Appendix L. Hydraulics Study

Lincoln Bridge Multi-Modal Bridge Improvements Hydraulics Study

Los Angeles County, California

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1 Introduction

This report summarizes an update to HEC-RAS numerical modeling and sediment transport analysis associated with Lincoln Bridge Multi-Modal Improvement Project (City of Los Angeles Department of Transportation [LADOT] TOS 27). Previously, Psomas completed sea level rise (SLR) analysis and HEC-RAS modeling of lower Ballona Creek and Lincoln Boulevard Bridge for the existing conditions for pre-2018 Caltrans and California Coastal Commission (CCC) SLR. Since the project started, new SLR criteria for California has been enacted (State of California Sea-Level Rise Guidance 2018 Update) (California 2018). Additionally, discussions between Psomas, CCC, Caltrans, LADOT and the US Army Corps of Engineers (USACE) have refined the regulatory requirements concerning hydraulic analysis and SLR related to the project.

The project is located along Ballona Creek bounded by Marina Del Rey to the north and the Ballona Wetlands to the south. The project includes the widening and other multimodal improvements of Lincoln Boulevard over the Creek south of Culver Boulevard (Figure 1). The project is approximately 8,700 feet upstream of the Pacific Ocean and approximately 3,200 feet downstream of the Marina Freeway crossing of the Creek.

1.1 Purpose

The purpose of the project is to create a new multi-modal corridor along SR-1/Lincoln Boulevard between Fiji Way and Jefferson Boulevard to improve traffic operations and to serve transit, bicyclists, and pedestrians while minimizing impacts to Ballona Wetlands Reserve, Ballona Creek, and other environmental resources. The purpose of this study is to assess the hydraulic impacts of the proposed bridge in order to minimize environmental impacts to Marina Del Rey and the Ballona Wetlands.

1.2 Need

Lincoln Boulevard serves as a critical north-south connection on the Westside. There are few arterial connections that provide continuous access through the Westside, which results in Lincoln Boulevard being oversaturated during peak commute periods. Lincoln Boulevard narrows from three to two lanes in the southbound direction, approximately 1,050 feet north of the existing Lincoln Bridge over Ballona Creek, and from four to three lanes in the northbound direction, approximately 320 feet north of the intersection with Jefferson Blvd, to the intersection with Fiji Way. These lane reductions create a major bottleneck.

The average vehicle travel speeds along Lincoln Boulevard are 15 mph during peak periods when measured between Ozone Ave in the City of Santa Monica and Sepulveda Boulevard while the design speed is 50 mph. Travel times are greatly impacted by bottlenecks resulting in slower speeds along much of the corridor.

In addition, access for pedestrians along Lincoln Boulevard is disjointed north and south of the Ballona Creek bridge which does not have sidewalks. Lincoln Boulevard also lacks bicycle facilities across the bridge. Pedestrian and bicycle facilities are also deficient along Culver Boulevard.

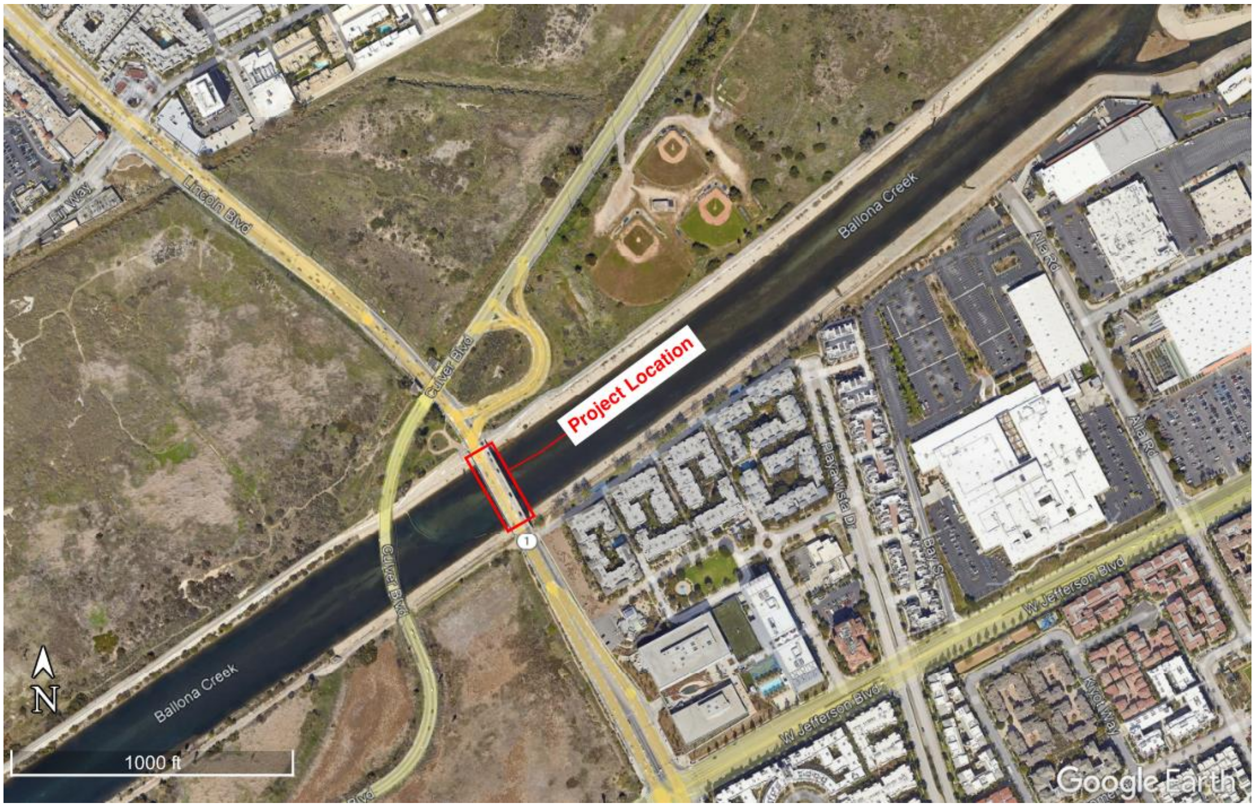

Figure 1: Project Location and Vicinity Map

1.3 Study Goals

The study has the following goals:

1. Two design discharges will be analyzed using the HEC-RAS hydraulics models of lower Ballona Creek: Los Angeles County Department of Public Works (LACDPW) Capital Storm discharge (QCAP) and USACE 100-year discharge (USACE).
2. Two sea level change criteria will be used for the downstream boundary conditions in HEC-RAS modeling: USACE and California (2018). No tsunami, wave run-up or other oceanographic factors are included as part of the SLR analysis because Lincoln Bridge is located approximately 2.5 miles inland of the coast. In addition, the Creek is leveed from its downstream terminus at the Pacific Ocean to upstream of the Lincoln Bridge crossing. The change in bottom elevation between the terminus and the Lincoln Bridge crossing is approximately 7 feet and the opening of the channel is approximately 300 feet. While some open ocean waves may diffract, refract, or reflect through the levee mouth and propagate upstream, it is highly unlikely that open ocean waves will impact Lincoln Bridge. Geotechnical subsidence or uplift is also not included in SLR analysis.
   USACE SLR values will be taken from USACE Sea-Level Change Curve Calculator Monica Gage intermediate value, and California (2018) SLR values will be taken from Table 25. Three values will be utilized from Table 25: Low, Medium-High and Extreme Risk Aversion (H++) for High Emissions. The basis for SLR will include two different starting water surface elevation datums: mean higher high water (MHHW) at the request of California Coastal Commission and Caltrans, and mean sea level (MSL), as per USACE ER 1100-2-8162 (local MSL) and ETL 1100-2-1 (non-ecosystem). Per the Santa Monica Gage, all elevations will be in NAVD88; bridge elevations will be adjusted accordingly.
3. All hydraulic modeling will be conducted using the HEC-RAS model developed by ESA in conjunction with USACE and modified by Michael Baker. The Michael Baker-modified model will be updated to incorporate:
   a. two design discharges (USACE and QCAP),
   b. two starting water surface elevations (MSL and MHHW),
   c. four SLR criteria (USACE Intermediate, and California 2018 Low, Medium-High, and H++),
   d. two bridge conditions (existing and proposed).
4. A scour analysis will be developed for Lincoln Bridge. Bridge scour for the existing and proposed bridge conditions will be developed in the HEC-RAS models using the software's hydraulic design function following HEC-18, Evaluating Scour at Bridges. Bridge scour will be calculated for the USACE and QCAP discharges assuming a MSL downstream boundary condition. The MSL boundary condition is expected to be the most conservative in that a lower water surface elevation for a given discharge will have a higher velocity in subcritical flow regimes. Only changes to Lincoln Bridge will be analyzed in the proposed condition bridge scour analysis.

2 Hydrologic and Bridge Design Conditions

2.1 Hydrologic Conditions

There are three design discharges available for the project reach of Ballona Creek: US Army Corps of Engineers (USACE) 100-year discharge; Federal Emergency Management Agency (FEMA) 100-year discharge; and the Los Angeles County Department of Public Works (LACDPW) 50-year burned-and-bulked, or Capital, (QCAP) discharge. For the purposes of the present study only the USACE and QCAP discharges are considered and are summarized in Table 1. No changes to the channel or watershed are proposed as part of the project, and the project will not alter the hydrology in the proposed condition.

Table 1: Design Discharges (cfs) for Ballona Creek at Lincoln Boulevard

FEMA	USACE	QCAP
44,270	46,000	51,240

2.2 Existing and Proposed Bridge Conditions

In the existing condition, the bridge is a four-bent structure with three pier walls. The piers are 90.0 feet apart with a width ranging from 3.25 to 4.50 feet (average 3.875 feet) without debris and a 7.75-foot debris width (double the average width). The bridge deck is approximately 69.0 feet wide and 334.5 feet long. The deck is vertically curved with the low chord ranging from 17.9 to 21.3 feet NAVD88, and a high chord ranging from 21.4 to 25.8 feet NAVD88. The deck is not super-elevated. The representation of the existing bridge in HEC-RAS is shown in Figure 2.

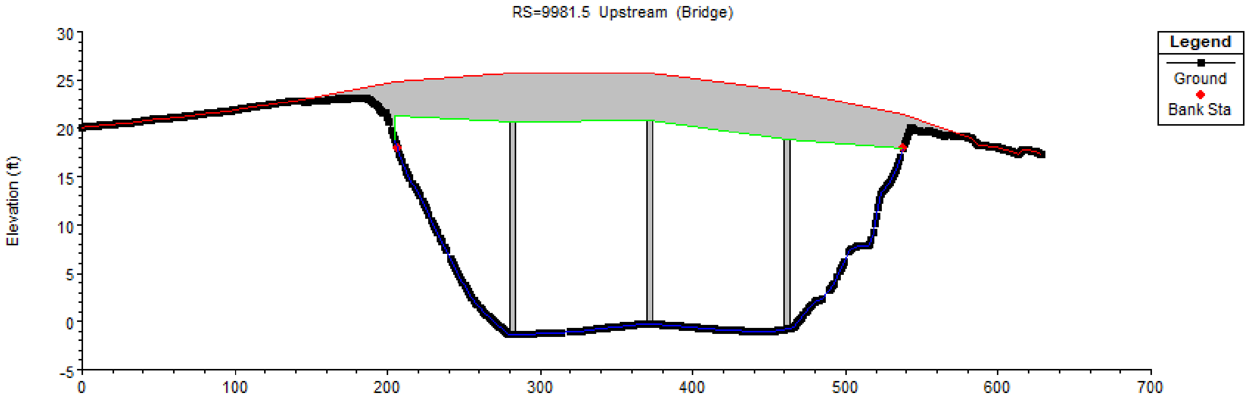

Figure 2: Existing Bridge (upstream section looking downstream)

In the proposed condition, the bridge is a three-bent structure with two pier groups. The circular pier groups are approximately 111.5 feet apart. Each pier is 5.5 feet wide without debris and has an 11.0-foot debris width. The bridge deck is approximately 130.0 feet wide and 334.5 feet long. The deck is vertically curved with the low chord ranging from 23.6 to 25.1 feet, and a high chord ranging from 28.6 to 30.2 feet. The representation of the proposed bridge in HEC-RAS is shown in Figure 3. All bridge design details of the existing and proposed conditions were provided by Psomas' (D. Fredricks, personal communication, 2021) and can be found in Appendix A. Deck elevations were provided in NGVD29 and were adjusted to NAVD88 to be consistent with the datums of the Santa Monica Gage.

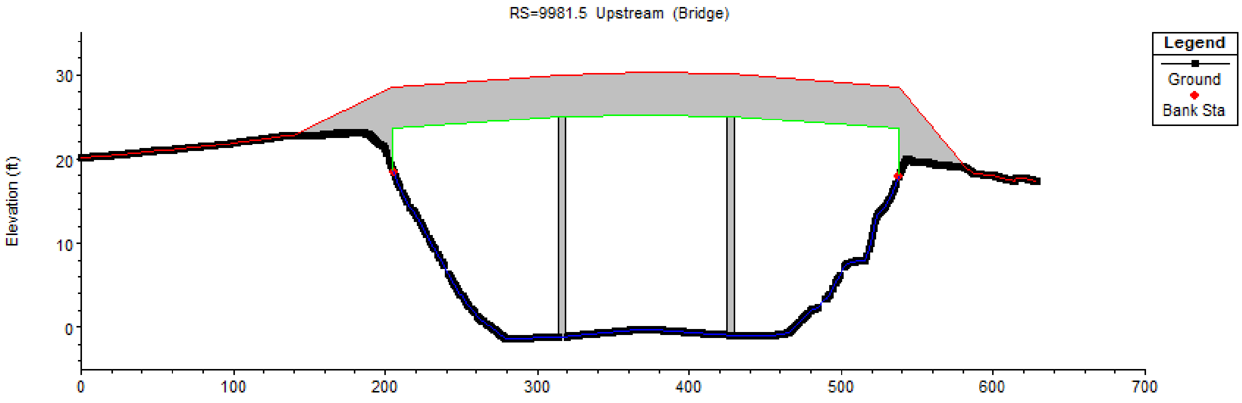

Figure 3: Proposed Bridge (upstream section looking downstream)

3 Sea Level Rise Design Considerations

All hydraulic analysis in the present study employs sea level rise design considerations based on two design parameters USACE (2019) and California (2018). USACE (2019) analysis is expected to be required to comply with future Clean Water Act (CWA) Section 408 permitting requirements. California (2018) analysis is expected to be required for State-related permitting (i.e. Caltrans, CCC, etc.).

Previous iterations (2018 and earlier) of this study included older Caltrans/CCC SLR values, and the present version of the report is intended to update the design to meet current SLR design guidelines within the State.

The USACE Sea-Level Change Curve Calculator is an online sea-level change calculator (at the time of writing, Version 2022.60: https://cwbi-app.sec.usace.army.mil/rccslc/slcc_calc.html). The present study utilizes the USACE 2013 dataset as well as the Santa Monica, CA Gage 9410840 for the year 2100, which is the furthest out in time for which the projections are valid. A copy of the USACE calculator output data is included in the Appendix B. The calculator indicates that relative sea-level change (SLC) for the intermediate projection is 4.15 feet relative to the NAVD88 datum. This value is used for all modeling with the USACE SLR boundary condition. It is important to note that the USACE projections include the local rate of vertical land movement. The estimated USACE relative SLC projections for the Santa Monica Gage are shown in Figure 4.

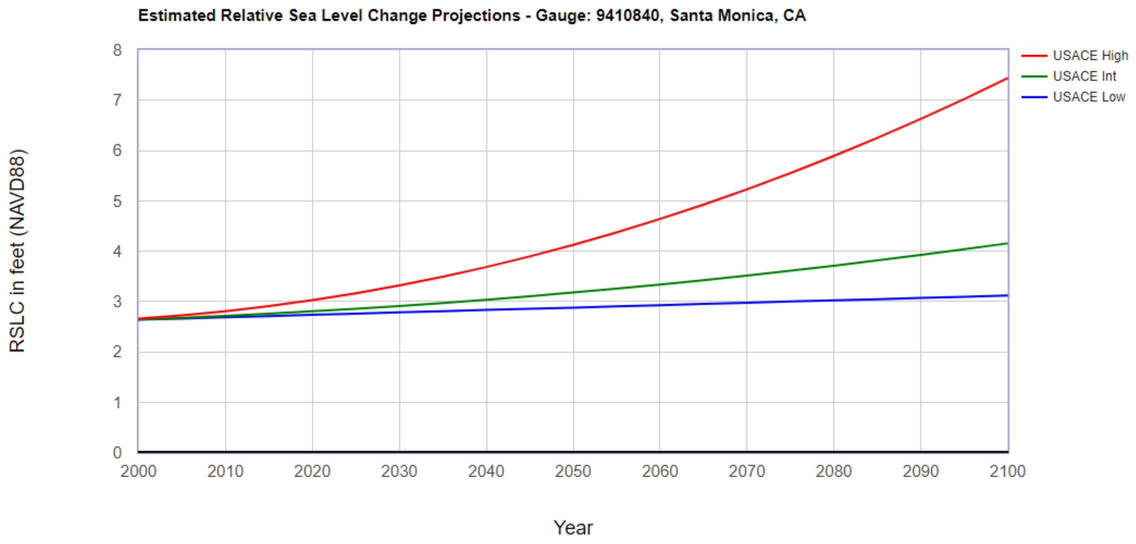

Figure 4: USACE Seal Level Change Projections for Santa Monica, CA

USACE has several guidance documents addressing SLC considerations for Corps-related projects. Both ER 1100-2-8162 (USACE 2013) and ETL 1100-2-1 (USACE 2014) address starting water surface elevations for analysis in SLC in coastal projects. While the documents appear to give latitude to local Corps Districts for final selection of starting water surface elevations, the documents give weight to MSL as local MSL, and non-ecosystem analyses, respectively. The present study uses both MSL (2.60 feet NAVD88) and MHHW (5.24 feet NAVD88) for USACE-related analyses of SLC to be consistent with analyses under California (2018) (see below, Section 4). Previous discussions with USACE staff (C. Mesa, personal communication, 2019) failed to produce additional guidance since no 408 permit application documentation had been provided to the Los Angeles District at the time of the communication.

State SLR criteria utilizes data from Table 25 in California (2018), Santa Monica gage. In the present study only the high emissions values for the low, medium-high and extreme risk aversion are used for modeling. These values are 3.3, 6.8 and 10.0 feet, respectively, for year 2010, which was chosen to be consistent with USACE analysis. It is important to note that California (2018) does not specify a starting sea surface elevation from which to conduct analysis. Additionally, multiple meetings with CCC and Caltrans staff in 2018 and 2019 failed to produce documentation specifying a starting sea surface elevation. For calculations herein both mean sea level (MSL) and mean higher high water (MHHW) for Santa Monica gage 9410840, 2.60 and 5.24 feet NAVD88, respectively, were employed. Datums are shown in the Appendix.

The values used for SLC/SLR for present study are summarized in Table 2.

Table 2: Sea Level Change/Rise Values by Agency for Santa Monica, CA

AGENCY	USACE	CALIFORNIA		
CRITERIA	INTERMEDIATE	LOW	MEDIUM-HIGH	EXTREME
VALUE	4.15	3.30	6.80	10.0

Several other design considerations may be included in SLC/SLR analyses. These considerations include local sedimentation/erosion, channel/levee overtopping, tsunamis, geotechnical uplift/subsidence, local inundation, and coastal erosion. While these topics are generally beyond the scope of the present study a discussion of them can be found in the Ballona Wetlands Restoration Project Draft EIS/EIR, Appendix F (ESA 2017). ESA (2017) notes that some bed aggradation has occurred in the area of Lincoln Bridge in the period on the order of 1 to 2 feet over the period 1961 to 2012. Between the Bridge and the end of the South Jetty, the bed aggradation has ranged from approximately 0 to greater than 3 feet during the same period. A discussion of aggradation in the proposed condition is included in Section 4.

4 Hydraulic Analysis of Existing and Proposed Conditions

4.1 HEC-RAS Model

All hydraulic modeling is conducted using the HEC-RAS numerical model developed initially by ESA (2017). The model is run in steady state, sub-critical mode, with downstream boundary conditions as described previously. All model geometry information remains unchanged, and only the proposed bridge geometry is included in proposed conditions modeling.

In the present study, HEC-RAS modeling consists of two discharges (USACE and QCAP), two starting water surface elevations (MSL and MHHW), four SLR criteria (USACE Intermediate, and California [2018] Low, Medium-High, and H++), and two bridge conditions (existing and proposed). The combination of modeling scenarios results in 32 discrete model plans. All HEC-RAS model files can be found in Appendix C. For readability, this report focuses on the design limits of Lincoln Bridge, and a discussion of all simulations is not included.

Part of the reason for not discussing all of the simulation results is because some simulations are not expected alter the critical basis of design values since they produce less conservative results than other simulations (i.e. simulations utilizing MSL produce lower changes in velocity, water surface elevation and/or greater freeboard than simulations utilizing MHHW). Other simulations are not discussed because the Ballona Creek Levees are overtopped in the model results. For overtopping cases, the results are both not valid (that is, the cross sections do not contain the discharge), and the model results raise the larger issue of coastal retreat. Coastal retreat becomes important for the purposes of the present project as rising SL inundates the areas adjacent to the project including Ballona Wetlands, Marina Del Rey and the roads which cross them. For example, there is no need to consider the design elements of Lincoln Bridge as sea levels rise and inundate portions of Ballona Wetlands where Lincoln Boulevard drops under Culver Boulevard to the north of the project site: the road to and from the Bridge would be impassable. Therefore, the discussions that follow focus on simulations that are valid. Table 3 summarizes the inputs and validity of all HEC-RAS model runs.

Table 3: Validity of HEC-RAS model runs

	Plan #	Plan Name in HEC-RAS	Discharge	Initial Elevation	Sea Level Rise	Change in WSE (ft) [NAVD88]	Is the analysis valid?
Existing	1	EX-USACE-MHHW-USACE	USACE	MHHW	USACE - Int	9.39	YES
	2	EX-USACE-MHHW-Low	USACE	MHHW	CA - Low	8.54	YES
	3	EX-USACE-MHHW-MH	USACE	MHHW	CA - M-H	12.04	NO
	4	EX-USACE-MHHW-HH	USACE	MHHW	CA - H++	15.24	NO
	5	EX-USACE-MSL-USACE	USACE	MSL	USACE - Int	6.75	YES
	6	EX-USACE-MSL-Low	USACE	MSL	CA - Low	5.90	YES
	7	EX-USACE-MSL-MH	USACE	MSL	CA - M-H	9.40	YES
	8	EX-USACE-MSL-HH	USACE	MSL	CA - H++	12.6	NO
	9	EX-QCAP-MHHW-USACE	QCAP	MHHW	USACE - Int	9.39	YES
	10	EX-QCAP-MHHW-Low	QCAP	MHHW	CA - Low	8.54	YES
	11	EX-QCAP-MHHW-MH	QCAP	MHHW	CA - M-H	12.04	NO
	12	EX-QCAP-MHHW-HH	QCAP	MHHW	CA - H++	15.24	NO
	13	EX-QCAP-MSL-USACE	QCAP	MSL	USACE - Int	6.75	YES
	14	EX-QCAP-MSL-Low	QCAP	MSL	CA - Low	5.90	YES
	15	EX-QCAP-MSL-MH	QCAP	MSL	CA - M-H	9.40	YES
	16	EX-QCAP-MSL-HH	QCAP	MSL	CA - H++	12.60	NO
Proposed	17	PR-USACE-MHHW-USACE	USACE	MHHW	USACE - Int	9.39	YES
	18	PR-USACE-MHHW-Low	USACE	MHHW	CA - Low	8.54	YES
	19	PR-USACE-MHHW-MH	USACE	MHHW	CA - M-H	12.04	NO
	20	PR-USACE-MHHW-HH	USACE	MHHW	CA - H++	15.24	NO
	21	PR-USACE-MSL-USACE	USACE	MSL	USACE - Int	6.75	YES
	22	PR-USACE-MSL-Low	USACE	MSL	CA - Low	5.90	YES
	23	PR-USACE-MSL-MH	USACE	MSL	CA - M-H	9.40	YES
	24	PR-USACE-MSL-HH	USACE	MSL	CA - H++	12.60	NO
	25	PR-QCAP-MHHW-USACE	QCAP	MHHW	USACE - Int	9.39	YES
	26	PR-QCAP-MHHW-Low	QCAP	MHHW	CA - Low	8.54	YES
	27	PR-QCAP-MHHW-MH	QCAP	MHHW	CA - M-H	12.04	NO
	28	PR-QCAP-MHHW-HH	QCAP	MHHW	CA - H++	15.24	NO
	29	PR-QCAP-MSL-USACE	QCAP	MSL	USACE - Int	6.75	YES
	30	PR-QCAP-MSL-Low	QCAP	MSL	CA - Low	5.90	YES
	31	PR-QCAP-MSL-MH	QCAP	MSL	CA - M-H	9.40	YES
	32	PR-QCAP-MSL-HH	QCAP	MSL	CA - H++	12.60	NO

4.2 Bridge Hydraulics

The impacts of the proposed bridge on channel hydraulics are summarized in Table 4 by comparing the existing and proposed velocity and water surface elevations (WSE) for different events. These events considered a combination of hydrologic conditions and sea level rise scenarios as necessary to maintain validity of the hydraulic analysis as described in Section 4.1.

Table 4 shows the changes in velocity from existing to proposed for the cross sections (XS) in the vicinity of Lincoln Bridge (located at XS 9981.5). For all scenarios examined, the average difference in velocity is approximately +0.01 foot per second (fps). That is, all valid hydraulic analyses show that the proposed bridge condition has a negligible impact on velocity compared to the existing bridge condition.

Table 4 also shows the changes in water surface elevation in NAVD88 from existing to proposed for the cross sections in the vicinity of the bridge. For all scenarios examined, the difference in WSE ranges from zero to a decrease in 0.02 ft. Therefore, all valid hydraulic analyses show that the proposed project has a negligible impact on depth compared to the existing bridge condition.

4.3 Sea-Level Rise Impact on Channel Hydraulics

As noted in Section 4.1, the magnitude of SLR plays a significant role on flow containment within the Ballona Creek channel and the validity of this analysis. However, for cases in which the analysis is valid, the impacts of different SLR scenarios are significantly low with regards to velocity and depth. Per Table 4, increasing the SLR while maintaining the same discharge and initial elevation yields no more than an increase in 0.1 fps in velocity or 0.3 ft in WSE. Because of these insignificant differences observed in both the existing and proposed conditions, no additional analysis of future aggradation/degradation impacts to channel hydraulics are described here. This approach is further supported by the findings of ESA (2017) which indicate that long-term aggradation of the channel bed has occurred since 1961 (see Section 3, above). That is, for the purposes of design of the Lincoln Bridge, additional or accelerated aggradation is expected to decrease the capacity of Ballona Creek channel fostering overtopping of the levees at lower SLR magnitudes and/or at less frequent discharge events than the USACE design discharge. In any case, the primary driver of the design of Lincoln Bridge improvements is not the local hydraulics within the Ballona Creek channel, but the ability of the levees and surrounding area to contain and resist the local relative increase in sea surface elevation. It is recommended that future analyses of proposed Lincoln Bridge improvements proceed under the most conservative hydrologic conditions that yielded valid hydraulic analyses—that is, scenarios considering the QCAP design discharge of 51,240 cubic feet per second, the MSL initial elevation of 2.6 feet, and the California Medium-High SLR scenario of 6.8 feet.

Table 4: Impacts of the Proposed Bridge on Channel Hydraulics

Discharge	Initial Elevation	SLR Scenario	Existing		Proposed		Change in Velocity	Existing		Proposed		Change in WSE
			XS	Velocity (fps)	XS	Velocity (fps)	(fps)	XS	WSE (ft)	XS	WSE (ft)	(ft)
USACE	MHHW	USACE - Intermediate	12520	10.53	12520	10.54	0.01	12520	17.66	12520	17.65	-0.01
			12121	10.74	12121	10.75	0.01	12121	17.35	12121	17.34	-0.01
			11613	10.67	11613	10.68	0.01	11613	17.08	11613	17.06	-0.02
			11028	10.63	11028	10.64	0.01	11028	16.76	11028	16.74	-0.02
			10424	10.64	10424	10.65	0.01	10424	16.41	10424	16.39	-0.02
			10037	10.09	10037	10.10	0.01	10037	16.29	10037	16.27	-0.02
			9886	10.85	9886	10.85	0	9886	15.61	9886	15.61	0
		CA - Low	12520	10.57	12520	10.58	0.01	12520	17.60	12520	17.58	-0.02
			12121	10.79	12121	10.80	0.01	12121	17.29	12121	17.27	-0.02
			11613	10.73	11613	10.74	0.01	11613	17.01	11613	16.99	-0.02
			11028	10.69	11028	10.70	0.01	11028	16.68	11028	16.66	-0.02
			10424	10.71	10424	10.72	0.01	10424	16.32	10424	16.30	-0.02
			10037	10.16	10037	10.17	0.01	10037	16.20	10037	16.18	-0.02
			9886	10.94	9886	10.94	0	9886	15.49	9886	15.49	0
	MSL	USACE - Intermediate	12520	10.63	12520	10.65	0.02	12520	17.52	12520	17.51	-0.01
			12121	10.86	12121	10.87	0.01	12121	17.20	12121	17.19	-0.01
			11613	10.80	11613	10.81	0.01	11613	16.92	11613	16.9	-0.02
			11028	10.77	11028	10.78	0.01	11028	16.58	11028	16.56	-0.02
			10424	10.80	10424	10.81	0.01	10424	16.21	10424	16.19	-0.02
			10037	10.24	10037	10.26	0.02	10037	16.08	10037	16.06	-0.02
			9886	11.06	9886	11.06	0	9886	15.35	9886	15.35	0
		CA - Low	12520	10.65	12520	10.66	0.01	12520	17.50	12520	17.49	-0.01
			12121	10.87	12121	10.88	0.01	12121	17.18	12121	17.17	-0.01
			11613	10.82	11613	10.83	0.01	11613	16.89	11613	16.88	-0.01
			11028	10.78	11028	10.80	0.02	11028	16.56	11028	16.54	-0.02
			10424	10.82	10424	10.84	0.02	10424	16.18	10424	16.16	-0.02
			10037	10.26	10037	10.28	0.02	10037	16.05	10037	16.03	-0.02
			9886	11.09	9886	11.09	0	9886	15.31	9886	15.31	0
		CA - M-H	12520	10.53	12520	10.54	0.01	12520	17.66	12520	17.65	-0.01
			12121	10.74	12121	10.75	0.01	12121	17.35	12121	17.34	-0.01
			11613	10.67	11613	10.68	0.01	11613	17.08	11613	17.07	-0.01
			11028	10.63	11028	10.64	0.01	11028	16.76	11028	16.74	-0.02
			10424	10.64	10424	10.65	0.01	10424	16.41	10424	16.39	-0.02
			10037	10.09	10037	10.10	0.01	10037	16.29	10037	16.27	-0.02
			9886	10.85	9886	10.85	0	9886	15.61	9886	15.61	0

Discharge	Initial Elevation	SLR Scenario	Existing		Proposed		Change in Velocity	Existing		Proposed		Change in WSE
			XS	Velocity (fps)	XS	Velocity (fps)	(fps)	XS	WSE (ft)	XS	WSE (ft)	(ft)
QCAP	MHHW	USACE - Intermediate	12520	10.53	12520	10.54	0.01	12520	17.66	12520	17.65	-0.01
			12121	10.74	12121	10.75	0.01	12121	17.35	12121	17.34	-0.01
			11613	10.67	11613	10.68	0.01	11613	17.08	11613	17.06	-0.02
			11028	10.63	11028	10.64	0.01	11028	16.76	11028	16.74	-0.02
			10424	10.64	10424	10.65	0.01	10424	16.41	10424	16.39	-0.02
			10037	10.09	10037	10.1	0.01	10037	16.29	10037	16.27	-0.02
			9886	10.85	9886	10.85	0	9886	15.61	9886	15.61	0
		CA - Low	12520	10.57	12520	10.58	0.01	12520	17.6	12520	17.58	-0.02
			12121	10.79	12121	10.8	0.01	12121	17.29	12121	17.27	-0.02
			11613	10.73	11613	10.74	0.01	11613	17.01	11613	16.99	-0.02
			11028	10.69	11028	10.7	0.01	11028	16.68	11028	16.66	-0.02
			10424	10.71	10424	10.72	0.01	10424	16.32	10424	16.3	-0.02
			10037	10.16	10037	10.17	0.01	10037	16.2	10037	16.18	-0.02
			9886	10.94	9886	10.94	0	9886	15.49	9886	15.49	0
	MSL	USACE - Intermediate	12520	10.63	12520	10.65	0.02	12520	17.52	12520	17.51	-0.01
			12121	10.86	12121	10.87	0.01	12121	17.2	12121	17.19	-0.01
			11613	10.8	11613	10.81	0.01	11613	16.92	11613	16.9	-0.02
			11028	10.77	11028	10.78	0.01	11028	16.58	11028	16.56	-0.02
			10424	10.8	10424	10.81	0.01	10424	16.21	10424	16.19	-0.02
			10037	10.24	10037	10.26	0.02	10037	16.08	10037	16.06	-0.02
			9886	11.06	9886	11.06	0	9886	15.35	9886	15.35	0
		CA - Low	12520	10.65	12520	10.66	0.01	12520	17.5	12520	17.49	-0.01
			12121	10.87	12121	10.88	0.01	12121	17.18	12121	17.17	-0.01
			11613	10.82	11613	10.83	0.01	11613	16.89	11613	16.88	-0.01
			11028	10.78	11028	10.8	0.02	11028	16.56	11028	16.54	-0.02
			10424	10.82	10424	10.84	0.02	10424	16.18	10424	16.16	-0.02
			10037	10.26	10037	10.28	0.02	10037	16.05	10037	16.03	-0.02
			9886	11.09	9886	11.09	0	9886	15.31	9886	15.31	0
		CA - M-H	12520	10.53	12520	10.54	0.01	12520	17.66	12520	17.65	-0.01
			12121	10.74	12121	10.75	0.01	12121	17.35	12121	17.34	-0.01
			11613	10.67	11613	10.68	0.01	11613	17.08	11613	17.07	-0.01
			11028	10.63	11028	10.64	0.01	11028	16.76	11028	16.74	-0.02
			10424	10.64	10424	10.65	0.01	10424	16.41	10424	16.39	-0.02
			10037	10.09	10037	10.1	0.01	10037	16.29	10037	16.27	-0.02
			9886	10.85	9886	10.85	0	9886	15.61	9886	15.61	0

4.4 Scour Analysis

Two approaches to scour analysis are utilized to understand the impacts to sediment transport and channel bed response resulting from the proposed Lincoln Bridge improvements. The first approach follows the guidelines of LACDWP (2006) and the second employs bridge scour calculations using the hydraulic design package in HEC-RAS based on HEC-18 (FHWA 2012). The benefit of the former is that it considers the total bed response, including general and long-term bed adjustment, and local scour. The benefit of the latter is that considers the different elements of bridge scour directly in the HEC-RAS model. Generally, both approaches follow all or part, respectively, of Federal Highways guidelines for scour analysis for stream crossings. The methods and analysis results are described below.

4.4.1 LACDPW Scour Analysis

LACDPW (2006) requires that the sum of several design parameters be used to develop the scour-depth toe-down. These parameters include long-term bed change (degradation component only), general bed change (degradation component only), and several elements of local scour (general local scour, bend scour, low flow incitement and bed form height). In the present study, the long-term bed change is set to 0.0 feet following the findings of (ESA 2017) that indicates long-term aggradation has occurred historically at the site. General adjustment is calculated using Appendix C of the Manual, which is represented with a second-order polynomial. No bends are present in the project reach of the channel so bend scour is set to 0.0 feet. Low flow incisement is set to 2.0 feet as a conservative estimate of the thalweg depth, which is a typical approach for channels in Los Angeles County. Bed form height is calculated following Appendix C of the Manual, which relies upon academic literature (Kennedy's equation). Local scour is based on the impacts of piers (Neill's equation) and abutments (Lin's equation), and generally follows the approach of FHWA (2012). The maximum scour is then compared to the design scour depth in the legacy County Design Manual (LACFCD 1982) and the greater of the two values is used for design toe-down. The LACDPW scour calculations for all modeled scenarios are presented in Appendix D. Table 5 summarizes the total scour results for the total design scour after LACDPW (2006) comparing the existing and proposed condition bridges for all valid analyses. The proposed bridge condition results in an additional 0.01 feet of bridge scour compared to the existing condition for all valid analyses.

Table 5: LACDPW Scour Results (feet) at Lincoln Bridge

Discharge	Initial Elevation	SLR Scenario	Existing	Proposed
USACE	MHHW	USACE - Int	24.22	24.23
		CA - Low	22.48	22.49
	MSL	USACE - Int	22.56	22.57
		CA - Low	22.57	22.58
		CA - M-H	22.42	22.43
QCAP	MHHW	USACE - Int	23.11	23.12
		CA - Low	23.15	23.16
	MSL	USACE - Int	23.21	23.22
		CA - Low	23.22	23.23
		CA - M-H	23.11	23.12

4.4.2 HEC-18 Scour Analysis

HEC-18 analysis is conducted in the HEC-RAS model using the software's hydraulic design function. The function utilizes hydraulic information from the model to perform the scour calculations. The calculations are limited to contraction, pier and abutment components of local scour. Table 6 summarizes the HEC-18 scour results after FHWA (2012) comparing the existing and proposed condition bridges for all valid simulations examined. The analyses show that on average, the proposed bridge condition results in an increase of 2.5 feet of pier scour and a decrease in 0.1 feet of contraction score when compared to the existing condition.

Table 6: HEC-18 Scour Results (feet) at Lincoln Bridge

Discharge	**Initial Elevation**	**SLR Scenario**	**Existing**				**Proposed**			
			Contraction	Pier	Abutment	**Total**	Contraction	Pier	Abutment	**Total**
USACE	MHHW	USACE - Int	0.94	9.72	0.0	10.66	0.87	12.21	0.0	13.08
		CA - Low	0.97	9.74	0.0	10.71	0.88	12.23	0.0	13.11
	MSL	USACE - Int	0.99	9.76	0.0	10.75	0.92	12.26	0.0	13.18
		CA - Low	1.00	9.77	0.0	10.77	0.91	12.27	0.0	13.18
		CA - M-H	0.94	9.72	0.0	10.66	0.87	12.20	0.0	13.07
QCAP	MHHW	USACE - Int	1.00	9.97	0.0	10.97	0.92	12.51	0.0	13.43
		CA - Low	1.02	9.98	0.0	11.00	0.93	12.52	0.0	13.45
	MSL	USACE - Int	1.02	10.00	0.0	11.02	0.94	12.55	0.0	13.49
		CA - Low	1.03	10.00	0.0	11.03	0.95	12.56	0.0	13.51
		CA - M-H	0.99	9.97	0.0	10.96	0.92	12.51	0.0	13.43

Because there is no abutment scour observed, the pier and abutment scour cones are not expected to overlap at Lincoln Bridge in either the existing or proposed condition. Therefore, when using HEC-18 guidelines for determining scour under Lincoln Bridge, the pier and abutment scour should not be summed; the contraction scour should instead be summed with either the pier or abutment scour for an appropriate analysis. HEC-18 analysis results for all valid simulations are included in the Appendix D.

5 Conclusion and Final Recommendations

The purpose of the Lincoln Bridge Multi-Modal Bridge Improvement Project is to create a new multi-modal corridor along SR-1/Lincoln Boulevard in order to improve traffic operations and services while minimizing impacts to Ballona Creek and Ballona Wetlands Reserve. The purpose of this hydraulic study is to update the HEC-RAS model provided by Psomas with revised SLR criteria and up-to-date design plans in an effort to analyze the hydraulic impacts of the proposed bridge design. It is worth noting that using updated SLR criteria yielded overtopping of the modeled channel for certain proposed runs; runs in which the channel could not contain the full flow are invalid analyses for which conclusions cannot be drawn.

Results of the hydraulic analysis show that the proposed bridge design has minimal impacts on channel water surface elevation and velocity in the vicinity of the bridge. For all valid model runs, the proposed bridge design yields a channel velocity increase of 0.01 feet per second on average. Additionally, the proposed design yields an average decrease in water surface elevation (NAVD88) of 0.02 feet when compared to the hydraulic results of the existing bridge design. The LACDPW scour analysis of the Lincoln Bridge show that the proposed bridge design results in an additional 0.01 feet of bridge scour compared to the existing condition for all valid analyses. Results of the HEC-18 scour analysis show an average increase of 2.4 feet of total scour for the proposed design in comparison to the existing bridge.

It is recommended that all future analyses of proposed bridge designs use the most hydrologically conservative scenario that yielded valid hydraulic analyses. That is, scenarios considering the QCAP design discharge of 51,240 cubic feet per second, the MSL initial elevation of 2.6 feet, and the California Medium-High SLR scenario of 6.8 feet. If future models require using hydrologic conditions that resulted in channel overtopping for more conservative analyses, it is recommended that Psomas obtain additional terrain data to expand the area of analysis to include the Ballona Wetlands Reserve. Additional terrain data would make it possible to extend the HEC-RAS cross sections to contain the full flow or to add a 2D area to capture surface flow if needed.

6 References

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7 Appendices

Please refer to digitally submitted appendices.