

State Route 37 Integrated Traffic, Infrastructure and Sea Level Rise Analysis: Final Report



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State Route 37 Integrated Traffic, Infrastructure and Sea Level Rise Analysis

Task 3 Technical Memorandum: Designs and Cost Estimates for Possible Resilient Structures

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Executive Summary

California State Route 37 (SR 37) is the Bay Area highway most vulnerable to temporary and permanent inundation due to sea level rise (SLR). Like most coastal highways in the Bay Area, it is positioned adjacent to tidal marshes and mudflats, meaning that any activity on the highway is subject to regulatory oversight. The marshes and upland area adjacent to SR 37 are active sites of restoration, with many millions of dollars in public investment over the last decade. Both SR 37 and the surrounding marshes are vulnerable to the effects of SLR, which include increased wave action, increased exposure times to saltwater and inundation during all tides.

In recognition of the vulnerability of SR 37 and associated marshlands to sea level rise impacts, the Transportation Concept Report (TCR, 1/2015) for SR 37 developed by Caltrans District 4 recommends raising the highway on a levee or causeway structure. To relieve congestion and provide multi-modal transportation options, Caltrans is also considering how to include transit and bike/pedestrian travel on the improved corridor. Because of the expense of the new structure, understanding the locations and extent of vulnerability and risk to the existing structure is critical.

In order to understand which stretches of SR 37 might be most vulnerable to SLR effects and to what degree, a model of potential inundation was developed using a recent, high-resolution elevation assessment conducted using LiDAR. This model projects potential inundation based upon comparison of the elevation of adjacent areas with a flooded area at a certain sea elevation. If a land area is lower elevation than a flooded area, then it becomes flooded too. Much of the North Bay coastal area is protected by berms and levees. In addition, an assessment was carried out of the vulnerability and risks for each segment of SR 37, as delineated by Caltrans (Figure 1). Segment A lies between SR 101 and SR 121; segment B is



Figure 1. SR 37 segments used in Caltrans' corridor planning

between SR 121 and Mare Island; and segment C lies between Mare Island and Interstate 80.

The vulnerability of each segment was scored according to its exposure to SLR effects, sensitivity to SLR, and adaptive capacity (ability of other roadways to absorb traffic). The risk to each segment from SLR was determined by estimating and aggregating impacts to costs of improvement, recovery time (from impacts), public safety impacts, economic impact on commuters and goods transport, impacts on transit routes, proximity to communities of concern, and impacts on recreational activities.

Based upon the model of potential inundation, the assessment of risk and vulnerability, and previous recommendations of appropriate structures to consider, we developed conceptual engineering scenarios for SR 37 and cost estimates for each scenario. These scenarios included 1) the highway on top of a levee, raised to accommodate sea level rise, 2) the route on top of a causeway with box girder design, and 3) the highway on top of a causeway with concrete slab and pier design. Each was designed based on the Caltrans Highway Design Manual, input from stakeholders and Caltrans staff, and previous experience of the team. Cost estimates for each scenario were developed and are summarized below.

Table 1. Cost estimates for each engineered concept by reach

Segment	Scenario Costs (in \$M)		
	1 – Levee/ Embankment	2 – Box Girder Causeway	3 – Slab Bridge Causeway
A	\$460	\$1,400	\$1,300
B	\$650	\$2,500	\$2,200
C	\$150	\$400	\$340
Total	\$1,260	\$4,300	\$3,840

Background

The University of California, Davis (UC Davis) is carrying out a collaborative project with Caltrans to examine the potential impacts of sea level rise (SLR) on North Bay infrastructure and associated natural systems, with a focus on California State Route 37 (SR 37). The study area includes 21 miles of SR 37 (Figure 1) from the SR 37/Route 101 interchange (west) to the Interstate 80/SR 37-Columbus Parkway interchange (east). As part of this project, AECOM was retained by UC Davis to conduct engineering concept design and order of magnitude cost estimates for potential scenarios to elevate the highway.

The Task 1 memorandum, *Sea Level Rise Inundation Modeling and Mapping for SR 37 Region and Preliminary Vulnerability Assessment* (AECOM 2015a), provided an overview of the SLR and storm surge modeling and mapping for the SR 37 study area and introduced the preliminary findings of the vulnerability assessment. The Task 2 memorandum, *State Route 37 Sea Level Rise Vulnerability and Risk Assessment* (AECOM 2015b) presented the methodology and results of the vulnerability and risk assessment. This memorandum presents conceptual engineering design and cost estimates for three structural adaptation scenarios for the highway (Task 3).

Existing Conditions

Infrastructure and Ecosystem Context

The project study area consists of SR 37 from Highway 101 to Interstate 80 (approximately 21 miles long), as well as the associated/adjoining aquatic, marsh, and upland ecosystems. For the purpose of this assessment, the SR 37 corridor was divided into three segments that generally correspond to Caltrans' Segment A, B, and C presented in Caltrans (2015). The names and boundaries of the segments are provided below and shown in Figure 1.

- **Segment A. Highway 101 to SR 121.** Located east of the town of Novato, north of Bel Marin Keys, and west of the SR 37/SR 121 junction in the vicinity of Sonoma Baylands and Sears Point. This segment is approximately 7.1 miles long, includes two-lanes in each direction and about a 50-ft wide median separated by a three-beam barrier. The existing roadway includes the bridges over Novato Creek, Simonds Slough Creek, Petaluma River, Atherton Ave, an interchange at Highway 101 and Atherton Avenue – Harbor Drive, and at-grade signalized intersections at Lakeville Road and SR 121. There are three minor access roads/driveway intersections that connect to SR 37. The existing roadway grade is relatively flat and low-lying along the western part of the segment (except between Atherton Ave. and Petaluma River which is along rolling terrain) and transitions to rolling and upland along the eastern end near the SR 37/SR 121 junction.

Other existing features include:

- the Northern Pacific Railroad tracks (currently owned by Sonoma-Marín Area Rail Transit (SMART)) runs south of and parallel to SR 37 between Highway 101 and Atherton Ave.;
 - PG&E transmission line runs approximately 180 feet south of SR 37 between HWY 101 and Simonds Slough Bridge;
 - Overhead utility poles run approximately 20 feet north of SR 37 between Petaluma River Bridge and SR 121; and,
 - Truck pullout area east of Lakeville Road in each direction.
- **Segment B. Highway 121 to Mare Island.** Located east of SR 121 and west of Napa River Bridge along the San Francisco Bay shoreline. The segment is approximately 9.6 miles long and includes one lane in each direction with a 10-ft wide median separated by a concrete barrier. The existing roadway includes an at-grade railroad crossing just east of the SR 37/SR 121 junction, bridges over Tolay Creek and Sonoma Creek, and at-grade unsignalized intersections at Noble Road and Skaggs Island Road. There are six minor access roads/driveway intersections including an access road to a PG&E transmission station and trailheads. The existing roadway grade is relatively flat and low-lying. Other existing reach features include:
 - Utility poles running about 50' north of the roadway between SR 121 and Sonoma Creek Bridge;
 - Utility poles running about 10 to 35 feet south between Skaggs Island Rd. and Island No. 1 intersection; and,
 - PG&E Transmission lines east and west of Sonoma Creek Bridge.
 - **Segment C. Mare Island to Interstate 80.** Located east of Napa River Bridge and west of the Interstate 80 interchange. This reach is approximately 4 miles long and includes two lanes in each direction with a 22-ft wide median separated by a concrete barrier. The existing roadway includes bridges over Napa River and White Slough and interchanges at Wilson Ave./Sacramento St., SR 29 (Sonoma Blvd), Fairgrounds Dr., and Interstate 80.

Table 2 provides information on the segment characteristics, typical elevations, and shoreline protection features.

Table 2. SR 37 Asset Characteristics, Typical Elevations, and Shoreline Protection Features

Segment	A	B	C
Roadway Designation	Expressway	Conventional Highway	Freeway
Speed Limit (MPH)	65	55	65
Transit Route (Bus)	Yes (Sonoma Valley-San Rafael Route 38)	None	None
Bicycle/Pedestrian Access Allowed?	Yes (partial)	Yes*	No
Roadway Elevation (flat portions, ft NAVD) ¹	2 to 6	7 to 11	>13
Shoreline Protection Feature(s)	Novato Creek Petaluma River, Sonoma Baylands, Sears Point, and Tolay Creek levees	West of Sonoma Creek: Tolay Creek, Sonoma Creek, and bayfront levees, East of Sonoma Creek: No bayfront levee; new levee along Cullinan Ranch	None
Shoreline Protection Feature Elevation (ft NAVD)	9 to 13	West of Sonoma Creek: 9 to 12 East of Sonoma Creek: N/A	N/A

Sources: Caltrans (2015); National Oceanic and Atmospheric Administration (NOAA) topographic Lidar data.

Notes: *Access is permitted, but inadvisable and seldom used. ¹The typical daily high tide (MHHW, mean higher high water) has an elevation of approximately 6.2 ft NAVD88 and the 100-yr extreme high tide has an elevation of approximately 9.7 ft NAVD88 (see AECOM (2015a) for more information on San Pablo Bay water levels).

Potential Inundation, Risk and Vulnerabilities

SR 37 is protected from inundation and flooding by a complex interconnected system of levees and berms that run along the shoreline of San Francisco Bay and along the five rivers and creeks that intersect the highway. These Bay and riverine flood sources provide a conduit for Bay floodwaters to inundate the highway during coastal flood events. A SLR exposure analysis was conducted to identify the extent and timing of permanent inundation or temporary flooding for each segment of SR 37 under different combinations of SLR and tide level. Inundation and

flooding due to typical daily high tides and extreme tides were evaluated to map the depth and extent of overtopping of the highway and protective shoreline assets for each segment.

Vulnerability to SLR was evaluated by considering the exposure, sensitivity, and adaptive capacity of each segment. Each highway segment exhibits different physical characteristics (e.g., elevation, proximity to Bay shoreline), use attributes (e.g., commuter and truck traffic), and SLR impacts, which affected the vulnerability and risk ratings developed as part of the assessment. Exposure was evaluated by examining the depth and extent of inundation, length of overtopped highway, and vulnerability of shoreline protection features. Sensitivity was evaluated by examining indicators such as age, level of use, historical performance during storm events, seismic sensitivity, and liquefaction susceptibility. The adaptive capacity of the regional transportation system was evaluated by examining the existence and viability of alternate routes in the event of SR 37 closure due to flooding.

Exposure, sensitivity, and adaptive capacity ratings were combined to develop composite vulnerability ratings for each segment. Segments A and B were predicted to be most vulnerable to potential SLR impacts and Segment C much less so. Based on the findings of the risk assessment, Segment B is predicted to have the highest immediate risk, Segment A is vulnerable to future risk, and Segment C is the least at risk.

Adaptive Structures: Conceptual Designs

This section discusses the conceptual design approach, assumptions, and details of the design scenarios and key findings of the design study. Conceptual plan, profile, and typical cross sections for each design scenario are provided in the Attachments.

Design Approach

Three engineering design scenarios were considered for the conceptual design study:

- 1) Roadway elevated on levee/embankment,
- 2) Roadway elevated on concrete beam/box girder bridge causeway supported by columns, and
- 3) Roadway elevated on concrete slab bridge causeway supported by piles.

Detailed descriptions of each scenario are provided in subsequent sections. The level of study conducted was considered to be high-level conceptual engineering only, and therefore was less detailed than that required for environmental review and documentation. Initial tasks for the concept design involved evaluating segment characteristics using available maps, field visits, and “as-built” drawings. Segment characteristics include alignment length, existing topography

and grades, existing roadway cross section, presence of existing structures/bridges, and roadway connections. Our team also assessed design constraints such as nearby utility corridors, such as PG&E transmission lines, or gas lines and/or adjacent transportation features such as railroad corridors. The primary considerations for the conceptual design under this study included:

- Existing characteristics and constraints,
- Proposed future configurations (e.g. proposing 4 travel lanes vs. 2 travel lanes)
- SLR, storm surge, and wave action caused by a coastal storm event
- Feasibility and constructability of the design
- Some environmental considerations

The conceptual design did not consider:

- The exact future alignment location
- Construction phasing or staging; and,
- Comprehensive environmental considerations.

The base mapping for the concept design was generated from GIS information and as-built plans. It was assumed that one horizontal alignment (plan layout) option can be used for all “Build” scenarios; however, the causeway scenarios (Scenarios 2 and 3) required separate profiles (vertical grades and elevations) due to the nature of the structure depth requirements. For the purposes of this study, AECOM assumed that the proposed horizontal alignment would run along the existing roadway alignment; however, from a constructability standpoint, the roadway will need to be aligned to the north or south of the existing roadway if the highway is to remain in operation during construction. Exact alignment will be determined during future design and environmental clearance phases.

Roadway Section

During a project meeting with Caltrans District 4 staff held on June 10, 2015, it was agreed that the assumed proposed roadway section would consist of the following:

- Standard four-lane highway with standard concrete barrier median (12' lanes, 36' median);
- Standard outside shoulders (10'); and,
- 12'-wide Class I bikeway (multi-use path), one side of the highway only.

According to Section 305.1 (1) of the Caltrans Highway Design Manual (HDM), “where managed lanes” or transit facilities are planned, the minimum median width should be 62 feet. Where there is little or no likelihood of managed lanes or transit facilities are planned for the future,

the minimum median width should be 46 feet. However, where physical limitations and economic limitations are such that a 46-foot median cannot be provided at reasonable cost, the minimum median width for freeways and expressways in urban areas should be 36 feet.” Under Section 305.1 (3) (a), for freeways and expressways, **in areas where restrictive conditions prevail, the minimum median width shall be 22 feet.** Under Section 305.1 (2), **“in rural areas, the minimum median width for multilane conventional highways shall be 12 feet”.** Under the levee/embankment scenario, a 5-ft separation between the mainline edge of shoulder and edge of bikeway is required based on requirements under the HDM for clearance to obstructions. For the purposes of the study, the median width for Reaches A, B, and C were assumed to be 36’ although most of Reach B is currently categorized as a conventional highway. For Reach B, a minimum median width of 12 feet may be proposed if it remains a conventional highway in the future. During a follow-up meeting with Caltrans District 4 staff held on September 16, 2015, Caltrans staff indicated that a 5-ft wide inside shoulder is acceptable for the 4-lane configuration proposed under each scenario, but a 36’ wide median should be maintained under the levee/embankment scenario.

Under the causeway scenarios, the two separate structures for the eastbound and westbound lanes and bike path each with 5-ft wide inside shoulders are assumed. A concrete barrier is assumed to separate the roadway from the bikeway without the 5’ separation in order to reduce structural costs. Typical sections for the three scenarios are provided as Attachments.

Sea Level Rise Design Criteria

AECOM investigated all three design scenarios for the above reaches based on water surface elevations for the 2100 Most-Likely Scenario (100-yr tide level +36”) from the inundation mapping study (AECOM 2015a)¹. A memorandum documenting the recommended minimum design elevations for each reach was prepared under separate cover and is provided as an attachment. The following table summarizes the minimum design elevations.

¹ The 2100 Most-Likely SLR Scenario (36”) coupled with the 100-yr ride level and additional freeboard exceeds the San Francisco Bay Conservation and Development Commission’s Guidelines.

Table 3. Minimum design elevations for levee and structural scenarios

Reach	Levee Scenario Min. Design Elevation (ft NAVD88)	Structural Scenario Min. Design Elevation (ft NAVD88)
A	15	15
B	17	17
C	14.5*	14.5*

Note: Minimum design elevation for the levee scenario indicates the minimum elevation of the edge of levee required to prevent overtopping onto the roadway. Minimum design elevation for the structural scenarios indicates the minimum elevation of the lowest structural element.

* 14.5' design elevation applies to area east of Napa River Bridge. 17' design elevation applies to area west of Napa River Bridge for Reach C.

Figure 2 provides a breakdown of the various elements included in the minimum design elevation calculations.

Figure 2. Calculation breakdown of design elevation

<p>Sheltered* Reaches: 100-yr Storm Surge (10 ft NAVD88) + SLR (3 ft) + Freeboard (2 ft) = 15 ft NAVD88</p> <p>Exposed* Reaches: 100-yr Storm Surge (10 ft NAVD88) + SLR (3 ft) + Wave Runup (3 ft) + Freeboard (1 ft) = 17 ft NAVD88</p>
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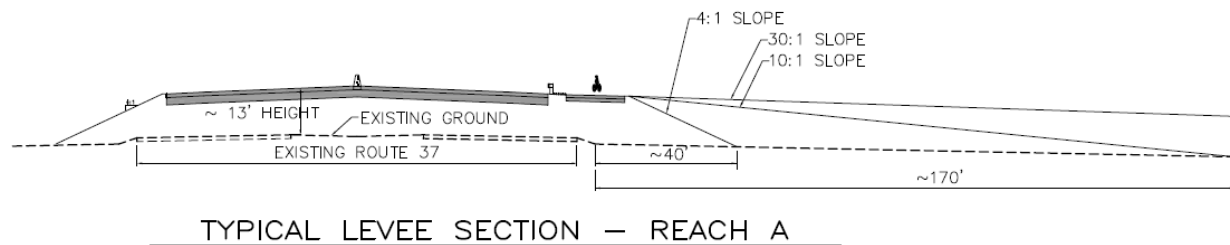
*Note: "Sheltered" reaches are located behind existing levees and it is assumed that these levees will continue to act as a barrier to Bay waves in the future, even in the event of inland flooding during a coastal storm event. "Exposed" reaches are located immediately adjacent to the Bay and would be exposed to wave effects during a coastal storm event.

Levee/Embankment Design

This scenario assumes that the full length of each segment, except along Reach C, would be on embankment except at existing bridges, which would be reconstructed under this scenario. For Reach C, approximately 1.5 miles of the reach (the western portion) would be on embankment which includes Mare Island Interchange and between Napa River Bridge and SR37/SR29 Interchange. The replaced structures would have a similar roadway width as the causeway scenario, approximately 97 ft wide (42-ft wide westbound, 55-ft wide eastbound + bikeway). The assumed pavement structural section would be similar to the existing pavement section and is based on available as-built drawings for the corridor.

The assumed levee/embankment sideslope is 4:1 which meets HDM standards for sideslopes. The following figure provides an example of the footprint of the roadway on levee/embankment scenario for Segment A relative to the existing highway with the various sideslope options. These options can be used for both reaches. The 10:1 and 30:1 sideslopes are for potential use of a living levee concept. The living levee would provide a broader outboard slope for transitional and wetland habitat as well as natural wave dissipation.

Figure 3. Typical Levee Design Footprint – Segment A



Box-Girder Causeway Design

This scenario assumes that almost the full length of the reach, except along Reach C, would be on concrete box girder causeway supported by concrete columns. For Reach C, approximately 1.5 miles of the reach (the western portion) would be on embankment which includes Mare Island Interchange and between Napa River Bridge and SR37/SR29 Interchange. The existing bridges would be replaced in-kind but would have a similar roadway width as the box girder causeway (approximately 97 ft wide – 42-ft wide westbound, 55-ft wide eastbound + bikeway). In most locations, constructability of the concrete structures using conventional falsework is not an issue; however, with restriction of falsework over the water ways, creeks or rivers, precast, prestressed concrete girder or steel girder options would be utilized in these cases. This design is most cost effective for medium to long spans (50' to 100'), with profile of a minimum 10 ft from the ground and would have lower maintenance costs than the embankment design. Depending on the future alignment, this option may not be applicable if the profile of the structure is less than 10' from the ground. More accurate mapping information would be required to determine the most applicable locations. For the purpose of the study, it was assumed that the box girder causeway can be applied along similar stretches as the slab-pile causeway design.

For this type of structural system, the superstructure consists of cast-in-place, post-tensioned, multi-celled box girders supported by cast-in-place concrete columns/piers, which is supported by a cast-in-drilled-hole (CIDH) pile shaft. For an assumed 3.5 ft thick box girder, spans can be up to 88 ft (depth/span ratio = 0.04). The causeway would be divided into frames using

expansion joints within the spans. Expansion joints are placed in locations that will satisfy temperature, creep, and economical requirements.

With the assumed structure widths of 45 ft and 55 ft, the selected substructure types for the 3.5 ft thick prestressed concrete box girder spans up to 88 ft are six 4 ft diameter columns on 5 ft diameter (minimum) pile shaft, or four 5.5 ft diameter columns on 7 ft diameter pile shaft. For the purposes of this study, the four 5.5 ft columns are shown in the typical sections, which provide the least number of columns to minimize construction impacts.

Slab-Pile Causeway Design

This scenario assumes the full length of the segment, except along Reach C, would be on concrete slab bridge causeway supported by concrete piles. For Reach C, approximately 1.5 miles of the reach (the western portion) would be on embankment which includes Mare Island Interchange and between Napa River Bridge and SR37/SR29 Interchange. The existing bridges would be replaced in-kind, but would have similar roadway width as the proposed slab bridge causeway (approximately 97 ft wide – 42-ft wide westbound, 55-ft wide eastbound + bikeway). Similar to the box girder design, constructability of the concrete structures using conventional falsework is not an issue; however, with restriction of falsework over the water ways, creeks or rivers, precast, prestressed concrete girder or steel girder options would be utilized in these cases. This structural system is cost effective for small spans up to 40 ft and shallow structures with profile up to 20 ft from the ground. This scenario would have lower maintenance costs than the embankment design.

With the assumed structure widths of 45 ft and 55 ft, the selected substructure types for the 20 inch thick concrete slab spans up to 40 ft are seven 42 inch diameter cast-in-steel-shell pile shaft, or eleven 24 inch diameter columns on 42 inch diameter pile shaft. For the purposes of this study, the seven 42-inch diameter columns are shown in the typical sections, which provide the least number of columns to minimize construction impacts.

Conceptual Engineering Design Key Findings

The key findings of the conceptual engineering design study are discussed in the following paragraphs.

Under all scenarios, the following potential construction impacts would result for Segment A:

- Reconstruction of Novato Creek, Simonds Slough, Atherton Ave., and Petaluma River bridges;

- Modifications to intersections (if maintained) which include Lakeville Road, SR 121, driveways, and minor access roads;
- Modifications to interchange ramps at Hwy 101 and Atherton Ave.
- Potential realignment of railroad tracks; and
- Potential relocation PG&E transmission lines and utility poles.

Under all scenarios, the following potential construction impacts would result for Segment B:

- Reconstruction of Tolay Creek and Sonoma Creek bridges;
- Modifications to intersections (if maintained) which include Skaggs Island Road, Noble Road, driveways, and minor access roads including trailheads and maintenance roads;
- Reconstruction of railroad crossing east of SR 121; and,
- Potential relocation of PG&E transmission lines and utility poles.

Under all scenarios, the following potential construction impacts would result for Segment C:

- Reconstruction of Walnut Ave. Overcrossing and Sacramento Street Overcrossing
- Modifications to west approach of Napa River Bridge;
- Modifications to Mare Island interchange including reconstruction of west approach interchange ramps and replacement of Walnut Ave. Overcrossing;
- Modifications to Wilson Ave./Sacramento Street interchange including reconstruction of east approach interchange ramps and replacement of Sacramento Street Overcrossing;
- Replacement of White Slough Bridge; and,
- Modifications to SR 37/SR 29 interchange including reconstruction of the eastbound off-ramp.

For Segments A, B, and C, the levee scenario would result in the widest footprint of all the scenarios.

Adaptive Structures: Cost Estimates

We prepared Rough-Order of Magnitude (ROM) estimates for Segments A, B, and C under all three scenarios. The following sections discuss the basis of estimates, cost estimates for each concept design based on segment, and assumptions. An Estimate Summary and Detail Report for each reach and scenario are provided in the Attachments.

Basis of Estimates

We prepared Rough-Order-of-Magnitude (ROM) estimates using Caltrans Planning Level Cost Estimate Excel Spreadsheets. The Caltrans Preparation Guidelines for Project Development Cost

Estimates (August 2014) was used as a reference for developing the order of magnitude estimates. Furthermore, the Caltrans Preliminary Cost Estimate template in Excel was used to input quantities and allowances to develop the cost totals for each scenario and reach. All material unit prices are based on construction costs from published 2014 Caltrans Cost Data as applicable.

The primary elements of the order-of-magnitude cost estimates are:

- Construction items (e.g., pavement, barrier, fill, drainage, structure, lighting, striping);
- Right-of-way acquisition and utility relocations;
- Environmental mitigation; and,
- Support costs (e.g., administration, planning, engineering, right of way, construction management).

The assumptions for each cost element are described in the following paragraphs.

Construction Items

Material units of measurement and prices are based on 2014 construction costs from the Caltrans Cost Data Book as applicable. Since no detailed design information has been developed for drainage, environmental mitigation, traffic items, construction staging, and traffic handling, allowances were applied based on experience from similar projects. In addition,

Right-of-Way and Utilities

Allowances for right of way were included assuming that the Northern Pacific Railroad may need relocation depending on the alignment for the embankment design, properties west of Petaluma River Bridge may need acquisition (Reach A), properties at Mare Island east of Napa River Bridge may need acquisition, and PG&E transmission towers would also need relocation for all scenarios.

Support Costs (also called Soft Costs)

Support costs include project administration, engineering, planning, environmental clearance support, right of way, supervision, and construction management.

Soft Costs are applied as follows:

- Total Construction Costs, Levee/Embankment Scenario -- 50%
- Total Construction Costs, Bridge Scenarios -- 42%

The soft costs for the Bridge Scenarios are less than the Levee/Embankment Scenario, because it is assumed that engineering support costs would be less given that fewer engineering disciplines would be required to support the design for the Bridge Scenarios.

Finance Charges

Finance charges are not included in the estimates prepared by AECOM.

Contingency

Contingency is an allowance to compensate for use of limited information and uncertainty as to the precise content of all items in the estimate, how work will be performed, what work conditions will be like when the project is executed. It also recognizes the approximate estimating methods used at this early stage of project development. Contingency was developed as a percentage in the areas of Construction and based on the information provided. The recommended contingency has been applied as follows:

- Construction (excluding Structures) = 40%
- Structures = 30%

Cost Escalation

Cost escalation to time of expenditure dollars is included to Year 2030 at 3% annually. The estimate has been prepared in Mid-2015 base-year dollars.

Cost Estimate for Levee/Embankment Design

The approximate rough-order-of-magnitude costs for Segments A, B, and C under this scenario are **\$463,000,000**, **\$647,000,000**, and **\$151,000,000** respectively. The assumptions for the levee/embankment design cost estimates were:

- All existing bridges would be reconstructed (except Napa River Bridge (Reach C));
- Railroad tracks on Segment A would be relocated;
- 40% contingency on roadway construction;
- 30% contingency on Structures; and,
- Support Costs are about 50% of Roadway and Structures Construction Cost.

Cost Estimate for Box-Girder Causeway Design

The primary construction cost element for this design would be structural costs. Based on Caltrans Cost Data, the construction cost ranges from \$160 to \$300 per sq ft of bridge deck for this system. The approximate rough-order-of-magnitude costs for Segments A, B, and C under this scenario are **\$1,416,000,000**, **\$2,454,000,000**, and **\$386,000,000** respectively. The assumptions for the box girder causeway design cost estimates were:

- 75% of Segment A would be on structure;
- 95% of Segment B would be on structure;
- 55% of Segment C would be on structure;
- All existing bridges would be reconstructed (except Napa River Bridge (Reach C));
- 40% contingency on roadway construction;

- 30% contingency on structures; and
- Support costs are about 40% of roadway and structures construction cost.

Cost Estimate for Slab-Pier Causeway Design

The primary construction cost element for this design would be structural costs. Based on Caltrans Cost Data, the construction cost ranges from \$90 to \$200 per sq ft of bridge deck for this system. The higher end of the range was used for this study. The approximate rough-order-of-magnitude costs for Reaches A, B, and C under this scenario are **\$1,261,000,000**, **\$2,170,000,000**, and **\$336,000,000**, respectively. The assumptions for the slab bridge causeway design cost estimates were:

- 75% of Segment A would be on structure;
- 95% of Segment B would be on structure;
- 55% of Segment C would be on structure;
- All existing bridges would be reconstructed (except Napa River Bridge (Reach C));
- 40% contingency on roadway construction;
- 30% contingency on structures; and
- Support costs are about 40% of roadway and structures construction cost.

Adaptive Structures: Accommodating Tides, Transit and Access

The primary intended function of elevating SR 37 onto the proposed structures is to adapt to potential SLR and storm events. At the same time, transportation interests would like to accommodate more non-transit vehicles, as well as transit, cyclists, and pedestrians. The structures are likely to vary in their provision of these intended services. This variation is discussed in the following sections.

“Adaptation planning and implementation should be based on the principles of adaptive management so that they take into account uncertainty and maximize the opportunities to learn from management actions.” (BCDC, 2011)

Accommodating Tides, Sea Level Rise and Marsh Ecosystems

As sea elevation rises, high tides will increasingly intrude into currently non-saline marshes and terrestrial areas. For some areas, such as the restored Baylands and Sears Pt marshes, or the marshes facing the Bay south of segment B, this will be a gradual process. For farmed and upland areas currently protected by levees along segments A and B, this could be a stochastic

flooding event, or a managed change in land-status (e.g., from lowland terrestrial area to tidal marsh). The SR 37 road berm currently provides some protection to certain lands from high tides and is likely to for a few decades. In addition, levees intended to protect the current SR 37 and rail alignments are also likely to continue protecting adjacent currently freshwater and terrestrial systems from tidal inundation.

Levees, such as the one proposed for elevating SR 37 (e.g., figure 3) are designed to limit flows of water from one side of them to the other. Although structures can be inserted into the levee to allow managed, tidal or other flows, the primary intent is to limit hydrological connectivity. This limitation of free flows across the right-of-way is likely to reduce the adaptive responses of marsh and non-marsh areas to new sea elevations and tidal intrusions. What this means is that, if SR 37 is placed on a levee, certain low-elevation areas will become increasingly “stranded” from adapting to new conditions.

“Integrating mitigation and adaptation planning can reduce inefficiencies and potential conflicts while providing greater protection. For example, conserving and restoring tidal marsh provides flood protection and achieves mitigation by sequestering carbon. In addition, increased habitat will be available to climate-stressed species.”
(BCDC, 2011)

Levees can be made permeable to water flows, which changes their functions as levees. Short-span bridges and culverts could be used to allow constrained flows of tidal water back and forth beneath the highway. This back and forth flow would change significantly during storm events and as sea levels rise. Constrained flows would inevitably change erosion and deposition patterns and in the worst case could actually result in loss of marsh sediments, reducing the adaptive capacity of marshes. In the case of SR 37, a permeable levee design is essentially a less-costly way to elevate SR 37 above new sea elevations than the causeway scenarios.

Accommodating Transit Needs

State policy is for new and expanded highways to include transit and high-occupancy vehicle opportunities. All 3 engineered scenarios for SR 37 include lane widths useable by bus transit. Although there was discussion of rail transit during the project, it was not obvious what agency would take the lead for constructing a new alignment adjacent to or near SR 37. Because of this, no consideration was given to rail-based transit on the constructed scenarios. Obviously, a parallel rail alignment would still be possible, assuming its impacts to adjacent ecosystems were mitigatable.

Any new transit would need to have infrastructural support at either end of SR 37 to connect to existing transit and other commuting options. Because any bus transit supported by the SR 37 project would rely upon this new transit infrastructure, mitigation for impacts of SR 37

expansion could include transit support. This would ideally occur in Vallejo and Novato, cities which anchor either end of SR 37.

Accommodating Access to and From Route Designs

There is current, limited access to SR 37 through intersecting roads and highways. Pedestrian and cycling access is almost non-existent, including safe opportunities to cross the highway. Expanding and raising the highway provides opportunities to modify (further limit or expand) access to and from the route and to change barriers to access that SR 37 currently provides.

The elevated designs that are adaptive to rising sea elevations will require that any remaining connections to highways, streets, and private driveways will need to be reconstructed. This project's scope included acknowledging this requirement, but did not include anticipating the designs or costs associated with changing these access points. Nor did it include determining which access points would be retained once SR 37 is elevated and expanded.

The access points cover several types of activity, summarized below:

- 1) **Regional circulation** Access to and from I-80, SR 29, SR 121, Lakeville Highway, and US 101 is critical to maintaining connections between SR 37 and regional cities. Of these, the intersections with SR 121 and Lakeville Highway are particularly low elevation, posing risks to the routes themselves, as well as implying that maintaining connections between them and SR 37 will require new intersection structures.
- 2) **Local circulation** There are several local streets that connect with SR 37, providing access to Vallejo, Mare Island, Sears Pt, and Black Pt/Atherton. Of these, Sacramento St, Wilson Ave, Sears Pt Rd, and Railroad Ave are low elevation and potentially at risk from inundation themselves with SLR. Of these, Railroad Ave (access to Mare Island) at Guadalcanal Village is probably both the most exposed and has the greatest difference between current elevation and the likely elevation of segment B after elevation of SR 37.
- 3) **Private property access** Besides access via local roads, there are several properties along segment A and B that are accessed directly from SR 37. In every case, this access is either at grade or below grade compared to SR 37.
- 4) **Public/recreational site access** Several recreational access points can only be accessed from SR 37. For example, undeveloped fishing sites near Vallejo and on Sonoma Creek are accessed from parking lots directly accessed from SR 37. There are also trails accessed from SR 37, such as the trail-head and trail adjacent to Tolay Lagoon.

Citations

AECOM 2015a. Sea Level Rise Inundation Modeling and Mapping for State Route 37 Region and Preliminary Vulnerability Assessment (Tasks 1 and 2). Prepared for: University of California, Davis.

AECOM 2015b. State Route 37 Sea Level Rise Vulnerability and Risk Assessment (Task 2) Memorandum. Prepared for: University of California, Davis.

BCDC (Bay Conservation and Development Commission) 2011. Living with a rising bay: Vulnerability and Adaptation in San Francisco Bay and on its shoreline.

Caltrans 2015. Transportation Concept Report. State Route 37. District 4. January 2015.

Attachments

1. Scenario 1 Levee/Embankment Design Conceptual Plan and Profile
2. Scenario 2 Box Girder Causeway Conceptual Plan and Profile
3. Scenario 3 Slab Pile Causeway Conceptual Plan and Profile
4. Conceptual Design Typical Cross Sections
5. Memorandum: SR37 Conceptual Engineering Design – Minimum Design Elevation (Task 3)
6. Scenario 1 Order of Magnitude Cost Estimate (Reach A)
7. Scenario 1 Order of Magnitude Cost Estimate (Reach B)
8. Scenario 1 Order of Magnitude Cost Estimate (Reach C)
9. Scenario 2 Order of Magnitude Cost Estimate (Reach A)
10. Scenario 2 Order of Magnitude Cost Estimate (Reach B)
11. Scenario 2 Order of Magnitude Cost Estimate (Reach C)
12. Scenario 3 Order of Magnitude Cost Estimate (Reach A)
13. Scenario 3 Order of Magnitude Cost Estimate (Reach B)
14. Scenario 3 Order of Magnitude Cost Estimate (Reach C)