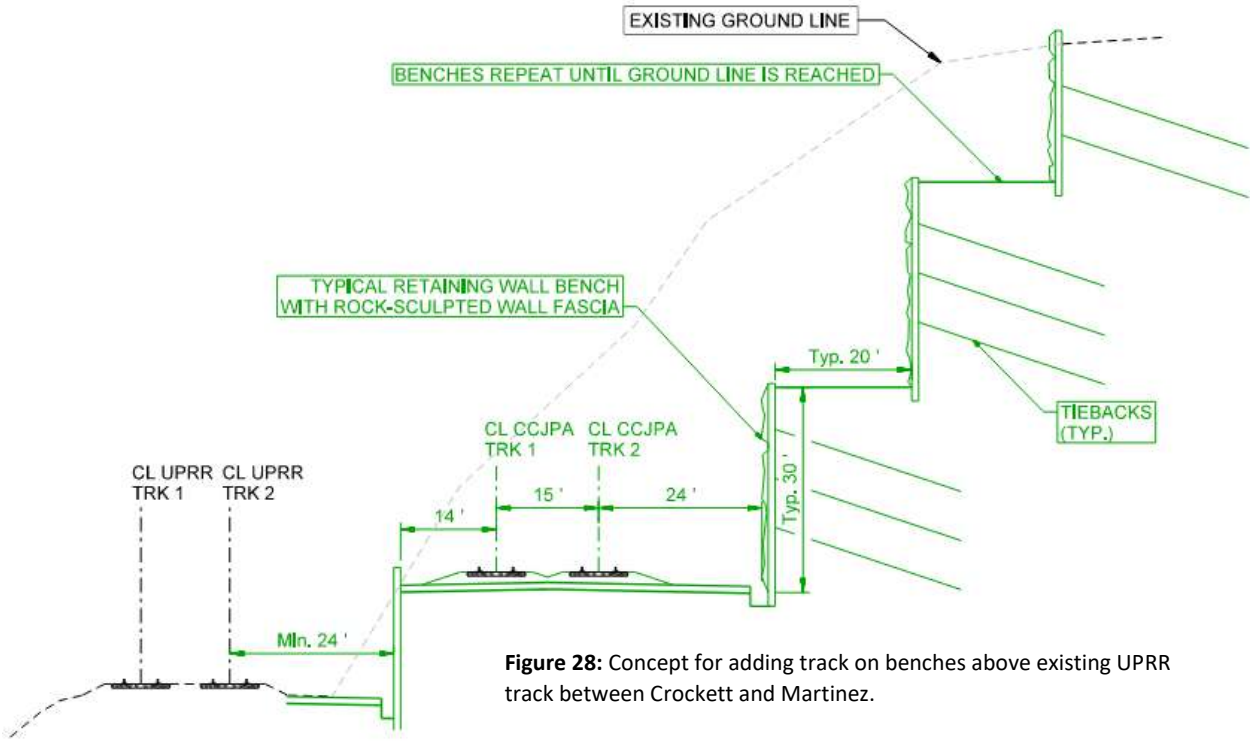


Figure 28: Concept for adding track on benches above existing UPRR track between Crockett and Martinez.

Key assumptions for retaining walls:

- Tiered walls with 30 feet maximum vertical height and bench steps 20 feet wide to enable constructability and allow for long-term inspection and maintenance access
- Drilled shaft soldier pile walls with secant pile lean concrete or other lagging method depending on size and conditions
- Soil tiebacks or rock anchors as required
- Sculpted aesthetic facing with natural rock finish and coloring

1. Opportunities:

- May gain efficiency in construction and cost with significant quantities of wall required
- Several options for wall face treatments are available to provide the desired aesthetic qualities or natural look in order to minimize visual effects.
- Retaining walls are intended to minimize ground disturbance; reinforced slopes and other alternatives can be considered separately or in combination with the walls

2. Challenges:

- Large structural elements and deep embedments are anticipated due to high demands
- Difficult conditions for construction on existing steep slopes must be carefully planned to avoid creating issues with slope stability
- Highly variable soil and rock conditions along the alignment will require flexible design and testing of soil or rock anchors
- High seismic demands
- Potential for groundwater seepage
- Avoiding or minimizing effects on the Carquinez Strait Regional Shoreline Park

G. Martinez-Benicia East Suisun Marsh bridges

To cross low-lying marsh and wetland areas with thick deposits of Young Bay Mud, it is likely that a structural approach with deep foundations will be required to counter otherwise very large settlements and low bearing capacities. Repetitive standard railroad trestle-type bridges have been used successfully over many decades in similar conditions. As the basis for this conceptual study, in order to provide certainty of adequate support for the tracks without impacting existing operations or causing additional settlement, conceptual design for a very long continuous trestle has been used across the full extent of the Suisun Marsh. It may be possible to reduce costs significantly if lightweight fill were viable, though additional analysis would be required to determined the feasibility of a lightweight fill approach.

Key assumptions for Suisun Marsh bridges:

- Typical repetitive short span railroad trestle bridges
- Standard precast/prestressed concrete double box beams, typically 30 or 45 feet span lengths
- Driven pipe pile foundations with reinforced concrete infill and reinforced concrete bent caps

1. Opportunities:

- Repetitive nature of construction and large quantities could result in efficiency in construction and lower costs
- Elevations of the proposed bridge set to accommodate future sea level rise and wave runup
- If subsurface investigations show thinner layers of Young Bay Mud, it may be possible to substitute soil embankments between bridges
- Deep foundations can take into account potential liquefaction and lateral spreading, if those conditions are encountered in soft subsurface layers

2. Challenges:

- Such a long structure results in a large cost
- High moisture and chloride-rich environmental conditions require consideration of corrosion potential and durability of construction materials
- Seismic and geotechnical challenges may drive heavier substructures and foundations than typical railroad trestles

H. Typical Bridges and Culverts

Low and short bridges over drainage ways and small creeks would be standard precast/prestressed concrete double box beams, typical 30 or 45 feet span lengths.

Taller and longer bridges over creeks and roadways, including most grade separation underpasses (railroad over roadway) would be steel rolled beams or welded steel deck plate girders with steel plate decks and reinforced concrete substructures supported on driven piles or drilled shaft foundations. Welded steel through plate girders may be an alternative where clearances are critical.

Small culverts would be standard polymer-coated corrugated metal pipes with concrete headwalls. Larger culverts would be cast-in-place reinforced concrete box culverts.

VI. Concept-Level, Rough Order of Magnitude Cost Estimate

Rough order of magnitude cost estimates have been prepared for the Vallejo, Interstate 80, and Martinez-Benicia East representative route options, separated by segment. Note that there are sub-options for several of the representative route options.

These rough order of magnitude cost estimates are based on the construction assumptions identified in previous sections. These estimates assume a 100% contingency, reflective of the large number of uncertainties at this early, conceptual stage of design, such as geotechnical conditions, locations of buried utilities, ROW acquisition, effects on residential and industrial properties, and environmental mitigation. Although allowances have been made for each of these uncertainties, their exact effect on cost is not yet known and, in some cases, a 100% contingency may not be sufficient. Note that, at this stage, no cost has been assigned to the use of UPRR property. These costs are summarized in Table 2.

Below is a summary of major considerations for the cost estimates:

- General: estimates include a high-level approximation of property acquisition costs outside UPRR ROW; remediation costs at industrial sites are similarly high-level.
- Vallejo representative route option, “Passenger + Freight” sub-option:
    - Assumes three tracks (two passenger, one freight); maximum grade of 1.5%.
    - Assumes tracks at-grade through Vallejo, with roads elevated over the tracks at each existing grade crossing location.
    - Reducing the grade at Jameson Canyon to 1.5% to be compatible with freight operations; involves adjustments to Interstate 680 in Cordelia.
- Vallejo representative route option, “Passenger Only” sub-option:
    - Assumes two dedicated tracks; maximum grade of 2%.
    - Assumes tracks at-grade through Vallejo, with roads elevated over the tracks at each existing grade crossing location.
    - Maintaining existing 2% grade through Jameson Canyon and minor adjustments at Interstate 680 crossing at Cordelia
- Interstate 80 representative route option, “Passenger Only”:
    - Assumes two tracks; maximum grade of 3%.
    - Assumes tracks below grade in a trench through Vallejo, with roads passing over the top of the trench, but maintaining their existing elevation.
- Martinez-Benicia East representative route option, “Passenger + Freight” sub-option:
    - Assumes two new dedicated passenger tracks; maximum grade of 1.5% for freight tracks, between 1.5% and 3% for passenger tracks (depending upon Martinez-Benicia bridge type). Accommodates 2 passenger and 2 freight tracks on bridge over Strait.
    - No encroachments (fill, bulkheads, etc.) into the Strait along the shoreline; all construction toward the inland side with tall retaining walls and tunnels.
- Martinez-Benicia East representative route option, “Passenger Only” sub-option:
    - Assumes two new dedicated passenger tracks; maximum grade of 1.5% for freight tracks, between 1.5% and 3% for passenger tracks (depending upon Martinez-Benicia bridge type). Only 2 passenger tracks, but no freight tracks on bridge over Strait.
    - No encroachments (fill, bulkheads, etc.) into the Strait along the shoreline; all construction toward the inland side with tall retaining walls and tunnels.

Table 2: Concept-Level, Rough Order of Magnitude Cost Estimates for Representative Route Options

Vallejo	Common Segment	Pinole To Rodeo	Rodeo To Crockett	Crockett To Highway 29	Highway 29 to Amer Canyon	Amer. Canyon to Suisun City	Vallejo Full Total	Vallejo: Cost of Minimum Useable Segment
Passenger Only:	$0.2B	$1.1B	$2.3B	$6.9B	$3.5B	$3.1B	Passenger Only **$17.1B**	Passenger Only **$15.8B**
Passenger+Freight:	$0.2B	$1.1B	$2.3B	$12.0B	$3.5B	$4.3B	Passenger + Freight **$23.4B**	Passenger + Freight **$22.1B**
Interstate 80	**Common Segment**	**Pinole To Hercules**	**Hercules To Crockett**	**Crockett To Highway 29**	**Highway 29 to Amer. Canyon**	**Amer Canyon to Suisun City**	**I-80 Full Total**	**Intestate 80: Cost of Minimum Useable Segment**
Passenger Only:	$0.2B	$0.5B	$3.8B	$6.7B	$3.9B	$3.1B	Passenger Only **$18.2B**	Passenger Only **$17.5B**
Martinez - Benicia East	**Common Segment**	**Pinole To Crockett**	**Crockett To Martinez**	**Martinez To Benicia**	**Benicia To Suisun City**		**Martinez - Benicia East Full Total**	**Martinez-Benicia: Cost of Minimum Useable Segment**
Passenger Only:	$0.2B	$3.3B	$1.7B	$10.2B	$4.5B		Passenger Only **$19.9B**	Passenger Only **$10.2B**
Passenger+Freight:	$0.2B	$3.3B	$1.7B	$12.9B	$4.5B		Passenger + Freight **$22.6B**	Passenger + Freight **$12.9B**

Notes: Costs are concept-level, rough order of magnitude.
"Cost of Minimum Usable Segment", in blue, is the sum of the segments highlighted in blue
All costs include 100% contingency.
Costs assume year of expenditure is 2024.

VII. Approach to Phasing the Project

Given the relatively high cost of the project, it may be possible to achieve some of the benefits of a new high-level bridge, travel time reductions, additional rail capacity, improvements to goods movement, or sea level rise resiliency, without committing to the entire project cost at one time. This would require implementing the project in phases, smaller sections that would, by themselves, be usable. Each smaller section would need to provide some level of benefit. Some agencies refer to this as "independent utility."

To define a minimum usable section, each end of that section would need to connect with the existing Capitol Corridor route in order to provide independent utility. Sample minimum usable segments for the three representative route options (excluding the Martinez-Benicia West option) are described below:

- **Vallejo representative route option:** The key feature of the Vallejo representative route option is that, to get the benefits of a high-level bridge crossing, nearly the entire route, from Rodeo across the Strait, to American Canyon, and on to Suisun City, would need to be constructed. Constructing only part of this route (for example, the bridge across the Strait at Crockett) would not provide connectivity to the rest of the Capitol Corridor system. The Vallejo representative route option offers the following minimum usable sections:
    - **San Pablo to Rodeo:** This relatively short section offers possible travel time reduction by providing curve widening and additional track capacity.
    - **Rodeo to Suisun City:** This section includes the new long-span bridge crossing, the at-grade segment through Vallejo, and the segment through Jameson Canyon to Suisun City. It would reduce curvature, add tracks, and would offer travel time reduction, additional passenger train capacity, some limited goods movement benefits, and the new high-level bridge crossing. Note that, to get any benefit from the high-level bridge crossing, the entire section from Rodeo to Suisun City would need to be constructed. Constructing only the bridge by itself would not offer any connectivity to the rest of the CCJPA system or any benefit. It is possible that, if the SMART system were also constructed between Ignacio and Suisun City, the two projects could share costs between American Canyon and Suisun City.

- **Interstate 80 representative route option:** Like the Vallejo option, to get the benefits of a high-level bridge crossing, nearly the entire route, from Rodeo across the Strait, to American Canyon, and on to Suisun City, would need to be constructed. Constructing only part of this route (for example, the bridge across the Strait at Crockett) would not offer connectivity to the rest of the Capitol Corridor system. The Interstate 80 representative route option offers the following minimum usable sections:
    - **San Pablo to Pinole:** This short section around Point Pinole offers possible travel time reduction by providing curve widening and additional track capacity.
    - **Pinole to Suisun City:** This section includes the segment along Interstate 80, the new long-span bridge crossing, the segment through Vallejo, and the segment through Jameson Canyon to Suisun City. It would reduce curvature, add tracks, and would offer travel time reduction, additional passenger train capacity, and the new high-level bridge crossing of the Strait. Note that, to get the benefit of the high-level bridge crossing, the

entire section from Hercules to Suisun City would need to be constructed. Constructing only the bridge by itself would not offer any connectivity to the rest of the CCJPA system or any benefit. This section would not provide any direct goods movement benefit. As with the Vallejo representative route option, it is possible that, if the SMART system were also constructed between Ignacio and Suisun City, the two projects could share costs between American Canyon and Suisun City.

- **Martinez-Benicia East representative route option:** The Martinez-Benicia East representative route option offers the most opportunities for phased implementation. There are several potential minimum usable segments, each offering a combination of travel time reduction, goods movement benefits, and increased passenger train capacity.
    - **San Pablo to Crockett:** This section, extending from the beginning of the study through the cut-and-cover tunnel under Crockett, would reduce curvature, add tracks, and would offer travel time reduction, additional passenger train capacity, and goods movement benefit. This section could be further phased as several even shorter sections. However, the benefits from the shorter sections would be reduced.
    - **Crockett to Martinez:** This section, extending from the east end of the cut-and-cover tunnel at Crockett would reduce curvature, add tracks and would offer travel time reduction, additional passenger train capacity, and goods movement benefit.
    - **Martinez to Benicia:** This section includes the new bridge crossing itself. It offers additional passenger train capacity, goods movement benefits, and the new high-level crossing of the Strait. This segment is necessary to achieve the full benefits of reduced impacts to train schedules from vessels passing beneath the existing vertical lift span.
    - **Benicia to Suisun City:** This section includes the bridge across the Suisun marsh area and the associated additional tracks. It offers increased capacity, goods movement benefit, and resiliency to sea level rise.
    - **"Optionality":** The Martinez-Benicia East representative route option does offer another type of phasing option. If the new bridge crossing from Martinez to Benicia were to be constructed by itself, it would still offer the possibility that other routes could be examined, including the possibility of revisiting route options from the first phase of the study, including concepts such as tunneling through Franklin Canyon to provide the most direct route option with, possibly, substantially shorter travel time. Such an approach would imply significant private property acquisition, though it would result in reduced travel times. See Appendix X, Exhibit 6 for an example of this concept.

VIII. Comparison Matrix

Table 3 illustrates a relative comparison for major considerations of the three representative route options, Vallejo, Interstate 80, and Martinez-Benicia East. The table entries, generally "Low", "Medium", and "High", provide a comparison between the three representative route options. At this early stage of study, the potential environmental effects on communities is at a qualitative level; no formal environmental analysis process (e.g., a Environmental Impact Report or Environmental Impact Study) has been initiated. Similarly, with regard to costs, the cost estimates are currently at a rough-order-of-magnitude level. Additional study may result in refinements, and possibly even changes in ranking where costs are "close" to one another.

Table 3: Comparison of Representative Route Options			
Route/Criteria	**Vallejo**	**Interstate 80**	**Martinez-Benicia East**
Ability to Serve New Markets	High	High	Low
Effects on Adjoining Properties	High	High	Medium
Potential Construction Effects on Residential & Commercial Areas	High	High	Medium
New Operational Effects on Residential & Commercial Areas	High	High	Medium
Potential for Phased Construction	Low	Low	High
Ability to Accommodate Goods Movement on New Route & Bridge	Low	Not Possible	High
Ability to Benefit other Passenger Corridors	May share costs/benefits with SMART in the American Canyon-Suisun corridor	May share costs/benefits with SMART in the American Canyon-Suisun corridor	May share costs/benefits with San Joaquins in the San Pablo-Martinez corridor
Cost of Passenger-Only "Full" Option (San Pablo-Suisun)	Lowest	Medium	Highest
Cost of Passenger-Only "Minimum Usable Segment"	Medium	Highest	Lowest
Cost of Passenger + Freight "Full" Option (San Pablo-Suisun)	Highest	Not Possible	Lowest
Cost of Passenger + Freight "Minimum Usable Segment"	Highest	Not Possible	Lowest

IX. Next Steps

This study has identified various route options and the basic constraints and opportunities associated with each. Three representative route options have advanced for further study, the Vallejo, Interstate 80, and Martinez-Benicia East options.

Potential next steps include:

- Stakeholder and Partner Agency Next Steps:
  - Discussions with Union Pacific Railroad.
  - Discussions with BNSF Railway (if Interstate 80 representative route option is pursued)
  - Discussions with key stakeholders, including goods movement stakeholders (such as the Port of Oakland).
  - Analyze how different markets would respond to increased (or new) or decreased passenger rail service.
  - Identification of possible partner agencies and potential funding sources.
  - Integrate project programming, planning, and funding approaches with Link21's efforts.
- Environmental Next Steps:
  - Environmental baseline studies and detailed environmental constraints analysis.
  - Ultimately, enter the environmental documentation process for both the California Environmental Quality Act and the National Environmental Policy Act.
- Engineering Next Steps:
  - Further geometric analysis to refine the footprints and costs for each option, using more detailed baseline information (e.g., recent photogrammetry and more refined digital terrain models) and refine range of potential environmental effects.
  - Assess whether encroachments into the Strait between Rodeo and Martinez are feasible as a potentially significant cost saving measure.
  - Preliminary geotechnical analysis, since geotechnical conditions are major cost drivers for each of the options.
  - Advance the structural analysis to further refine costs, since structures (bridges, tunnels, trenches, and retaining walls) represent the major cost elements for each representative route option.
  - Conduct operational analysis to confirm passenger train travel times on representative route options as the geometric analysis is completed. Assess potential for coordination with other passenger services, such as the proposed SMART service from Ignacio to Suisun City, or the existing San Joaquin service, which shares the existing UPRR / Capitol Corridor route between San Pablo and Martinez.
  - Focus on high-cost features to identify opportunities for savings and reduce contingency below the current 100% assumption.

X. Appendix

List of Exhibits

Exhibit 1: Concept for Georgia Street Roadway-Over-Railroad Grade Separation in Vallejo

Exhibit 2A: Concept for Redwood Street Roadway-Over-Railroad Grade Separation in Vallejo

Exhibit 2B: Concept for Broadway Roadway-Over-Railroad Grade Separation in Vallejo (where Broadway is elevated in conjunction with Redwood Street)

Exhibit 3A: Concept for Berrellesa (Foster) Street Roadway-Over-Railroad Grade Separation in Martinez

Exhibit 3B: Concept for Embarcadero Roadway-Over-Railroad Grade Separation in Martinez (where Embarcadero is elevated in conjunction with Foster Street)

Exhibit 4: Concept for Ferry Street Roadway-Over-Railroad Grade Separation in Martinez

Exhibit 5: Concept for Concrete Segmental Bridge between Martinez and Benicia

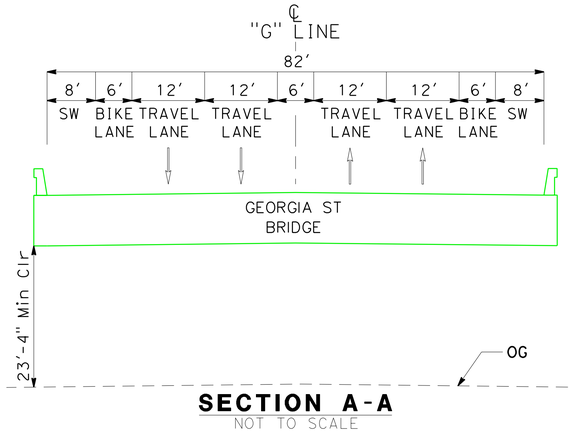
Exhibit 6: Concept illustrating potential route "optionality" associated with Martinez-Benicia East

NOTES

1. DESIGN SPEED 40 MPH (POSTED SPEED 30 MPH)
2. PROPOSED BRIDGE (GEORGIA ST) - 100 FOOT SPAN
3. PROPOSED RETAINING WALL - 8-29 FEET
4. EXISTING CROSS SECTION WIDTH - 80-82 FEET

CROSS STREET RECONSTRUCTION LIMITS

PROPERTIES POTENTIALLY IMPACTED OR LOSE ACCESS BY ELEVATING GEORGIA STREET



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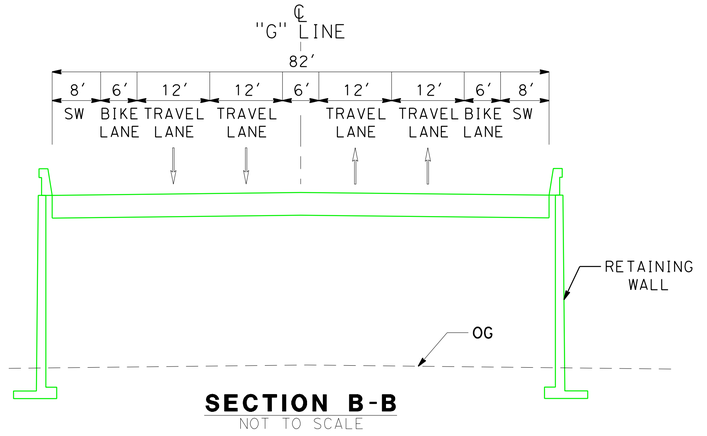

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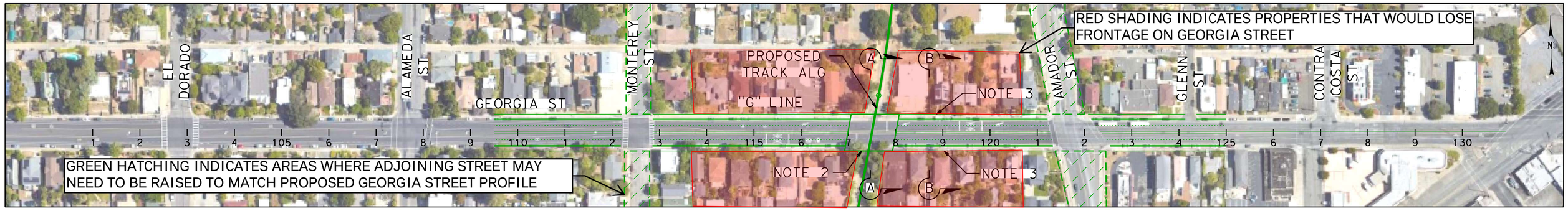

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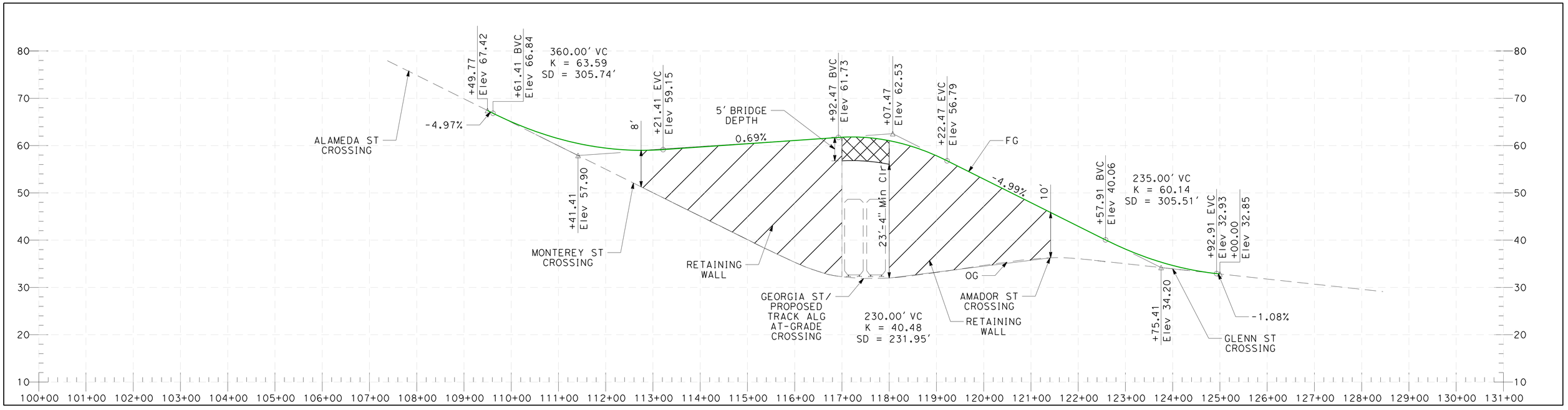


PROFILE
H: 1" = 100'
V: 1" = 10'

EX. 1 - GEORGIA STREET - OVERPASS CONCEPT

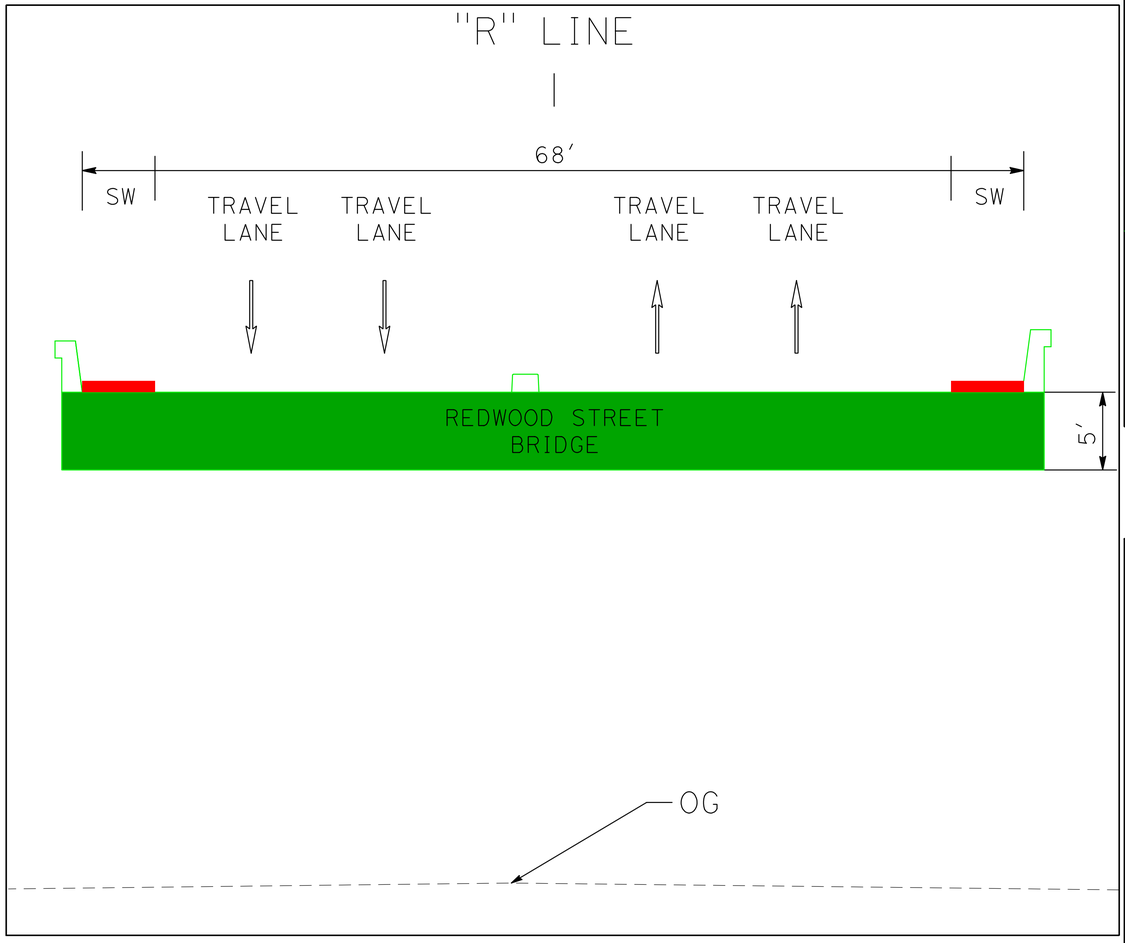
- CONCEPTUAL -
FOR REVIEW/DISCUSSION

NOTES

1. DESIGN SPEED 35 MPH (POSTED SPEED 30 MPH)
2. PROPOSED BRIDGE (REDWOOD ST) - 100 FOOT SPAN
3. PROPOSED RETAINING WALL - 2-8 FEET
4. EXISTING CROSS SECTION WIDTH - 56-68 FEET

PROPOSED BRIDGE

PROPOSED PEDESTRIAN PATH



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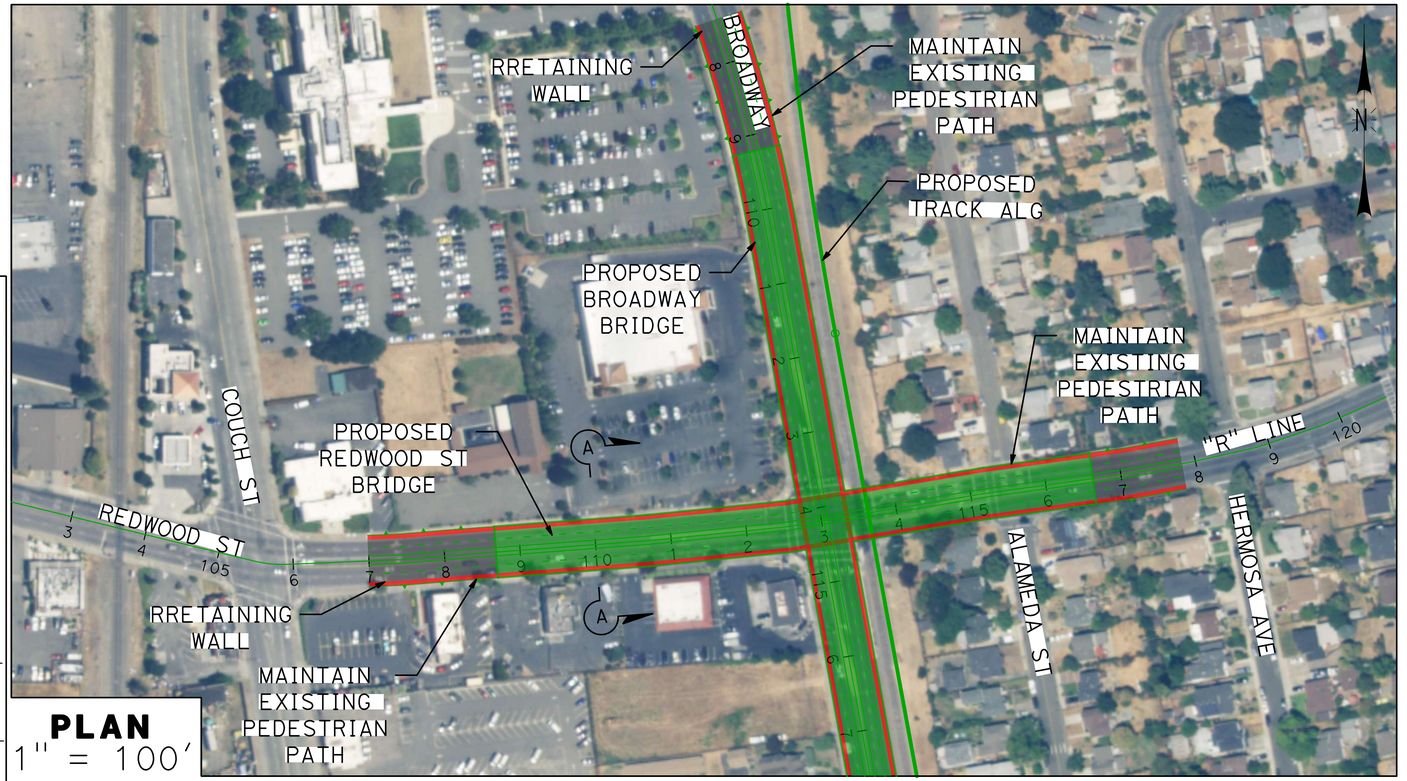

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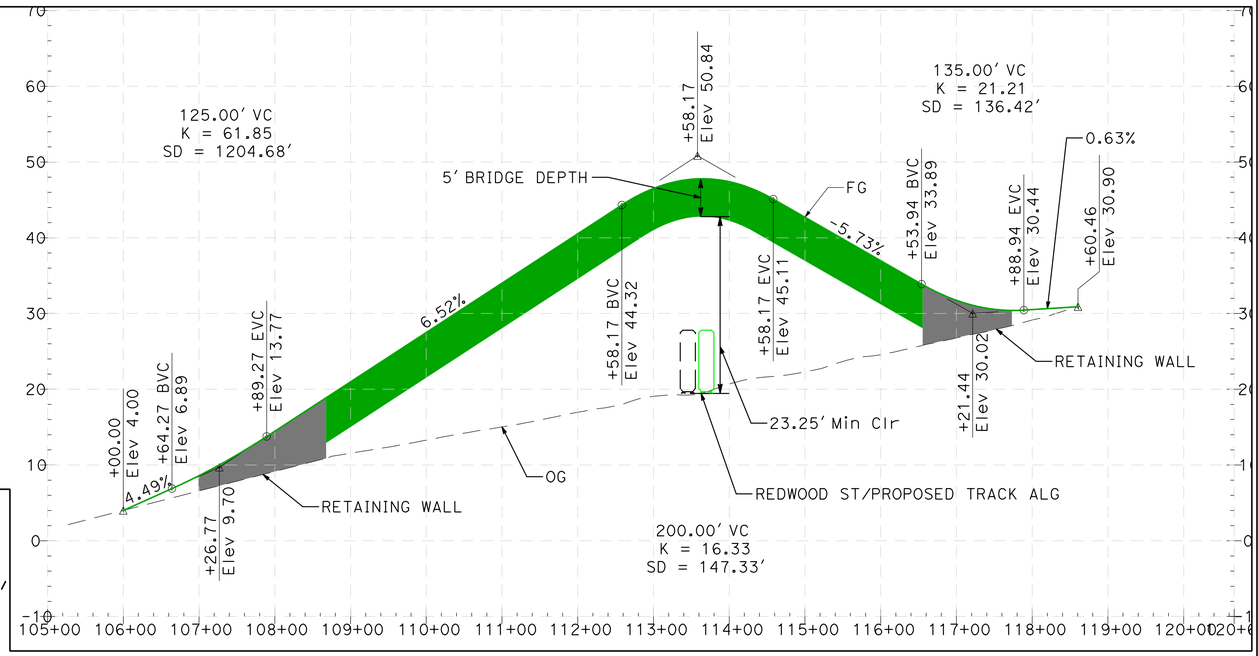


PROFILE
H: 1" = 100'
V: 1" = 10'

EX. 2A - REDWOOD STREET - OVERPASS CONCEPT

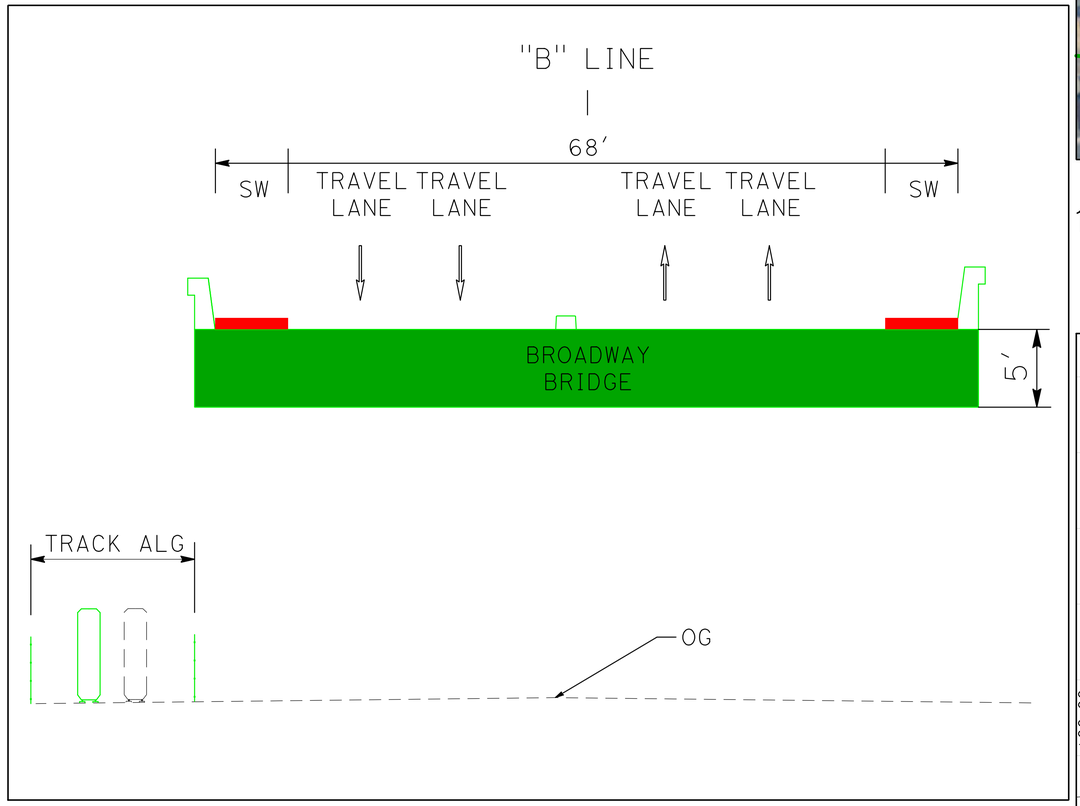
- CONCEPTUAL -
FOR REVIEW/DISCUSSION

NOTES

1. DESIGN SPEED 35 MPH (POSTED SPEED 30 MPH)
2. PROPOSED BRIDGE (REDWOOD ST) - 100 FOOT SPAN
3. PROPOSED RETAINING WALL - 2-8 FEET
4. EXISTING CROSS SECTION WIDTH - 56-68 FEET

PROPOSED BRIDGE

PROPOSED PEDESTRIAN PATH



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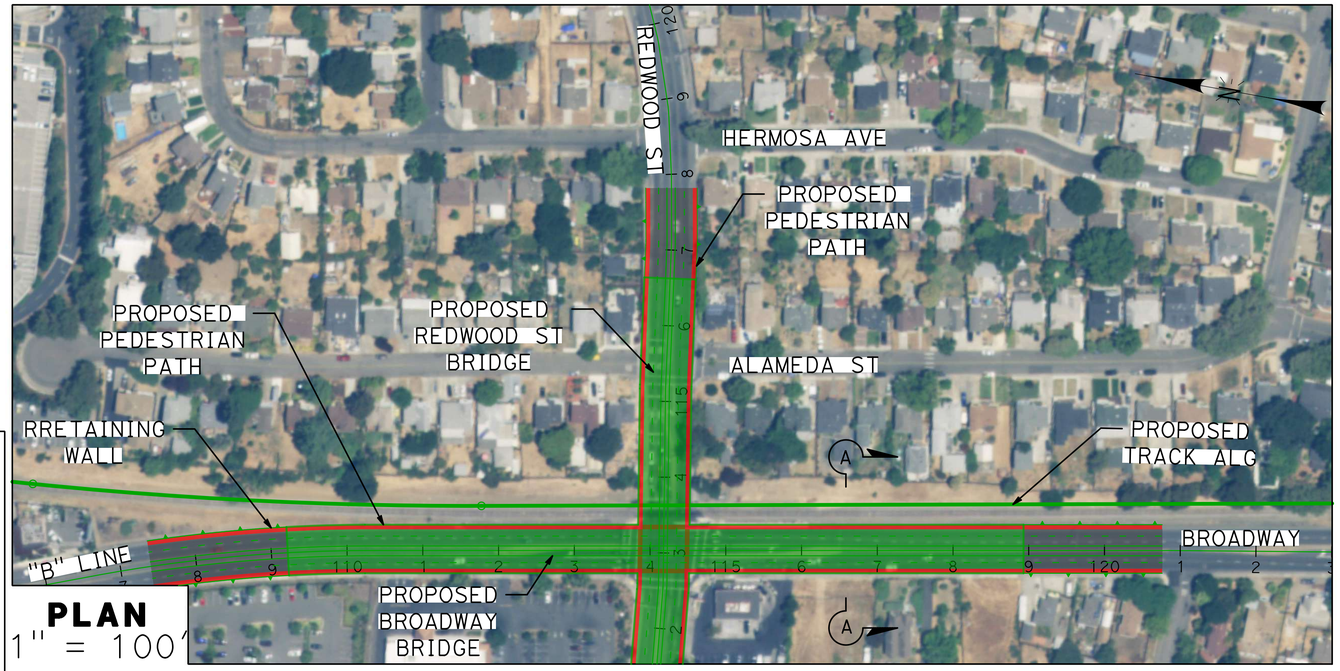
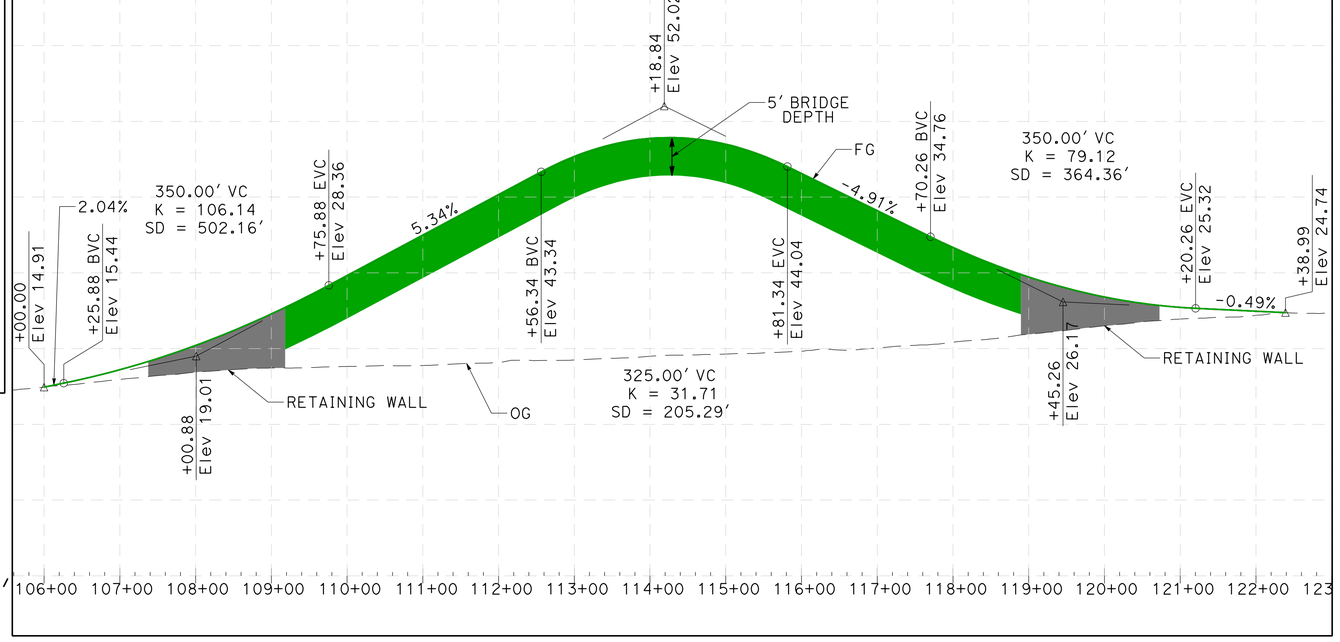


PLAN
1" = 100'

PLAN
1" = 100'



PROFILE
H: 1" = 100'
V: 1" = 10'

EX. 2B - BROADWAY - OVERPASS CONCEPT

- CONCEPTUAL -
FOR REVIEW/DISCUSSION

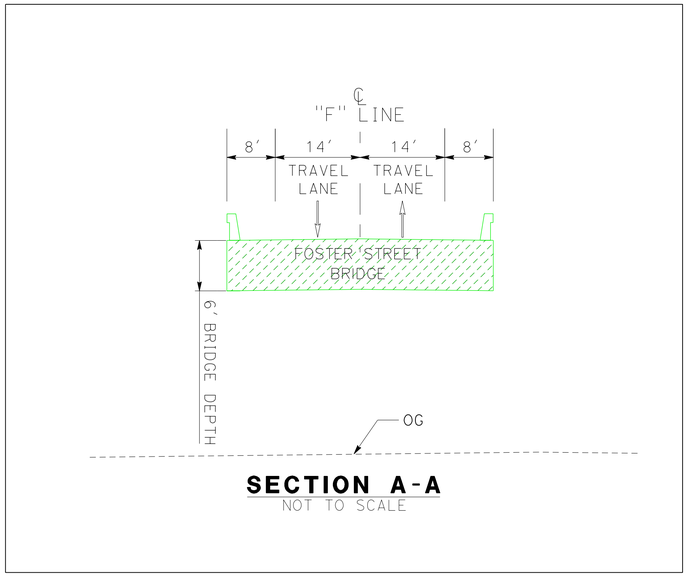
NOTES

1. DESIGN SPEED 20 MPH (POSTED SPEED 15 MPH)
2. PROPOSED OVERCROSSING (FOSTER ST) - 6 FOOT DEPTH
3. PROPOSED RETAINING WALL - 2-5 FEET
4. PROPOSED BRIDGE STRUCTURE - 4 FOOT DEPTH
5. CONFORM AT BERRELLESSA ST INTERSECTION

BRIDGE STRUCTURE

RETAINING WALL

PLAN
1" = 100'



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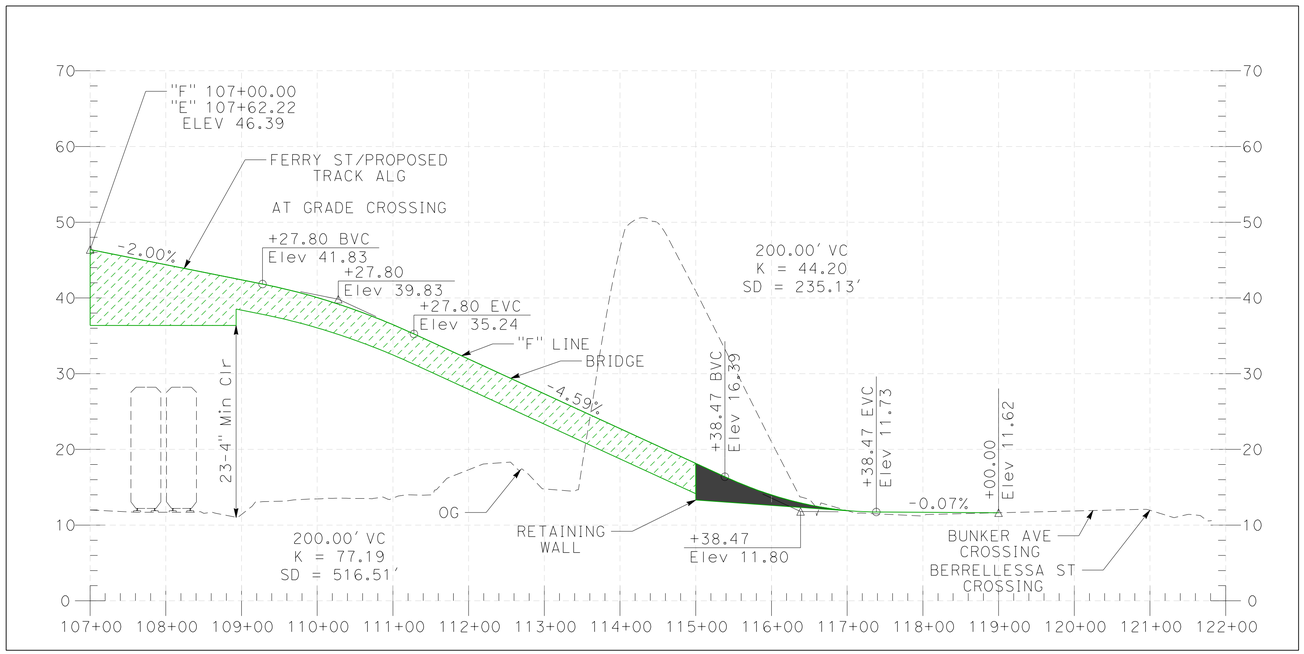


PROFILE
H: 1" = 100'
V: 1" = 10'

EX. 3A - FOSTER STREET - OVERPASS CONCEPT

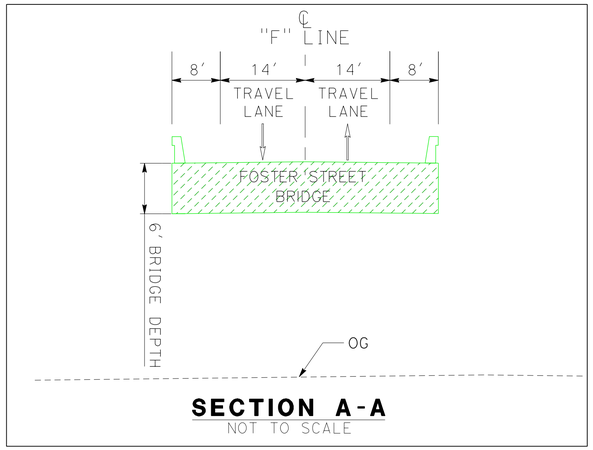
- CONCEPTUAL -
FOR REVIEW/DISCUSSION

NOTES

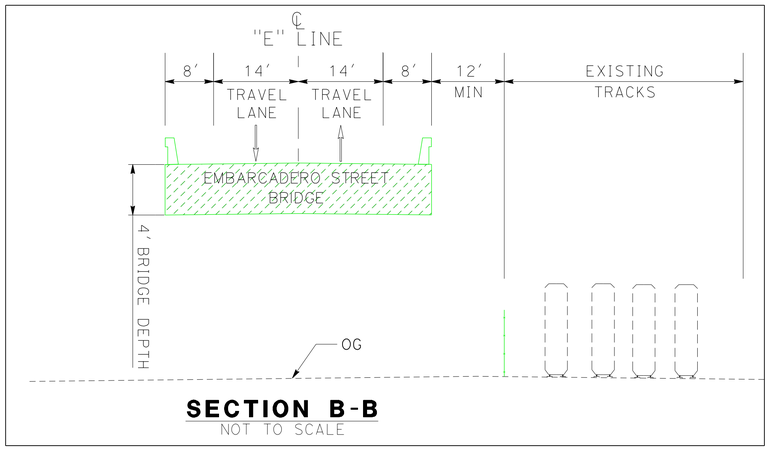
1. DESIGN SPEED 20 MPH (POSTED SPEED 15 MPH)
2. PROPOSED OVERCROSSING (FOSTER ST) - 6 FOOT DEPTH
3. PROPOSED RETAINING WALL - 2-13 FEET
4. PROPOSED BRIDGE STRUCTURE - 4 FOOT DEPTH
5. CONFORM AT BERRELLESSA ST INTERSECTION

BRIDGE STRUCTURE

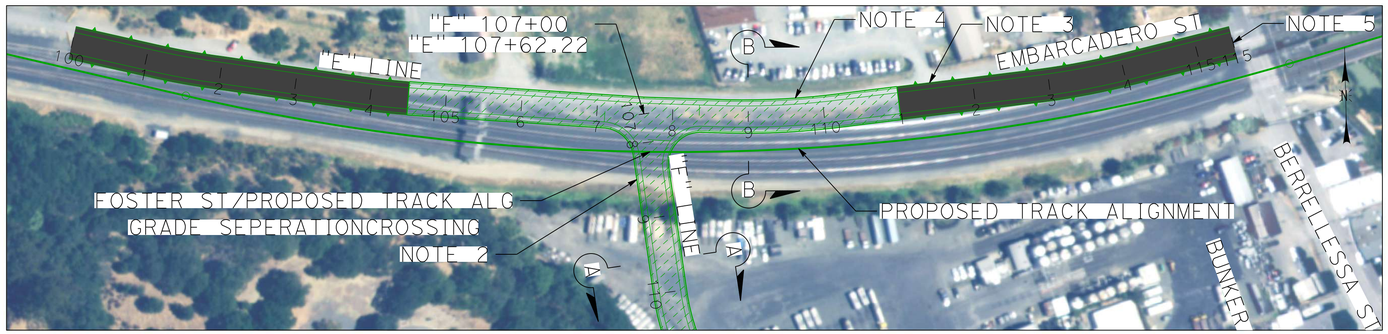
RETAINING WALL



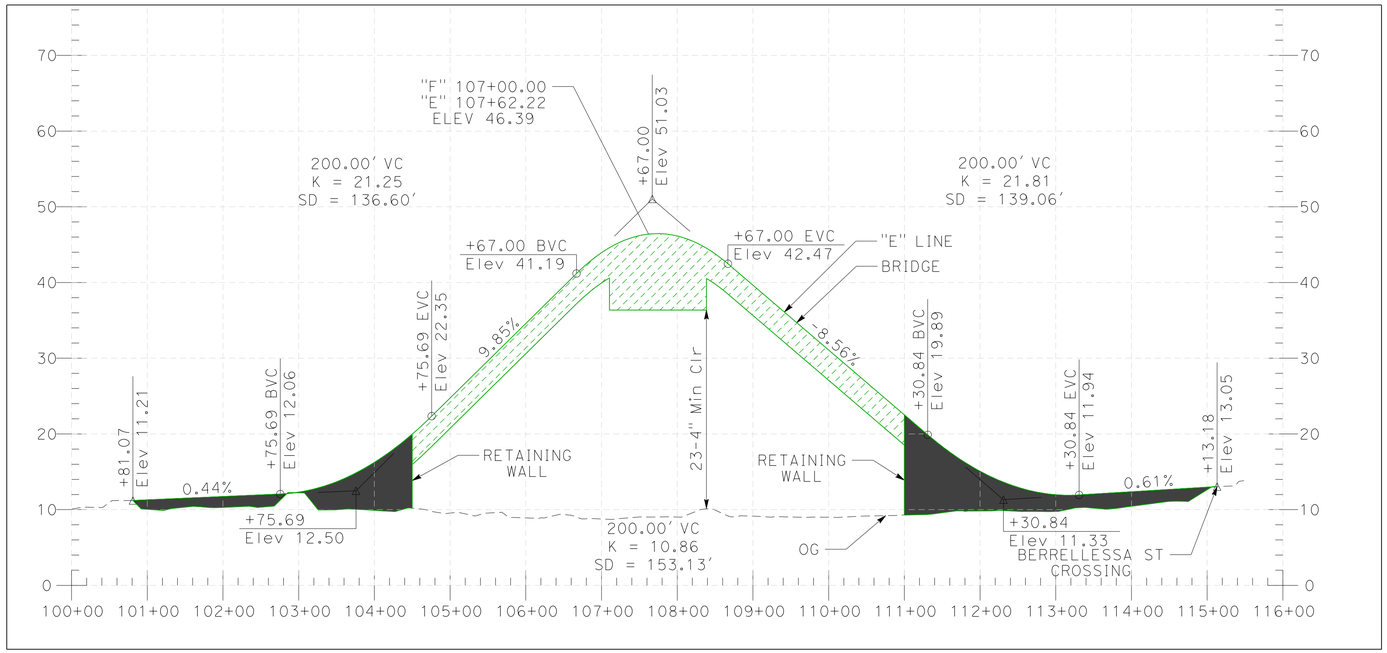
SECTION A-A
NOT TO SCALE



SECTION B-B
NOT TO SCALE



PLAN
1" = 100'



PROFILE
H: 1" = 100'
V: 1" = 10'

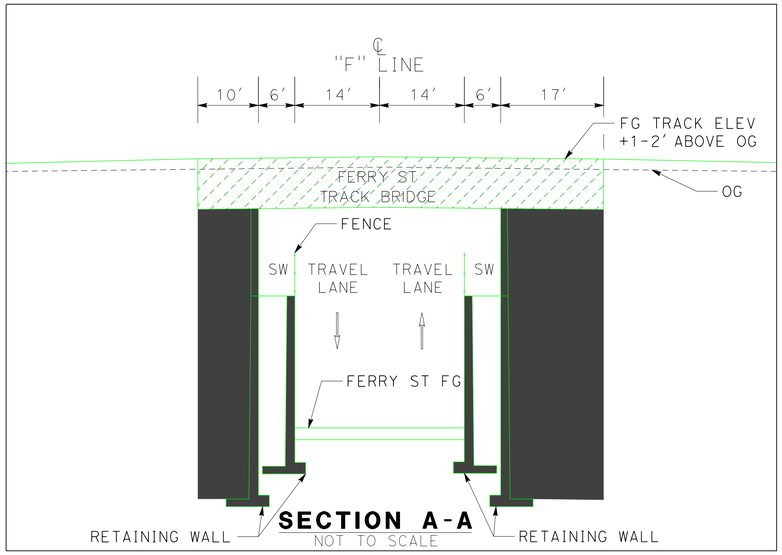
EX. 3B - EMBARCADERO STREET - OVERPASS CONCEPT

NOTES

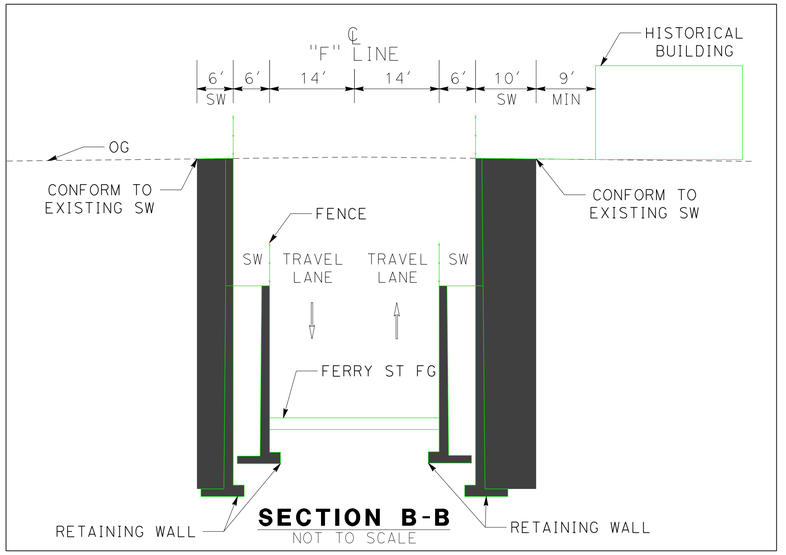
1. DESIGN SPEED 20 MPH (POSTED SPEED 15 MPH)
2. PROPOSED TRACK BRIDGE (FERRY ST) - 80 FOOT SPAN
3. PROPOSED RETAINING WALL - 2-25 FEET
4. EXISTING ROADWAY CROSS SECTION WIDTH ~30 FEET
5. CONFORM AT MARINA VISTA AVE INTERSECTION
6. EXISTING HISTORICAL SITE TO BE PROTECTED IN PLACE
7. **LOWER STATION ACCESS ROAD BETWEEN ESTUDILLO STREET AND FERRY STREET TO MATCH FERRY STREET ELEVATION OR CLOSE ACCESS ROAD.**

BRIDGE STRUCTURE

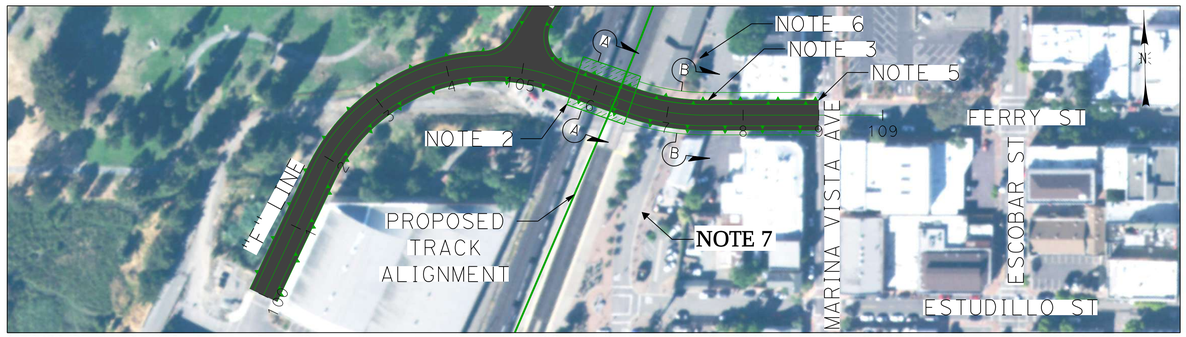
RETAINING WALL



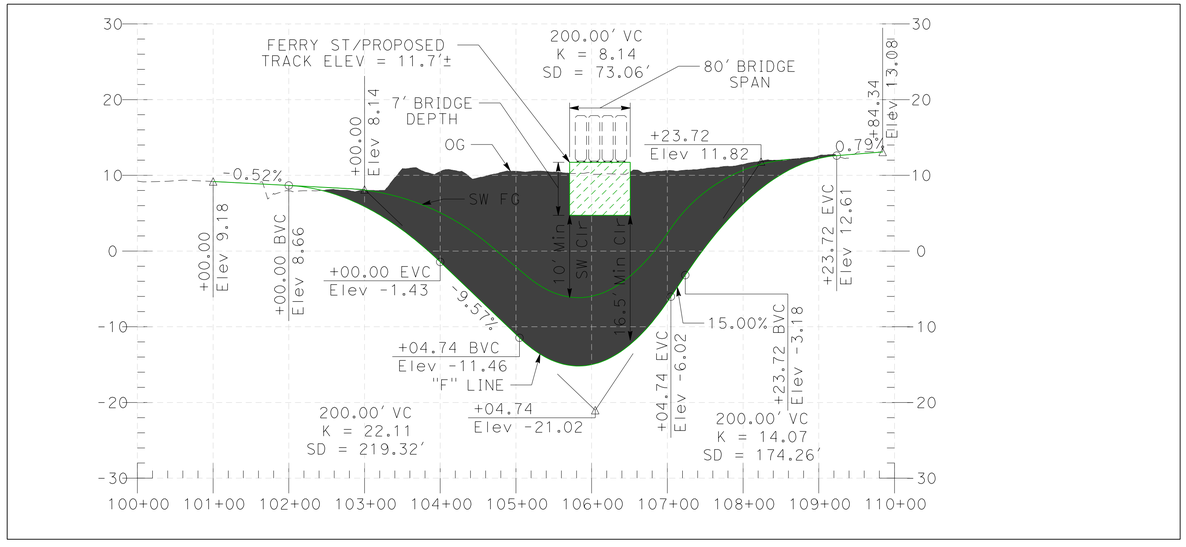
SECTION A-A
NOT TO SCALE



SECTION B-B
NOT TO SCALE

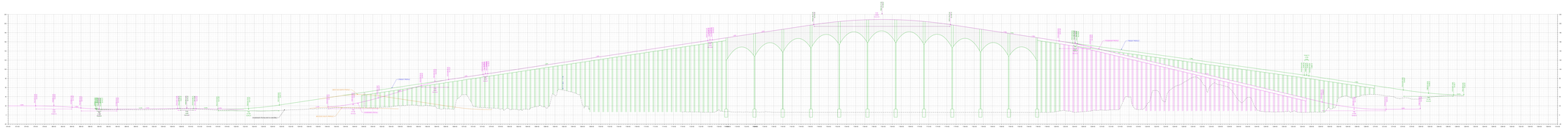


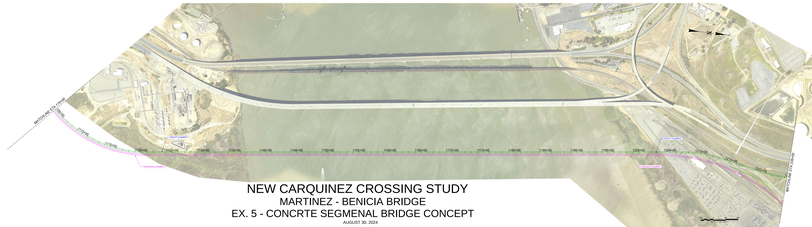
PLAN
1" = 100′



PROFILE
H: 1" = 100′
V: 1" = 10′

EX. 4 - FERRY STREET - OVERPASS CONCEPT





NEW CARQUINEZ CROSSING STUDY
MARTINEZ - BENICIA BRIDGE
EX. 5 - CONCRTE SEGMENAL BRIDGE CONCEPT
AUGUST 30, 2019

LEGEND

- Stations (existing/planned)
- Franklin Canyon - Martinez
- Benicia-Martinez-East
- Option Considered in Vision Plan
- Major Highways
- Existing Rail
- Approx Limits of Structures

If the Martinez-Benicia East bridge (i.e., the section between Martinez and Benicia, including the new high-levelbridge and its approaches) were constructed as the first phase of the project, it would leave the possibility to examine other approaches to the segment between San Pablo and Martinez.

For example, it would leave open for future consideration the possibility of a more direct, but also more expensive, route through Franklin Canyon (which would require entirely new rights of way and long tunnels), as shown by the purple line labeled "Franklin Canyon-Martinez."

It would also leave open the possibility to pursue the option suggested in the CCJPA Vision Plan, which contemplated routing freight on an entirely new alignment via a new bridge in the Pittsburg vicinity, as shown in the inset.

American Canyon
Fairfield
Vallejo
Benicia
Suisun Bay
Carquinez Strait
Benicia - Martinez East
Franklin Canyon Martinez
Richmond
Martinez
Pittsburg
Concord

Vision Plan Option
Sacramento
Davis
Elk Grove
Yountville
Vacaville
Napa
Fairfield
Suisun City
American Canyon
Vallejo
Grizzly Bay
Suisun Bay
Sacramento River
San Joaquin River
Pittsburg
Concord
Antioch
Richmond
El Cerrito
Pleasant Hill
Walnut Creek

EX. 6 - Options Associated with Martinez-Benicia East Crossing Location

CCJPA NEW CARQUINEZ STRAIT CROSSING CONCEPTS

0 1.5 Miles

DATA SOURCES: Caltrans, U.S. Census Tigerline 2019,

Preliminary - For Discussion Only
The route options shown are conceptual and are intended only to illustrate possible approaches for this study.

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HDR

PATH: C:\USERS\RSHRIVASTA\ONEDRIVE - HDR, INC\CCJPA CARQUINEZ NEW BRIDGE CROSSING\GIS\MXD\CCJPA CARQUINEZ STRAIT BRIDGE CONCEPTS.MXD - USER: RSHRIVASTA - DATE: 2/13/2024