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Memorandum

Date: **May 6, 2020**

To: **Rodney Pimentel and Lillie A. Lam, HNTB CORPORATION**

From: **Kazuya Tsurushita and Haimet Kassaye, WRECO**

Subject: **Review and Assessment of Sea-Level Rise at the Oakland Alameda Access Project**

1. INTRODUCTION

This memorandum is prepared to document the findings of the review of available information on the potential for Sea-Level Rise (SLR) at the Oakland Alameda Access Project (Project). All applicable SLR data, the pertinent project information, and the assessment of the implications of the findings were analyzed and summarized in this memorandum.

2. PROJECT DESCRIPTION

The proposed Project is located in the cities of Oakland and Alameda in Alameda County, California. The Project proposes to improve access along Interstate 880 (I-880) and in and around the Posey and Webster Tubes (Tubes), downtown Oakland, and the City of Alameda. Within the approximately 1-mile-long Project, I-880 (PM ALA 30.47 to PM 31.61) and State Route 260 (SR-260) (PM ALA R0.78 to R1.90) are major transportation corridors. Also, the I-880 freeway viaduct is a physical barrier, limiting bicycle and pedestrian connectivity between downtown Oakland and Chinatown to the north and the Jack London District and Oakland Estuary to the south. Existing local street patterns across I-880 are intertwined with on- and off-ramps and the Tubes connecting Oakland and Alameda affecting the cross-freeway circulation of motorists, bicyclists, and pedestrians.

Purpose and Need

Purpose

The purpose of the Project is to:

- Improve multimodal safety and reduce conflicts between regional and local traffic;
- Enhance bicycle and pedestrian accessibility and connectivity within the project study area;
- Improve mobility, and accessibility between I-880, SR-260 (Tubes), City of Oakland downtown neighborhoods, and City of Alameda;
- Reduce freeway-bound regional traffic and congestion on local roadways and in area neighborhoods.

Need

Access between the freeway and the roadway networks between I-880 and the Tubes is limited and indirect, and access to/from the cities of Oakland and Alameda is circuitous. Existing access to I-880 from Alameda and the Jack London District requires loops through several local streets and intersections, routing vehicles through the downtown Oakland Chinatown neighborhood, which has the following operational impacts on local streets:

- Streets in and around the downtown Oakland Chinatown area have a high volume of pedestrian activity and experience substantial vehicle-pedestrian conflicts, and the I-880 viaduct limits bicycle and pedestrian connectivity between downtown Oakland and the Jack London District.
- SB I-880 traffic heading to Alameda must exit at the Broadway/Alameda off-ramp, then travel south along 5th Street for more than a mile — through nine signalized and unsignalized intersections — before reaching the Webster Tube at 5th Street/Broadway.
- WB I-980 traffic heading to Alameda must exit at the Jackson Street off-ramp and circle back through Chinatown through seven signalized and unsignalized intersections to reach the Webster Tube.
- NB I-880 traffic heading to Alameda must exit at the Broadway off-ramp and form a queue on Broadway between 5th and 6th streets, which backs up onto the ramp. Alternatively, drivers may loop through Chinatown to access the Webster Tube.

No-Build (No-Action) Alternative

Under the No-Build Alternative, there would be no improvements to bicycle or pedestrian connectivity or safety. Freeway traffic to/from the cities of Oakland and Alameda would continue to use city streets through Oakland and Chinatown, which are areas with a high volume of pedestrian activity. Vehicle-pedestrian or -bicycle conflicts from traffic traveling through city streets would continue. The I-880 viaduct would continue to impede connectivity between downtown Oakland and the Jack London District, and access would not be improved for bicycles and pedestrians traveling between Oakland and Alameda.

Build Alternative

Under the Build Alternative, Caltrans and ACTC propose to remove and modify the existing freeway ramps and to modify the Posey Tube exit in Oakland. The Build Alternative would improve access to NB and SB I-880 from the Posey Tube via a right turn-only lane from the Posey Tube to 5th Street and a new horseshoe connector at Jackson Street below the I-880 viaduct that would connect to the existing NB I-880/Jackson Street on ramp. The existing WB I-980/Jackson Street off ramp would be reconstructed and shifted to the south.

The Webster Tube entrance at 5th Street and Broadway would be shifted to the east to create more space for trucks to make the turn from Broadway into the Webster Tube. A bulb-out would be constructed to extend the sidewalk, reducing the crossing distance and allowing improved visibility of pedestrians on the southeast corner.

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The NB I-880/Broadway off-ramp would be removed and the NB I-880/ Oak Street off-ramp to 6th Street would be widened. The NB I-880/Oak Street intersection would become the main NB I-880 off-ramp to downtown Oakland and to Alameda. 6th Street would become a one-way through street from Oak Street to Harrison Street and a two-way street from Harrison Street to Broadway.

The proposed Project would include the addition of a Class IV two-way cycle track on 6th Street between Oak and Washington streets and on Oak Street between 3rd and 9th streets. Bicycle and pedestrian improvements would be constructed at the Tubes' approaches in Oakland and Alameda, and the Webster Tube westside walkway would be opened to pedestrians. This would improve connectivity to existing and future planned bicycle paths in the City of Oakland and implement various "complete streets" improvements to create additional opportunities for non-motorized vehicles and pedestrians to cross under I-880 between downtown Oakland, the Jack London District, and Alameda. See Figure 1, Figure 2, Figure 3, and Figure 5 for proposed elements of the Build Alternative.

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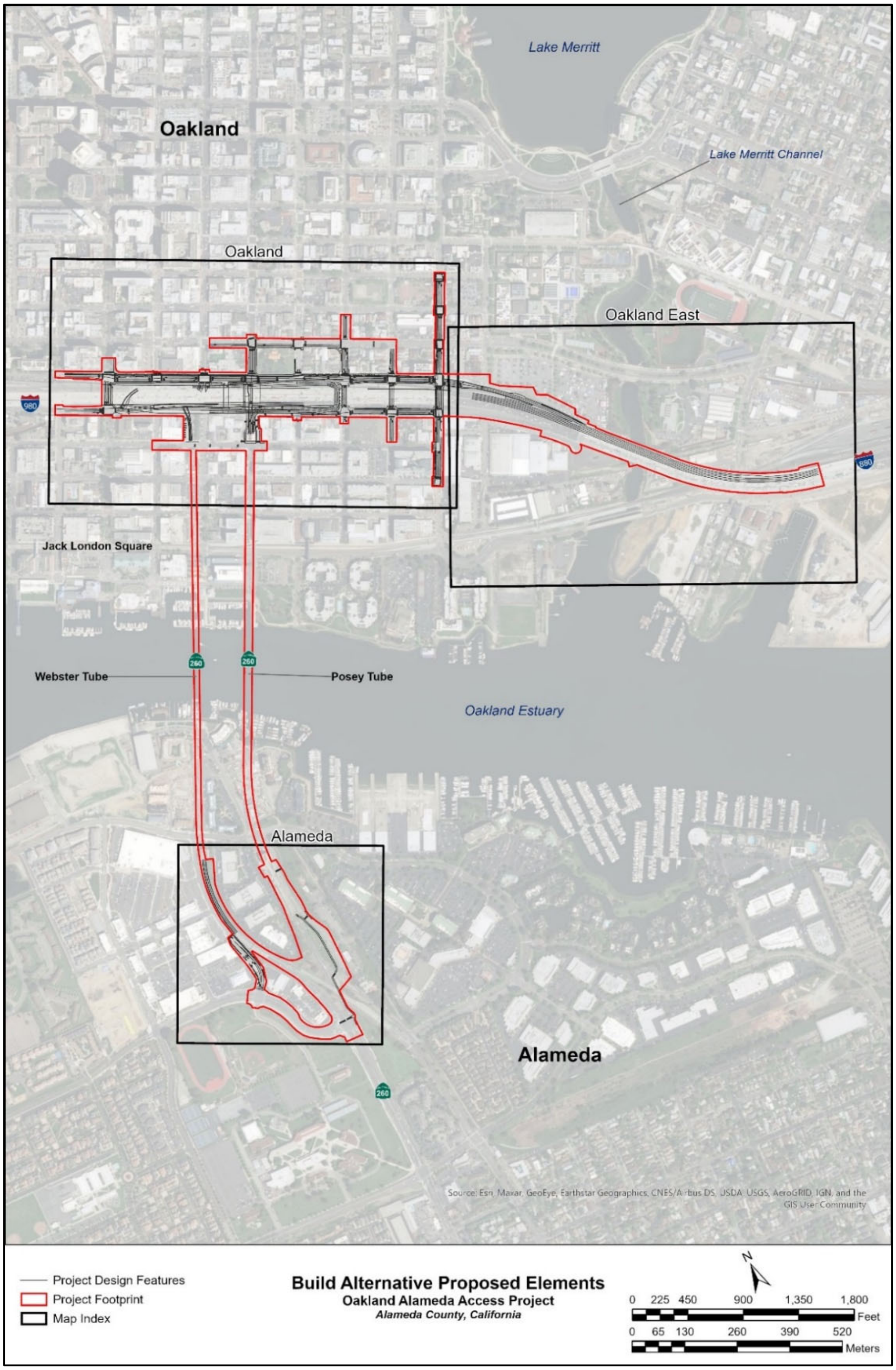

Figure 1. Build Alternative Proposed Elements, Project Overview

Source: HNTB

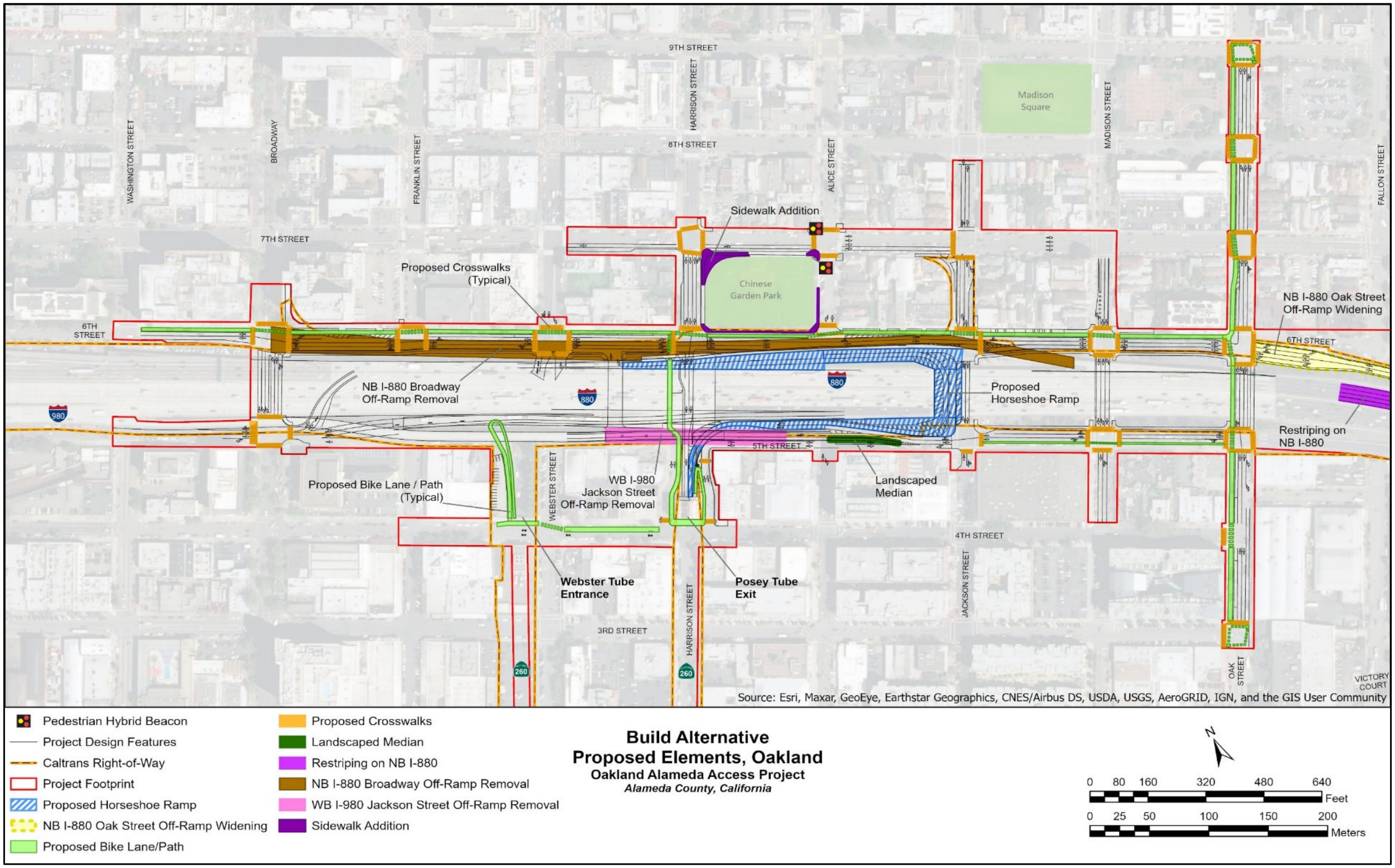

Figure 2. Build Alternative Proposed Elements, Oakland

Source: HNTB

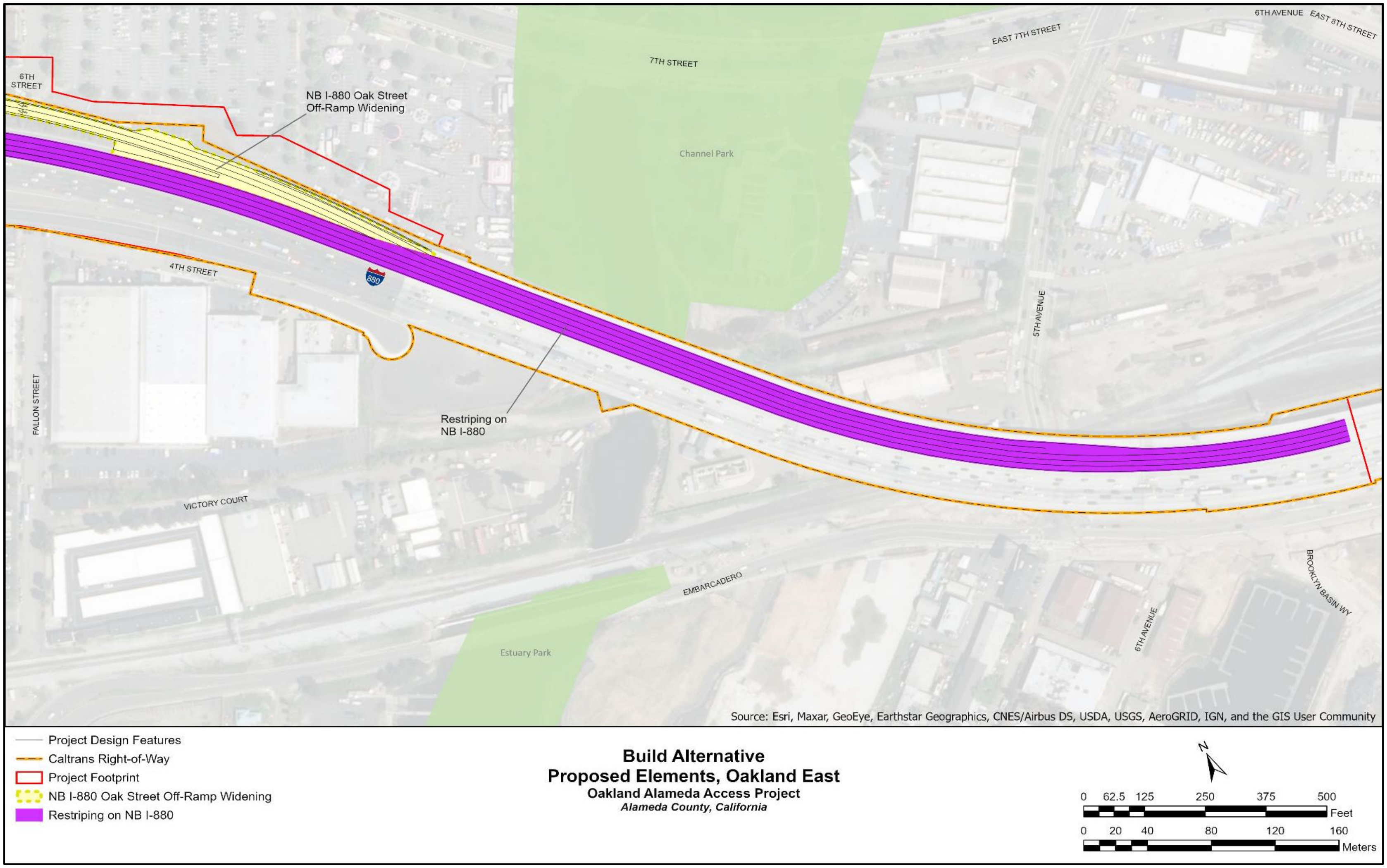

Figure 3. Build Alternative Proposed Elements, Oakland East

Source: HNTB

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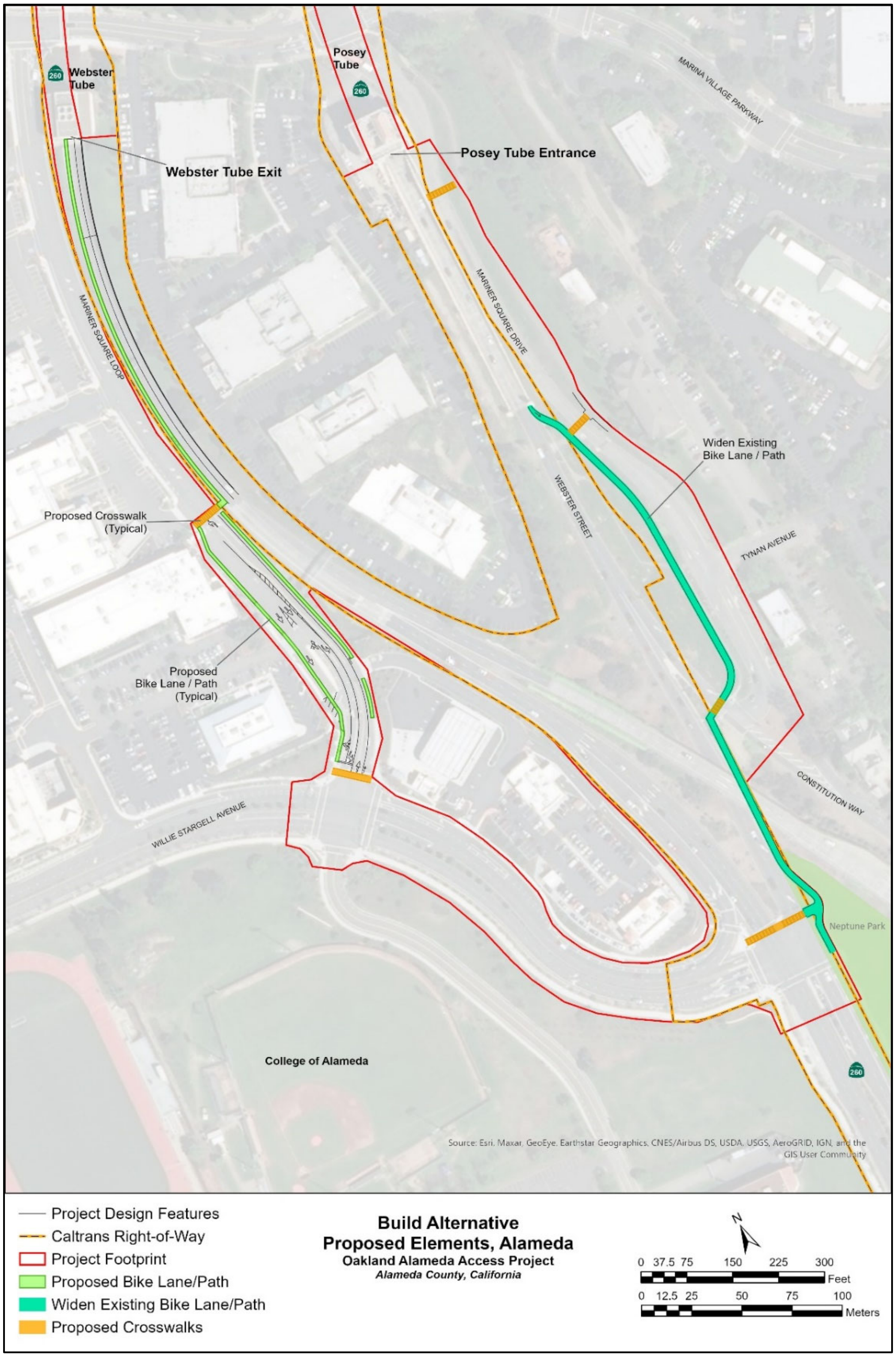

Figure 4. Build Alternative Proposed Elements, Alameda

Source: HNTB

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3. REGULATORY SETTING

In the state of California, then-Governor Arnold Schwarzenegger signed Executive Order S-13-08 on November 14, 2008. This executive order directed all state agencies planning to construct projects in areas vulnerable to future sea-level rise to consider a range of sea-level projections for the years 2050 and 2100, assess project vulnerability, and to the extent feasible, reduce expected risks and increase resiliency to sea-level rise. As stated in a recent report by the California Coastal Commission, *Sea Level Rise Policy Guidance* (2018), as a result of the Executive Order S-13-08 and agency needs for guidance, many state agencies, including the California Department of Transportation (Caltrans), have since developed climate change and sea-level rise policies and guidance documents.

Caltrans adheres to Order S-13-08 with guidance summarized in *Guidance on Incorporating Sea Level Rise – For use in the planning and development of Project Initiation Documents*, published by Caltrans on May 16, 2011 (Caltrans Guidance). This guidance includes statewide SLR projections published by the Ocean Protection Council in March 2011. The latest SLR study, *State of California Sea-Level Rise Guidance, 2018 Update* published by the California Natural Resources Agency and California Ocean Protection Council provides scenario-based SLR projections at local active tidal gauge locations including San Francisco. In addition, according to the 2019 *Climate Change Annotated Outline Non-Capacity Increasing Projects* (AO) found in the Forms and Templates section of the Caltrans Standard Environmental Reference (SER), a project is recommended to consider a list of factors to determine the need for SLR adaptation measures.

4. TIDAL, FLOODPLAIN, AND TOPOGRAPHIC DATA

Tidal Data

Tidal data was obtained from the National Oceanic Atmospheric Administration (NOAA). The published tidal datum data at the tidal gauge station closest to the Project site, Alameda Station (Station 9414750), was used to relate the tidal datums to geodetic datums (see Table 1 for the gauge data and Figure 5 in the Attachments for the gauge location map). The elevation of the tidal datums for this station referenced the Mean Lower Low Water (MLLW) datum. The station had a published Highest Observed Tide (HOT) as well as a Lowest Observed Tide (LOT). The National Average Vertical Datum of 1988 (NAVD 88) is 0.23 ft MLLW, which means an elevation of 0.0 ft NAVD 88 is equal to an elevation of 0.23 ft MLLW. Based on this conversion factor at Alameda Station, the relevant tidal datum was converted to NAVD 88 and summarized in Table 2. Accordingly, the Mean Higher High Water (MHHW) at this gauge is approximately 6.4 ft NAVD 88.

Table 1. Tidal Datum for Alameda Station 9414750

Elevations on Mean Lower Low Water

Station: 9414750, Alameda, CA
T.M.: 0
Status: Accepted (Oct 6 2011)
Epoch: 1983-2001
Units: Feet
Datum: MLLW
Control Station:

Datum	Value	Description
MHHW	6.60	Mean Higher-High Water
MHW	5.98	Mean High Water
MTL	3.56	Mean Tide Level
MSL	3.45	Mean Sea Level
DTL	3.30	Mean Diurnal Tide Level
MLW	1.14	Mean Low Water
MLLW	0.00	Mean Lower-Low Water
NAVD88	0.23	North American Vertical Datum of 1988
STND	-3.33	Station Datum
GT	6.59	Great Diurnal Range
MN	4.84	Mean Range of Tide
DHQ	0.62	Mean Diurnal High Water Inequality
DLQ	1.13	Mean Diurnal Low Water Inequality
HWI	8.01	Greenwich High Water Interval (in hours)
LWI	1.50	Greenwich Low Water Interval (in hours)
Max Tide	9.65	Highest Observed Tide
Max Tide Date & Time	12/03/1983 18:18	Highest Observed Tide Date & Time
Min Tide	-2.57	Lowest Observed Tide
Min Tide Date & Time	01/11/2009 01:42	Lowest Observed Tide Date & Time
HAT	7.98	Highest Astronomical Tide
HAT Date & Time	12/31/1986 19:18	HAT Date and Time
LAT	-1.94	Lowest Astronomical Tide
LAT Date & Time	05/25/1990 14:24	LAT Date and Time

Source: NOAA Tides and Currents, 2019

Table 2. Alameda Tidal Datum Conversion from MLLW to NAVD 88

Datum	MLLW ft	NAVD 88 ft
HOT (DHT)	9.65	9.42
MHHW	6.60	6.37
MHW	5.98	5.75
MTL	3.56	3.33
MSL	3.45	3.22
MLW	1.14	0.91
NAVD88	0.23	0.00
MLLW	0.00	-0.23
LOT	-2.57	-2.80

Source: NOAA Tides and Currents, 2019

Topographic Data

Due to the nature of the proposed work, the existing elevations would not change significantly as a result of the Project. Therefore, identification of tidally influenced areas is based on the existing topography within the limits of the Project.

The Oakland study area is located in the southern slope of the knoll that holds downtown Oakland. In addition to the sloped knoll, the Project site is also located on flatter terrain near the Oakland Estuary and San Francisco Bay. The Alameda study area is located on the northerly side of the ridgeline, where terrain gently slopes toward the Oakland Estuary. Figure 6 (see Attachments) shows all the elevations below the 6.4 ft NAVD 88 MHHW elevation. The map was developed using a 1/9th arc-second Digital Elevation Model (DEM) obtained from the United States Geological Survey (USGS). The topographic map shows that within the City of Oakland, all the proposed surface improvements would be above 6.4 ft NAVD 88, and therefore, these portions of the Project would not be tidally influenced.

Approximately 25% of the Project areas located within the City of Alameda are below 6.4 ft NAVD 88 and are therefore, tidally influenced. Figure 7, the topographic map (included in the Attachments), shows areas within the Project limits that are below 6.4 ft NAVD 88.

5. SEA LEVEL RISE PROJECTIONS

State of California Guidance

The *State of California Sea-Level Rise Guidance, 2018 Update* (2018 SLR Guidance), was used to obtain scenario-based SLR projections applicable to the Project site. The SLR projections for San Francisco included in the 2018 SLR Guidance are provided in Table 3. The 2018 SLR Guidance uses 2000 as the baseline for the probabilistic projections and have low and high emission scenarios leading up to 2150.

Table 3. SLR Projections for San Francisco

		Probabilistic Projections (in feet) (based on Kopp et al. 2014)				
		MEDIAN	LIKELY RANGE		1-IN-20 CHANCE	1-IN-200 CHANCE
		50% probability sea-level rise meets or exceeds...	66% probability sea-level rise is between...		5% probability sea-level rise meets or exceeds...	0.5% probability sea-level rise meets or exceeds...
				Low Risk Aversion		Medium - High Risk Aversion
High emissions	2030	0.4	0.3 -	0.5	0.6	0.8
	2040	0.6	0.5 -	0.8	1.0	1.3
	2050	0.9	0.6 -	1.1	1.4	1.9
Low emissions	2060	1.0	0.6 -	1.3	1.6	2.4
High emissions	2060	1.1	0.8 -	1.5	1.8	2.6
Low emissions	2070	1.1	0.8 -	1.5	1.9	3.1
High emissions	2070	1.4	1.0 -	1.9	2.4	3.5
Low emissions	2080	1.3	0.9 -	1.8	2.3	3.9
High emissions	2080	1.7	1.2 -	2.4	3.0	4.5
Low emissions	2090	1.4	1.0 -	2.1	2.8	4.7
High emissions	2090	2.1	1.4 -	2.9	3.6	5.6
Low emissions	2100	1.6	1.0 -	2.4	3.2	5.7
High emissions	2100	2.5	1.6 -	3.4	4.4	6.9

Source: Coastal and Ocean Working Group of the California Action Team (CO-CAT), 2018

Since the Project includes various types project improvements, the design life was determined in close coordination with Caltrans. The Project Design Team (PDT) reviewed the Project's design elements and decided upon a Project design life of 50 years. Therefore, based on an anticipated Project completion in 2027, the Project's SLR projections for 2077 were interpolated from the San Francisco SLR trends presented in the 2018 SLR Guidance for the low and medium-to-high risk scenarios. Based on the high emission SLR projections from 2030 and 2150, a low risk SLR projection of 2.2 ft and medium-to-high projection of 4.3 ft were interpolated using a second order polynomial best-fit curve (see Attachments for the calculations). The projections are summarized in Table 4.

United States Army Corps of Engineers Sea Level Change Curve Calculator

In addition to the 2018 SLR Guidance, the United States Army Corps of Engineers' (USACE) Sea-Level Change Curve Calculator (SLCC Calculator), Version 2019.21, was used to calculate SLR projections at the Project location. The USACE scenarios (USACE, 2013), the 2012 NOAA scenarios (NOAA et al., 2012), the Coastal Assessment Regional Scenario Working Group's scenarios (CARSWG, 2016), and the NOAA 2017 scenarios (NOAA et al., 2017) were used to obtain MSL at the Project site.

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The MSL values obtained from the SLCC Calculator were used to determine the changes from 2027 to 2077 for the low and medium-to-high risk values. Because some of the scenario sources had more than three risk levels, the range of the values were taken where applicable. The SLR changes calculated using the NOAA 2017 scenarios were the most conservative and therefore, selected as the basis of comparison with the SLR projections determined from the 2018 SLR Guidance (see Table 4). Because the NOAA 2017 scenarios provide MSL values at the end of each decade between 2000 and 2100, the MSL values were interpolated using a second order polynomial best-fit curve to determine the MSL change that could occur during the Project's design life timeframe (see Attachments for the calculations).

Table 4. SLR Projections at Project Site

Scenario Source	2018 SLR Guidance Projections at Year 2077 (ft)	
	Low Risk	Medium-to-High Risk
2018 SLR Guidance	2.2	4.3
NOAA et al. 2017	0.4	0.6 – 3.4

Source: CO-CAT and USACE

Compared to the SLCC Calculator results, the SLR projections for the San Francisco Bay from the 2018 SLR Guidance were more conservative. Therefore, the 2018 SLR Guidance Medium-to-High Risk scenario SLR of 4.3 ft was used to determine the potential impacts of SLR on the Project. On April 10, 2020, the PDT selected the MHHW as the baseline for the Project's SLR evaluation as used in BCDC's mapping tool, Adapting to Rising Tides: Bay Shoreline Flood Explorer. Table 5 summarizes the MHHW elevation projected to 2077.

Table 5. Design Tidal Elevations at Project Site with SLR

Elevation/Datum	Existing Elevations (ft NAVD 88)	Year 2077 Elevations (ft NAVD 88)
MHHW	6.4	10.7

Source: FEMA, 2018

The potential inundations that could result from the determined SLR projections within the Project vicinity were obtained from the NOAA and BCDC mapping tools. An SLR value of 52 inches (4.3 ft) was used in the Bay Shoreline Flood Explorer to map the potential inundation in the Project vicinity. Because only whole numbers could be selected in the NOAA SLR mapping tool, Sea Level Rise Viewer, a 5 ft SLR was used (see Figure 7 and Figure 8 in the Attachments for the inundation maps). Note that the SLR elevation of 10.7 ft NAVD 88 does not account for temporary factors such as El Nino or storm surges that could also increase water levels. King Tides, which occur every winter, would raise the water levels above the typical daily high tide elevation, as well.

6. SEA-LEVEL RISE IMPACTS AND ADAPTATION MEASURE CONSIDERATIONS

Based on the estimated 2077 SLR projected elevation of 10.7 ft NAVD 88, the Project is prone to potential inundations caused by the overtopping of the waterbodies in the Project vicinity as shown on the inundation maps.

The Project areas at or below 10.7 ft NAVD 88 that are predicted to be inundated by the projected SLR, include the Project Areas adjacent to the 5th Street on-ramp near the Lake Merritt Channel, and a majority (approximately 70% of the Project area) of the proposed improvements in the City of Alameda. These areas are shown on the inundation maps. Based on the Bay Shoreline Flood Explorer mapping, flooding depths could be up to approximately 1 ft in the inundated Project areas in the City of Oakland and greater than 15 ft near the Tube portals in the City of Alameda.

Factors Considered to Determine the Need for SLR Adaptation Measures

As mentioned in Section 3, the proposed Project was evaluated for the need to incorporate SLR adaptation measures according to the AO guidelines and Table 1 of the Guidance on Incorporating Seal Level Rise (Caltrans, 2011). The 10 steps and factors used to aid in the determination of the need to consider adaptation measures are provided below. Definitions and/or explanations of the factors, as stated in the Caltrans Guidance, are provided in italics.

1. Project Design Life

"Those projects that have a longer design life of 20+ years should include further SLR analysis. These projects have a very high likelihood of being impacted by SLR at some point during their lifespan. The shorter lifespan projects may be less likely to face SLR impacts, and as a result be less inclined to incorporate SLR, depending on their proximity to the coast line."

As stated in Section 5, the proposed Project's design life was determined to be 50-years per the PDT.

2. Redundancy/Alternative Route(s)

"Looking at the State Highway System (SHS), as a system, there are, however, some locations that are serviced by multiple routes. Even in cases where the SHS does have parallel routes, it is important to keep in mind that the need for traveler and goods movement necessitated the construction of those parallel routes."

In the City of Oakland, Project routes would have multiple alternative routes during the predicted SLR inundation effect. In the City of Alameda, the roadway access routes (including the Tubes) and ferry service are all anticipated to be impacted by the projected SLR. Therefore, there would likely be no alternative routes available within Alameda.

3. Anticipated Travel Delays

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"What impacts will result if SLR impacts a roadway? For instance, if during high tides or a storm event a roadway is splashed by spray, the travel delays would be minimal. However, if a roadway is inundated by waves, the delays will be substantial and should warrant further consideration of incorporating SLR."

In the City of Oakland, Project roadway closures due to the projected SLR impacts would not be substantial because of the multiple available alternative routes and minimal inundations by the projected SLR. In the City of Alameda, there are four other routes connecting Oakland and Alameda, none which are located close to the Tubes. These routes are also anticipated to be impacted by SLR inundation. Therefore, substantial travel delays would occur due to Project roadway closure resulting from the estimated SLR impacts.

4. Goods Movement/Interstate Commerce

"If the route is a high priority commercial goods movement route in the State, the cost of delays due to impacts from SLR will be high, and the project should incorporate SLR consideration."

The Project routes in both the cities of Oakland and Alameda were determined to be non-critical routes for interstate or commercial goods movement.

5. Evacuations/Emergencies

"If the route is vital for emergency evacuations, and SLR impacts would greatly increase emergency response time, the project should incorporate SLR analysis."

In the City of Oakland, there are multiple alternative routes and minimal SLR inundation. Therefore, potentially flooded roadways within the proposed Project footprint would likely not impact emergency evacuation routes. In the City of Alameda, roadways within the footprint are considered to be emergency evacuation routes and the estimated SLR impacts are anticipated to increase emergency response time substantially.

6. Traveler Safety

"If incorporating SLR considerations will substantially delay a safety project getting to construction, then the risk to traveler safety must take precedent. However, it is also important to weight the possibility that if the highway is not designed to incorporate SLR that the result could be flooding of the facility in the future and that inundation of the facility may prevent the route from being used in the event of an emergency or evacuation."

Incorporation of SLR measures would delay Project construction, funding, and acquisition of necessary clearances. Within the existing Project area, traffic accident rates on SR 260 are above the statewide average. Reducing the speed in the Tubes should improve driver awareness. Additionally, there is a high incidence of accidents between motorists and pedestrians on local streets in Oakland. The proposed improvements will reduce motorist and pedestrian conflicts within the Project footprint.

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7. Expenditure of Public Funds

"Future allocations of resources should consider SLR impacts on the SHS and Caltrans' facilities. Considerations include potential or increased facility maintenance costs and/or more frequent repair/rehabilitation needs due to SLR impacts."

Considerations to include SLR measures will have high increased maintenance costs for both the cities of Oakland and Alameda.

8. Scope of Project – "point" vs. "linear"

"If the scope of a project is a single "point" or single project task, it may be less necessary to incorporate SLR (given all other factors)."

This is a linear project located within the cities of Oakland and Alameda. Additionally, its scope is considered to be substantial (important) by Caltrans and the local communities. The proposed Project will address existing and projected traffic congestion, geometric deficiencies, and multi-modal connectivity within and between the cities of Oakland and Alameda.

9. Effect of Incorporating SLR on Non-State Highway

"Consideration should be given to whether the infrastructure around Caltrans' facility (adjacent local streets and roads) is being adapted for SLR. For example, if Caltrans were to raise the grade of its roadway to what extent, if any, are the surrounding local entities raising their roadways? Will the two systems interconnect efficiently and effectively?"

The City of Oakland has no adopted plans for SLR infrastructure improvements. The City of Alameda recently implemented their SLR resiliency plan in 2019 (Climate Action and Resiliency Plan [CARP]). Incorporation of SLR adaptation measures within the project area could substantially increase interconnectivity issues between Caltrans infrastructure and local roadways. For example, raising the grade of state roadways would require corresponding work on local roadways to ensure connectivity.

10. Environmental Constraints

"Adapting the project to SLR may mean an increase in the environmental impacts of the project due to design aspects of adaption, such as more reinforced bridge structures, larger culverts, or alternative pavements. There is also the potential that adapting the project to SLR may mean modifying the hydrology in the area in ways that could be beneficial to some species while doing greater harm to others."

Incorporating SLR adaptation measures into the proposed Project would likely have substantial additional environmental impacts. Measures would generally expand the project footprint, increasing the likelihood of additional environmental and engineering impacts. For example, a measure proposed along the shoreline would likely impact biological communities/resources. Work on the National Register Historic Posey Tube would result in adverse cultural resource impacts. The level and type of impacts would depend upon the scope of the proposed SLR

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measure(s). Additional impacts to visual resources, cultural resources, hydrology (including floodplain), and biological resources would also be expected with the measures analyzed.

Only three of the 10 considered factors pertaining to the proposed Project area in the City of Oakland indicated the need to incorporate SLR adaptation measures: project design life, expenditure of public funds, and scope of project. The Project area in the City of Oakland has multiple alternative routes and would have minimal flooding per the estimated SLR projections. Therefore, the PDT determined that it was not beneficial for the proposed Project to consider SLR adaptation measures within the City of Oakland.

Six of the 10 considered factors (Table 6) indicated the proposed Project areas within the City of Alameda should consider incorporating SLR adaptation measures. Therefore, SLR adaptation measures were evaluated for the proposed Project area within the City of Alameda.

Table 6: Factors to Consider Regarding the Incorporation of SLR into Programming and Design (Source: Caltrans, 2011)

	Factor	Towards Incorporating SLR into Project Design		----→		Towards Not Incorporating SLR into Project Design	
1	**Project design life**	Long (20+ years)	✓			Short (less than 20 years)	
2	**Redundancy/ alternative route(s)**	No redundant/ alternative route	✓			Redundant/ alternative route	
3	**Anticipated travel delays**	Substantial delays	✓			Minor or no delay	
4	**Goods movement/ interstate commerce**	Critical route for commercial goods movement				Non-critical route for commercial goods movement	✓
5	**Evacuations/ emergencies**	Vital for emergency evacuations; loss of route would result in major increases to emergency response time	✓			Minor or no delay in the event of an emergency or evacuation	
6	**Traveler safety (delaying the project to incorporate SLR would lead to ongoing or new safety concerns)**	Safety project in which little or no delay would result; non-safety project				Safety project and delay would be substantial	✓
7	**Expenditure of public funds**	Large investment	✓			Small investment	
8	**Scope of project — "point" vs. "linear"**	Project scope is substantial — important to the community	✓			Project scope is not substantial — e.g., ?	
9	**Effect of incorporating SLR on non-state highways (interconnectivity issues with local streets and roads)**	Minor or no effect — adjacent local streets and roads would not have to be modified		Medium to minor interconnectivity issues		Substantial interconnectivity issues	✓
10	**Environmental constraints**	Minor or no increase in project footprint in an Environmentally Sensitive Area (ESA)		Less than significant increase in project footprint in ESAs		Substantial increase in project footprint in ESAs	✓

* Note that this table only reflects the portion of the Project located within the City of Alameda, which was identified as being more susceptible to SLR inundation.

Considered SLR Adaptation Measures

Adaptation measures were researched using other coastal areas in the country, similar local projects, as well as other on-going SLR adaptation efforts currently proposed by the City of Alameda. Measures researched included inflatable dams, seawalls, and deployable floodwalls. See Attachments for sample photos. SLR adaptation measure recommendations within the City of Alameda were grouped into two categories, which were then reviewed for feasibility and cost-benefit.

SLR Adaptation Measure Categories

I. Category I – SLR Adaptation Measures along the Oakland Estuary Shoreline:
   - Seawalls/Floodwalls/Deployable Floodwalls
   - Tide Gates/Storm Surge Barriers
   - Levees

II. Category II – SLR Adaptation Measures within the Proposed Project Area:
   - Portal plugs at the Tube portals
   - Raising existing retaining walls/watertight roadway approaches
   - Resilient Electrical Infrastructure
   - Other considered measures:
     - Raising roadway and/or bicycle/pedestrian path elevations
     - Inflatable dams
     - Evacuation plans for the Tubes

Feasibility and Cost-Benefit Analysis

The feasibility analysis of incorporating SLR adaptation measures included the evaluation of the potential benefits of the proposed improvements, the potential impacts to the current Project scope, and the costs of the SLR adaptation measures.

1. Category I – SLR Adaptation Measures along the Oakland Estuary Shoreline

Category I SLR adaptation measures would need to be implemented along and/or near the shoreline of the Oakland Estuary bordering the City of Alameda. Implementing these shoreline SLR adaptation measures would be beneficial to the proposed Project because they would be implemented at the source of flooding and therefore, reduce additional impacts due to inland flooding. However, incorporating these SLR adaptation measures would extend the Project's footprint into areas adjacent to the Oakland Estuary. This biological habitat, and its various beneficial uses are detailed in the Project's Natural Environment Study and Water Quality Assessment Reports. This work would also extend into the 100-year floodplain. Therefore, work near and along the shoreline would potentially increase the proposed Project's impacts to biological resources and the floodplain. Various approvals/permits may be required for this work including (but not limited to) the following: BCDC permit, United States Army Corps of

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Engineers (USACE) Section 404 permit, Regional Water Quality Control Board (RWQCB) Section 401 permit, and United States Fish and Wildlife Service (USFWS) biological opinion.

The City of Alameda proposes SLR adaptation measures under CARP. Per this plan, the city has outlined both short-term (<5 years) and long-term (5-10 years) measures to address SLR inundation at the Tubes. Short-term measures include flood-proofing of facilities, regrading of SR 260, floodwall construction, and installing salt-resistant pumps. By the Project's anticipated completion in 2027, the City of Alameda's may have implemented some of these short-term SLR adaptation measures.

Per coordination with the City of Alameda, SLR adaptation measures that are currently being implemented for developers along the City of Alameda waterfront include:

- Design buildings and site construction to withstand 36 inches of SLR on day one (occupancy).
- Include a design, but not construct plans that show how a barricade or seawall could be added at a later date (in 15 or 20 years) if it is later determined that 36 inches is not sufficient.
- Include a funding mechanism that can be used by the Project in 15 or 20 years to construct the additional barricade, if needed.

CARP includes cost estimates to provide protection against the 2030, 2050, and 2100 SLR scenarios over the 100-year flood at the Tubes and the shoreline near the Tubes. These estimates range from $1.7 million to $2.2 million (see the Cost Estimate table from CARP in the Attachments). This would be a substantial cost increase (2.5%) for the proposed Project, which has a construction budget of $88,200,000. Because of this, and the increased environmental impacts previously discussed, these SLR adaptation measures appear to be infeasible for the Project.

2. Category II – SLR Adaptation Measures within the Project Limits

Three Category II SLR adaptation measures were evaluated after coordination with the PDT: portal plugs, elevating retaining walls/roadway approaches, and installation of resilient electrical infrastructure. The feasibility for all three of these measures was evaluated.

A. Portal plugs at the Tube portals

Tunnel portal plugs at the Tubes in the City of Alameda would protect the Tubes, which are critical emergency and evacuation routes, from being inundated due to the projected SLR. Preliminary plans illustrating these plugs are provided in the attachments. However, plugs would not be able to protect the remaining inundated areas including the tunnel approaches. Additionally, the Posey Tube is listed on the National Register of Historic Places and modifying this structure would result in an adverse impact to the resource. Implementing this measure would require additional environmental mitigation and significant additional cost and schedule delays.

The preliminary cost estimate for this option (Table 7) was substantial compared to the proposed Project's overall cost, representing an over a 5% increase in the Project's construction budget. Although this option protects the Tubes from the projected SLR impacts, both the environmental considerations and cost make this option infeasible for the Project.

Table 7. Estimated Costs for Portal Plugs at Tubes

Sub-Items	Unit	Quantity	Unit Price	Cost
Structural steel	LB	80,000	$ 2.00	$ 160,000.00
Hoist, Roller Bearing, and Seal Assembly	LS	2	$ 1,000,000.00	$ 2,000,000.00
Architectural Treatment	LS	1	$ 1,000,000.00	$ 1,000,000.00
50% Contingency	LS	1	$ 1,580,000.00	$ 1,580,000.00
			TOTAL =	**$ 4,740,000.00**

Source: HNTB, 2020

B. Raising existing retaining walls/watertight roadway approaches

Raising the existing retaining walls along the approach roadways of the Tubes (or providing watertight roadway approaches) in the City of Alameda would protect these critical emergency and evacuation routes from the projected SLR inundation. This option would raise the existing retaining walls along the Posey Tube approaches from an approximate elevation of 9.0 to 12.7 ft NAVD 88. Similarly, the existing retaining walls along the Webster Tube approaches would be raised from the existing elevation of 8.5 ft NAVD 88 to 12.7 ft NAVD 88. The preliminary plans illustrating this work are attached under Option 2.

The proposed Project does not currently propose improvements to these existing retaining walls. Therefore, adopting this SLR adaptation measure would have impacts to the Project's scope, cost, and schedule. The new retaining walls would need to be designed to withhold large hydraulic pressures, which would introduce additional cost. The preliminary cost estimate for this option (Table 8) was substantial, representing an approximate 21% increase in the Project's construction budget. Although this option protects critical emergency and evacuation routes from the projected SLR impacts, the potential budget impacts associated with incorporating the measure makes this option infeasible for the proposed Project.

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Table 8. Cost Estimates for Raising Existing Retaining Walls

Sub-Items	Unit	Quantity	Unit Price	Cost
Posey Retaining Walls	SQFT	18,000	$ 285.00	$ 5,130,000.00
Webster Retaining Walls	SQFT	22,000	$ 285.00	$ 6,270,000.00
Imported Borrow	CY	1,500	$ 15.00	$ 22,500.00
HMA	TON	2,200	$ 160.00	$ 352,000.00
Class 2 AB	CY	1,600	$ 60.00	$ 96,000.00
Class 2 AS	CY	1,800	$ 80.00	$ 144,000.00
Demolition	LS	1	$ 2,000,000.00	$ 2,000,000.00
Electrical	LS	1	$ 500,000.00	$ 500,000.00
30% Contingency	LS	1	$ 4,354,350.00	$ 4,354,350.00
			TOTAL =	**$ 18,868,850.00**

Source: HNTB, 2020

C. Resilient Electrical Infrastructure

Placement, relocation, and protection of electrical equipment that may be vulnerable to inundation such as communications and power equipment above the projected SLR inundation elevation would avoid and/or reduce potential loss or damage of the infrastructure. Because the existing electrical infrastructure in the Tubes is already placed at relatively high elevations, only the electrical equipment outside of the Tubes were considered. Preliminary plans are attached under Option 3.

The preliminary cost estimate for this option is presented in Table 9 and represents an approximate 4% increase in the proposed Project's construction budget. The electrical equipment outside the Tubes was not considered critical (street lighting) and it would not be cost effective to implement these measures because the light poles and lights would need to be replaced multiple times over the design life of the proposed Project. Therefore, a future adjustment or addition as part of other non-related projects could provide SLR adaptability and would be more appropriate than adding this component to this project. Therefore, given the estimated initial costs, and timing of lighting replacements, this measure offers no benefits to the proposed Project and was found to be infeasible.

Table 9. Cost Estimates for Resilient Electrical Infrastructure

Sub-Items	Unit	Quantity	Unit Price	Cost
Street Light and Splice Boxes	EA	82	$ 5,000.00	$ 410,000.00
Traffic Signal	LS	3	$ 500,000.00	$ 1,500,000.00
Controller Cabinet	EA	4	$ 25,000.00	$ 100,000.00
Water-resistant cable	LF	8,100	$ 20.00	$ 162,000.00
50% Contingency	LS	1	$ 1,086,000.00	$ 1,086,000.00
			TOTAL =	**$ 3,258,000.00**

Source: HNTB, 2020

D. Other considered measures

Raising roadways and/or bicycle/pedestrian path elevations would cause substantial interconnectivity issues with local streets and roads in the City of Alameda. Addressing these issues would have a high cost, and greatly expand the project footprint (and associated environmental impacts). As a result, this option was found to be infeasible and was not evaluated further.

Inflatable dams were considered as an alternative SLR adaptation measure to the tunnel portal plugs. These dams would prevent inundated due to the projected SLR. However, this option would incur costs for storage and maintenance. In addition, the degradation of equipment over time would add cost for replacement, which would potentially need to occur before SLR inundation occurred. Based on this, this option was found to be infeasible and was not evaluated further.

Caltrans' maintenance plan for the Tubes does not currently address SLR inundation, however, Caltrans is currently working on an update.

Conclusion

As discussed above, the PDT considered multiple SLR adaptive measures and calculated their associated cost estimates. However, evaluation of the benefits of the SLR adaptation measures against their potential impacts on the proposed Project, and the associated additional estimated costs, showed that incorporating the SLR adaptation measures considered here into the Project would be infeasible. The considered measures would either offer no benefits to the proposed Project because they would need to be replaced multiple times during the design life of the Project, would be too costly, cause greater environmental impacts, and/or delay the proposed Project's schedule.

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ATTACHMENTS

Figure 5. Alameda Tide Gage 9414750 Location Map
Figure 6. Topographic Map
Sea-Level Rise Projection Calculations
Figure 7. Bay Shoreline Flood Explorer Map
Figure 8. Sea-Level Rise Viewer Map
Sea Level Rise Adaptation Measures Sample Photos from Other Projects
City of Alameda Climate Action and Resiliency Plan Cost Estimates for Sea Level Rise Measures
Sea Level Rise Adaptation Measure Options – Options 1, 2, and 3

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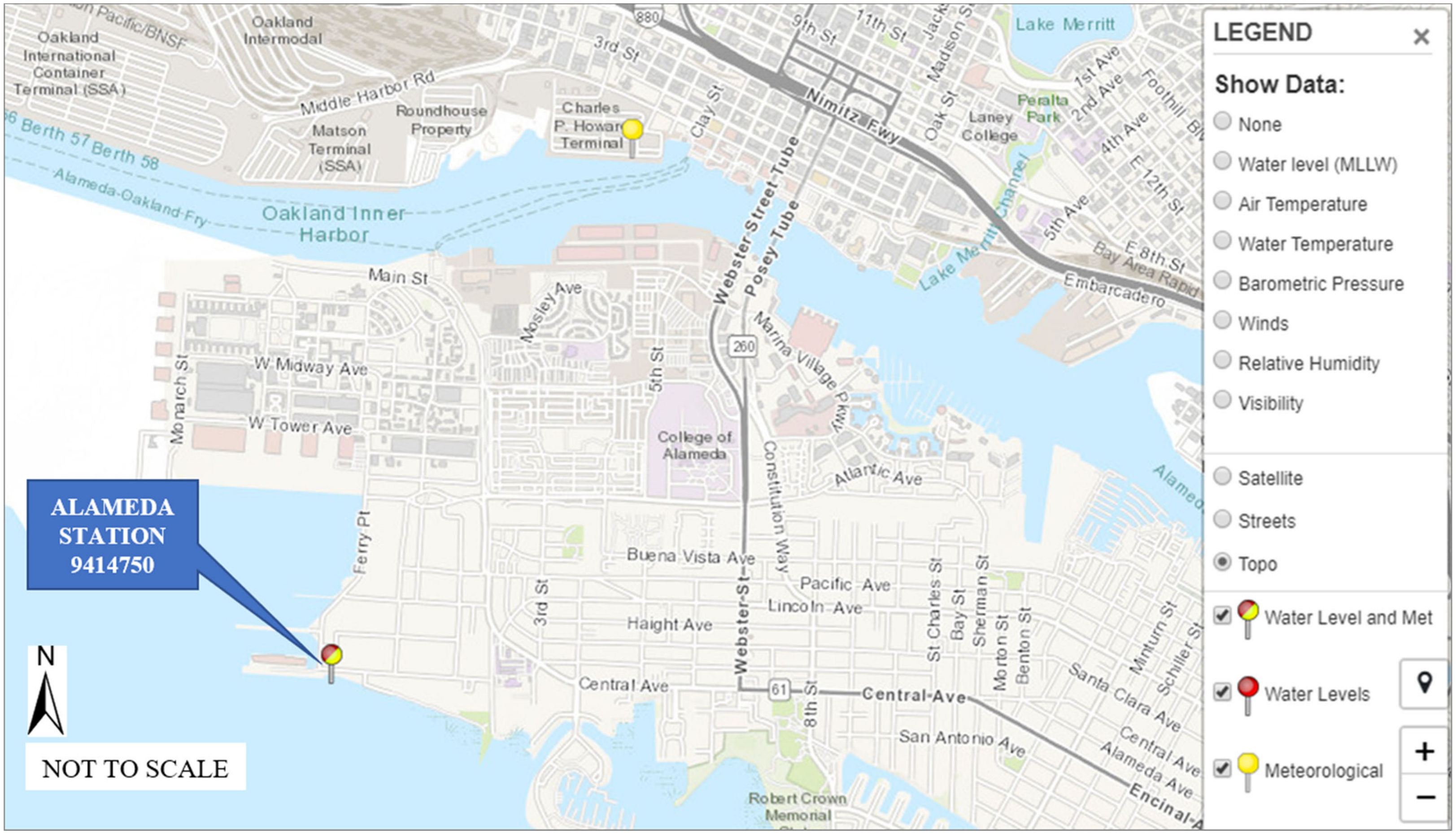

Figure 5. Alameda Tide Gage 9414750 Location Map

Source: NOAA, 2019

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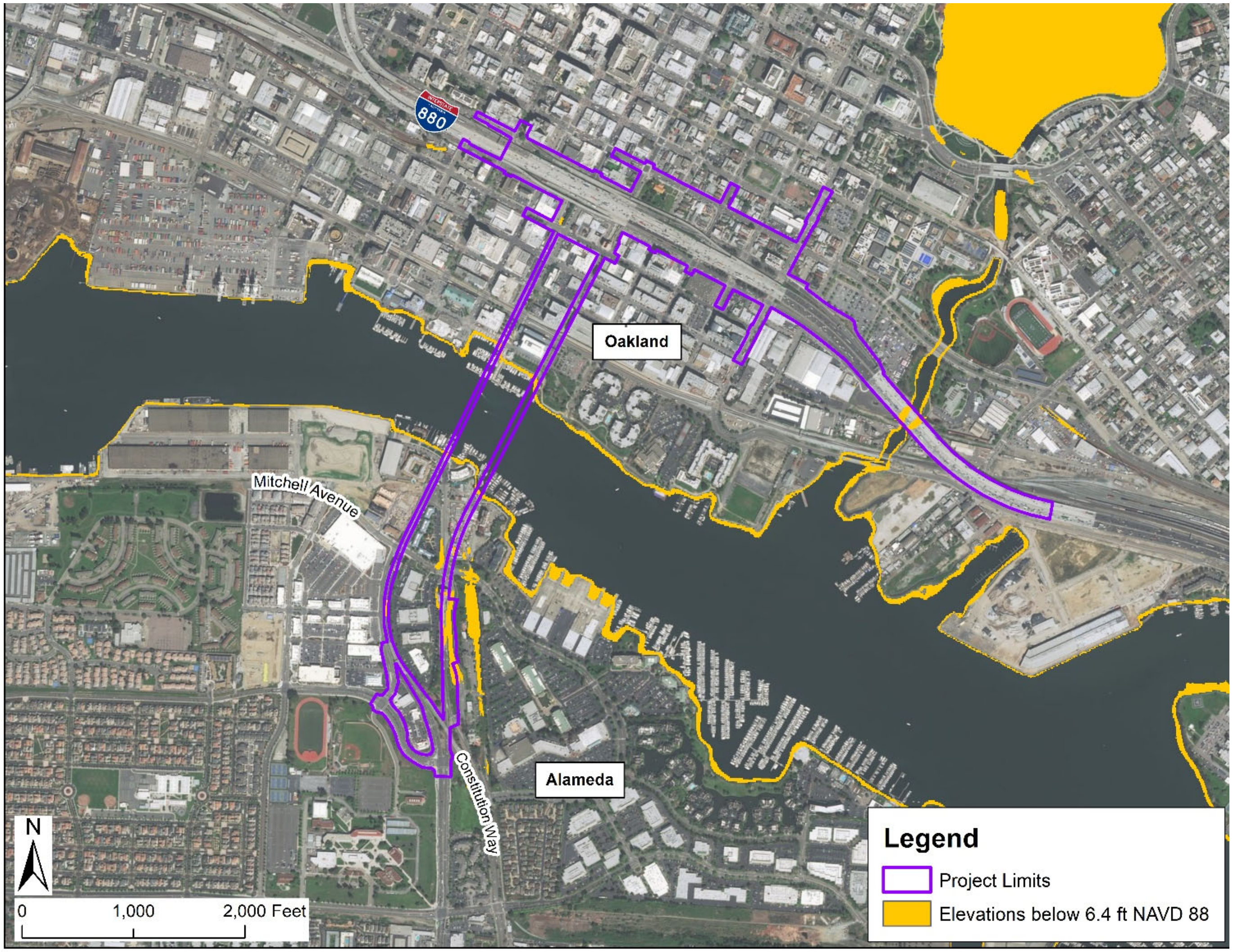

Figure 6. Topographic Map

Source: ESRI, FEMA, HNTB CORPORATION, and USGS

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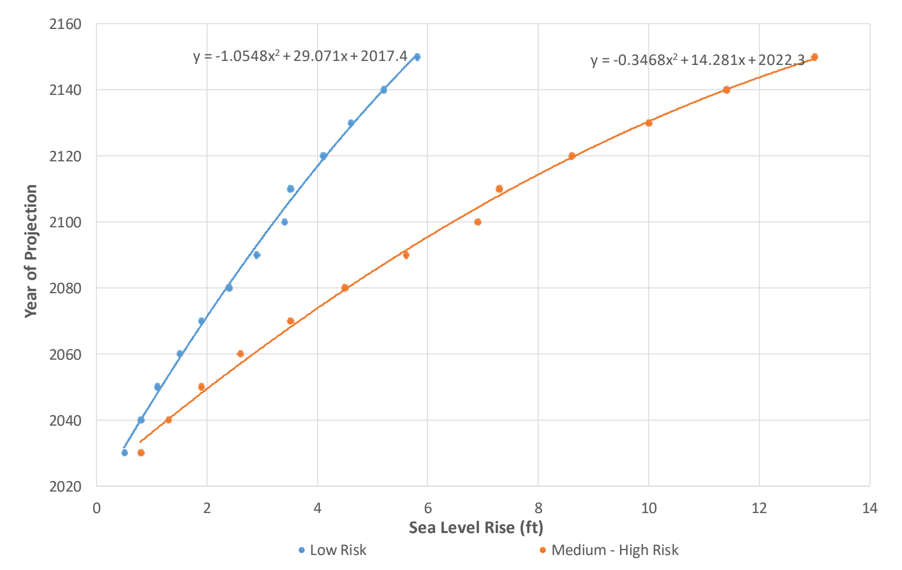
San Francisco High Emissions Sea Level Rise Values (State of California Sea-Level Rise Guidance, 2018 Update)

Year	Low Risk	Medium - High Risk
2030	0.5	0.8
2040	0.8	1.3
2050	1.1	1.9
2060	1.5	2.6
2070	1.9	3.5
2080	2.4	4.5
2090	2.9	5.6
2100	3.4	6.9
2110	3.5	7.3
2120	4.1	8.6
2130	4.6	10.0
2140	5.2	11.4
2150	5.8	13.0



	Low Risk	Medium - High Risk
Year	2077	2077
SLR (ft)	2.2	4.3

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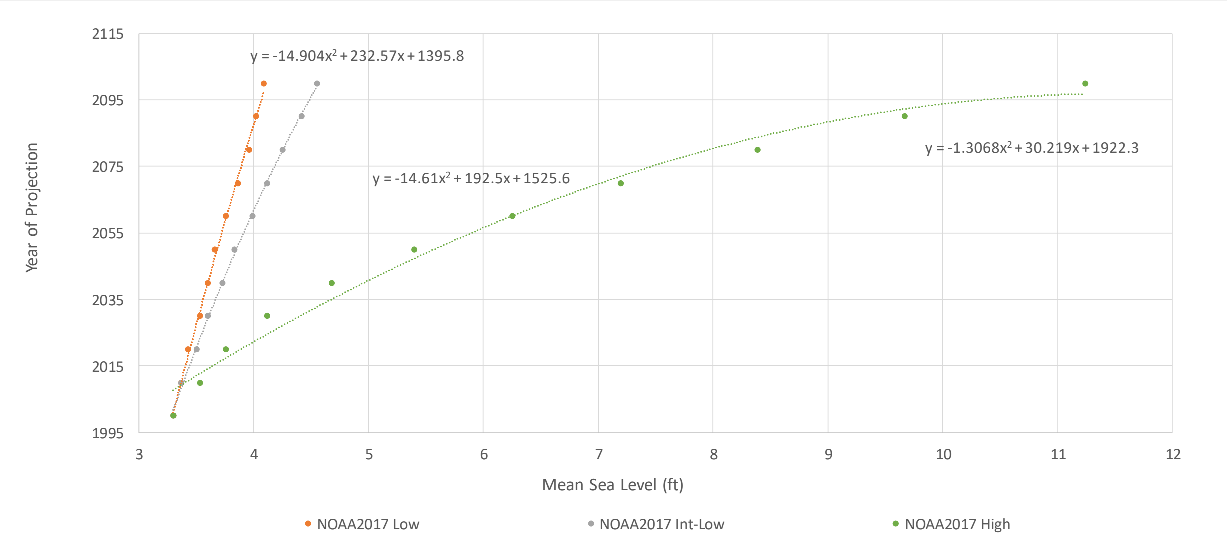
United States Army Corps of Engineers Sea Leve Change Curve Calculator - NOAA 2017 Mean Sea Level Projections

Year	NOAA2017 Low	NOAA2017 Int-Low	NOAA2017 Int	NOAA2017 Int-High	NOAA2017 High
2000	3.30	3.30	3.30	3.30	3.30
2010	3.37	3.37	3.43	3.5	3.53
2020	3.43	3.5	3.56	3.66	3.76
2030	3.53	3.6	3.76	3.92	4.12
2040	3.6	3.73	3.99	4.28	4.68
2050	3.66	3.83	4.28	4.78	5.4
2060	3.76	3.99	4.61	5.33	6.25
2070	3.86	4.12	4.97	5.99	7.2
2080	3.96	4.25	5.4	6.78	8.39
2090	4.02	4.42	5.86	7.63	9.67
2100	4.09	4.55	6.38	8.65	11.24
2026	3.50	3.57	--	--	4.24
2077	3.91	4.21	--	--	7.65
Change	0.41	0.63	--	--	3.41

*Note: Int = Intermediate



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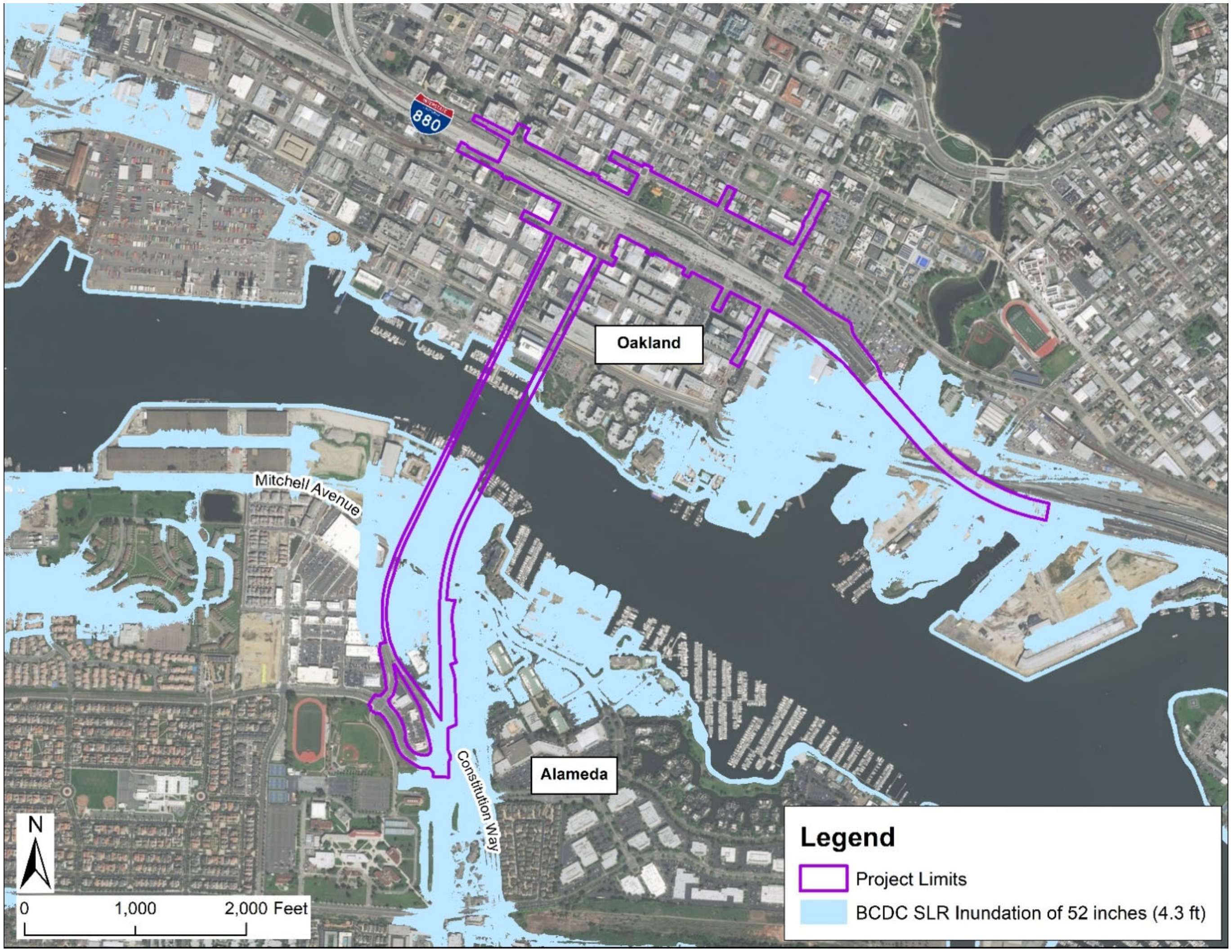

Figure 7. Bay Shoreline Flood Explorer Map

Source: BCDC, ESRI, and HNTB CORPORATION

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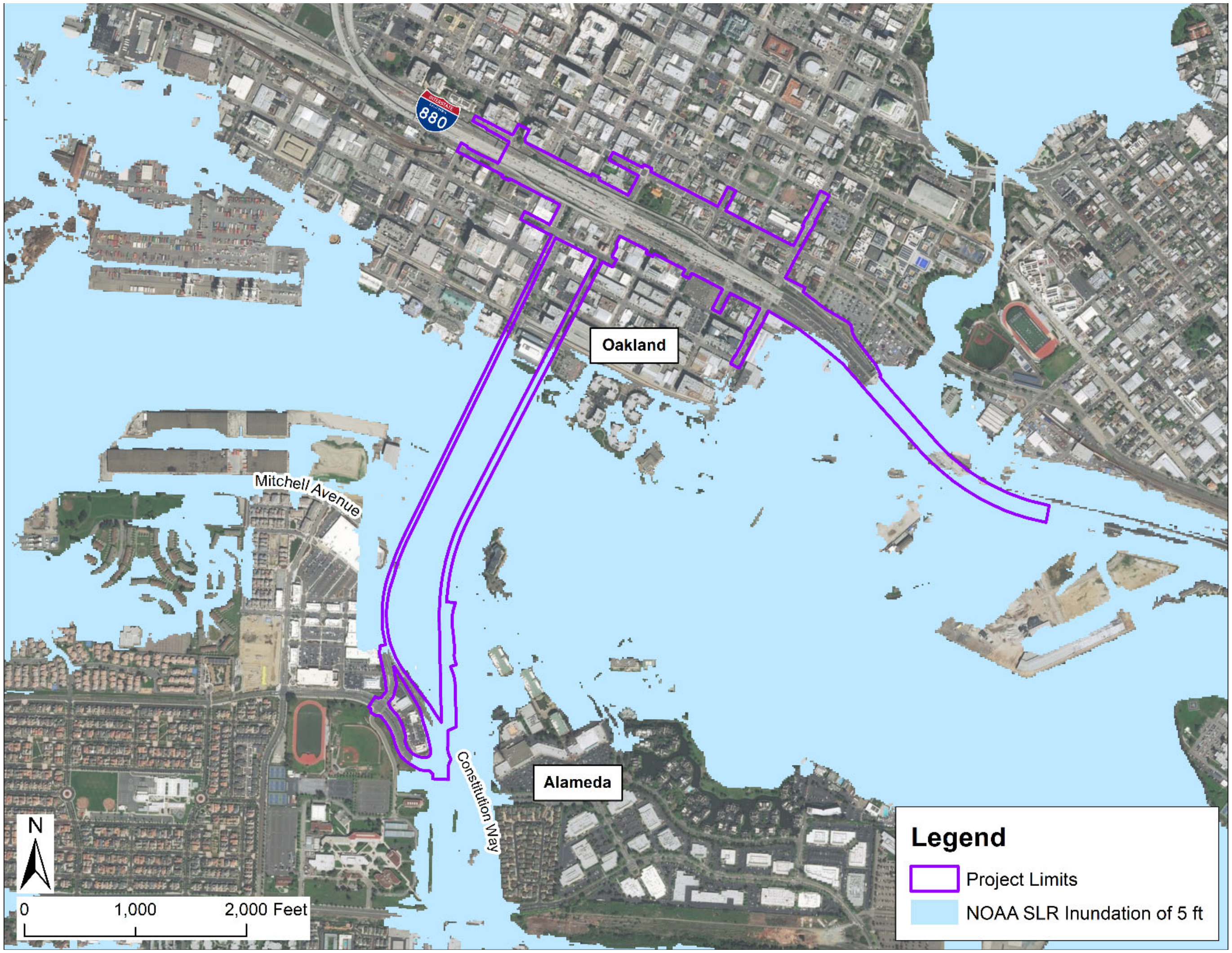

Figure 8. Sea-Level Rise Viewer Map

Source: ESRI, HNTB CORPORATION, and NOAA

Sample Photos of Inflatable Dams

Source: https://wwtonline.co.uk/features/inflated-dam-during-test-following-installation-at-omval-

Source: https://www.enr.com/articles/23773-tempe-had-plan-to-replace-inflatable-tubes-that-failed

Sample Photos of Seawalls

Photo 4-3: The Corpus Christi Seawall (Library of Congress/LC-USF34-038306)

Photo 4-4: Rubble mound structure in Bronx, New York (M&N, 2017)

Source: New York – New Jersey Harbor and Tributaries Coastal Storm Risk Management Feasibility Study

Sample Photo of Deployable Floodwalls

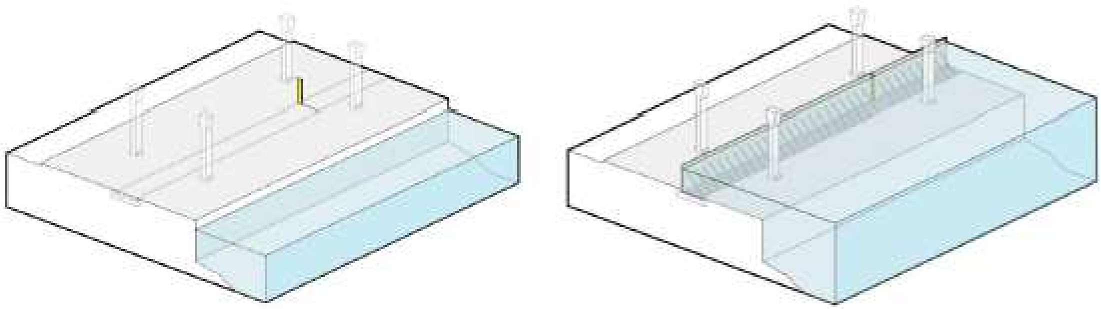

Figure 4-13: Schematic View of a Flip-up Barrier from LMCR

Photo 4-5: Flip-up barrier at Lourdes Hospital deployed automatically during a recent flood event (Floodbreak)

Source: New York – New Jersey Harbor and Tributaries Coastal Storm Risk Management Feasibility Study

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Table 5-5. CARP Adaptation Strategies and Cost Estimates for Addressing Location-Based Priority Flooding

Location	Scenarios		
	2030 Sea Level Rise Plus 100-Year Storm	2050 Sea Level Rise Plus 100-Year Storm	2100 Sea Level Rise Plus 100-Year Storm
Crown Beach Adaptation	Expand dunes Augment salt marshes Redistribute sand	Expand beach into the Bay Add oyster reefs, cobble berms	Allow beach to retreat inland
	$11 million	$7.5 million	Not estimated
Eastshore Drive	Augment mudflats Expand flood protection barriers	Integrate adaptation between public pathways and private parcels	Develop tidal neighborhoods
	$20 million [a]	Not estimated	Not estimated
Shoreline Near Webster and Posey Tubes	Expand levee and seawall to provide 100-year flood protection Flood-proof critical facilities (Hazardous Materials Transfer Station)	Expand levee and seawall to address sea level rise	Develop long-term northern waterfront shoreline strategy
	$1.7 million [a]	$2.2 million [a]	Not estimated
Bay Farm Lagoon Outlet and Seawall	Restore submerged aquatic vegetation Elevate existing seawall and upgrade pump	Explore large-scale shoreline modifications along Bay Farm's northern shore (e.g., living levee)	Coordinate approach to flooding across Bay Farm
	$ 3 million [a]	$9 million [a]	Not estimated
Veteran's Court Seawall	Regrade and elevate road to create flood protection structure Restore submerged aquatic vegetation	Investigate options to convert Veteran's Court area into a living levee	Integrate Veteran's Court flood protection into broader Bay Farm Island flood control strategies
	$4 million [a]	$9 million	Not estimated

Notes:

= Item(s) relevant to the Project

Location	Scenarios		
	2030 Sea Level Rise Plus 100-Year Storm	**2050 Sea Level Rise Plus 100-Year Storm**	**2100 Sea Level Rise Plus 100-Year Storm**
Bay Farm Island Touchdown and Towata Park	Repair/replace and elevate existing shoreline protection (Additional study is needed on identifying and costing natural shoreline adaptation)	Assess bridge vulnerability	Consider local ordinance requiring or encouraging flood retrofits in this neighborhood
	$300,000 [a]	Not estimated	Not estimated
SR260, Posey and Webster Tubes	Construct floodwalls at exit from/entrance to the tubes	Install separate crossing for bikes/pedestrians (Caltrans Bike Plan)	Investigate long-term options for replacement or reconstruction of tubes
	$2 million	Not estimated	Not estimated
SR61/Doolittle Drive	Augment mudflats	Explore opportunities to collaborate with golf course on flood control	Convert roadways to levees to provide flood control
	$3.3 million	Not estimated	$15 million
Critical and High-Use Roadways	Unable to estimate cost	Unable to estimate cost	Unable to estimate cost
Storm Drains and Pump Station	Implement recommendations in existing stormwater master planning	Not yet planned	Not yet planned
	$40 to $154 million [b] (note that some actions elsewhere in this table are included in this total)	Not estimated	Not estimated
Bayview Weir and Outfall	Install new flap gates, dredge near outfall	Install pump station	Integrate pump station upgrades with Shoreline Drive upgrades
	$1.5 million	$20.5 million	Not estimated

[a] Strategies include cost to raise shoreline (as well as other adaptation actions). Costs to raise shoreline overlap with the cost estimate in Table 5-4.

[b] Stormwater system was discussed in "Cost of Action" section above but was not included in previous Table 5-4.

Note: Details on these adaptation strategies are provided in Chapter 4, "Adapting to Climate Change," and Appendix J, "Adaptation Strategies and Actions." In cases where adaptation strategies call for feasibility studies for the sake of costing, it is assumed that these studies will transition into project implementation. For example, it is assumed that the action to study opportunities for mudflat augmentation at Eastshore Drive (in Chapter 4) will transition into implementation of a mudflat augmentation project.

Notes:

= Item(s) relevant to the Project

OAKLAND ALAMEDA ACCESS PROJECT
SEA LEVEL RISE ADAPTATION MEASURE - OPTION 1
TUNNEL PORTAL PLUG

LEGEND

PROJECT FOOTPRINT

SCALE: 1" = 100'

04/13/2020

PRELIMINARY
FOR DISCUSSION ONLY

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OAKLAND ALAMEDA ACCESS PROJECT
SEA LEVEL RISE ADAPTATION MEASURE - OPTION 1
TUNNEL PORTAL PLUG

Horiz SCALE: 1" = 100'
Vert SCALE: 1" = 20'

04/13/2020

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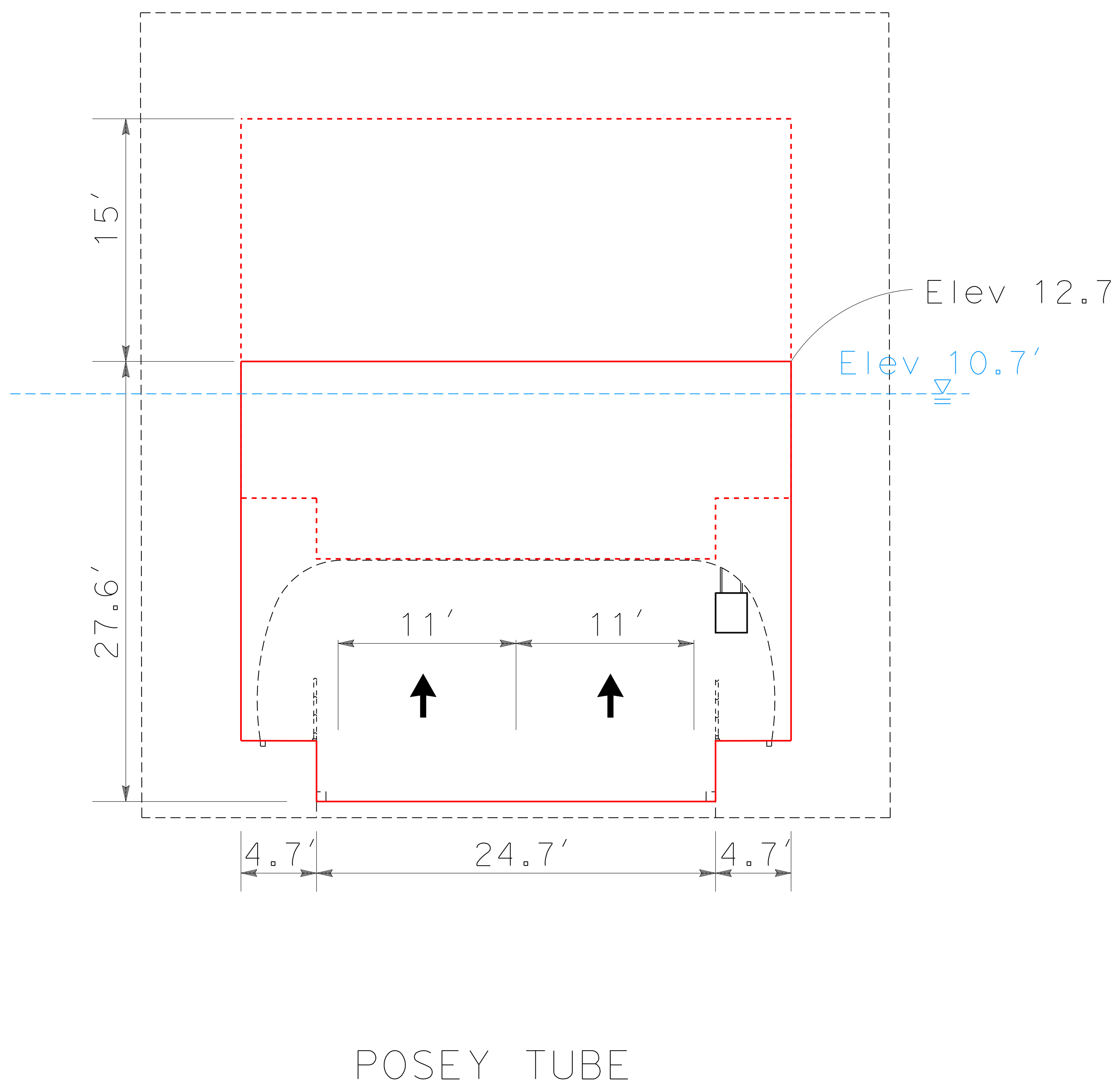
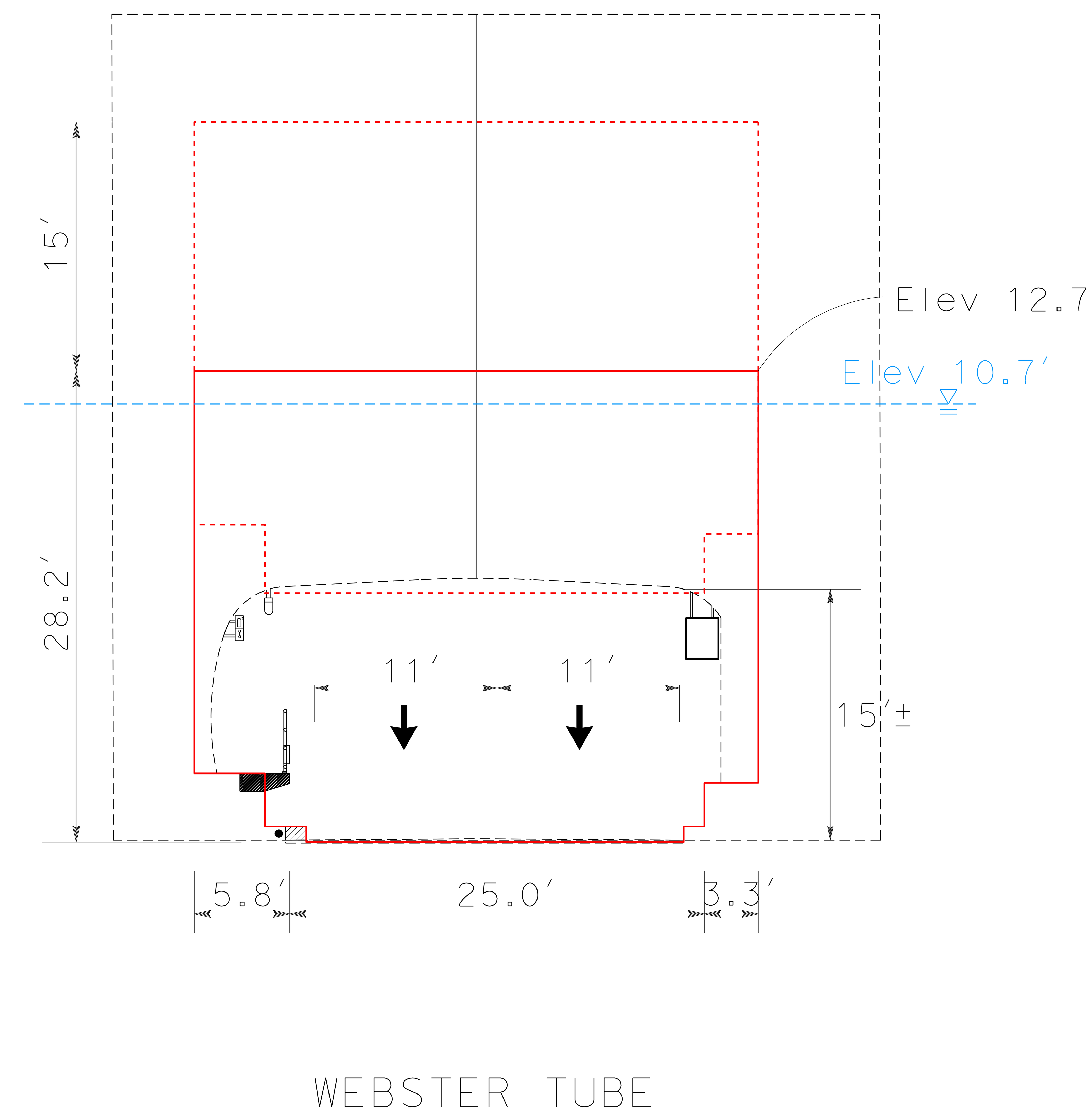
OAKLAND ALAMEDA ACCESS PROJECT
SEA LEVEL RISE ADAPTATION MEASURE - OPTION 1
TUNNEL PORTAL PLUG





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OAKLAND ALAMEDA ACCESS PROJECT
SEA LEVEL RISE ADAPTATION MEASURE - OPTION 2
WATERTIGHT ROADWAY APPROACHES

SCALE: 1" = 100'

04/13/2020

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OAKLAND ALAMEDA ACCESS PROJECT
SEA LEVEL RISE ADAPTATION MEASURE - OPTION 2
WATERTIGHT ROADWAY APPROACHES

Horiz SCALE: 1" = 100'
Vert SCALE: 1" = 20'

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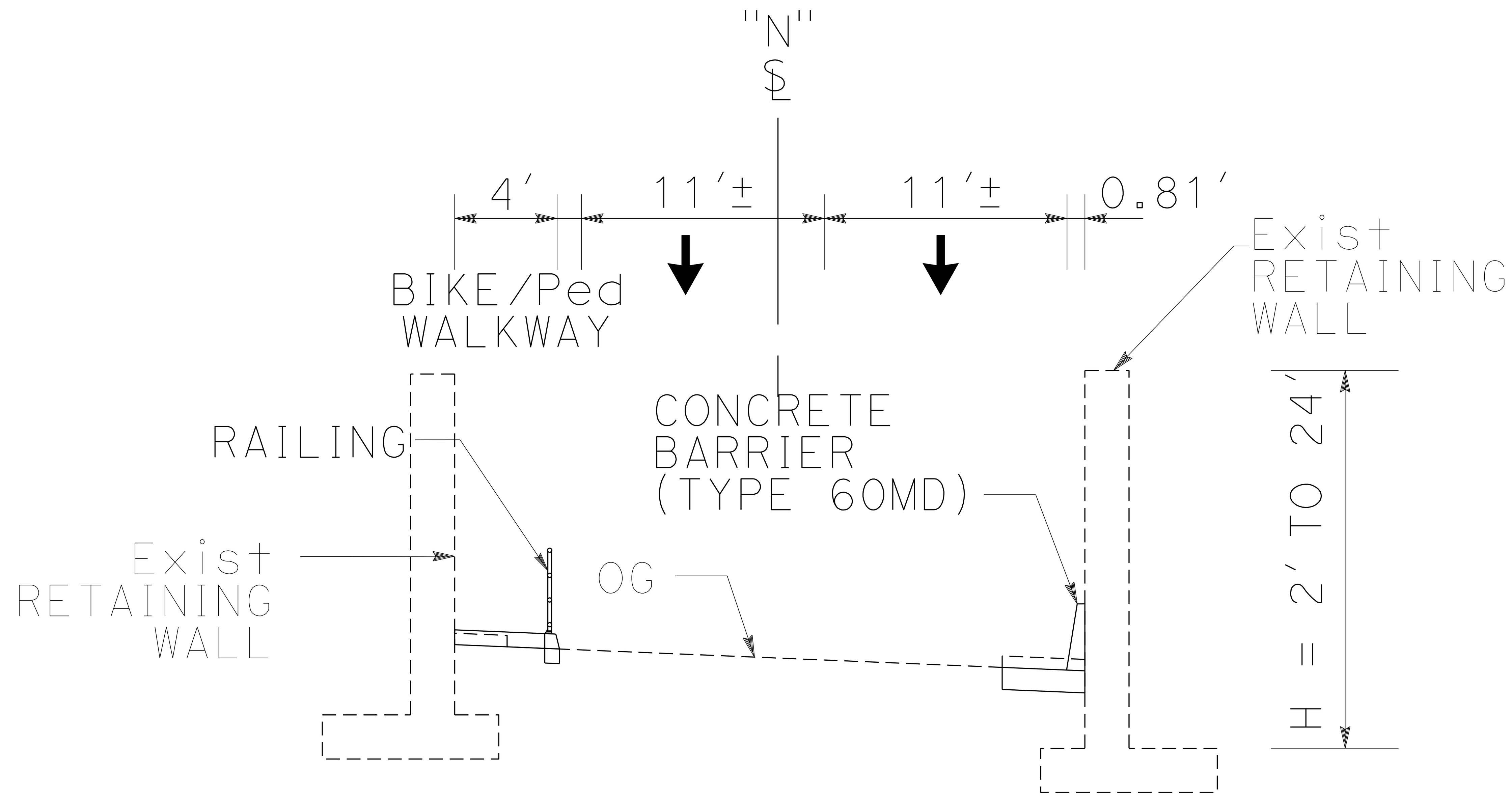
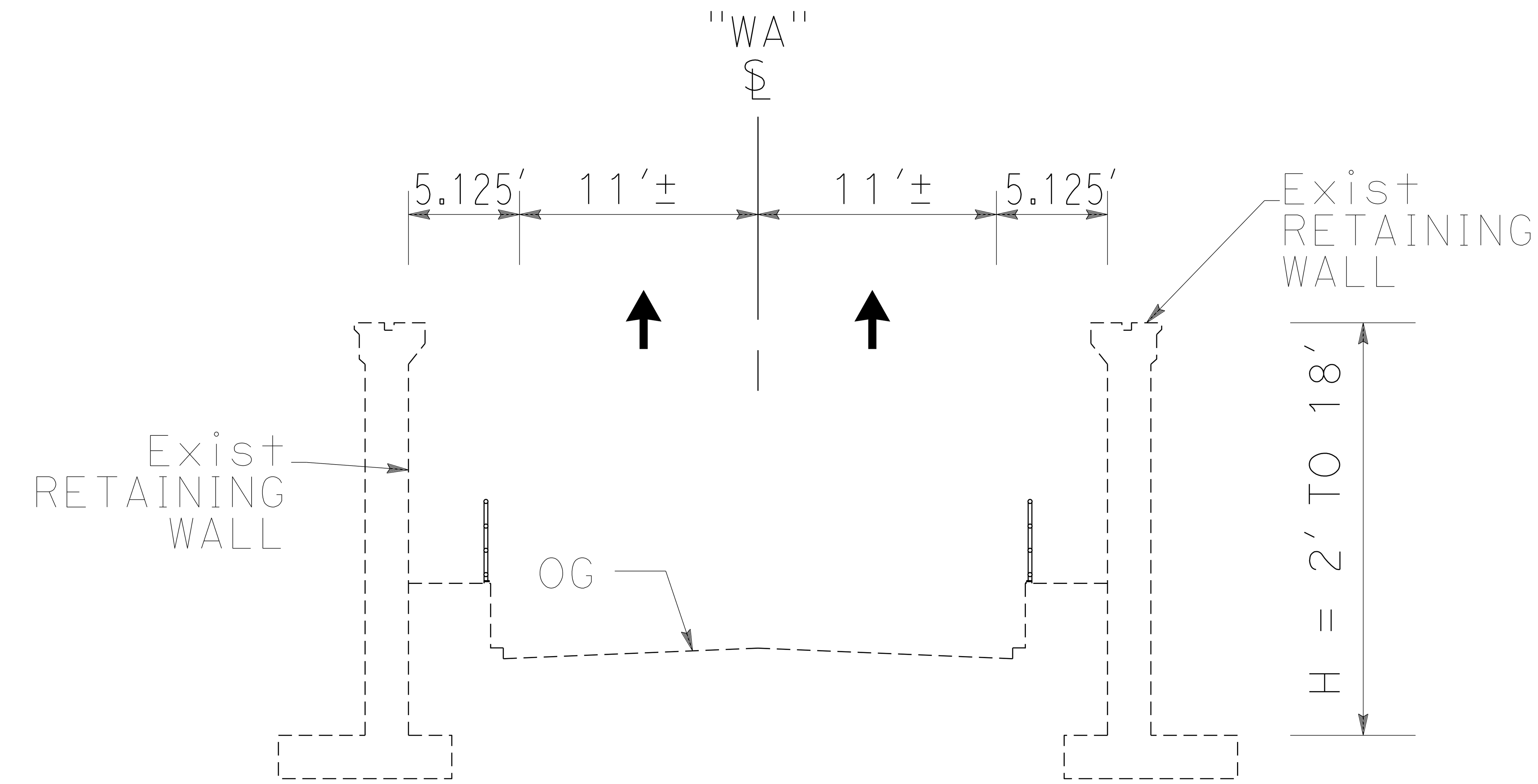
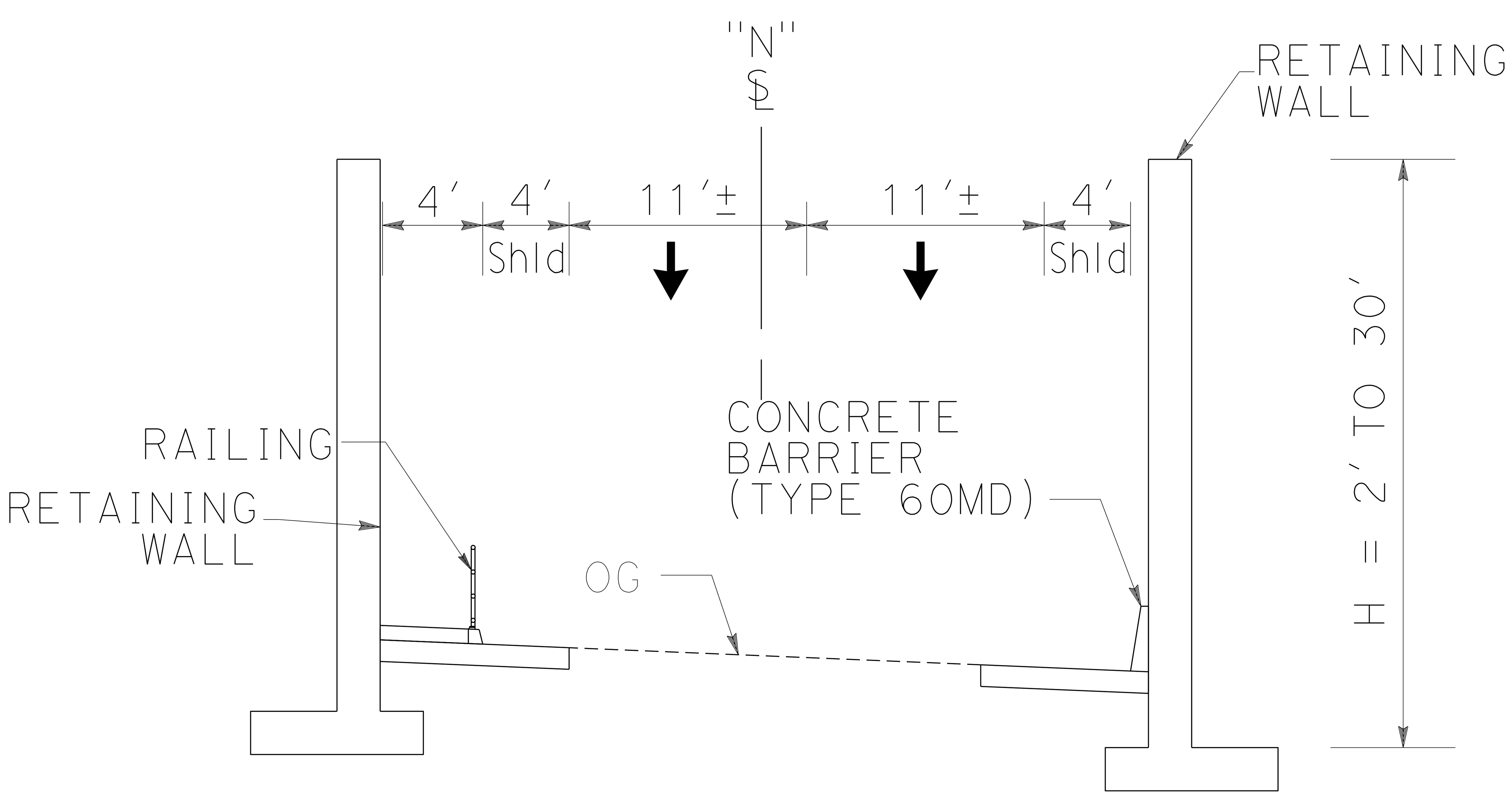
OAKLAND ALAMEDA ACCESS PROJECT
SEA LEVEL RISE ADAPTATION MEASURE - OPTION 2
WATERTIGHT ROADWAY APPROACHES



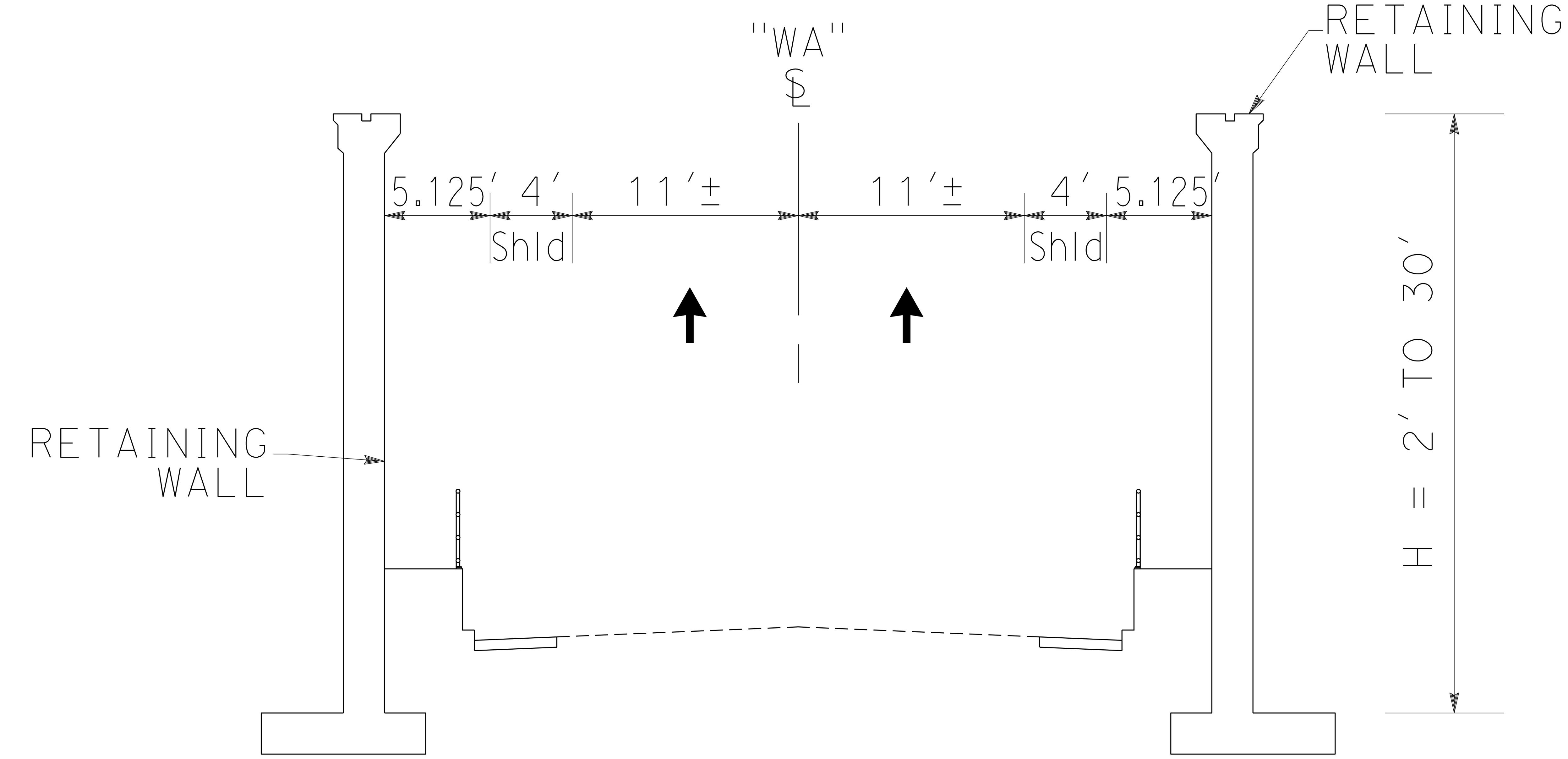
WEBSTER TUBE - EXISTING



POSEY TUBE - EXISTING



WEBSTER TUBE - PROPOSED



POSEY TUBE - PROPOSED

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OAKLAND ALAMEDA ACCESS PROJECT
SEA LEVEL RISE ADAPTATION MEASURE - OPTION 3
RESILIENT ELECTRICAL INFRASTRUCTURE

SCALE: 1" = 100'

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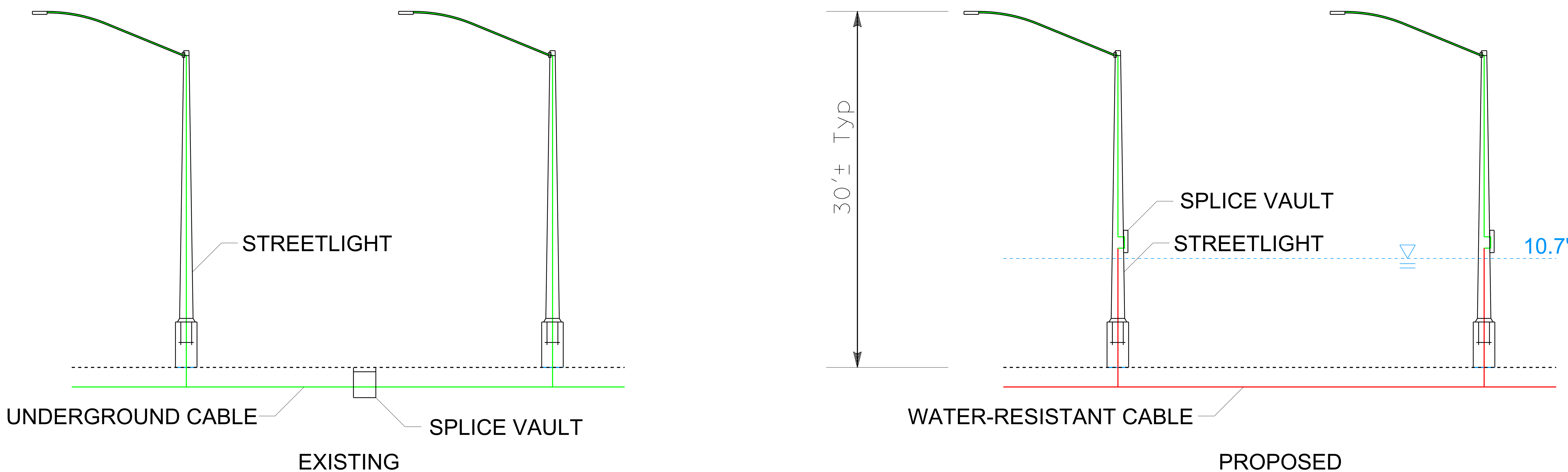
SEA LEVEL RISE ADAPTATION MEASURE - OPTION 3
RESILIENT ELECTRICAL INFRASTRUCTURE



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