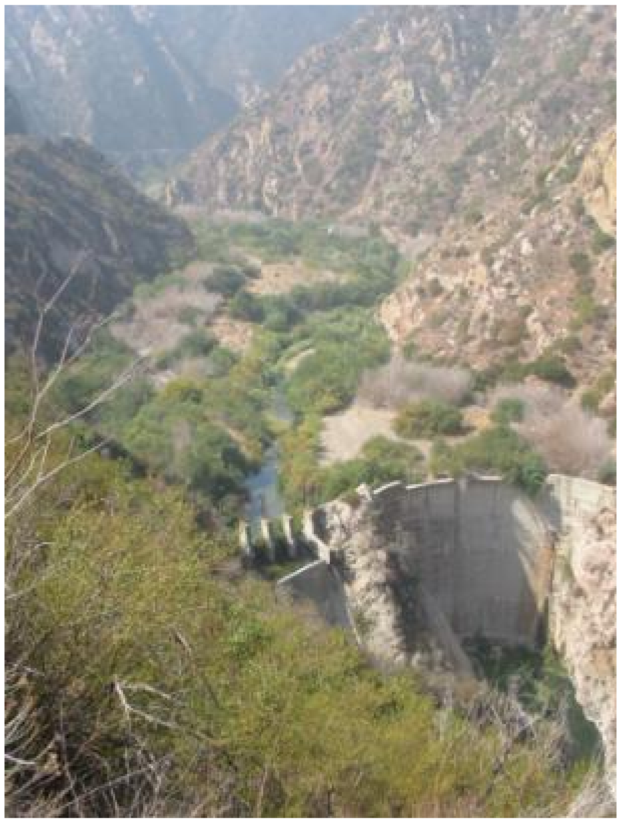
Malibu Creek Ecosystem Restoration Study

Los Angeles and Ventura Counties, California

Appendix B

Hydrology, Hydraulics and Sedimentation



U.S. Army Corps of Engineers
Los Angeles District

August 2020

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ABBREVIATIONS AND ACRONYMS USED IN THIS APPENDIX

ACE	Annual Chance Exceedance
CalTrans	California Department of Transportation
CERES	California Environmental Resources Evaluation System
CP	Concentration Point
CRWQCB	California Regional Water Quality Control Board
DSS	Data Storage System
DTM	Digital Terrain Model
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
HEC	Hydrologic Engineering Center
LACDPW	Los Angeles County Department of Public Works
LARWQCB	Los Angeles Regional water Quality Control Board
LVMWD	Las Virgenes Municipal Water District
MCWNRP	Malibu Creek Watershed Natural Resource Plan
PCH	Pacific Coast Highway
PDT	Project Delivery Team
MWD	Metropolitan Water District
NRCS	Natural Resources Conservation Service
RAS	River Analysis System
RS	River Station (cross section locations)
TAC	Technical Advisory Committee
TIN	Triangulated Irregular Network
TWRF	Tapia Water Reclamation Facility
USACE	U.S. Army Corps of Engineers
USGS	United States Geological Survey
WY	Water Year

UNITS

ac	acres	ft^3/s	cubic feet per second
af/yr	acre-feet per year	in	inch
af	acre-feet	mi^2	square miles
yd^3	cubic yards	ft	feet
ft/mi	feet per mile	MHHW	mean higher high water
mgd	million gallons per day		

1.0 INTRODUCTION

The intent of the Feasibility Study is to evaluate ecosystem restoration potential within the Malibu Creek watershed. The watershed is located in Los Angeles and Ventura Counties in California. The purpose of the Hydrology, Hydraulics, and Sedimentation Appendix is to supplement information provided in the Final Integrated Feasibility Report (IFR) with detailed hydrologic, hydraulic, and sedimentation analyses. The focal point of this study is to determine if removal of Rindge Dam would provide significant ecosystem benefits. The watershed is highly modified by residential development, recreational reservoirs, and agriculture operations.

This Hydrology, Hydraulics, and Sedimentation Appendix supplements the Final IFR. The results presented herein are for Existing Conditions, Future Conditions, and four selected alternatives. Detailed descriptions and results for each alternative are presented. The recommended plan includes removal of Rindge Dam and several upstream barriers to extend the habitat for fish and other riparian species.

2.0 GENERAL DESCRIPTION OF THE DRAINAGE AREA

Malibu Creek is located approximately 30 mi west of downtown Los Angeles, California (**Plate 2-1**). The drainage area covers approximately 110 mi² of the Santa Monica Mountains and Simi Hills. The feasibility study area currently includes Rindge Dam (**Plate 2-2**), which is located about 3 mi upstream of Malibu Lagoon. The non-federal sponsor of the feasibility study is the California Department of Parks and Recreation (CDPR).

Malibu Creek and its tributaries drain into Malibu Lagoon and Santa Monica Bay. Malibu Canyon Road/Las Virgenes Road forms the primary north/south route through the watershed. Approximately two-thirds of the watershed is located in northwestern Los Angeles County, and the remaining one-third is in southeastern Ventura County. Elevations in the watershed range from over 3,100 ft at Sandstone Peak in Ventura County, to sea level at Santa Monica Bay. Malibu Creek invert slopes range from 0.032 ft/ft in the vicinity of Rindge Dam to 0.003 ft/ft where Malibu Creek emerges from the canyon to the Pacific Ocean.

For the purposes of this study, reaches have been defined so that, within a given reach, the river and associated habitat has similar characteristics (**Table 2-1** and **Plate 2-3**). The reach definitions are used in this report to describe sediment impacts and are referenced throughout the report. Note, the break between Reaches 2a and 2b was for modeling purposes and was determined by visual inspection of the aerial photographs and was noted as a break in the slope on the profile of the channel. It is understood there may be a difference between the geomorphologic definition of a lagoon and where the upstream end of the lagoon actually is.

Concentration points, or CPs, are nodes along Malibu Creek located at the upstream or downstream extent of each reach. Hydrologic information was generated at each CP and used as input to the hydraulic and sedimentation models. CPs are shown on **Plate 2-4** and described in **Table 2-2**.

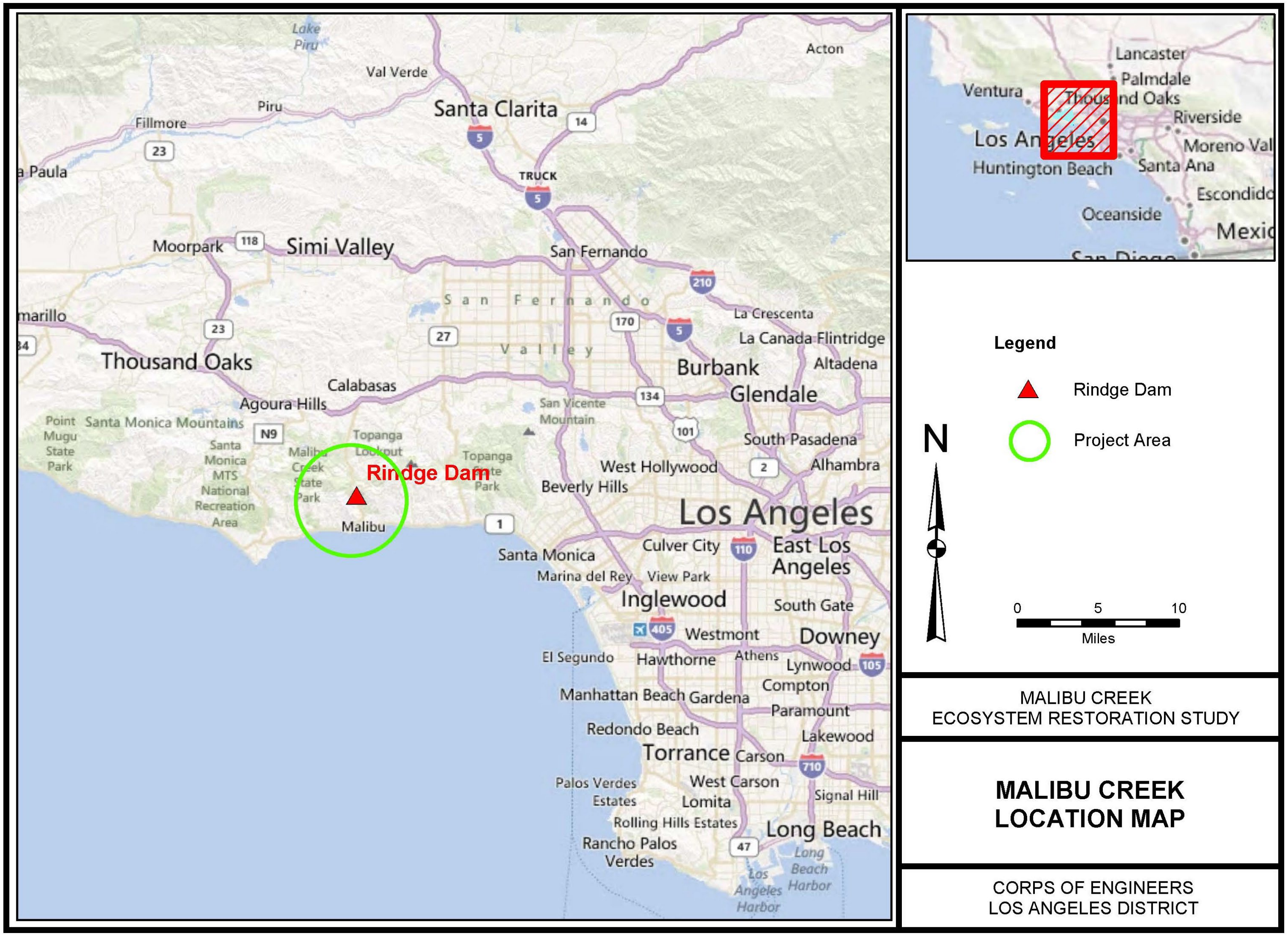


Plate 2-1 Malibu Creek Location Map

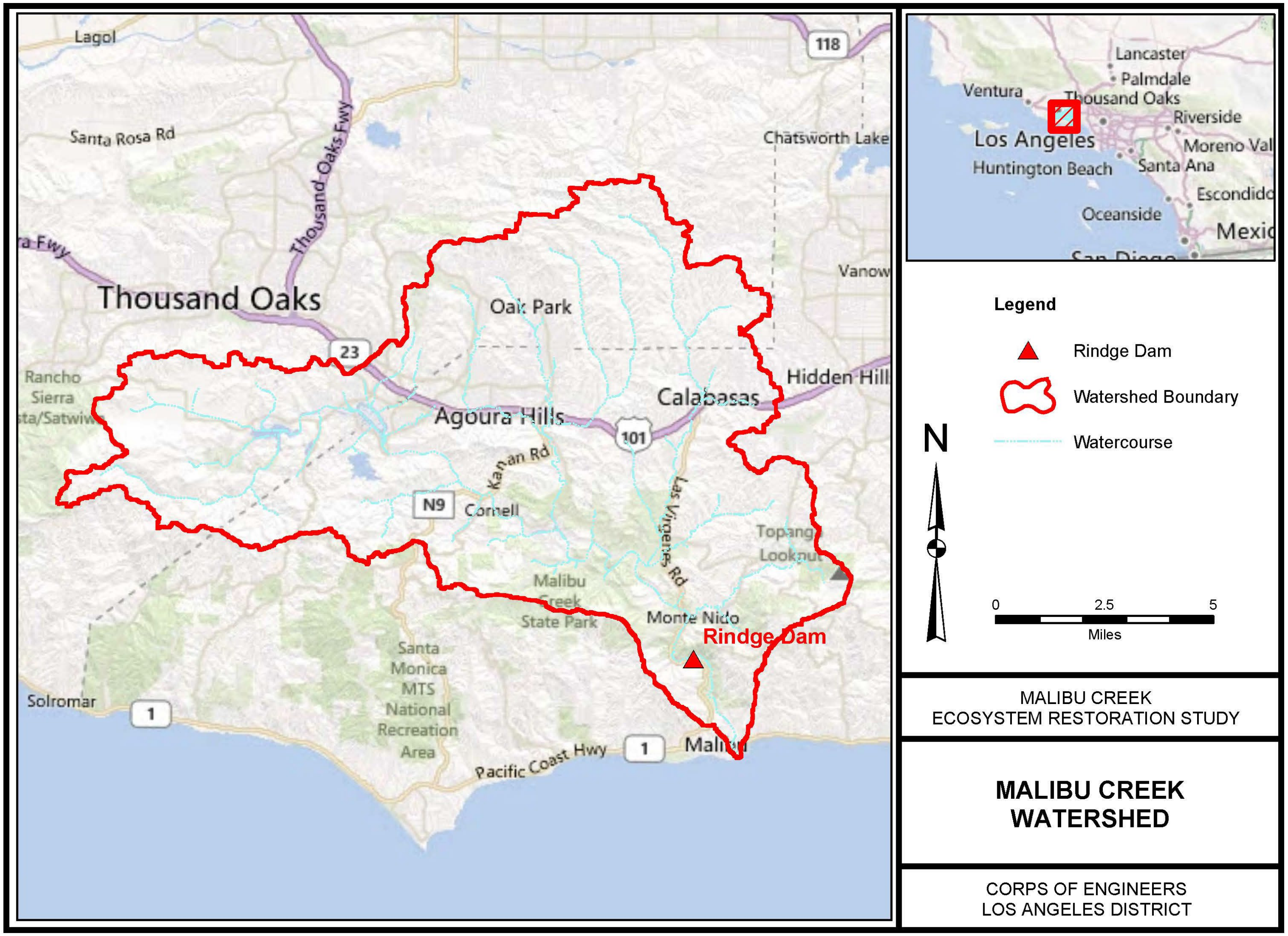


Plate 2-2 Malibu Creek Watershed

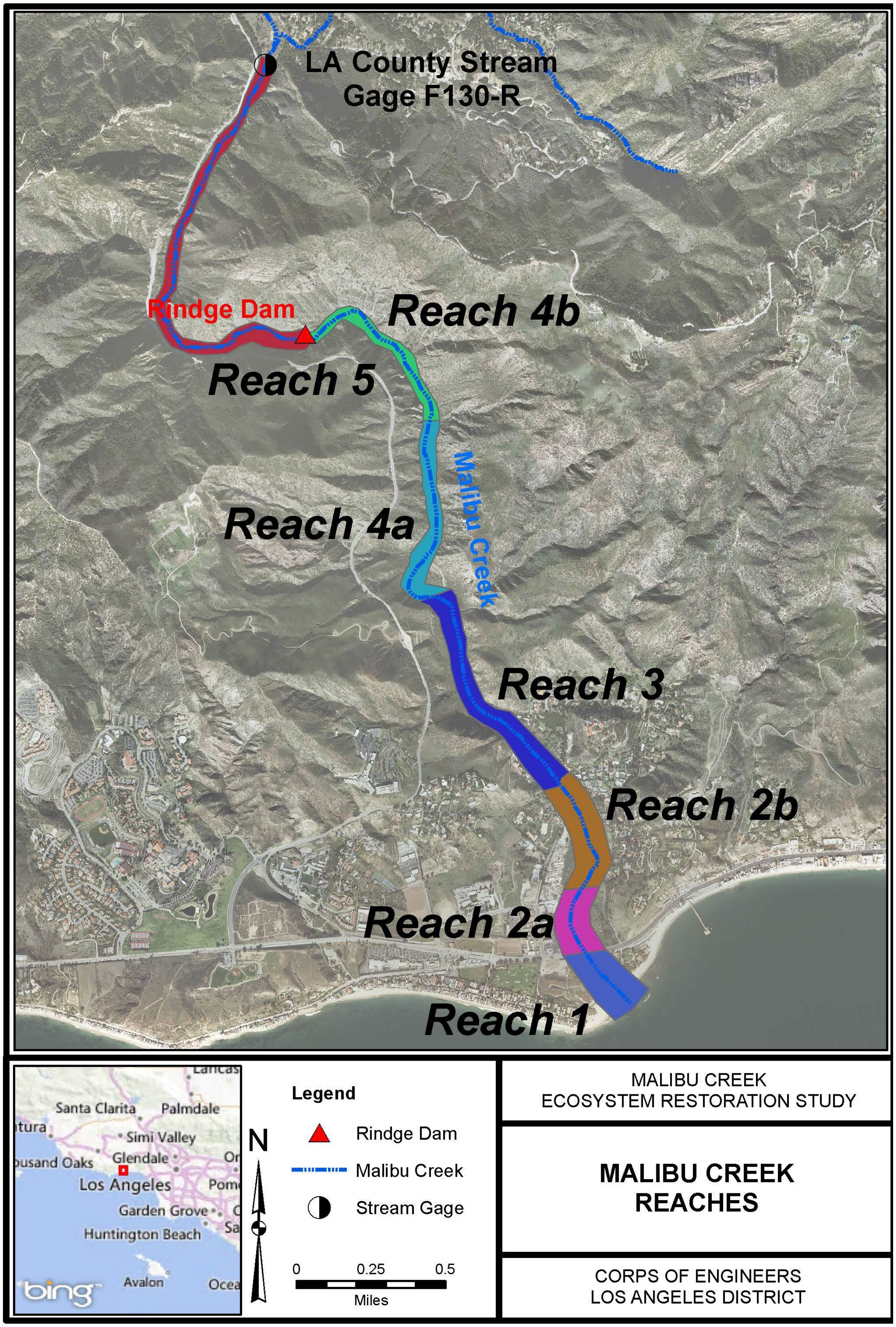


Plate 2-3 Malibu Creek Reaches

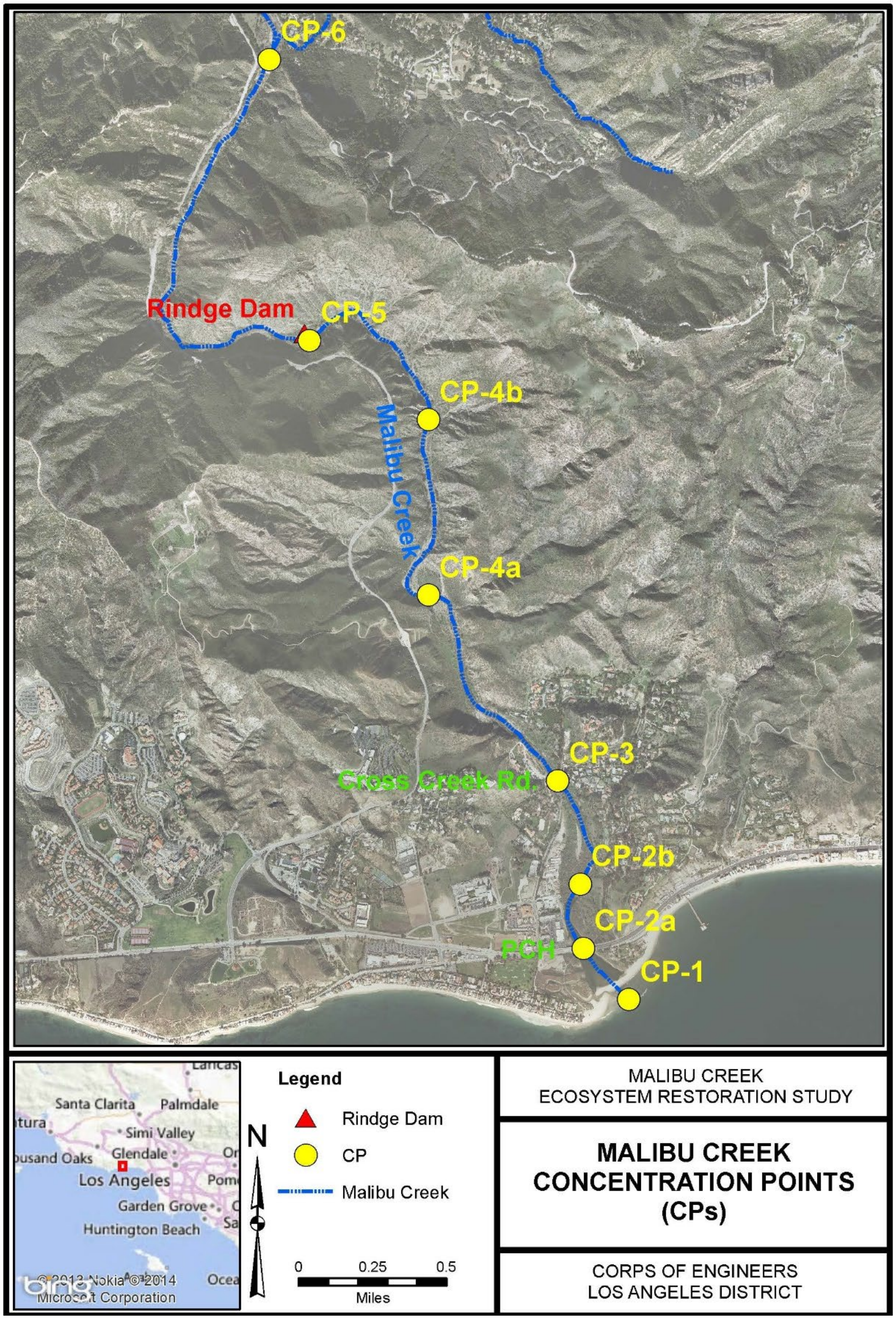


Plate 2-4 Malibu Creek Concentration Points (CPs)

Table 2-1 Reach Descriptions for Malibu Creek

Reach	Upstream River	Downstream River	Reach Description
5	245+00.0	162+00.7	Cold Creek to Rindge Dam
4b	162+00.7	126+89.5	Rindge Dam to RM 2.4
4a	126+89.5	90+72.9	RM 2.4 to “Big Bend”
3	90+72.9	47+04.5	“Big Bend” to Cross Creek Bridge
2b	47+04.5	26+03.4	Cross Creek Bridge to Malibu
2a	26+03.4	13+20.8	Malibu Lagoon to PCH
1	13+20.8	0+00	PCH to Pacific Ocean

Reach 4 was divided into 2 sub-reaches based on initial sediment transport modeling results. The cross section at RM 2.4 is approximately the downstream limit (during the first 5 years) of the sediment deposition for Alt. 2a, the natural transport alternative with full dam removal. Reach 2 was also divided into 2 sub-reaches to show impacts in Malibu Lagoon separate from the creek. The break between Reaches 2a and 2b was for modeling purposes and was determined by visual inspection of the aerial photographs and a noted break in the slope on the profile of the channel. It is understood there is may be a difference between the geomorphology definition of a lagoon and where the upstream end of the lagoon actually is.

Table 2-2 Concentration Point Descriptions

CP	CP ID	Location	Drainage Area (mi²)
6	MCBLCCK	Malibu Creek below Cold Creek	104.9
5	MCATRD	Malibu Creek at Rindge Dam	106.4
4	MCATBB	Malibu Creek at "Big Bend"	107.7
3	MCATCRCK	Malibu Creek at Cross Creek Bridge	109.1
2	MCATPCH	Malibu Creek at Pacific Coast Highway	109.6
1	MCATPO	Malibu Creek at Pacific Ocean	109.6

Construction of Rindge Dam was completed in 1926 by the Rindge family and originally provided approximately 574 af of water storage for agricultural needs. Rindge Dam is located on Malibu Creek approximately 3 mi upstream from the coast. Rindge Dam is a concrete arch structure 100 ft in height with an arc length of 140 ft at its crest (excluding spillway & rock outcrop) and 80 ft at its base (**Figure 2-1** and **Figure 2-2**). The dam is 2 ft thick at the crest and 12 ft thick at the base. The dam was declared non-jurisdictional by the State of California in 1967. The dam site is currently part of California's State Parks System (Malibu Creek State Park).

A gated spillway was built in a rock outcrop adjacent to the right dam abutment. The spillway had four radial gates, each measuring 11 ft high by 8 ft wide, and had a maximum capacity of 7,000 ft^3/s. During normal seasonal operations, the gates were raised (open) during the rainy winter months and lowered to the closed position during the summer to maintain maximum reservoir capacity during peak agricultural use. An 8- inch steel pipe, approximately 34 ft down from crest of dam, conveyed water from the reservoir, down the canyon, to the Malibu plain. Based on the aerial survey data generated for this study (Landata Airborne Systems, contour interval 2 ft, 1" to 200' scale. NAVD88, NAD83, dated May 2002), the top of dam elevation is approximately 298 ft. The center section is 5 ft lower than the raised ends (El. ~293 ft). Both ends of the dam crest featured five steps; each step measured 12 in. The spillway crest elevation is approximately 285 ft. The elevation just downstream from the dam is about 185 ft.

Rindge Dam created an obstruction along Malibu Creek, thus trapping the sediment behind the dam. Since there was no maintenance performed for this dam, the sediment accumulated to the crest of this structure. Sediment carried by Malibu Creek deposited behind the dam until the 1950's, at which point the pool behind the dam was almost completely filled with sediment and therefore, lost functionality as a water storage reservoir. It is estimated that approximately 780,000 yd^3 of sediment lies trapped behind the dam (refer to Geotechnical Appendix for details on calculation). Rindge Dam no longer serves its original purpose. It neither provides water storage nor flood control protection due to sedimentation behind the dam. During peak events, the entire flow in Malibu Creek rises over the dam's crest. Presently, the dam impedes the migration of endangered species into the upper tributaries of Malibu Creek. Pertinent information for Rindge Dam is presented in **Table 2-3**.

Malibu Lagoon is one of the two last remaining estuaries in Los Angeles County. It is a small shallow water embayment, covering approximately 13 acres. The lagoon is a remnant of a once more extensive group of estuaries within the Southern California region, from Point Conception to the international border with Mexico. The lagoon has been severely degraded due to urbanization of the Malibu Creek watershed. Unseasonable flows, increased sedimentation, instream structures, loss of habitat, loss of tidal prism, mechanical breaching of the mouth, encroaching development, heavy recreational use, and eutrophication are some of the difficult conditions encountered in the lagoon. In 1996, over 2,000 yd^3 of old fill material was removed from the lagoon. A new renovation of the lagoon is almost finished.

Table 2-3 Pertinent Data for Rindge Dam (sta. 162+00.7)

Location:	Malibu Creek, 30 mi west of Los Angeles; approx. 3 mi upstream from coast
Drainage Area:	106.4 mi^2
Top of Dam Elevation:	298.4 ft*
Top of Dam Notch Elevation:	293.4 ft*
Spillway Crest Elevation:	285.4 ft*
Downstream Elevation:	184.8 ft*
Current Owner:	California State Parks
Dam Purpose:	Water Supply (reservoir is virtually filled in with sediment and no longer functional)
Construction:	Concrete Arch, 140 ft arch length x 102 ft high
*Note: Elevations estimated using Landata Airborne Systems aerial survey, contour interval 2 ft, dated May 2002, and field measurements.	

Figure 2-1 Rindge Dam

Figure 2-2 Rindge Dam (photo courtesy D. Pritchett)

3.0 STRUCTURES AFFECTING RUNOFF

Several dams and lakes in the watershed have been constructed for water supply and recreation: Eleanor Dam built in 1881, Sherwood Dam in 1904, Crags Dam in 1913, Malibu Dam in 1923, Rindge Dam in 1926, and Westlake Dam in 1965. None have any significant impact on larger flood events.

There are 2 bridge crossings between Rindge Dam and the Pacific Ocean (**Plate 2-4**). These are the Pacific Coast Highway (PCH) bridge (sta. 13+20.8) and the Cross Creek Road bridge (sta. 47+04.5). PCH crosses Malibu Creek approximately 1,200 ft upstream from the ocean. The Cross Creek Road bridge is about 0.6 mi upstream from PCH. There is extensive development along the lower portions of Malibu Creek with several businesses and communities located in areas where flooding has previously occurred. Many of these developments are within the existing FEMA 100-year (1% ACE event) floodplain. Malibu Lagoon is situated at the lower terminus of Malibu Creek at the Pacific Ocean.

4.0 GEOLOGY

The Santa Monica Mountains and Simi Hills are part of the Transverse Ranges. They were formed through a process of deposition, erosion, volcanic activity, and tectonic forces. Approximately 135 million years ago, the ocean covered the area where the Santa Monica Mountains are located. Over millions of years, sediments settled on the ocean bottom, and eventually through pressure and chemical processes, were transformed into sedimentary rocks – shale and sandstone – that compose most of the area (Jorgen 1995).

The greatest volume of rock mass in the Malibu Creek watershed is composed of young sandstone, shale, and volcanic flows that occurred between 10 to 20 million years ago during the Miocene Epoch (Warshall, et al. 1992). The distinctive black-gray and reddish volcanic rocks in the watershed are known as the Conejo Volcanics. It was not until four million years ago that northward pushing tectonic forces caused the Santa Monica Mountains to thrust their way out of the ocean (Warshall, et al. 1992). Erosion of the volcanic and sedimentary rocks created sediments that were deposited by flowing water, filling valleys and streambeds with alluvial soil. This alluvial layer is 30 ft deep in portions of the streambeds and canyon bottoms and tapers off rapidly to less than four ft up canyon slopes (MCWNRP 1995[1]).

5.0 SOILS

The soils in the Malibu Creek watershed are susceptible to high erosion rates. This is due to a combination of climate, topography, vegetation, and soil structure. Mediterranean climates tend to have the highest sediment yields (Levy and Korkosz 1997). Soils in the area are derived from sandstone, shale, volcanic and igneous rock, and from alluvium composed of a mixture of rock sources that compose the Santa Monica Mountains. Soil types determine the amount of water storage and the ability to absorb and filter runoff within the watershed. The Malibu Creek watershed contains 40 soil mapping units in the Los Angeles County portion and 38 soil mapping units in the Ventura County portion of the watershed (MCWNRP 1995).

For purposes of hydrologic analysis, the wide variety of soil types is divided into soils groups. The USDA, Soil Conservation Service (now NRCS) has defined four general soil groups (A-D). Soils falling within Soil Group A have a higher infiltration rate than those in B, soils in Group B have a higher infiltration rate than those in Group C, while soils in Group D have the lowest infiltration rate. The four groups with descriptions from the Handbook of Hydrology by Maidment, 1992, are described below. Soil groups within the Malibu Creek watershed fall into all four groups and are shown on **Plate 7-1**.

- Soil Group A. Soils have a low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels. The USDA soil textures normally included in this group are sand, loamy sand, and sandy loam. These soils have a hydraulic conductivity rate greater than 0.76 cm/h.
- Soil Group B. Soils have a moderate infiltration rates when thoroughly wetted and consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. The USDA soil textures normally included in this group are silt loam and loam. These soils have a hydraulic conductivity rate between 0.38 and 0.76 cm/h.
- Soil Group C. Soils have a low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water soils with moderately fine to fine textures. The USDA soil texture normally included in this group is sandy clay loam. These soils have a hydraulic conductivity rate between 0.13 and 0.38 cm/h.

- Soil Group D. Soils have high runoff potential. They have very low infiltration rates when thoroughly wetted and consist mainly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over a nearly impervious material. The USDA soil textures normally included in this group are clay loam, silty clay loam, sandy clay, silty clay, and clay. These soils have a very low rate of water transmission (0.0 and 0.13 cm/h). Some soils are classified in group D because of a high water table that creates a drainage problem; however, once these soils are effectively drained, they are placed into another group.

6.0 VEGETATION

The Malibu Creek watershed is covered with plants that have evolved to fit the unique soils and climate of the region. Chaparral, Coastal Sage Scrub, and Chamise are plant communities that dominate this area of the Santa Monica Mountains. These plant communities are adapted to wet winters and dry summers. Vegetation plays a critical role in the watershed by helping control erosion. Vegetation holds soil together with its roots and reduces the force of rainfall with its canopy of leaves and branches. This slows the flow of water and increases the volume of percolation into the ground. Runoff is minimized and less water flows all at once into streams. Riparian vegetation can be found alongside Malibu Creek and tributaries and around bodies of water. The riparian zone helps curtail erosion along the channel inverts. General vegetation classes within the Malibu Creek watershed are shown on **Plate 7-2**. Detailed vegetation information is presented in the Affected Environment Section of the Final IFR.

7.0 CLIMATE

The climate in the Malibu Creek watershed is generally characterized as a Mediterranean type with mild wet winters, hot dry summers, and coastal fog occurring in spring and mid-summer between the months of May and July. The area is frost-free 275-325 days a year on average. Spring temperatures range from 65-85 degrees Fahrenheit (°F) during the day and drop as low as 45-65 °F at night. Inland summer daytime temperatures general remain around 85 °F and will occasionally exceed 100 °F degrees with low temperatures dipping into the mid-fifties. Coastal temperatures are generally 15 °F cooler than those of the inland valleys (Jorgen 1995).

Fall temperatures range from 65-90 °F inland during the day and dip to 20-60 °F at night. Fall is usually associated with the warm, dry Santa Ana winds that blow in from the deserts. Due to these dry summer and fall conditions, fire has become an integral part of the local ecosystem.

Winter is characterized by periodic rainfall, which accounts for nearly all the precipitation in the area. The majority of rainfall occurs between November and March averaging 25 inches over the mountainous regions to the north and along the coast, to about 13 inches in the inland valleys. Measurable precipitation occurs on average 35 days per year with December and January usually the wettest months (Jorgen 1995). Average winter temperatures reach highs in the mid-60s °F with average lows in the mid-40s °F. Freezing temperatures sometimes occur in the higher elevations of the Santa Monica Mountains. Snow rarely falls but has occurred within the watershed.

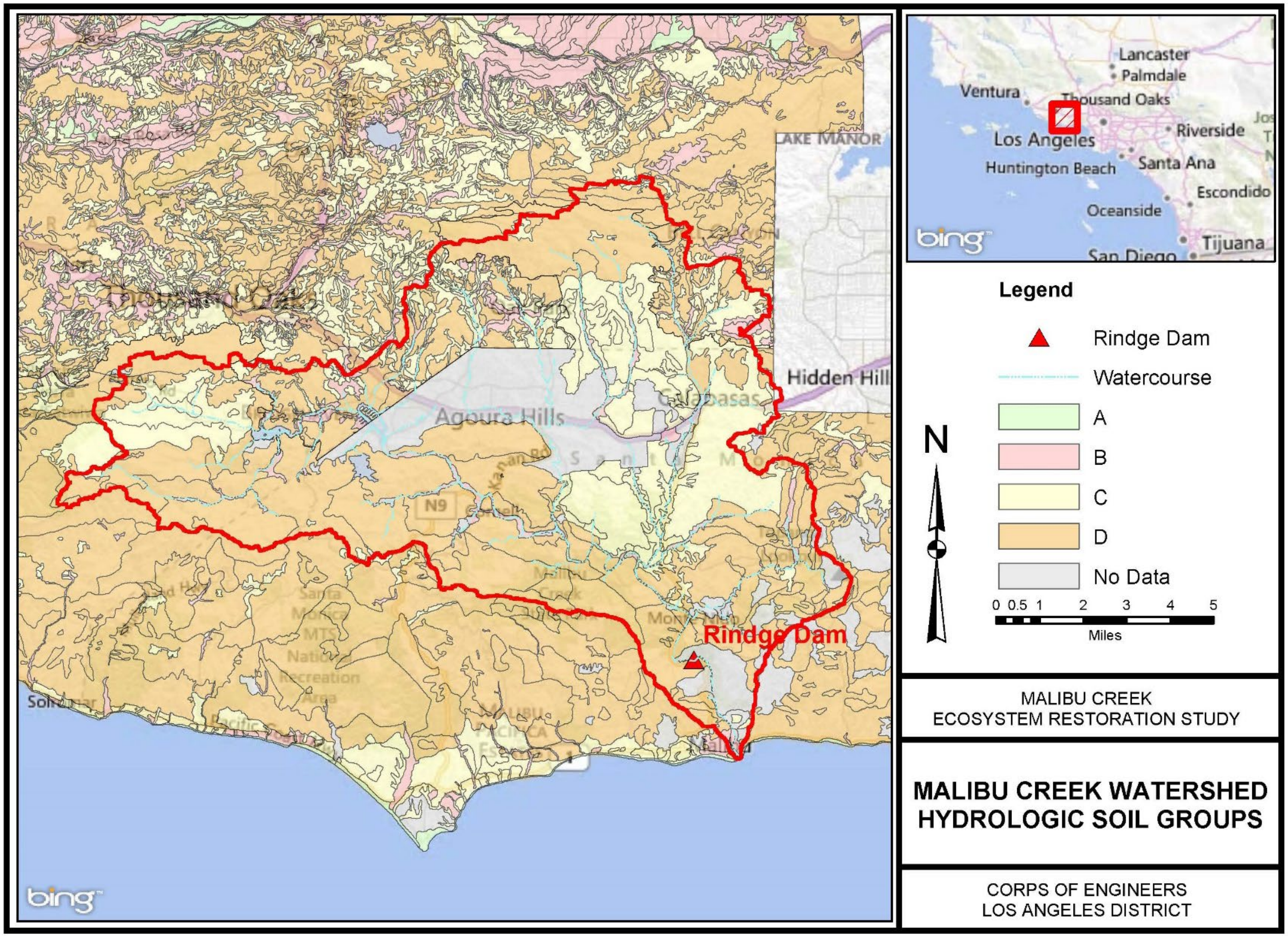


Plate 7-1 Malibu Creek Watershed Hydrologic Soil Groups

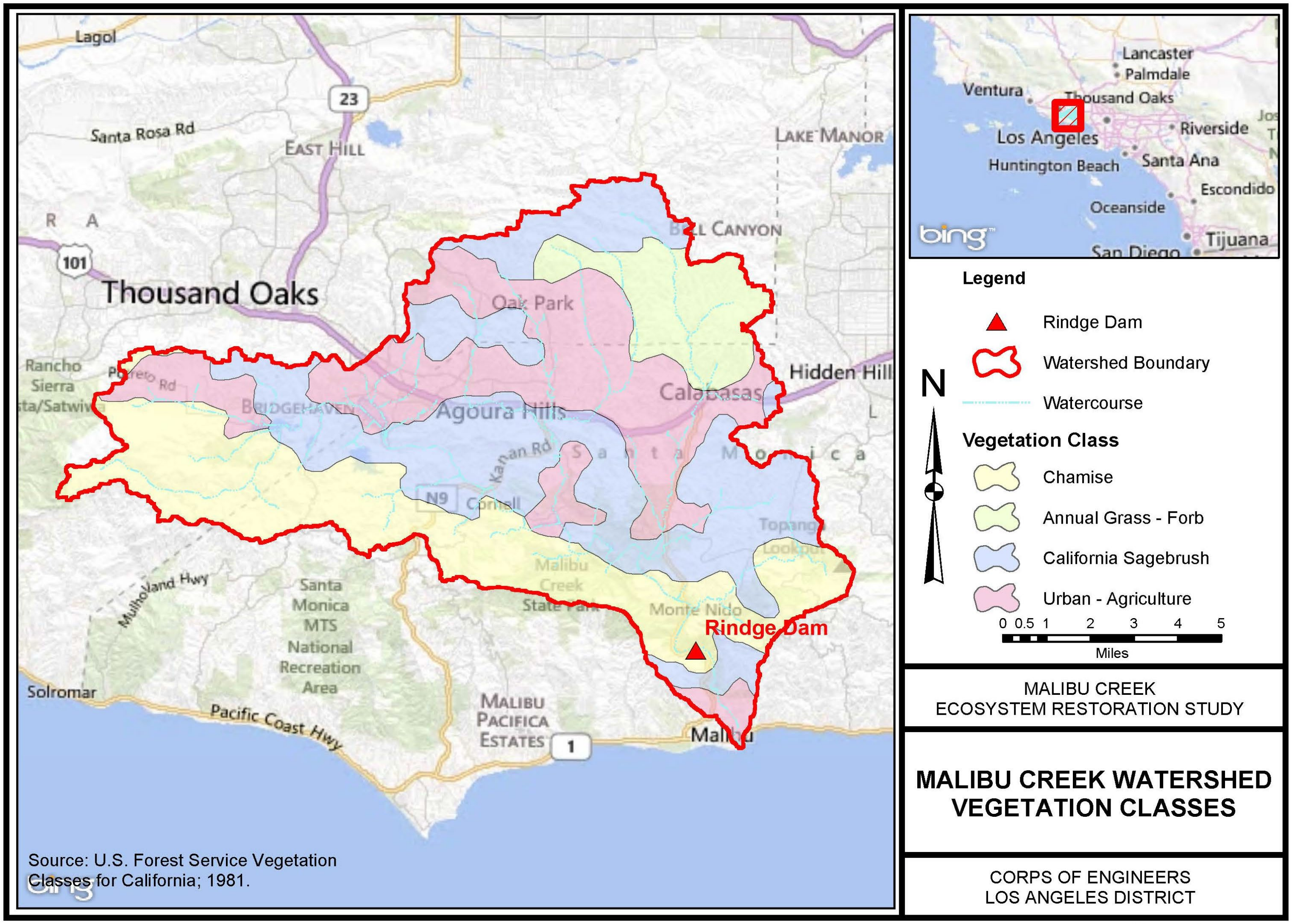


Plate 7-2 Malibu Creek Watershed Vegetation Classes

8.0 CLIMATE CHANGE

The U.S. Army Corps of Engineers (USACE) considers the effects of climate change in all civil works projects involving coastal waterways and inland hydrology. While sea level rise is quantitatively considered along coastal waterways per Engineer Regulation (ER) 1100-2-8162 (Ref. Appendix O – Coastal Engineering), the effects of climate change on inland waterways are considered through a qualitative analysis of regional climate and hydrology as mandated in Engineering and Construction Bulletin (ECB) 2016-25. The Bulletin aims to “reduce vulnerabilities and enhance the resilience” of all Civil Works projects (ECB 2016-25). It requires a review of existing and projected changes to regional climate and a qualitative assessment of how any changes in watershed hydrology could impact project purpose and relevant business lines. This section represents review and analysis of climate and climate change within the Malibu Creek watershed and greater southern California region in fulfillment of ECB 2016-25. It also details how the results of such an analysis have been incorporated in related project modeling.

8.1 Current Climate and Climate Change

The climate of the Malibu Creek watershed is typical of small coastal basins in southern California. The Mediterranean climate described in Section 7.0 means that watershed hydrology is dominated by wet season (winter) precipitation as well as the terrain of the Santa Monica Mountains. Local climate records and gage data inform the past climate trends for the watershed, but future changes are considered at a broader scale. In order to avoid false precision when downscaling global climate models, USACE considers the 2-digit and 4-digit hydrologic unit code (HUC) boundaries, at their respective regional and subregional scales, to be appropriate for interpreting climate change (USACE, 2015). The Malibu Creek watershed is part of HUC 18, California Region, and HUC 1807, Southern California Coastal (SCC) Subregion.

8.1.1 *Temperature*

According to USACE (2015), there has been an increasing trend in both annual average and extreme temperatures throughout the California Region over the past century. Studies of the American Southwest by Kunkel (2013) and Hoerling (2013) both reported significant temperature increases at the 95% confidence interval. Kunkel used data recorded from 1895 to 2011 and found an average increase of 0.17 ºF per decade (Kunkel, et al., 2013). Hoerling used data recorded from 1901 to 2010 as well as paleoclimate data and reported an increase in average annual daily temperature of 0.9 to 4.5 ºF (Hoerling, et al., 2013). In a study of California in 2008, Bonfils found an average annual increase of 0.65 to 1.66 ºF using a record from 1950 to 1999 which was found to be significant through least squares regression (Bonfils, et al., 2008). The same studies by Kunkel and Hoerling also reported a significant increase in the occurrence of heatwaves (Hoerling, et al., 2013; Kunkel, et al., 2013).

There is strong consensus that the climate record for the California Region shows a significant warming trend over the last century. Climate modeling efforts show this trend continuing with a higher rate of increase throughout the 21st Century despite variability in model scales and emissions scenarios. Model projections from the third National Climate Assessment (NCA) indicate an increase in annual average temperature range from up to 3.5 °F for a lower-emissions scenario to up 8.5 °F for a higher-emissions scenario (Garfin, et al., 2014). An earlier study by Cayan (2008) modeled the same scenarios specifically for the California Region which predicted a similar range of increase between 2.7 and 8.1 ºF by the end of the century (Cayan, Maurer, Dettinger, Tyree, & Hayhoe, 2008).

8.1.2 *Precipitation*

The USACE Civil Works Technical Report for Water Resources Region 18 identified no consistent annual precipitation trend for the California region as a whole, as changes in annual precipitation totals are spatially variable (USACE, 2015). However, multiple authors evaluating precipitation trends on a national and regional scale have reported no change or decreasing precipitation trends in the Southern California Coastal (SCC) region.

Using precipitation records from 1901 to 2010 for the western U.S., Hoerling et al. reported a statistically significant decrease in precipitation (95% C.I.) of approximately 20% for the SCC region between 1901 and 2010 (Hoerling, et al., 2013). In comparison, Kunkel use of records from 1895 to 2011 for the American southwest revealed no significant trends historically, annually, seasonally, or with precipitation extremes or event frequency. A look at the last millennium through tree ring data from 1000 to 2005 also found no significant trends in precipitation (Cook, Smerdon, Seager, & Cook, 2014).

Future projections of precipitation trends for the SCC region vary spatially and temporally. Hagemann et al. projects a precipitation decrease of 20 mm annually in southern California by a 2071 to 2100 planning horizon compared to a 1971 to 2000 baseline (Hagemann, et al., 2013). Liu et al. projects precipitation in southern California to increase in fall and winter and decrease in spring and summer for period from 2041 to 2070 relative to the same baseline has Hagemann (Liu, Goodrick, & Stanturf, 2013). Gutzler and Robbins, meanwhile, predict a slightly decreasing or no change trend in precipitation southern California for 2076-2100, relative to 1976-2000 (Gutzler & Robbins, 2010). A study of the southwestern U.S. by Cayan ran multiple future horizon simulations from 2021 to 2099 which showed precipitation totals in southern California to be 80 to 100% of their historical averages with only medium-low confidence (Cayan, et al., 2013). While there is wide variability in both historical and projected future precipitation trends in southern California, literature agrees that the area is trending towards more frequent extreme storm events (USACE, 2015).

8.2 Climate Hydrology Assessment

8.2.1 *Streamflow*

The USACE Climate Hydrology Assessment Tool was used to analyze the observed streamflow trend at a single USGS stream gage along Malibu Creek. USGS gage 11105500 Malibu Creek at Crater Camp near Calabasas, California is located approximately 4.5 miles upstream of Malibu Lagoon. Mean daily streamflow records exist from 1931 to 1979. There are no other USGS gages on Malibu Creek. Hydrologic data was developed from LA County gage F130-R, however the records of this gage are not available in the USACE climate hydrology assessment tool. **Plate 8-1** shows the trends in annual peak instantaneous streamflow from 1931 to 1979. The time series exhibits an increasing trend which is not statistically significant as indicated by the high p-value ($p>0.05$).

This trend agrees with a study by Regonda that found generally increased streamflow trends with no statistical significance in the western U.S. (Regonda, Rajagopalan, Clark, & Pitlick, 2005). Subsequent studies of the California Region also found no significant trends in streamflow, all using similar periods of record falling between 1950 and 2010 (Karla, Piechota, Davies, & Tootle, 2008; Sangarika, Karla, & Ahmad, 2014; Xu, Liu, Rafique, & Wang, 2013).

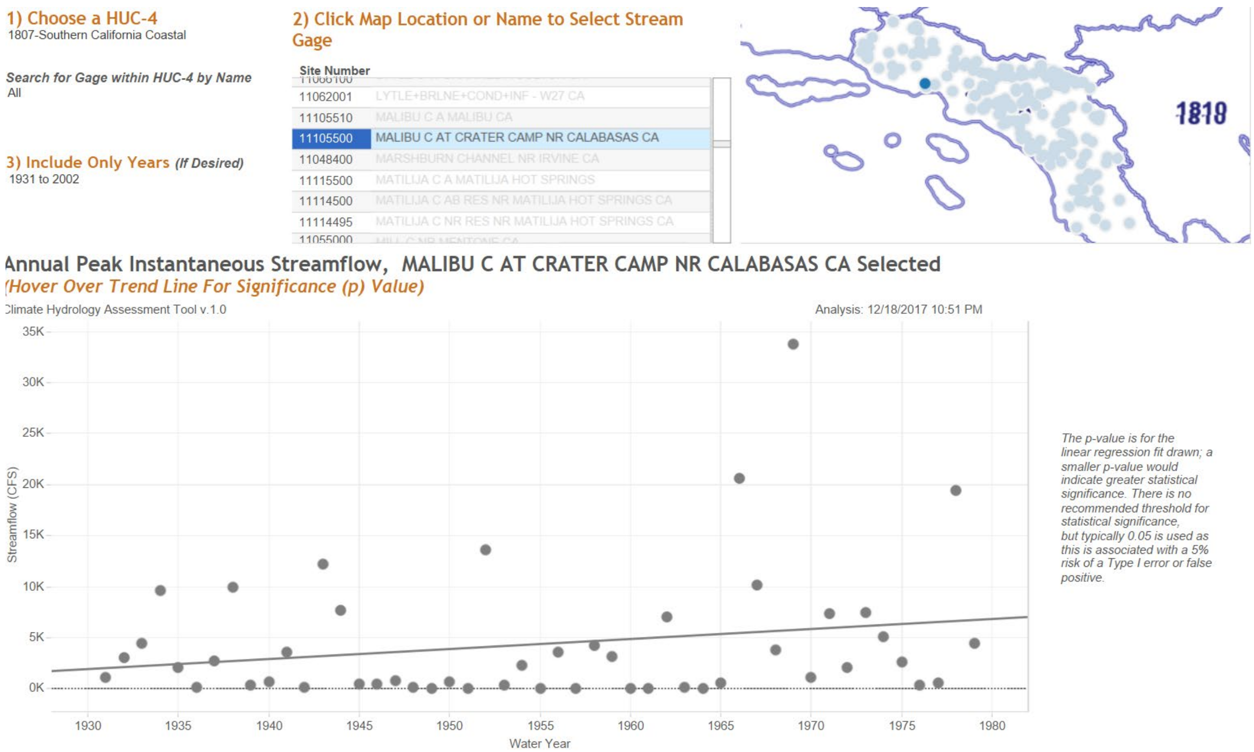


Plate 8-1 Annual Peak Instantaneous Streamflow, Malibu Creek at Crater Camp near Calabasas, California. Trendline Equation Q = 98.1476 * (Water Year) + - 187496, p = 0.136677

8.2.2 *Stationarity*

In order to determine if the USGS gage record is reflective of current watershed hydrology, the Nonstationarity detection tool was used. Statistical stationarity indicates that time series properties such as variance and mean remain constant overtime. In the context of climate, a non-stationarity indicates a break in the historical time series that can be discovered through a variety of statistical tests. The non-stationarity detection tool performs tests on streamflow records to determine potential deviation from historical climate norms.

The non-stationarity detection tool did not detect any breaks in stationarity over the period of record for the watershed (**Plate 8-2**). However, some regional climate studies show a statistically significant decrease in mean annual precipitation for the southern California region. As such, stationarity of two other USGS gages was analyzed. The gages selected are both located on southerly flowing streams, Santa Paula Creek and Sespe Creek, within the Topatopa Mountains to the north of the Malibu Creek watershed. The Santa Paula Creek near Santa Paula Gage showed no breaks in stationarity over the period of record of 1927 to 2014 (**Plate 8-3**). The Sespe Creek near Fillmore gage did, however, identify one break in stationarity in 1969 based on gage records from 1933 to 2014 (**Plate 8-4**). Looking at the streamflow record all three gages, 1969 stands out as a major peak flow year. The trend analysis for this gage reveals no significant trends in streamflow before (**Plate 8-5**) or after this event (**Plate 8-6**). It is noted that the gage record in **Plate 8-5** is missing some years in the period of record and that the other two gages in the area did not note stationarity irregularities during this time period. Based on the non-stationarity tool and comparison of similar regional streams, there is no evidence to suggest that hydrology in the Malibu Creek watershed is currently experiencing nonstationarity from historical trends. Identification of historical trends may therefore be reasonably assessed using the period of record of the gage on Malibu Creek.

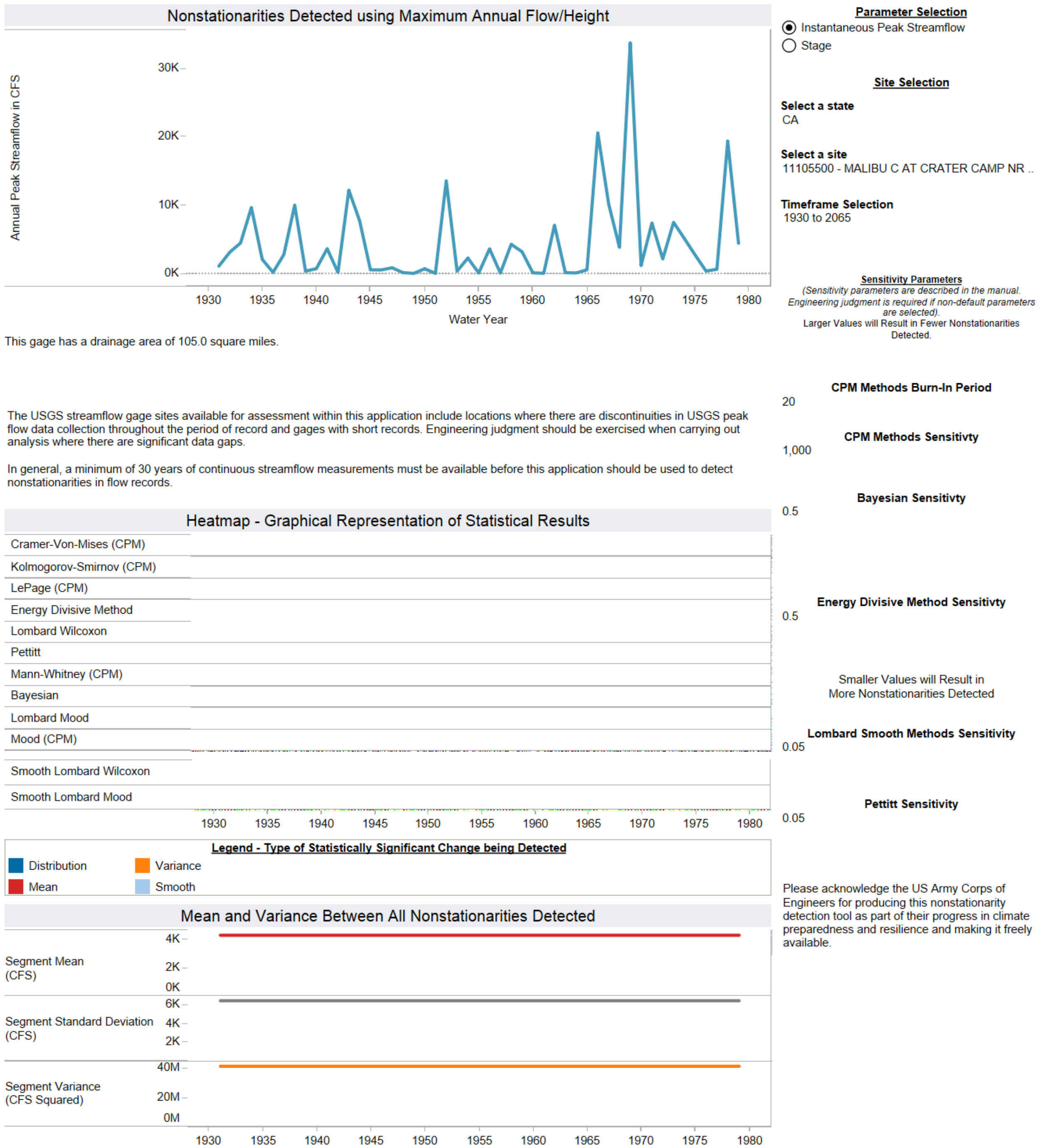


Plate 8-2 Nonstationarity Analysis of Maximum Annual Flow, Malibu Creek at Crater Camp near Calabasas, California

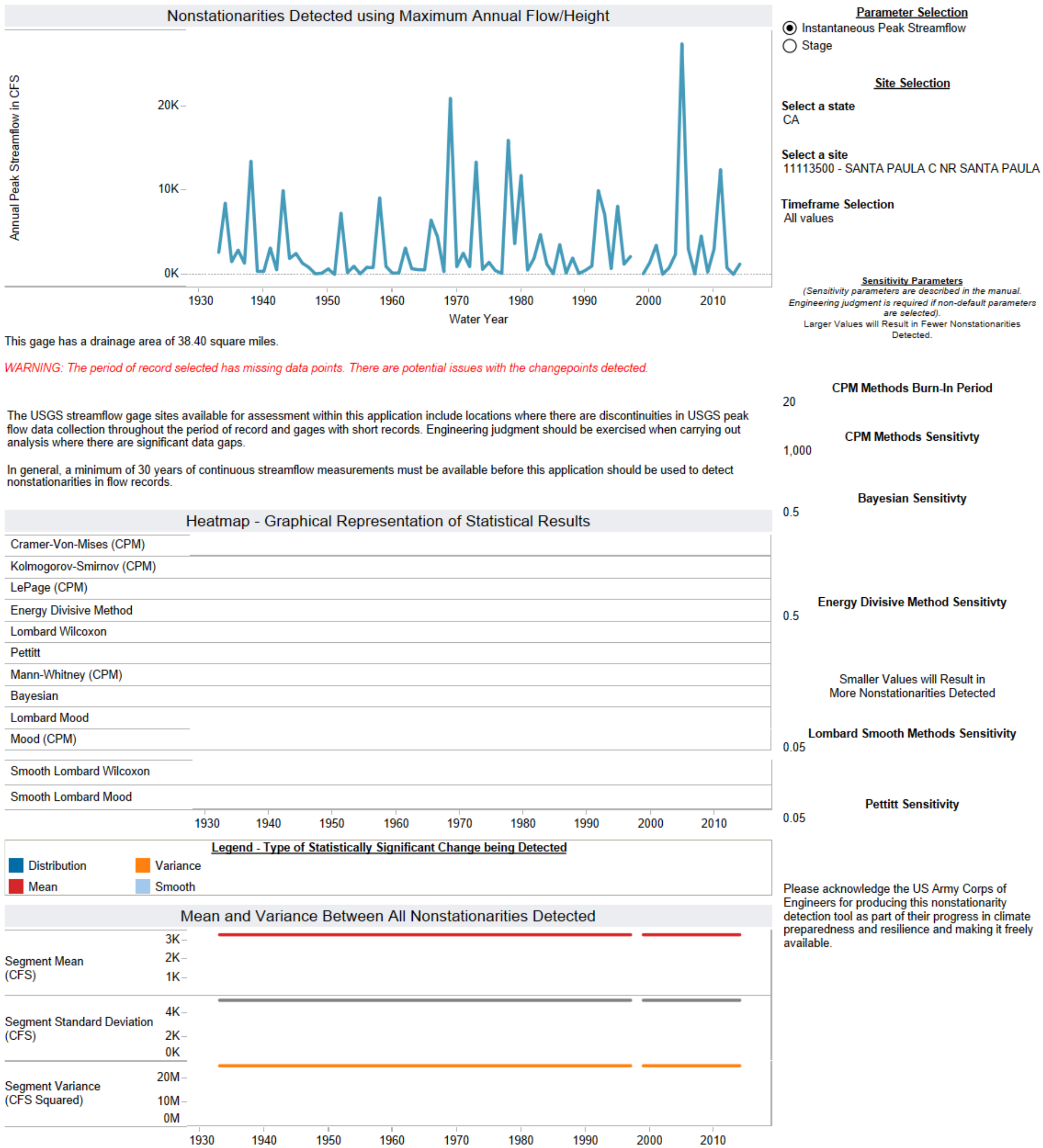
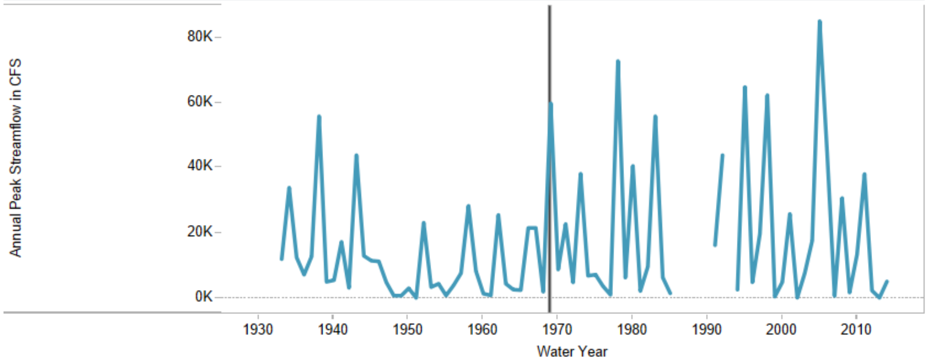


Plate 8-3 Nonstationarity Analysis of Maximum Annual Flow, Santa Paula Creek near Santa Paula, California

Nonstationarities Detected using Maximum Annual Flow/Height



Parameter Selection

◉ Instantaneous Peak Streamflow

○ Stage

Site Selection

Select a state
CA

Select a site
11113000 - SESPE C NR FILLMORE

Timeframe Selection
1930 to 2065

Sensitivity Parameters
(Sensitivity parameters are described in the manual. Engineering judgment is required if non-default parameters are selected).
Larger Values will Result in Fewer Nonstationarities Detected.

This gage has a drainage area of 252.0 square miles.

WARNING: The period of record selected has missing data points. There are potential issues with the changepoints detected.

CPM Methods Burn-In Period
20

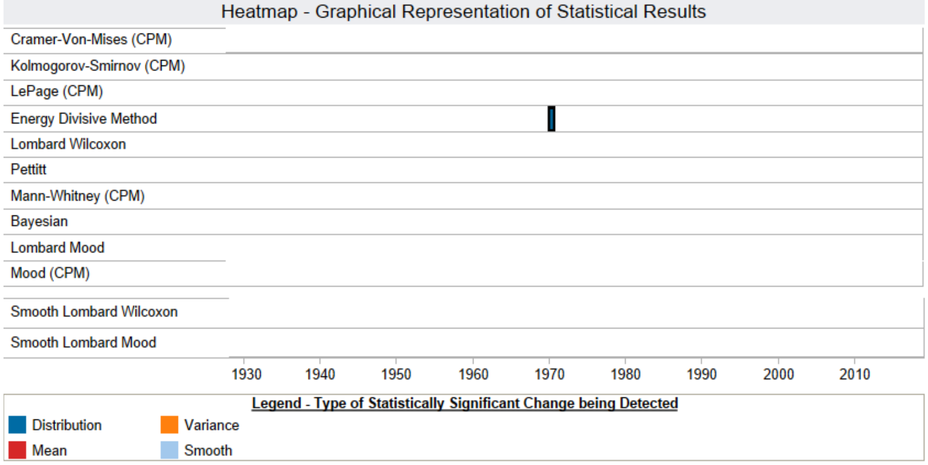
CPM Methods Sensitivty
1,000

The USGS streamflow gage sites available for assessment within this application include locations where there are discontinuities in USGS peak flow data collection throughout the period of record and gages with short records. Engineering judgment should be exercised when carrying out analysis where there are significant data gaps.

In general, a minimum of 30 years of continuous streamflow measurements must be available before this application should be used to detect nonstationarities in flow records.

Bayesian Sensitivty
0.5

Heatmap - Graphical Representation of Statistical Results



Energy Divisive Method Sensitivty
0.5

Smaller Values will Result in More Nonstationarities Detected

Lombard Smooth Methods Sensitivity
0.05

Pettitt Sensitivity
0.05

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Mean and Variance Between All Nonstationarities Detected

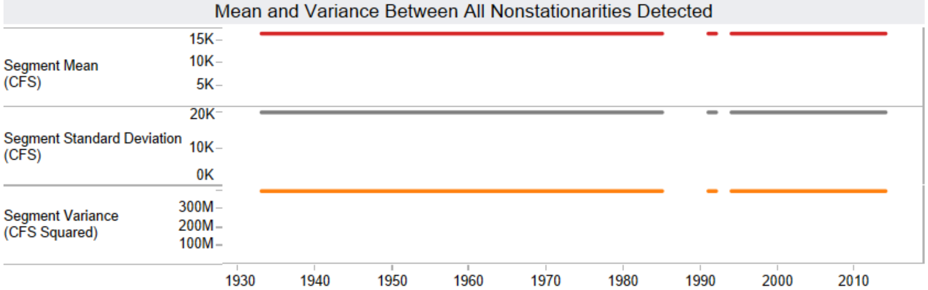
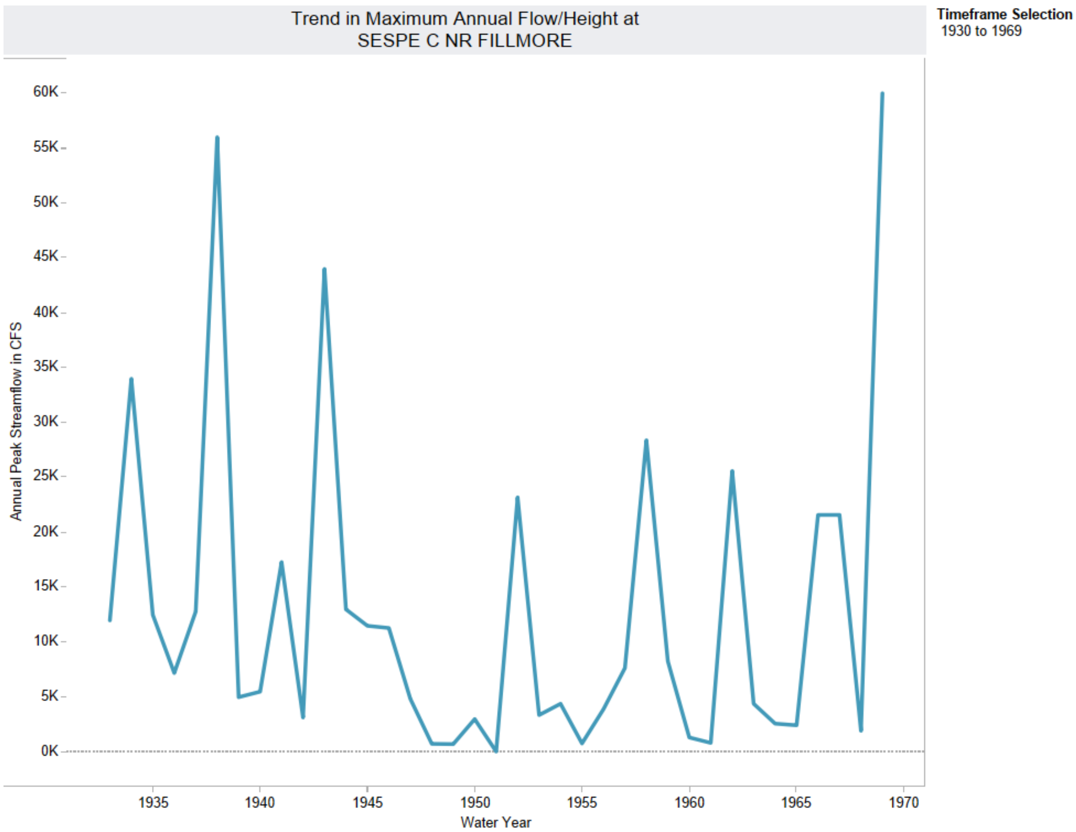


Plate 8-4 Nonstationarity Analysis of Maximum Annual Flow, Sespe Creek near Fillmore, California



Monotonic Trend Analysis

Is there a statistically significant trend?
No, using the Mann-Kendall Test at the .05 level of significance. The exact p-value for this test was 0.186.
No, using the Spearman Rank Order Test at the .05 level of significance. The exact p-value for this test was 0.229.

What type of trend was detected?
Using parametric statistical methods, **no trend** was detected.
Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Plate 8-5 Trend Analysis from 1931 to 1969 for Sespe Creek near Fillmore, California

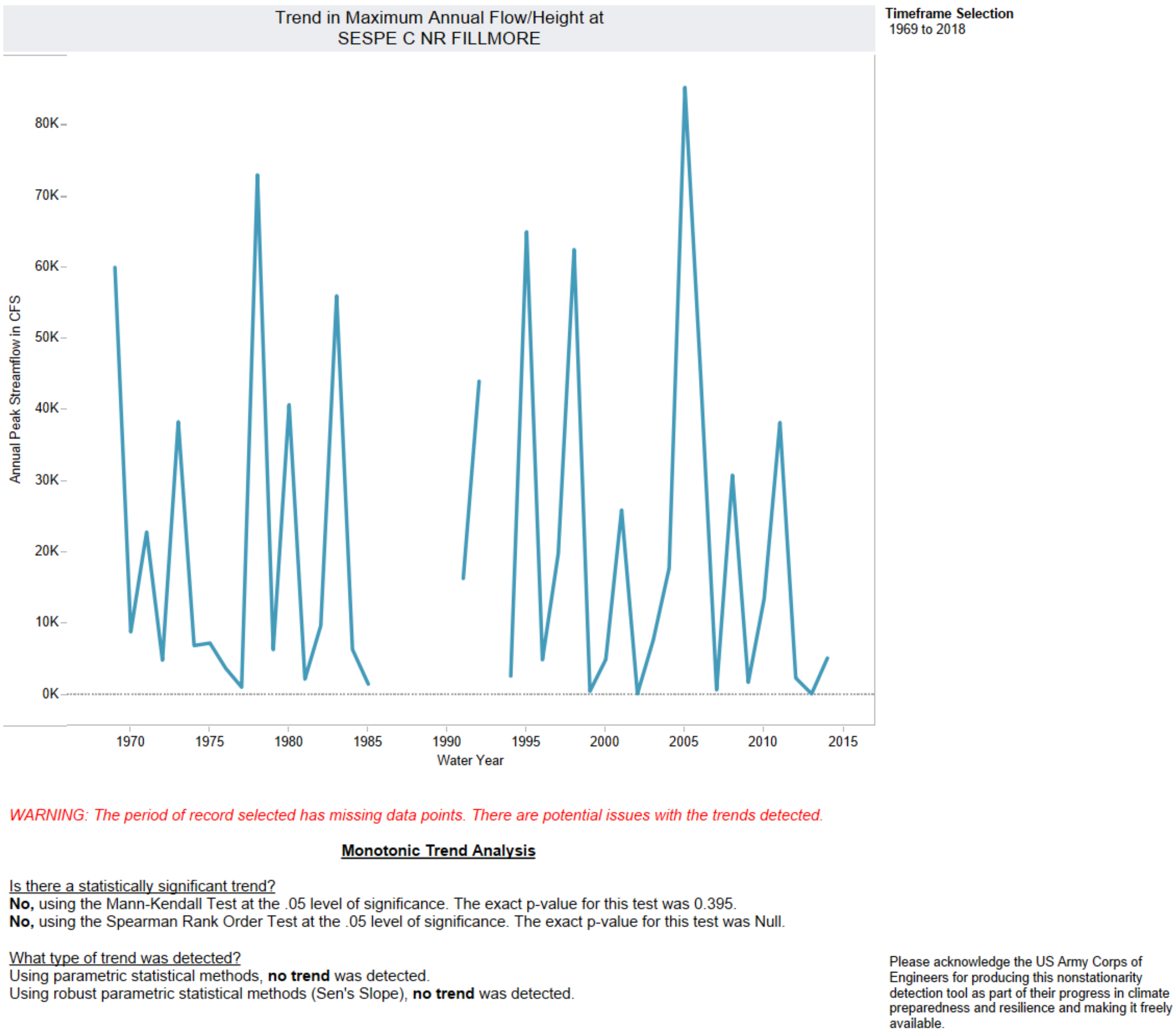


Plate 8-6 Trend Analysis from 1969 to 2014 for Sespe Creek near Fillmore, California

8.2.3 *Regional Trends*

The Climate Hydrology Assessment Tool also includes forecasting features which incorporate multiple climate models to search for significant future runoff patterns. Because the presence of stationarity is nearly ubiquitous in the region and because no significant trends were found using the ECB tools, the entire period of record was used to look at past and future trends in annual maximum monthly streamflow (**Plate 8-7**) and mean annual maximum monthly streamflow (**Plate 8-8**) in the SCC subregion. The analysis tool shows a clear increase in the forecasted range of projected annual maximum monthly streamflows forecasts as compared to the modeled historical record from 1950 to 2000 (**Plate 8-7**). This may be due to model uncertainty, increase in extreme hydrologic events, or both.

Isolation of the mean annual monthly maximum flows provides a better opportunity to identify significant trends. The tool used to create **Plate 8-8** allows the user to discriminate between earlier and later periods of record which would be useful to identify streamflow trends before and after some discrete event such as a nonstationarity. **Plate 8-8** instead does not divide the period of record but instead looks for a significant trend in the historical record as modeled from 1950 and forecasted up to 2099. The identified trend is significant with a p-value < 0.0001. The trendline shows an increase in annual maximum monthly flows by nearly 30 cfs per year for the entire SCC region (HUC 1807). If earlier and later years are segregated before and after 1969, the subsequent forecast trendline remains significant (p = 0.0004759) showing an increasing trend with similar rate of change (30.1339 cfs per year).

The increase in annual maximum monthly peak flows suggests future hydrology with higher peaks events and uncertainty with regard to total annual runoff (ref. Section 8.1.2). To determine potential impacts of climate change trends on project business lines, USACE developed the Watershed Vulnerability Assessment Tool as part of the ECB analysis guidance.

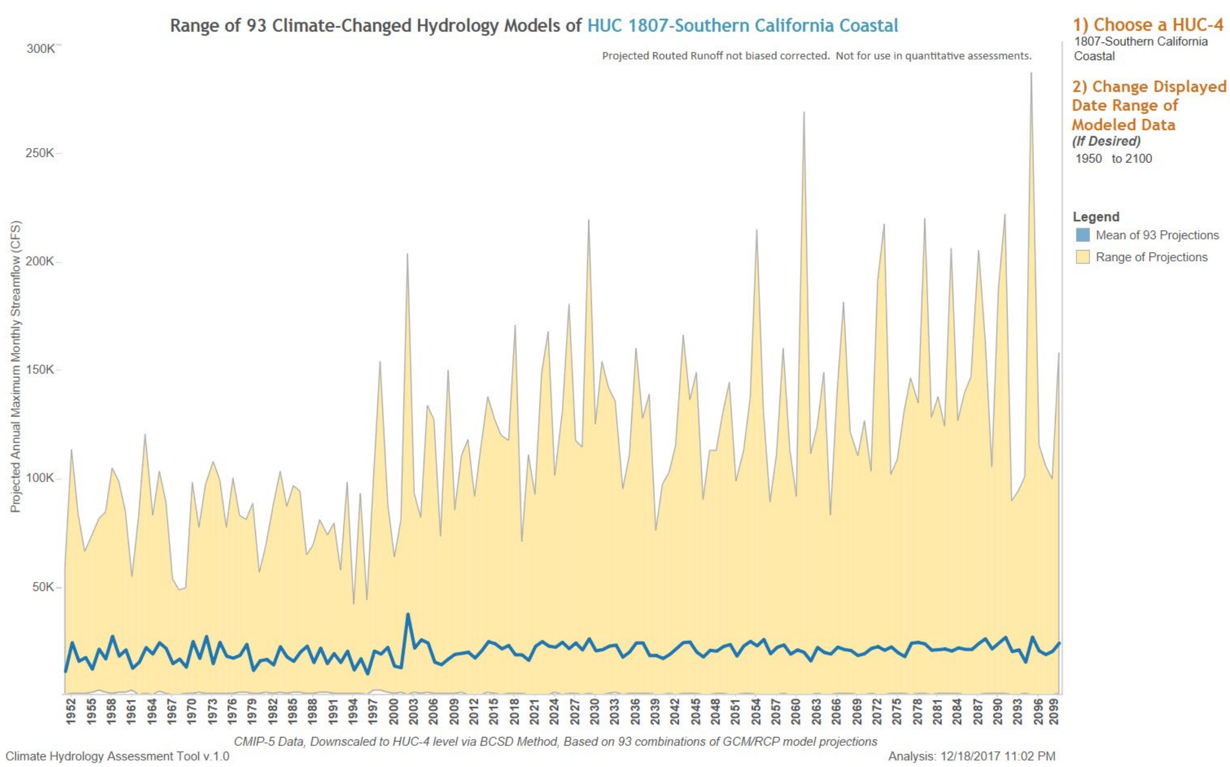


Plate 8-7 Range in the Projected Annual Maximum Monthly Flows, HUC 1807 Southern California Coastal

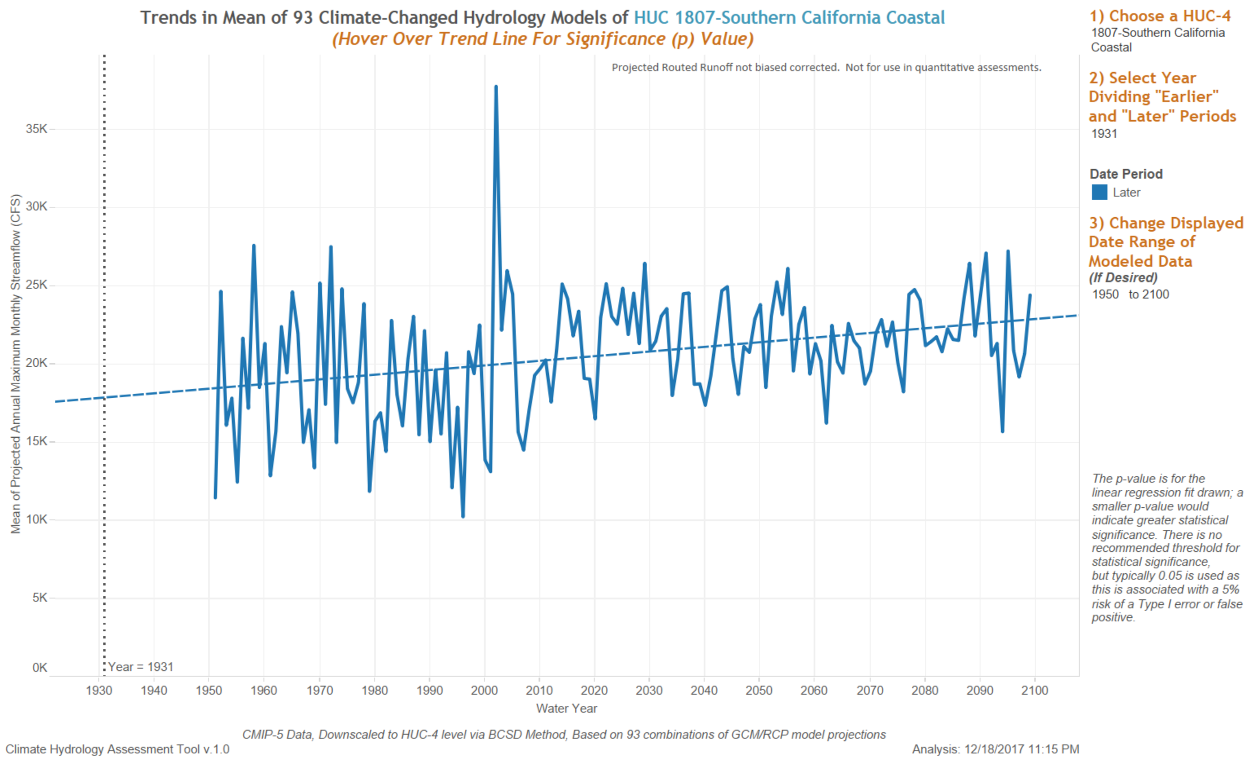


Plate 8-8 Mean Projected Annual Maximum Monthly Streamflow, HUC 1807 Southern California Coastal. Trendline Equation Q = 29.7334 * (Water Year) + -39549.8, p < 0.0001

8.3 Watershed Vulnerability

The Watershed Vulnerability Assessment Tool was used to examine the vulnerability of the project area to its ecosystem restoration objective as well as future flood risk which is considered in the hydraulic modeling of the alternatives. The tool looks at both wet and dry future climate scenarios in 2050 and 2085 to conservatively identify all the ways in which a project may be impacted by climate change in the near term and long term.

For the SCC region (HUC 1807), the tool shows that the subregion is projected to be highly vulnerable to climate change as it pertains to ecosystem restoration. **Plate 8-9** shows the breakout of indicators for four future climate scenarios. The two dominating indicators that could affect the viability of ecosystem restoration in this area are loss of freshwater riparian habitat, and short term (monthly) changes in regional hydrology. This is true for all four climate scenarios, however the dry scenarios both show less vulnerability than the wet ones.

Within the context of aquatic ecosystem restoration, some indicators may be of greater concern than others. The recommended plan proposes dam removal which will provide a benefit to aquatic resources even under a dry future scenario by removing an impediment to upstream passage. Since most of the project is located within a canyon, there is no investment in inland wetland restoration which would be vulnerable if it were a major project feature. Variability in short term hydrology may increase (or decrease) peak flows but the watershed lies within a mountainous region with a flashy hydrologic regime and rarely receives snowfall leaving it unaffected by changes in snowmelt runoff timing like further inland watersheds within the SCC region (ref. Section 9.1). Based on the qualitative assessment the tool provides, ecosystem restoration projects within the SCC subregion are vulnerable to climate change, but the recommended plan measures will provide benefit to the watershed regardless of future climate scenario and have been developed to be resilient to future changes in the watershed.

In addition to ecosystem restoration, the tool also shows that the project region is vulnerable to increased future flood risk. The two dominant indicators of all four climate scenarios in **Plate 8-10** are urban areas within the 500-year floodplain (dominant in dry scenarios), and flood magnification (dominant in wet scenarios). Similar to the ecosystem restoration business line, vulnerability is slightly reduced under the future dry scenarios. The vulnerability to increased flood risk within the SCC subregion lends itself to conservative modeling assumptions especially when considering sea level rise at the downstream end of the project area.

Table 8-1 lists and describes the potential climate change hazards to project elements and the residual risk associated with those hazards. The qualitative likelihood discussed refers to probability of the harm being realized from a hazard and not the likelihood of the trigger or hazard being realized. The key climate change variables and the resulting increase in precipitation could create larger volumes that occur more frequently. This in turn could cause hard to the recommended plan features and measures such as increasing streambed elevation, loss of habitat, and flooding downstream. While these consequences have potential to impact the project, their likelihood is low. While there is a statistically significant forecast for increased annual maximum flows there was disagreement with regard to mean annual streamflow, meaning peak flows may increase and a flashier trend can be expected, but total stream volume is not expected to change or may actually decrease. This is reflected in the indicators 175C_Annual_Covariance (**Plate 8-9**) and 221C_Monthly_Covariance (**Plate 8-10**) which are indicators of short term (month to month) and long term (year to year) variability; They use the standard deviation of mean runoff to describe the flashiness of a system. This indicates that the system will become more variable, but is unlikely to change in overall runoff volume. Another indicator that the system is becoming flashier, and that large magnitude events will occur more frequently are the 568C/L_Flood_Magnification (**Plates 8-9 and 8-10**) indicators which describe how often runoff mean values are exceeded. Similar to the covariance indicators, these describe changes to the variability of a system but do not indicate the mean volumes of that system changing.

Indicators of increased system variability could have positive or negative effects to freshwater habitat depending on the time of year and increase in variability is observed. For example, increased flows during fish migration may be beneficial but may lead to increased erosion and sediment movement. While sediment transport will be affected by increased frequency or magnitude of flood flows, the impact to annual sediment budget is expected to be negligible. This is because mean annual sediment yield is a function of the channel forming discharge (lower flows) as opposed to large storm events. Short term consequences may include additional sediment pulses coincident with large flood events but this sediment is expected to continue to move through and be flushed by the system through regular channel forming discharge. Likelihood of impacts from changes to sediment transport are therefore expected to be low. See **Table 8-1** for additional details on short term and long term potential climate change hazards.

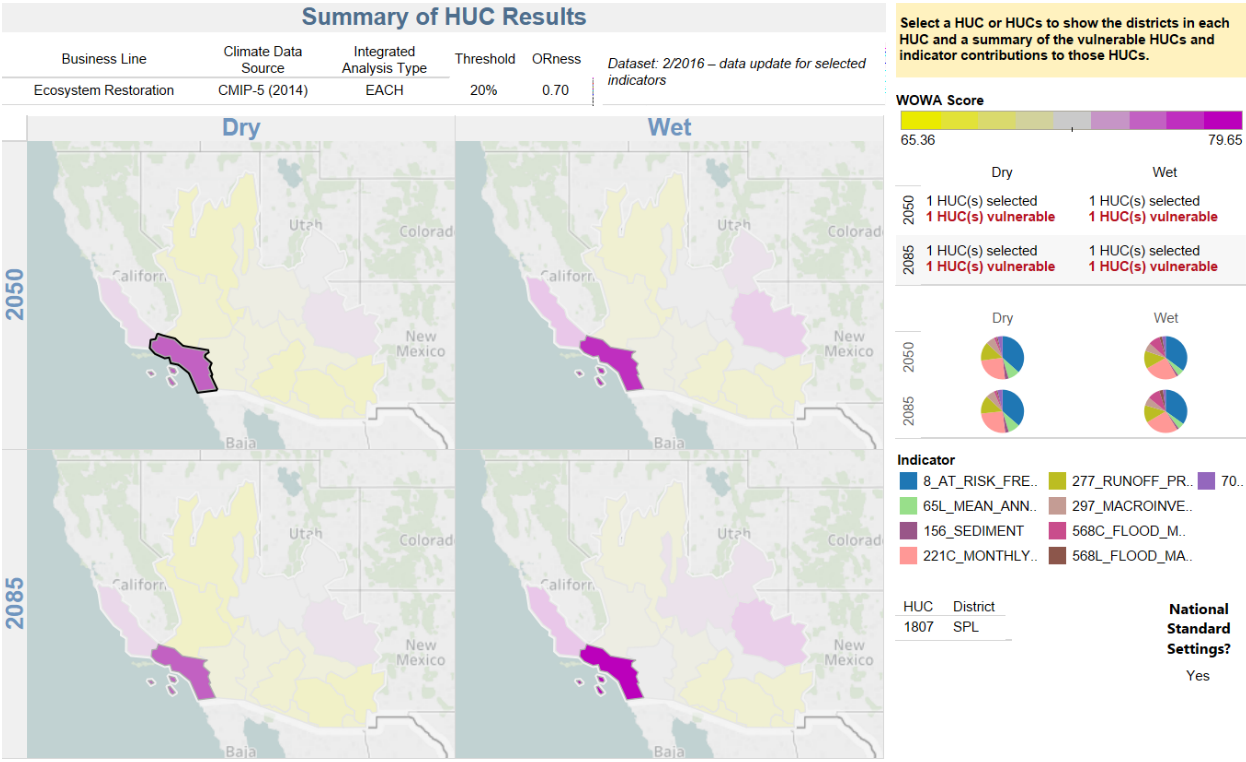


Plate 8-9 Projected Vulnerability for Malibu Creek (HUC 1807) with Respect to Ecosystem Restoration

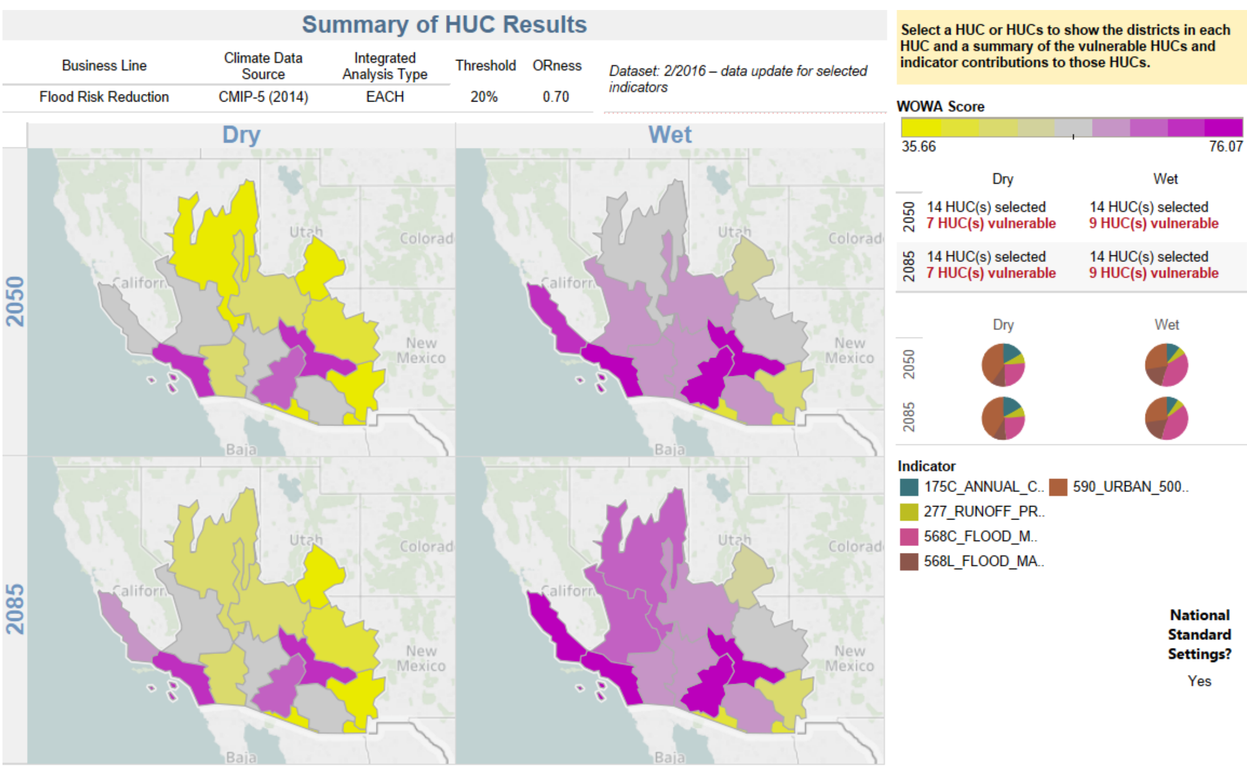


Plate 8-10 Projected Vulnerability for Malibu Creek (HUC 1807) with respect to Future Flood Risk

Table 8-1 Inland Climate Change Residual Risk Matrix

Feature or Measure	Trigger	Hazard	Harm	Likelihood
Dam Removal (During Construction)	Increased runoff from larger storms	Large flood volumes events could occur more frequently and with higher magnitudes	Increased magnitude in precipitation events could disrupt construction efforts	Unlikely
Dam Removal (After Construction)			Increased streambed elevation resulting from additional erosion and sediment transport	Unlikely
Aquatic Habitat Barrier Modification (During Construction)	Increased runoff from larger storms	Large flood volumes events could occur more frequently and with higher magnitudes	Larger flows than anticipated could lead to overtopping bridges and channel embankments	Unlikely
Aquatic Habitat Barrier Modification (After Construction)				Somewhat Likely
Sediment Removal (During Construction)	Increased runoff from larger storms	Large flood volumes events could occur more frequently and with higher magnitudes	An unexpectedly large flood event could wash impounded sediment downstream and temporarily increase the flood risk	Unlikely
Sediment Removal (After Construction)			Increased streambed elevation resulting from additional erosion and sediment transport	Unlikely

Feature or Measure	Trigger	Hazard	Harm	Likelihood
Malibu Lagoon	Increased urbanization	Increased impervious surfaces may increase runoff and contaminants	Lagoon degradation from additional runoff, and/or contaminants	Somewhat Likely
	Increased runoff from larger storms	Large flood volumes events could occur more frequently and with higher magnitudes	Lagoon degradation from additional sediment load	Unlikely
Aquatic Habitat	Increased runoff from larger storms	Large flood volumes events could occur more frequently and with higher magnitudes	Habitat benefits and/or detriments depending on flow variation and/or sediment deposition patterns	Somewhat Likely
		Increase in short-term sediment load		Somewhat Likely

8.4 Modeling and Analysis

Climate change and consideration to project resilience has been incorporated into the hydraulic modeling for the project. Appendix O, Section 2.2.2 outlines the expected sea level change near Malibu Lagoon and forms the basis for the downstream boundary condition in hydraulic modeling of Malibu Creek. Since the broader coastal region is susceptible to increased future flood risk and sea level rise, the hydraulic and sediment transport modeling incorporated a very conservative downstream boundary condition that would capture multiple facets of climate change.

The mean higher-high water (MHHW) elevation was selected as a downstream boundary condition to capture sea level rise and the variability and vulnerability associated with climate change on the ecosystem restoration objective and necessary consideration to flood risk. Initially, a sensitivity analysis was performed for the downstream boundary condition as part of the sediment transport modeling certification. It revealed that a temporally variable boundary condition provided the highest accuracy, however this level of detail was not available for period of record sediment transport modeling. With the effects of sea level rise limited to the vicinity of the lagoon (ref. Appendix O, Figure 2.2-3) the most conservative future sea elevation could be used without significant upstream propogation or influence. The MHHW elevation was projected to the end of the economic period of analysis using the “high” rate of sea level rise as required by EM 1100-2-8162 (USACE, 2013) as well as a worst-case sediment deposition scenario with which to determine flood risk in the context of climate change.

9.0 PRECIPTATION AND RUNOFF

9.1 General Winter Storms

Most precipitation in southern California coastal drainages occurs during the cool season, primarily from November through early April, as mid-latitude cyclones from the north Pacific Ocean occasionally move across the West Coast of the United States to bring precipitation to southern California. Most of these storms are of the general winter type, with hours of light to moderate steady precipitation, but with occasionally heavy showers or thunderstorms embedded.

These storms frequently produce significant snow above 6,000 ft, with snow falling below 2,000 ft on rare occasions. Snowmelt can at times contribute to runoff in Malibu Creek, but the amount of high-elevation area that receives snowfall is not sufficient to generate large peak flows.

9.2 Local Thunderstorms

Local thunderstorms can occur in southern California at any time of the year, but are least common and least intense during the late spring. These types of storms occur fairly frequently in the coastal areas during or just after general winter storms. They can also occur between early July and early October, when desert thunderstorms occasionally drift westward across the mountains into coastal areas, sometimes enhanced by moisture drifting northward from tropical storms off the west coast of Mexico. Local thunderstorms can also occur throughout the fall, as upper-level low-pressure centers sometimes trigger left over summer moisture. These local thunderstorms can at times result in very heavy rain for short periods of time over small areas, causing very rapid runoff from small drainages. Some of the smaller tributaries within the Malibu Creek watershed can be especially vulnerable to this type of storm.

9.3 General Summer Storms

General summer storms in southern California are quite rare; but on occasion a tropical storm from off the west coast of Mexico can drift far enough northward to bring rain, occasionally heavy, to southern California, sometimes with very heavy thunderstorms embedded. The season in which these storms are the most likely to significantly affect southern California is mid-August through early October, although there have been some effects in southern California from tropical storms as early as late June and as late as early November.

On rare occasions, southern California has received light rain from non-tropical general summer storms, some of which have exhibited characteristics of general winter storms.

Most of the major flood events in the history of southern California have been the result of general winter storms, but several local thunderstorms have produced significant flows on various Los Angeles County streams.

9.4 Runoff

In the mountains, runoff concentrates quickly from the steep slopes; hydrographs show that the stream flow increases rapidly in response to effective rainfall. High rainfall rates, in combination with the effects of shallow surface soils, impervious bedrock, fan-shaped stream systems, steep gradients, and occasional denudation of the area by fire, result in intense debris-laden floods.

The flow in Malibu Creek and its tributaries can vary rapidly. Portions of the upper watershed are highly urbanized. Runoff from urban watersheds is characterized by high flood peaks of short duration that result from high-intensity rainfall on watersheds that have a high percentage of impervious cover. Flood hydrographs from single storm events are typically of less than 12 hours duration and are almost always less than 48 hours duration. The channel of Malibu Creek has not been channelized but short reaches along the tributaries have been improved. The project area of Malibu Creek is undeveloped through the canyon reaches, but the creek is narrow and steep. Flows originating in the upper watershed flow through this portion of the project area at high velocities. Where Malibu Creek emerges from the canyon (near RS 60+56.2), the bed slope decreases and the overbank area increases. Flow velocities decrease and the potential for sediment deposition increases.

10.0 UPLAND SEDIMENTATION AND EROSION

Much of the Malibu Creek watershed's soils are considered highly erodible. Increased dry weather flows, unstable stream banks, fires, construction, and poorly-graded hillsides all contribute to the watershed's existing sedimentation and erosion problems. These problems include increased turbidity, some bank erosion just upstream of PCH and deposition within the lagoon area. Brush clearing practices and roadside maintenance activities where dirt and debris are left on the side of the road and/or up- slope of creeks also increase sediment loads to receiving waters. During seasonal high flow conditions (primarily during the rainy season), the impacts of sedimentation and erosion are especially pronounced.

11.0 WATER QUALITY AND SUPPLY

Numerous and extensive studies have been performed on water quality within the Malibu Creek watershed. These include quality of surface water, groundwater, reclaimed or treated water, and imported water and the impacts of one upon the other. The effects of freshwater from Malibu Creek on the Malibu Lagoon have also been examined. Opinions vary as to the quality of the various components. There are no additional water quality analyses or modeling included as part of this study. The data presented is a summary of the previous aforementioned studies.

11.1 Monitoring

The Los Angeles County Department of Public Works (LACDPW) monitors surface water quality at the Malibu Creek Monitoring Station (S02). The Malibu Creek monitoring station is located at the existing stream gage (Stream Gage No. F130-R; see **Plate 2-3**) near Malibu Canyon Road, south of Piuma Road. At this location, the tributary watershed to Malibu Creek is 104.9 mi². The entire Malibu Creek Watershed is 109.6 mi². Heal the Bay also monitors water quality at several locations within the watershed on a monthly basis. The Las Virgenes Municipal Water District monitors all releases from its facilities.

11.2 Reclaimed and Treated Water

The Tapia Water Reclamation Facility is located within the Malibu Creek watershed. The facility is jointly owned by the Las Virgenes Municipal Water District and Triunfo Sanitation District. The plant is located adjacent to Malibu Creek approximately 4.5 mi upstream from Malibu Lagoon. Reclaimed and Treated Water This facility treats municipal wastewater primarily from the cities and unincorporated areas of the upper watershed. Tapia has a processing capacity of 16 mgd (about 25 ft^3/s), but currently operates at 9 mgd (about 14 ft^3/s). The tertiary-treated wastewater generated from this facility is either recycled or discharged into the creek, depending on the time of year, demand and/or other circumstances.

11.3 Imported Water

Importation of water began in the late 1960s[2]. About 18,000 af of water is imported into the Malibu Creek watershed each year. The imported water is purchased from the Metropolitan Water District of Southern California. The water is brought into the watershed via a system of pipes and reaches the creek after it has been used. The main uses are domestic, landscape irrigation, and some agricultural irrigation. Ultimately, this imported water contributes to higher groundwater tables, increased creek flows, more frequent lagoon breaching events and greater volumes of polluted urban runoff entering storm drains and local water bodies.

11.4 Low Flow Conditions

Once seasonal, Malibu Creek flows are now predominantly perennial. The annual flows from 1931 through 2002 averaged 20,100 af (LA County stream gage F130-R; which includes storm runoff, local runoff, imported water, and permitted reclaimed water discharge. The average daily flow from 1931-2002 is 27.1 ft^3/s compared to the maximum daily flow of 24,200 ft^3/s and the minimum of 0 ft^3/s (the instantaneous peak flow was 33,800 ft^3/s for the same period of record -- data for water years 1931, 1980, 1990, and 1993 are not available). The maximum-recorded annual flow was 120,000 af in 1969. Runoff from home uses and irrigation enters Malibu Creek at a rate of 2,500 to 3,500 af annually. Seepage from septic tanks enters into the lagoon at an estimated rate of 500 af/yr. (CERES website).

Malibu Creek flows are augmented by discharges from the Tapia Water Reclamation Facility (TWRF) located about four miles upstream from the Pacific Ocean. Historically, zero flow conditions occurred in the lower reaches of Malibu Creek (mostly during the dry summer months), but none have occurred since the Tapia Water Reclamation Facility began discharging treated effluent to Malibu Creek in the late 1960's. Some of the zero flow conditions in the stream prior to releases from the Tapia Water Reclamation Facility may be attributable to water diversions (such as Rindge Dam) and the lack of mandatory daily environmental flow requirements.

The Las Virgenes Municipal Water District (LVMWD), which operates the Tapia Water Reclamation Facility, is attempting to market the reclaimed water. Some of this water has been exported in the past, but the majority is discharged to Malibu Creek. An increase in the amount of reclaimed water marketed and exported could substantially alter the present flow regime. The combined service area is approximately 100,000 acres with 90,000 residents in the Santa Monica Mountains. TWRF provides tertiary treatment of up to 16.1 million gallons per day of secondary treated water. In 1997 the Los Angeles Regional Water Quality Control Board (LARWQCB) proposed new discharge criteria that prohibited TWRF from discharging to Malibu Creek between May 1 and October 31. In April 1998 that schedule was modified to include the month of April as well.

12.0 HYDROLOGIC ANALYSIS

12.1 Discharge-Frequency Analysis

Runoff records were available for one stream gage in the Malibu Creek watershed. The LA County stream gage No. F130-R is located along the main stem of Malibu Creek just below the confluence with Cold Creek (**Plate 2-3**). The drainage area at this location is approx. 105 mi². The USGS operated and maintained the stream gage from 1931 to 1979, at which time the LACDPW took over; LACDPW has kept records for the gage from 1979 to present. There is also a gage along Cold Creek included in the USGS database. The period of record for this gage is only for 1961-1973. This data was not used in this analysis. Pertinent data for these gages are provided in **Table 12-1**.

Table 12-1 Pertinent Data for Stream Gages

Malibu Creek Stream Gage Pertinent Data Prior to 1979	
Gage Name:	Malibu Creek at Crater Camp near Calabasas, CA
USGS Gage No.:	11105500
Drainage Area:	105.0 mi²
Latitude:	34:04:40
Longitude:	118:42:03
Elevation:	430.51 ft NGVD
Period of Record:	1931-1979
Malibu Creek Stream Gage Pertinent Data Subsequent to 1979	
Gage Name:	Malibu Creek below Cold Creek, CA
Location:	0.2 mile downstream of Cold Creek, 6.0 miles southwest of Calabasas
Gage No.	F130-R (location shown Plate 3)
Drainage Area:	104.96 mi²
Regulation:	Lake Sherwood Dam, Lake Eleanor Dam, Malibu Lake Dam and Crags Dam. Other small recreational dams affect low summer flows*
Diversions:	None
Channel:	Coarse sand and gravel, lines with trees and brush, natural in section
Control:	Concrete stabilizer
Length of Record:	January 17, 1931 to Present

Cold Creek Stream Gage Pertinent Data	
Gage Name:	Cold Creek tributary near Malibu Beach, CA
USGS Gage No.:	11105200
Drainage Area:	0.3 mi²
Latitude:	34:05:55
Longitude:	118:40:18
Elevation:	NA
Period of Record:	1961-1973
* these dams are regulated for low flows but are not operated for flood risk management	

Other gages exist in nearby watersheds but are not considered useful to the current analysis. For determination of the peak flows along Malibu Creek within the project area, the gage record for stream gage F130-R was the only data used.

A discharge-frequency analysis was performed on the Malibu Creek stream gage using the Hydrologic Engineering Center's Flood Frequency Analysis (HEC-FFA) computer program. The HEC-FFA program is based on the "Guidelines for Determining Flood Flow Frequency, Bulletin 17B", by the Hydrology Subcommittee, revised September 1981. The techniques presented in Bulletin 17B have been adopted for all Federal planning involving water and related land resources. In addition, since the dams within the watershed are regulated for low flows and not operated for flood risk management, the gage was not altered by regulating projects from upstream and it is valid to apply Bulletin 17B analyses.

The period of record for the gage on Malibu Creek below Cold Creek is from 1931 to present. At the time of this analysis, peak flow data was only available through water year 2002. The highest peak flow recorded at the stream gage was 33,800 ft³/s on January 25, 1969. There are four water years with no information for peak flows. These are 1935, 1980, 1990, and 1993. In addition, the 1938 event is labeled as an estimate in the peak flow database. Looking at other stream gages in Los Angeles and Ventura Counties with information for the missing water years, the 1980 and 1993 were significant events and the 1935 and 1990 lesser so. The 1980 event ranks in the top 10 for most gages and the 1993 event ranks in the top 20. The annual precipitations totals, as shown in **Table 12-2** for the Los Angeles Civic Center, list the 1993 rainfall as number 8 in rank, the 1980 rainfall as number 9, the 1935 rainfall as number 18, and the 1993 rainfall as number 116. This is based on 126 years of record. (Note these five years are highlighted in **Table 12-2**.)

The computed results, treating these four years as missing data (systematic events = 68), indicated the discharges for the rarer events were consistently higher than the gaged data. It is not anticipated that a detailed regional analysis to estimate these missing data will significantly alter the discharge-frequency relationships for Malibu Creek. Peak flow data is presented in **Table 12-3**. A graph of peak flows is shown on **Plate 12-1**.

The computed results using 68 years of record indicated a mean peak discharge of 1,420 ft³/s. The standard deviation was 0.8524. A generalized skew of -0.3 from the skew figure in the back of Bulletin 17B was used to weight the computed skew as recommended in Bulletin 17B. The computed skew was -0.8175 and the adopted skew value was -0.7. A log-Pearson Type III distribution was fit to the observed annual peaks. One outlier was screened out of the Flood-Frequency Analysis which is the 1949 event that had an annual peak of 1 cfs. Plotting positions for peak values were determined using median plotting positions. The discharge-frequency curve for the Malibu Creek stream gage plotted on log-probability paper is shown on **Plate 12-2**.

Discharges along Malibu Creek at selected locations were estimated using the contributing drainage area and the discharge-frequency relationship for Malibu Creek below Cold Creek stream gage. Ratios of drainage area (calculated against a drainage area of 104.96 mi² for the stream gage) were multiplied by frequency discharges for 5 additional locations – concentration points (CPs). The frequency discharge results for these locations are shown in **Table 12-4**.

For comparison purposes, a brief description of the discharges computed for the current FEMA FIS (Flood Insurance Study) for Los Angeles County Unincorporated areas is included herein. The FIS was published and revised in 1998. The 1998 FIS report presents 1% ACE event (100-year) floodplain delineation maps for the mainstem of Malibu Creek along with several tributaries. The 1% ACE event (100-yar) peak flow for Malibu Creek at the Pacific Coast Highway Bridge was 40,544 ft³/s. A detailed study extended from the Pacific Coast Highway Bridge upstream approximately 4,400 ft and included a 0.2% ACE event (500-yr) floodplain. Discharges used in the FEMA study are presented in **Table 12-5**.

Table 12-2 Los Angeles Civic Center - Annual Precipitation Totals

Year*	Total	Rank	Year*	Total	Rank	Year*	Total	Rank
1878	21.26	19	1920	12.52	69	1962	18.79	35
1879	11.35	88	1921	13.65	60	1963	8.38	105
1880	20.34	24	1922	19.66	27	1964	7.93	112
1881	13.13	62	1923	9.59	96	1965	13.68	59
1882	10.40	94	1924	6.67	122	1966	20.44	23
1883	12.11	75	1925	7.98	111	1967	22.00	17
1884	38.18	1	1926	17.56	41	1968	16.58	45
1885	9.21	99	1927	17.76	40	1969	27.47	7
1886	22.31	16	1928	9.77	95	1970	7.74	114
1887	14.05	55	1929	12.66	65	1971	12.32	73
1888	13.87	56	1930	11.52	87	1972	7.17	119
1889	19.28	31	1931	12.53	68	1973	21.26	20
1890	34.84	2	1932	16.95	43	1974	14.92	52
1891	13.86	57	1933	11.88	80	1975	14.35	54
1892	11.85	81	1934	14.55	53	1976	7.21	118
1893	26.28	10		21.66	18	1977	12.30	74
1894	6.73	121	1936	12.07	76	1978	33.44	3
1895	16.11	49	1937	22.41	15	1979	19.67	26
1896	8.51	104	1938	23.43	14		26.98	9
1897	16.86	44	1939	13.07	63	1981	8.96	101
1898	7.06	120	1940	19.21	33	1982	10.71	90
1899	5.59	123	1941	32.76	4	1983	31.28	5
1900	7.91	113	1942	11.18	89	1984	10.43	93
1901	16.29	47	1943	18.17	37	1985	12.82	64
1902	10.60	91	1944	19.22	32	1986	17.86	39
1903	19.32	29	1945	11.59	85	1987	7.66	115
1904	8.72	102	1946	11.65	83	1988	12.48	70
1905	19.52	28	1947	12.66	66	1989	8.08	109
1906	18.65	36	1948	7.22	117		7.35	116
1907	19.30	30	1949	7.99	110	1991	11.99	78
1908	11.72	82	1950	10.59	92	1992	21.00	22
1909	19.18	34	1951	8.21	106	1993	27.36	8
1910	12.63	67	1952	26.21	11	1994	8.11	108
1911	16.18	48	1953	9.46	98	1995	24.35	12
1912	11.60	84	1954	11.99	77	1996	12.44	71
1913	13.42	61	1955	11.94	79	1997	12.40	72
1914	23.65	13	1956	16.00	50	1998	31.01	6
1915	17.05	42	1957	9.54	97	1999	9.09	100
1916	19.92	25	1958	21.13	21	2000	11.57	86
1917	15.26	51	1959	5.58	124	2001	17.94	38
1918	13.86	58	1960	8.18	107	2002	4.42	126
1919	8.58	103	1961	4.85	125	2003	16.42	46

* The rain year is from July 1 thru June 30

Table 12-3 Malibu Creek below Cold Creek (F130-R) Peak Flow Data

Water Year	Daily Flow			Total Runoff (af)	Date	Peak Flow (ft^3/s)
	Maximum (ft^3/s)	Minimum (ft^3/s)	Mean (ft^3/s)			
1930-31	*	*	*	1,920	4-	723
1931-32	1,770.00	+	20.2	14,670	9-	3,100
1932-33	1,100.00	0.1	12.7	9,190	19-	4,460
1933-34	3,160.00	0.1	17.1	12,370	1-	9,650
1934-35	511	+	8.6	6,220		
1935-36	92	0	3.2	2,310	23-	147
1936-37	1,680.00	0	33.1	23,940	14-	2,760
1937-38	5,090.0E	0.2	47.1	34,100	2-	10,000 E
1938-39	139	0	6.4	4,630	20-	331
1939-40	335	+	8.4	6,100	2-	690
1940-41	2,200.00	0.1	101	73,220	20-	3,620
1941-42	32	0.1	2.5	1,820	28-	140
1942-43	5,370.00	0.1	65.8	47,600	22-	12,200
1943-44	3,400.00	0.7	41.6	30,170	22-	7,700
1944-45	210	0.2	5.8	4,240	2-	516
1945-46	267	0.1	5.2	3,800	30-	506
1946-47	142	0.1	5.3	3,820	13-	980
1947-48	15	+	0.2	177	24-	113
1948-49	0.6	+	0.1	90	18-	1
1949-50	64	0	0.7	477	6-	674
1950-51	0.3	0	0.1	56	11-	3
1951-52	6,720.00	0	80.2	58,200	15-	13,600
1952-53	81	+	4	2,940	15-	322
1953-54	655	0.1	6.9	4,990	13-	2,250
1954-55	16	0.1	1	758	18-	45
1955-56	1,260.00	0.1	6.5	4,680	26-	3,600
1956-57	12	+	0.6	444	23-	46
1957-58	1,630.00	+	43.7	31,660	3-	4,260
1958-59	114	0.1	2.1	1,510	6-	3,180
1959-60	17	+	0.7	504	27-	84
1960-61	2	+	0.1	99	26-	8
1961-62	3,920.00	+	36.3	26,150	10-	7,060
1962-63	24	+	1	701	16-	104

M	Data Missing	*	Record Incomplete
E	Estimate	N.D.	Not Determined
**	Record Not Computed	+	Less than 0.05 af or less than 0.05 ft^3/s, but greater than 0

Water Year	Daily Flow			Total Runoff (af)	Date	Peak Flow (ft³/s)
	Maximum (ft³/s)	Minimum (ft³/s)	Mean (ft³/s)			
1963-64	17	+	0.5	384	22-	65
1964-65	148	+	2.2	1,560	9-	521
1965-66	7,060.00	0.2	51.8	37,520	29-	20,600
1966-67	2,710.00	0.9	35.5	25,700	24-	10,200
1967-68	1,350.00	1	18.5	13,430	8-	3,830
1968-69	24,200.00	1.4	166	119,900	25-	33,800
1969-70	368	0.5	9.9	7,200	4-	1,150
1970-71	1,480.00	1.2	23.7	17,300	19-	7,390
1971-72	582	0.9	6	4,340	27-	2,120
1972-73	3,340.00	0.8	35.1	25,400	11-	7,480
1973-74	2,240.00	2.7	22	15,910	7-	5,100
1974-75	519	2.3	15.2	11,020	4-	2,670
1975-76	163	1.1	5.4	3,910	9-	339
1976-77	315	1.1	6.9	4,980	7-	597
1977-78	7,620.00	1.7	112.4	80,990	4-	19,400
1978-79	1,220.00	2.3	46.4	33,408	27-	4,420
1979-80	*	*	*	*	16-	
1980-81	357	1.7	13.5	9,832	5-	910
1981-82	400	2.2	13.9	10,031	17-	676
1982-83	7,720.00	2.7	121.8	88,148	1-	24,200
1983-84	758	2.5	0.8	17,411	25-	1,840
1984-85	588	0.9	0.5	12,002	19-	880
1985-86	1,480.00	1.4	39.3	27,881	15-	5,880
1986-87	216	0.5	8.6	6,236	18-	653
1987-88	559	0.6	24	17,337	28-	1,680
1988-89	257	1.6	0.4	8,876	9-	441
1989-90	*	*	*	*		
1990-91	982	0.8	20.5	14,872	19-	3,150
1991-92	5,850.00	2	92.7	67,330	10-	23,300
	*	*	*	*		
1993-94	880	0.9	16.7	11,090	12-	2,450
1994-95	4,530.00	3.1	97.8	68,700	11-	15,700
1995-96	637	1.5	12.9	9,395	21-	1,220

M	Data Missing	*	Record Incomplete
E	Estimate	N.D.	Not Determined
**	Record Not Computed	+	Less than 0.05 af or less than 0.05 ft³/s, but greater than 0

Water Year	Daily Flow Maximum (ft³/s)	Daily Flow Minimum (ft³/s)	Daily Flow Mean (ft³/s)	Total Runoff (af)	Date	Peak Flow (ft³/s)
1996-97	807	3.2	43.1	31,180	9-	1,800
1997-98	4,020.00	2.4	113	81,700	7-	19,100
1998-99	134	2.8	10.3	7,430	11-	761
1999-00	701	1.4	22.6	16,440	23-	2,380
2000-01	3,950.00	0.6	53.8	38,920	6-	10,900
2001-02	93.3	0.9	10.6	7,670.10	24-	413
2002-03	1,979	1.9	25.9	18,761	Feb	5,410
2003-04	1,470	1.2	13	9,442	Feb	5,130
2004-05	7,330	1.3		103,000	Jan	12,700
2005-06	845	3.1	31.9	23,120	Jan	2,586
2006=07	80	0.7	10.1	7,309	Feb	189
2007-08	1,940	0.9	32.4	23,510	Jan	3,851
2008-09	521	0.8	13.4	9,710	Feb	1,350
2009-10	816	1.97	27	19,530	Jan	2,970
2010-11	2,010	1.94	40.8	29,530	Mr	6,490

M	Data Missing	*	Record Incomplete
E	Estimate	N.D.	Not Determined
**	Record Not Computed	+	Less than 0.05 af or less than 0.05 ft³/s, but greater than 0

The FIS required 1% ACE event (100-yr) discharge estimates at many locations where stream gage info were not available. First, peak flow rates were computed at the stream gage locations using the guidelines in Bulletin 17B. Following this, discharges were computed at the same locations using regional runoff frequency equations developed by the Los Angeles County Flood Control District (now LACDPW). The peak discharges computed using Bulletin 17B guidelines were higher than those computed using the LACDPW regional runoff equations. Ratios of peak flows using each method were then calculated. Finally, peak discharges using the LACDPW regional runoff equations were computed for all ungaged locations in the watershed. The resulting discharges were multiplied by the ratio for the closest stream gage to get the final 1% ACE event (100-year) discharges. This process resulted in discharges somewhat lower for the 1% ACE event (100-year) than what is reported for this study. Since this study is focused on ecosystem restoration, further investigations into the accuracy of the regional runoff equations was not deemed necessary.

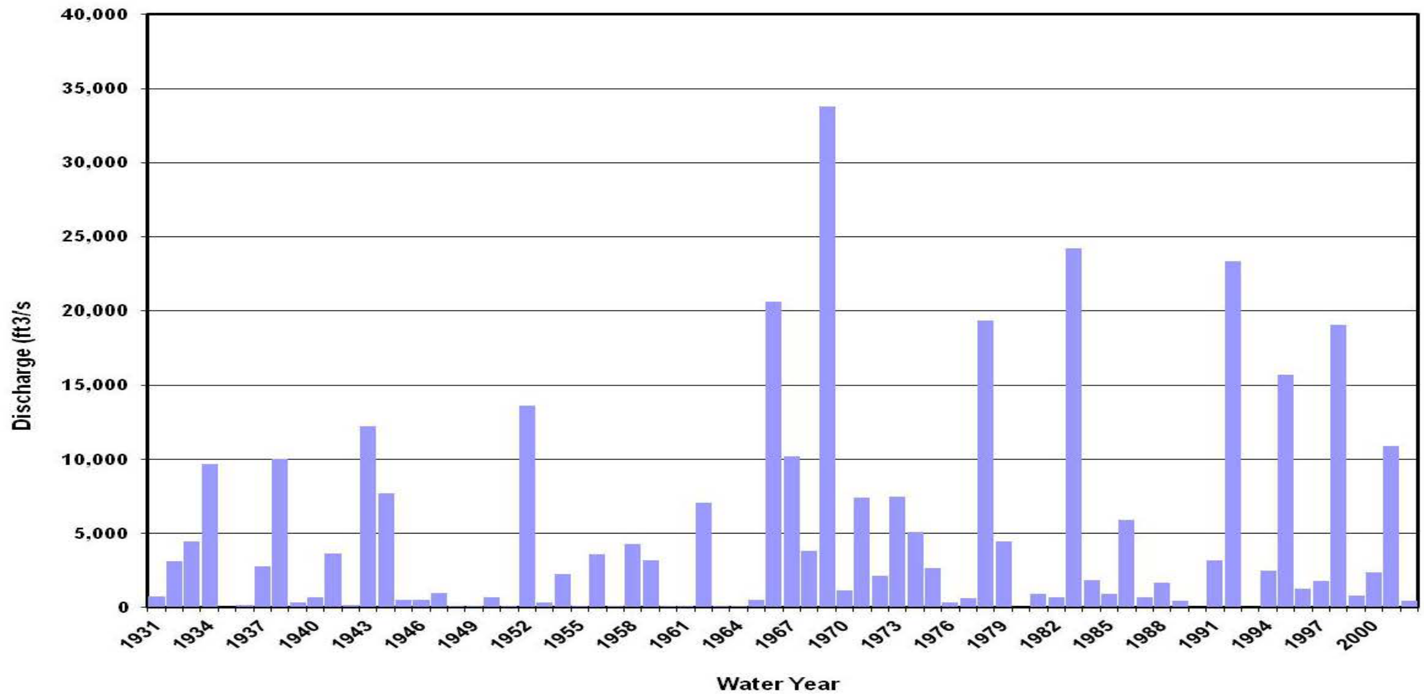
The Malibu Creek watershed is built-out for the most part and discharges for future conditions are not expected to change.

Table 12-4 Frequency Discharges for Concentration Points Used in Hydraulic Analyses

CP	ID	Name	Drainage Area (mi²)	Percent of CP-1 DA	Station	River Mile
6	MCBLCCK	Malibu Creek below Cold Creek	104.94	100.000%	245+00.01	4.55
5	MCATRD	Malibu Creek at Rindge Dam	106.41	101.401%	162+00.67	3.07
4	MCATBB	Malibu Creek at Pool	107.74	102.668%	90+72.93	1.72
3	MCATCRCK	Malibu Creek at Cross Creek Bridge	109.09	103.955%	47+35.88	0.89
2	MCATPCH	Malibu Creek at Pacific Coast Highway	109.55	104.393%	13+73.70	0.26
1	MCATPO	Malibu Creek at Pacific Ocean	109.60	104.441%	0+00	0.00

CP	ID	ACE Event								Q9Jan2005
		0.2% (500-yr)	0.5% (200-yr)	1% (100-yr)	2% (50-yr)	5% (20-yr)	10% (10-yr)	20% (5-yr)	50% (2-yr)	
6	MCBLCCK	80,600	62,300	49,200	37,200	23,200	14,500	7,640	1,780	12,700
5	MCATRD	81,700	63,200	49,900	37,700	23,500	14,700	7,750	1,800	12,900
4	MCATBB	82,800	64,000	50,500	38,200	23,800	14,900	7,840	1,830	13,000
3	MCATCRCK	83,800	64,800	51,100	38,700	24,100	15,100	7,940	1,850	13,200
2	MCATPCH	84,100	65,000	51,400	38,800	24,200	15,100	7,980	1,860	13,200
1	MCATPO	84,200	65,100	51,400	38,900	24,200	15,100	7,980	1,860	13,200

The results presented above are based on a period of record from 1931-2002. Note, the period of record was extended to water year 2011 in Feb 2013 to check the validity of the results. The 1% ACE (100-year) event was reduced by 2%, which was determined to be insignificant for purposes of this study and no further changes were made due to discharges.



Ref: Los Angeles County Department of Public Works (LACDPW) Gage F130-R; Malibu Creek below Cold Creek.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK
PEAK FLOWS FOR
PERIOD OF RECORD

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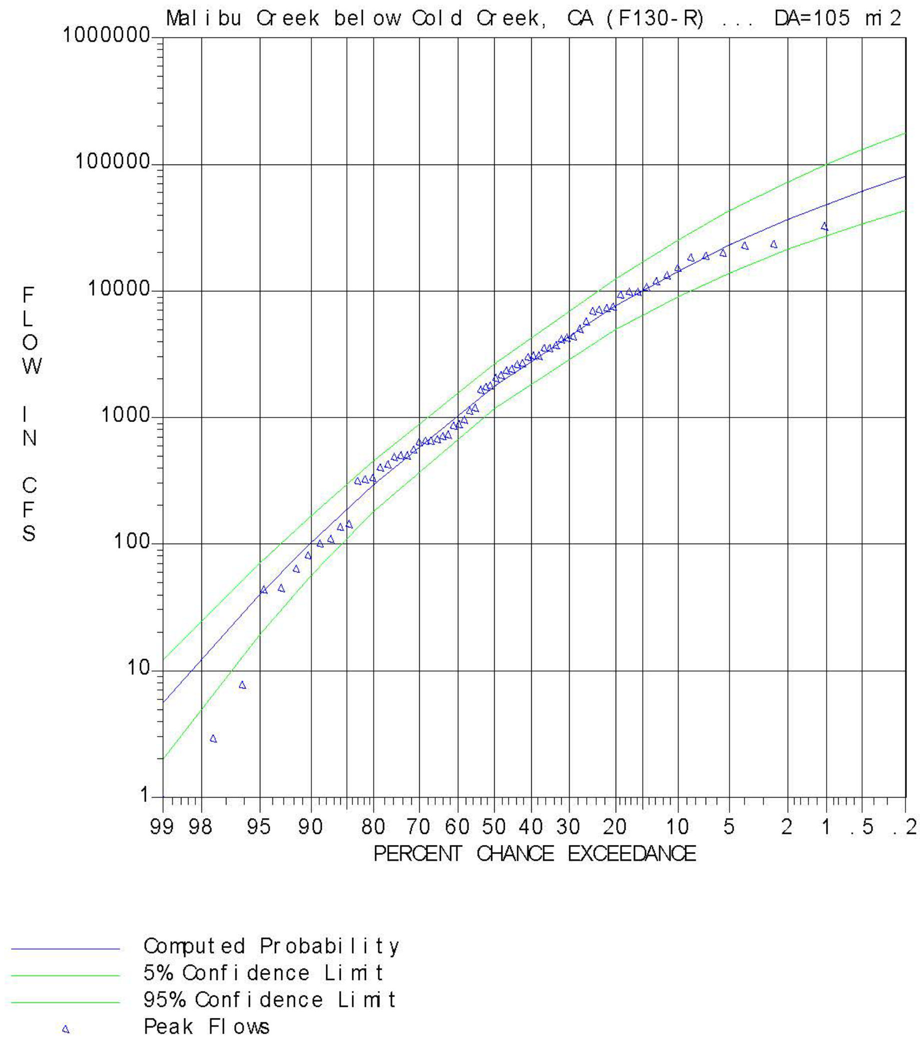
Plate 12-1 Malibu Creek Peak Flows for Period of Record



Based on Los Angeles County Department of Public Works (LACDPW) Stream Gage F130-R; Malibu Creek below Cold Creek	**MALIBU CREEK** **ECOSYSTEM RESTORATION STUDY**
	MALIBU CREEK **DISCHARGE-FREQUENCY** **CURVE**
	CORPS OF ENGINEERS LOS ANGELES DISTRICT

Plate 12-2 Malibu Creek Discharge Frequency Curve

Table 12-5 Discharges Used in 1998 FIS

Malibu Creek Drainage Area = 109.6 mi²	
10-yr	14,183 ft³/s
50-yr	31,648 ft³/s
100-yr	40,544 ft³/s
500-yr	63,934 ft³/s

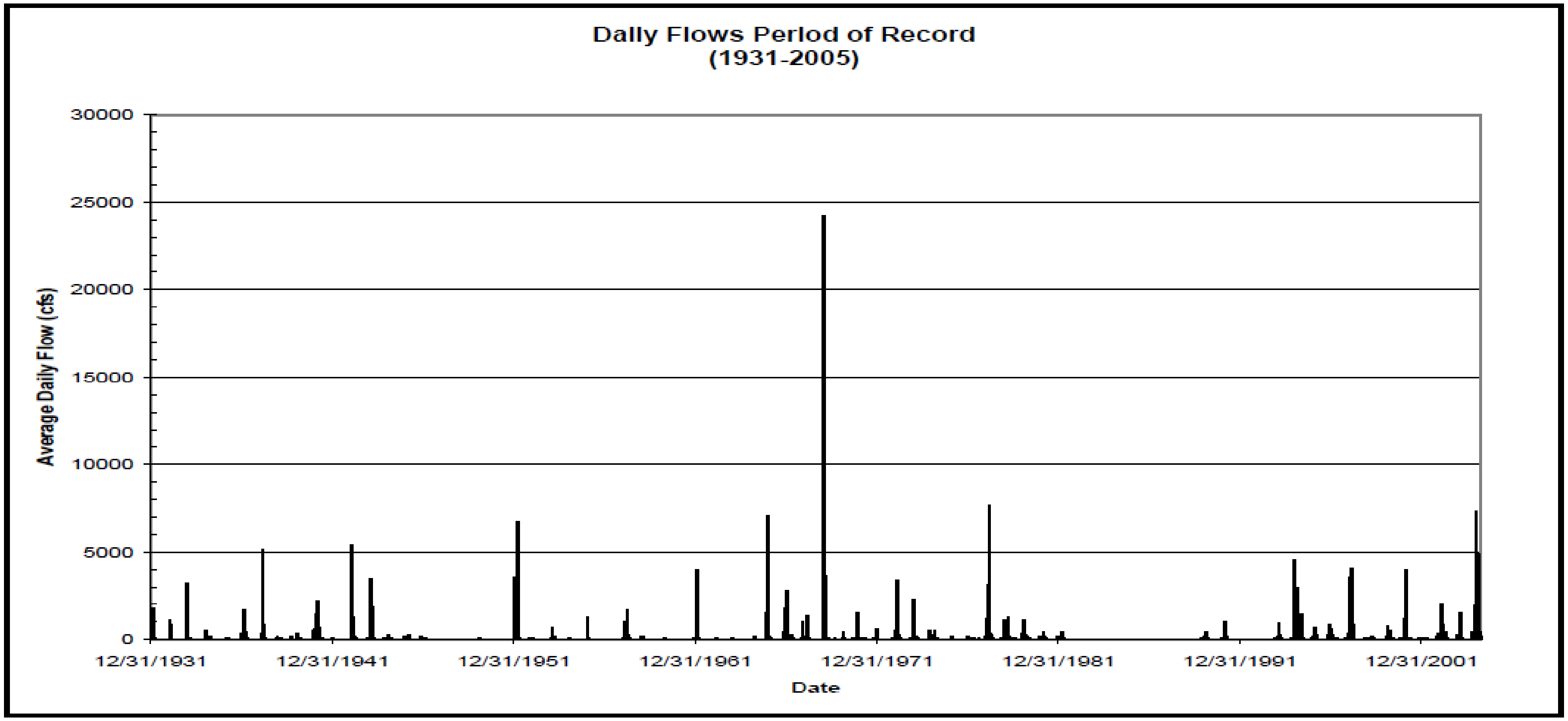
12.2 Balanced Hydrographs

Balanced hydrographs are synthetic hydrographs in which the frequency of exceedance is the same for all durations, i.e., for a 5% ACE event (20-year), the peak flow, 1-day flow, 2-day flow, etc. are all equaled or exceeded on average once every 20 years.

Typically, flood events are commonly characterized by their frequency of occurrence based on the peak discharge alone. For example, a flood event occurring on Malibu Creek with a peak discharge of 23,200 ft³/s would be said to be a 5% ACE event (20-year). However, when evaluating the transport of sediment, the volume of the event is generally as or more important than the peak. This same flood event with the same peak (23,200 ft³/s) may have a lesser daily volume than a 5% ACE event (20-year) based on volume. The purpose of using a balanced hydrograph is to evaluate the sediment transport capacity of the channel using a realistic estimate of volume.

Average daily flows were determined for the period of record for the Los Angeles County stream gage No. F130-R, Malibu Creek below Cold Creek, CA. **Plate 12-3** is a graph of daily flows for the period of record. Daily flows were available for the majority of water years from 1931 to present. Nine years had missing data. Hourly data was also available from 1995-present. A quick observation of the hourly data illustrated the larger events were of a flashy nature with most of the runoff passing through the watershed in 2-3 days. The balanced hydrographs were extended out to 5 days for the sediment transport analysis.

The maximum 1-day, 2-day, 3-day, 4-day, and 5-day flows were calculated for the available period of record. To account for the missing data, simple linear regression analyses were developed for peak versus 1-day, peak versus 2-day, peak versus 3-day, peak versus 4-day, and peak versus 5-day. Missing data was then estimated using the resulting regression equations. The daily flows were then ranked and ordered and a frequency analysis was performed. The HEC-FFA computer program was used for this purpose. The adopted skew from the peak frequency analysis (-0.7) was fixed so the volume frequency curves would be consistent with the peak curve. The volume frequency curves for Malibu Creek are shown on **Plate 12-4**. Volume frequency results are presented in **Table 12-6**.



Based on Los Angeles County Department of Public Works (LACDPW) Stream Gage F130-R; Malibu Creek below Cold Creek.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK DAILY FLOWS FOR PERIOD OF RECORD

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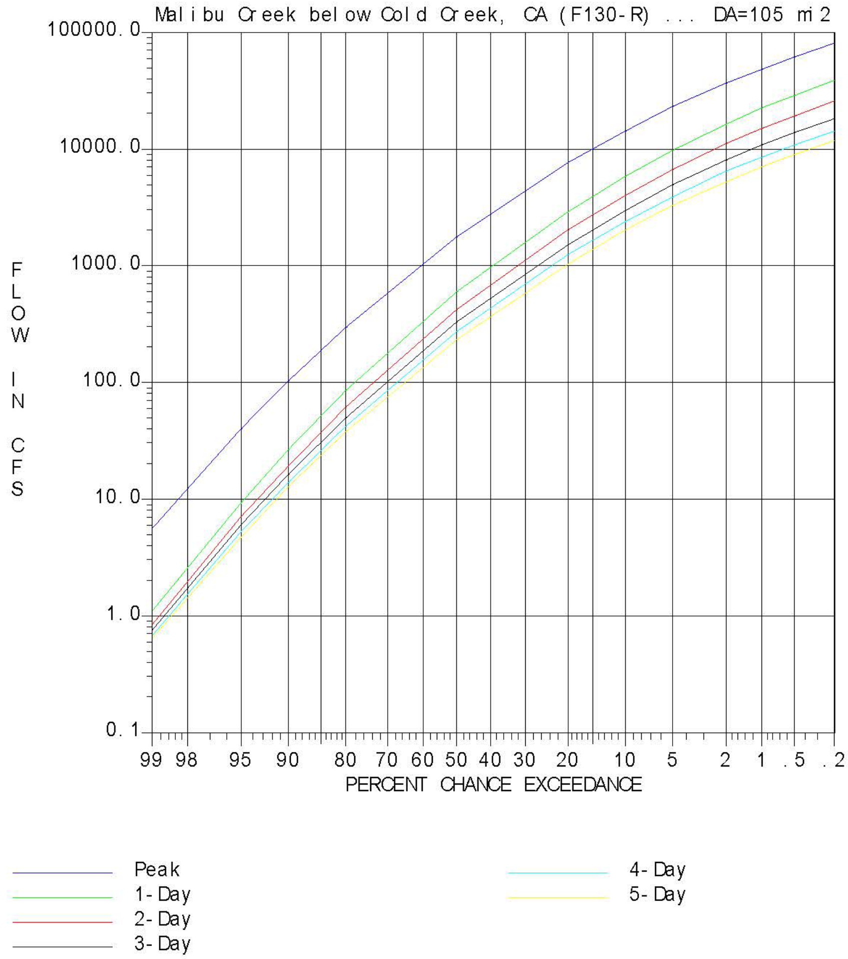
Plate 12-3 Malibu Creek Daily Flows for Period of Record



Based on Los Angeles County Department of Public Works (LACDPW) Stream Gage F130-R; Malibu Creek below Cold Creek

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK
VOLUME-FREQUENCY CURVE

CORPS OF ENGINEERS
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Plate 12-4 Malibu Creek Volume-Frequency Curve

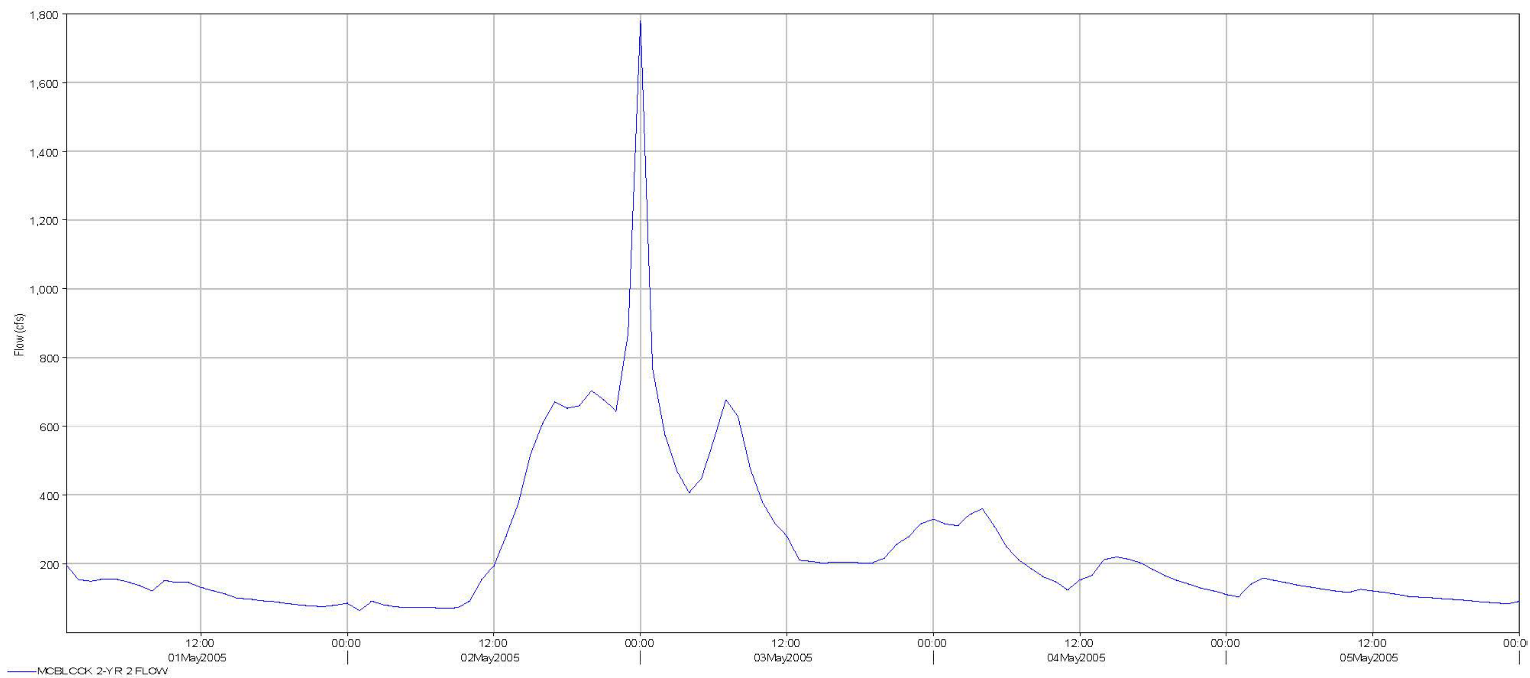
Table 12-6 Volume-Frequency Results for Malibu Creek

Flow Duration	ACE Event							
	0.2% (500-yr)	0.5% (200-yr)	1% 100-yr)	2% (50-yr)	5% (20-yr)	10% (10-yr)	20% (5-yr)	50% (2-yr)
Peak	80,600	62,300	49,200	37,200	23,200	14,500	7,640	1,780
1-Day	38,800	29,300	22,700	16,700	9,960	5,950	2,950	600
2-Day	25,900	19,600	15,200	11,200	6,760	4,070	2,040	420
3-Day	18,500	14,100	11,000	8,180	4,980	3,030	1,540	330
4-Day	14,500	11,100	8,700	6,490	3,980	2,430	1,250	270
5-Day	11,800	9,080	7,140	5,350	3,300	2,040	1,050	240

Period of record 1931-2002
Peak discharges based on analytical analysis of stream gage data; reference Table 7 for peak discharges along Malibu Creek.

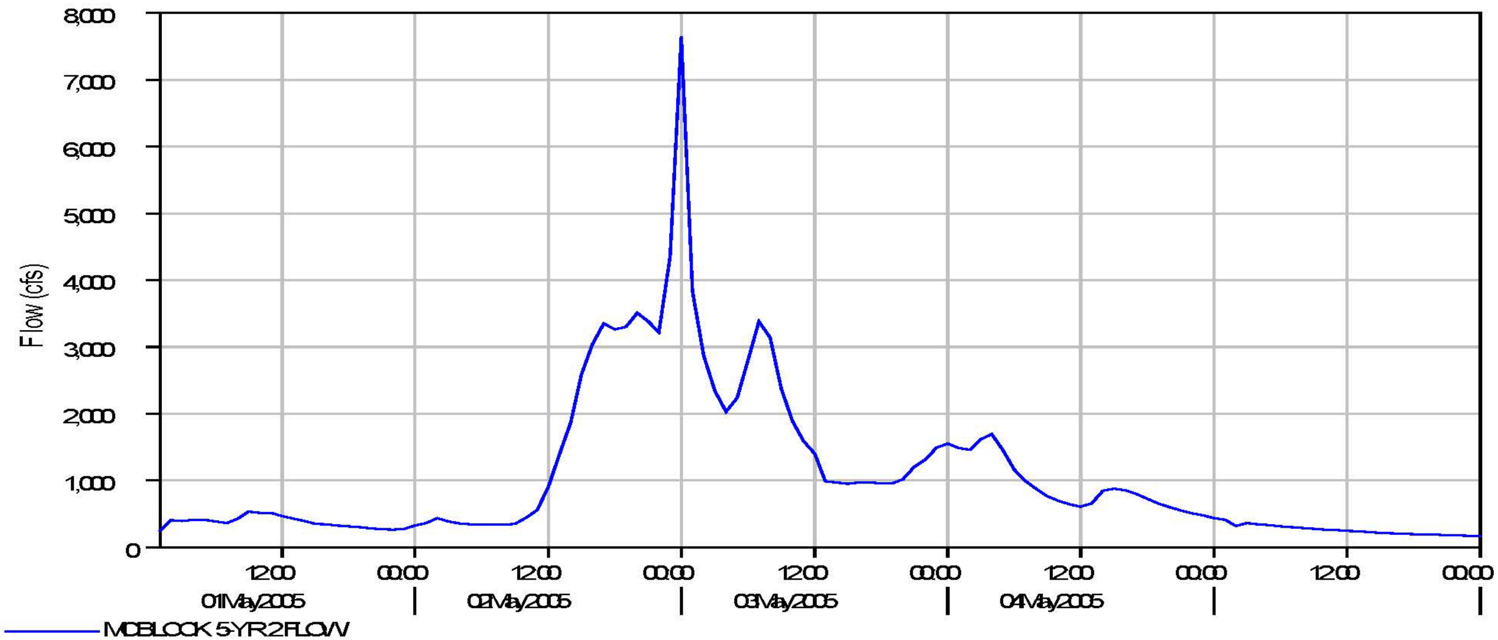
Hydrographs were generated which incorporated the peak and daily discharges for specified frequencies. These hydrographs are referred to as “balanced hydrographs”. The balanced hydrographs were developed using the BALHYD computer program. BALHYD is a flow volume-frequency program that computes various return interval hypothetical “balanced” hydrographs. The input consists of duration-frequency values in ft^3/s and a pattern hydrograph. Peak, 1-day, 2-day, 3-day, 4-day, and 5-day flows for the 50% (2-yr), 20% (5-yr), 10% (10-yr), 5% (20-yr), 2% (50-yr), 1% (100-yr), 0.5% (200-yr), and 0.2% (500-yr) ACE events were used as input. The results from the BALHYD program were then written to HEC-DSS.

The pattern hydrograph is usually a recorded hydrograph whose duration equals or exceeds the longest specified duration. The January 2005 hydrograph had an estimated peak discharge of 12,700 ft^3/s and a 1-day discharge of 7,330 ft^3/s. An inspection of the peak and 1-day volume frequency curves indicates this event is between a 20% and 10% ACE events (5- and 10-year). This hydrograph was used as a pattern hydrograph in the BALHYD computer program. The balanced hydrographs for discrete events are shown in **Plate 12-5 through Plate 12-12**.



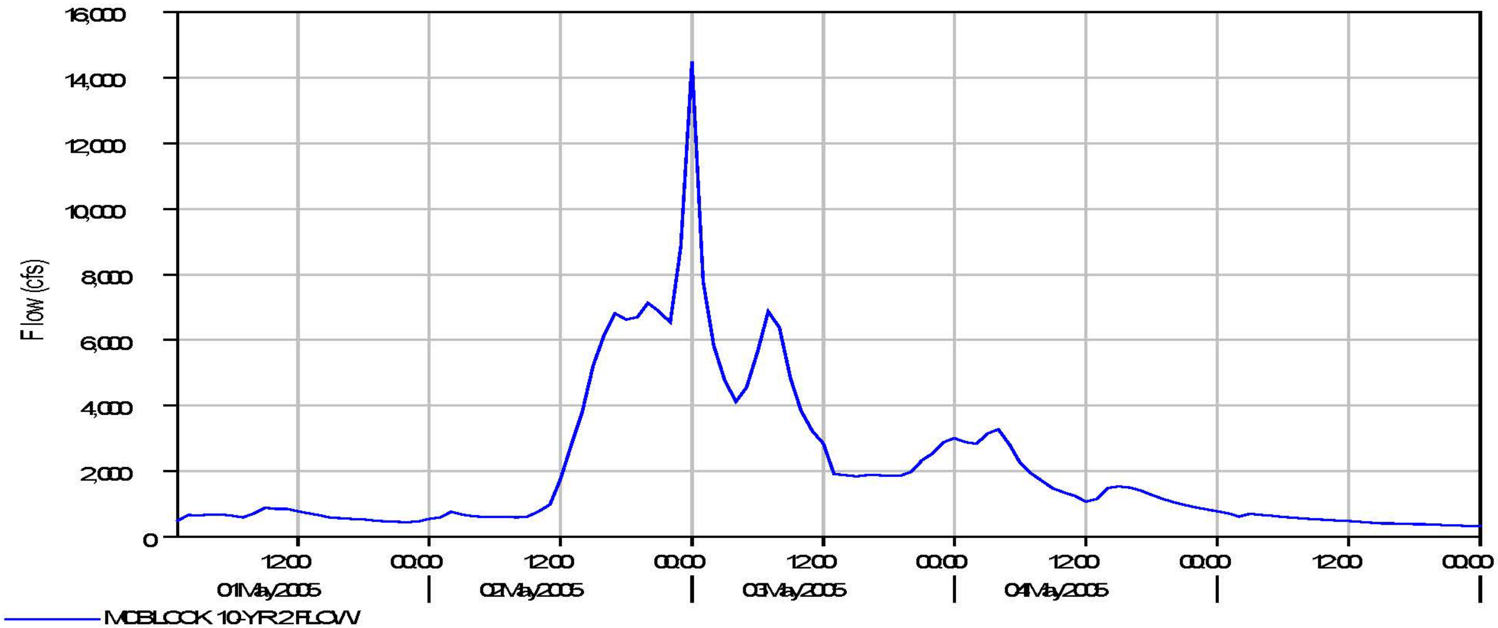
The 50% chance event is often referred to as the 2-yr event. The January 2005 hydrograph was used as a pattern hydrograph in the BALHYD computer program to generate the balanced hydrographs.	MALIBU CREEK ECOSYSTEM RESTORATION STUDY
	MALIBU CREEK **50% CHANCE EVENT** **BALANCED HYDROGRAPH**
	CORPS OF ENGINEERS LOS ANGELES DISTRICT

Plate 12-5 Malibu Creek 50% Chance Event (2-Year) Balanced Hydrograph



The 20% chance event is often referred to as the 5-yr event. The January 2005 hydrograph was used as a pattern hydrograph in the BALHYD computer program to generate the balanced hydrographs.	MALIBU CREEK ECOSYSTEM RESTORATION STUDY **MALIBU CREEK** **20% CHANCE EVENT** **BALANCED HYDROGRAPH** CORPS OF ENGINEERS LOS ANGELES DISTRICT

Plate 12-6 Malibu Creek 20% Chance Event (5-Year) Balanced Hydrograph



The 10% chance event is often referred to as the 10-yr event.

The January 2005 hydrograph was used as a pattern hydrograph in the BALHYD computer program to generate the balanced hydrographs.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK
10% CHANCE EVENT
BALANCED HYDROGRAPH

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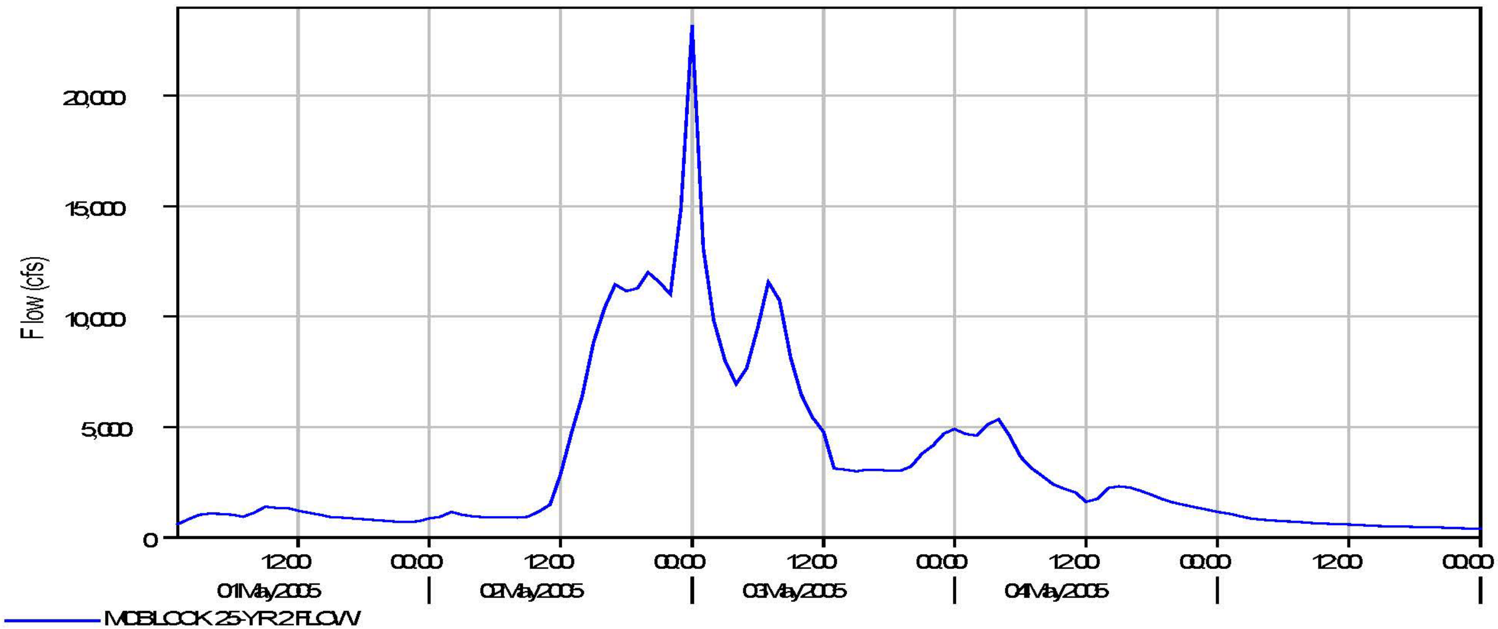
Plate 12-7 Malibu Creek 10% Chance Event (10-Year) Balanced Hydrography



The 5% chance event is often referred to as the 20-yr event.

The January 2005 hydrograph was used as a pattern hydrograph in the BALHYD computer program to generate the balanced hydrographs.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK
5% CHANCE EVENT
BALANCED HYDROGRAPH

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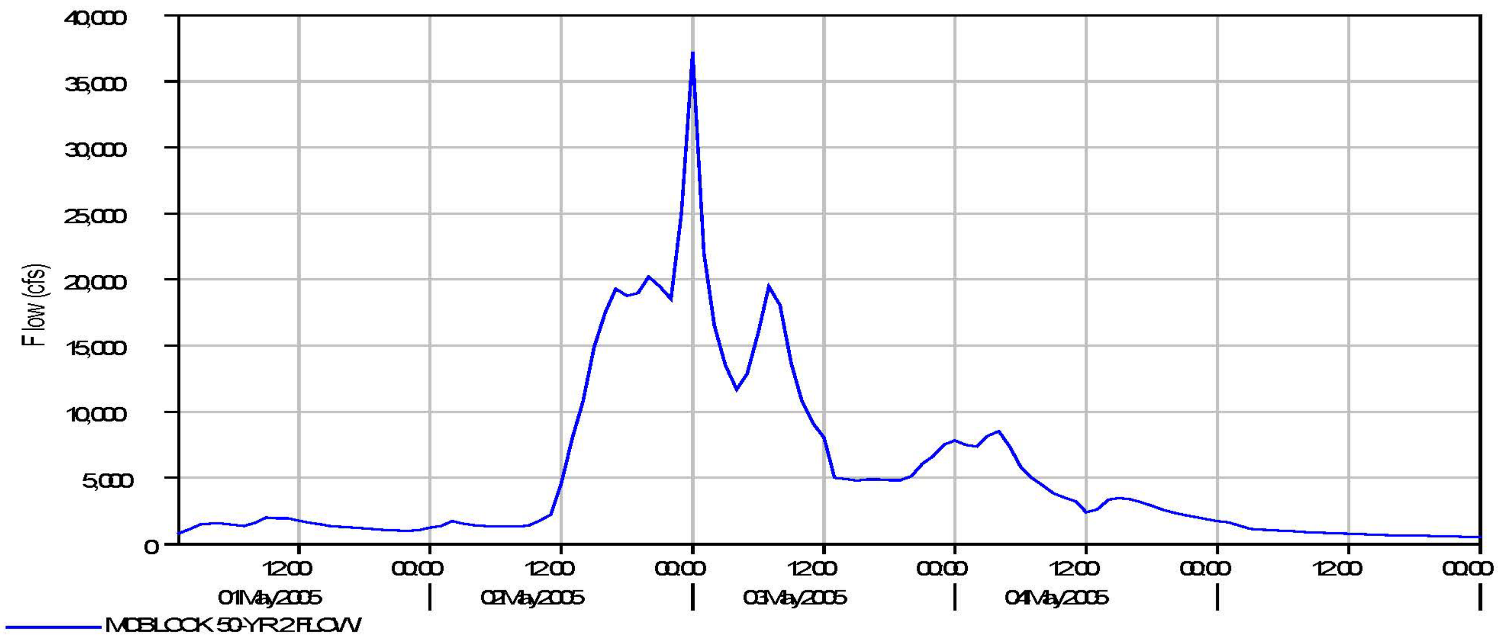
Plate 12-8 Malibu Creek 5% Chance Event (20-Year) Balanced Hydrograph



The 2% chance event is often referred to as the 50-yr event.

The January 2005 hydrograph was used as a pattern hydrograph in the BALHYD computer program to generate the balanced hydrographs.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK
2% CHANCE EVENT
BALANCED HYDROGRAPH

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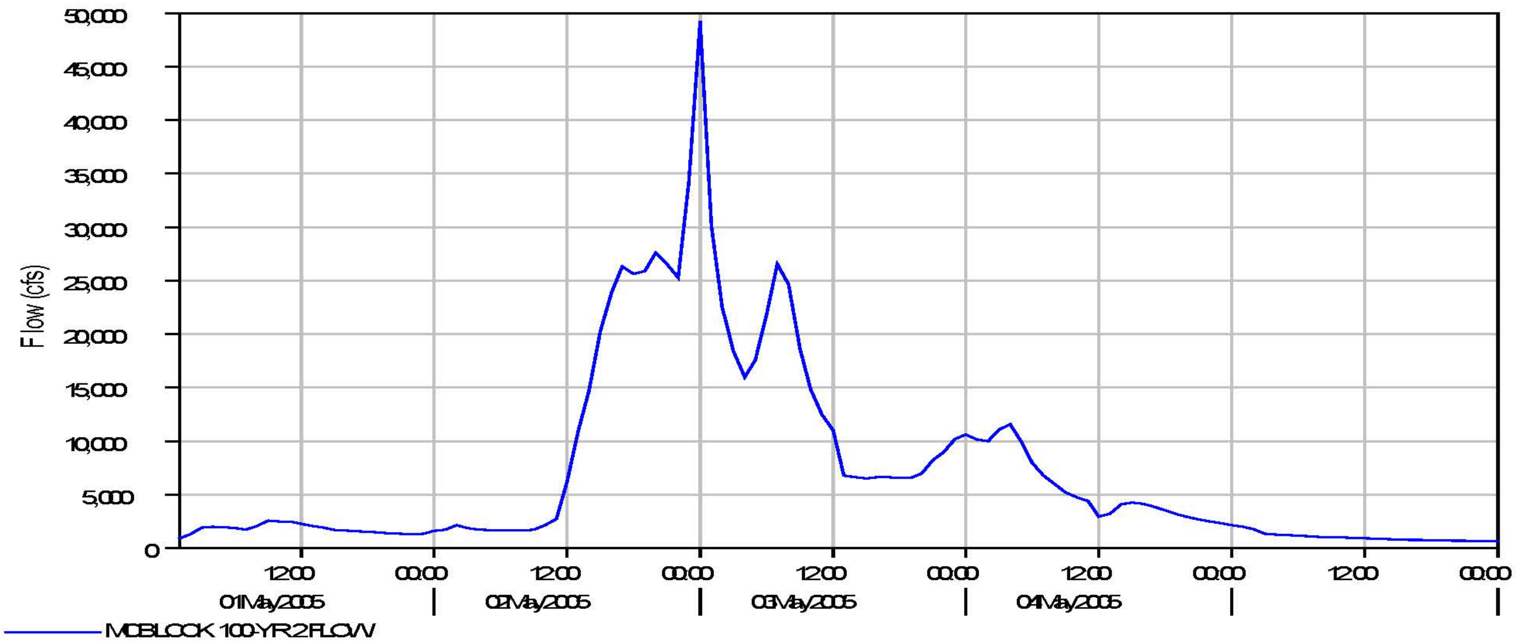
Plate 12-9 Malibu Creek 2% Chance Event (50-Year) Balanced Hydrograph



The 1% chance event is often referred to as the 100-yr event.

The January 2005 hydrograph was used as a pattern hydrograph in the BALHYD computer program to generate the balanced hydrographs.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK
1% CHANCE EVENT
BALANCED HYDROGRAPH

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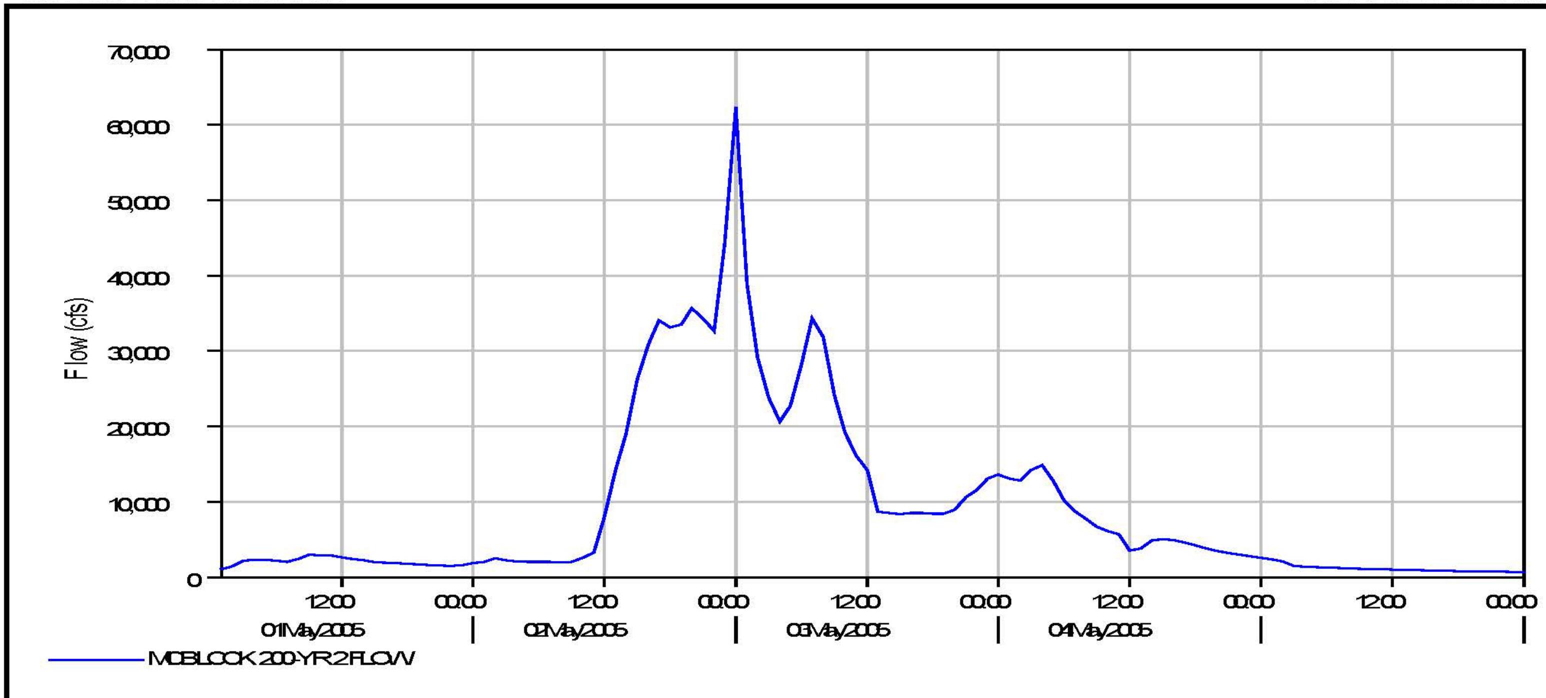
LOS ANGELES DISTRICT

Plate 12-10 Malibu Creek 1% Chance Event (100-Year) Balanced Hydrograph



The 0.5% chance event is often referred to as the 200-yr event.

The January 2005 hydrograph was used as a pattern hydrograph in the BALHYD computer program to generate the balanced hydrographs.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK
0.5% CHANCE EVENT
BALANCED HYDROGRAPH

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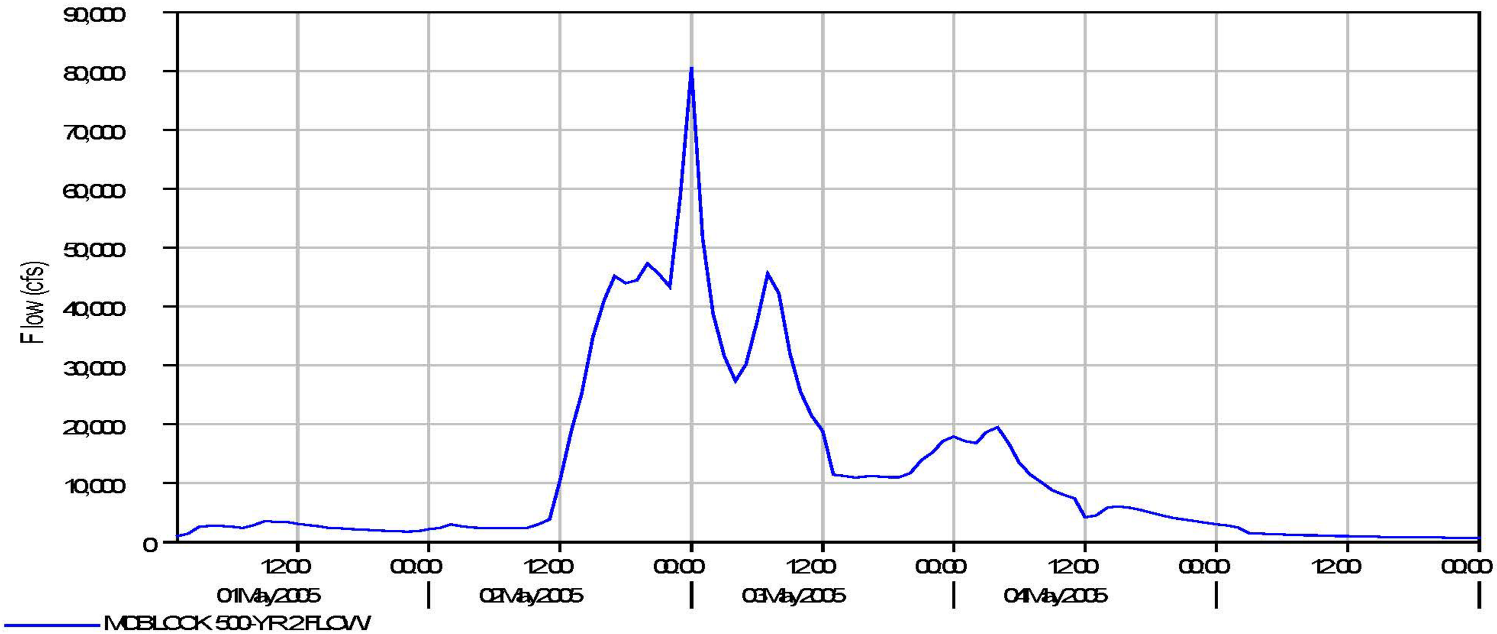
Plate 12-11 Malibu Creek 0.5% Chance Event (200-Year) Balanced Hydrograph



The 0.2% chance event is often referred to as the 500-yr event.

The January 2005 hydrograph was used as a pattern hydrograph in the BALHYD computer program to generate the balanced hydrographs.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK
0.2% CHANCE EVENT
BALANCED HYDROGRAPH

CORPS OF ENGINEERS
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Plate 12-12 Malibu Creek 0.2% Chance Event (500-Year) Balanced Hydrograph

13.0 HYDRAULIC ANALYSIS

13.1 GIS Processing

The USACE, Los Angeles District Survey Section, through contract services, developed digital terrain models (DTMs) and ortho-rectified photographs for the project reach based on a May 2002 aerial survey flight (Landata Airborne Systems, contour interval 2 ft, 1" to 200' scale. NAVD88, NAD83). Microstation CADD files were generated from points and breaklines files, as well as a TIN file in ArcGIS format. ArcGIS, along with the HEC-GeoRAS extension, were used to develop cross sections, streamlines, and flowpaths for the hydraulic models. Initially, cross sections were constructed at approximately500-foot intervals along the project reach. The HEC-RAS model cross sections are shown on **Plate 13-1**. After an initial computer run, it was determined that additional intermediate cross sections at key locations would help to improve the accuracy and stability of the model. The HEC-GeoRAS extension allows the user to extract elevations from the TIN, compile with lengths and distances, and export to HEC-RAS (River Analysis System from the Hydrologic Engineering Center, version 4.2). A streambed profile using the invert elevations from the cross sections is shown on **Plate 13-2**. Unless otherwise annotated, vertical datum of all tables and figures are NAVD88.

13.2 Hydraulic Model Preparation

The USACE computer program HEC-RAS was utilized to simulate the hydraulics for each flood. Bank stations were set based on aerial photography and using the estimated 20% ACE event (5-year) water surface elevation as a guide. Field investigations and preliminary hydraulic modeling results indicated the 20% ACE event (5-year) water surface was adequate to set initial bank stations. The actual bank stations were then adjusted for each cross section, as necessary. Channel roughness coefficients (Manning's n-values) were estimated using aerial photographs of Malibu Creek, previous studies in the Malibu Creek and similar watersheds, along with the widely accepted USGS publication from Barnes (1987), in addition to engineering judgment based on published studies of streams in southern California and field reconnaissance.

The aerial survey for this study did not include topography for areas under water. This is important for the Malibu Lagoon area. The cross sections at RS 12+69.1, RS 8+39.8, and RS 5+50.6 were adjusted using bathymetry from Moffat and Nichol dated 12 February 2004. The bank stations did not line up exactly, so a best-fit approach based on aerial photography, bathymetry, and the project TIN was used. The cross section at RS 13+73.7 on the upstream side of PCH was adjusted using the bathymetric section for RS 12+69.1 as a guide. For the other two cross sections upstream from PCH (RS 18+46.3 and RS 21+18.8) that were inundated at the time of the aerial mapping, the channel invert was set at the midpoint of the inundation area and one foot below the lowest elevation. No adjustments were made to the numerous pools that lie along Malibu Creek. The impact on significant flood events was assumed to be negligible.

Based on field observations and applicable references, Manning's n-values for the Malibu Creek area impacted by the lagoon were set to 0.040 for the channel and 0.060 for the overbanks. For the area downstream from the canyon mouth to the upstream extent of the lagoon the roughness coefficients were set to 0.045 for the channel and 0.065 for the overbanks. The roughness values were increased to 0.065 for the channel and 0.08 for the overbanks in the canyon area to reflect the large boulders and amount of vegetation present.

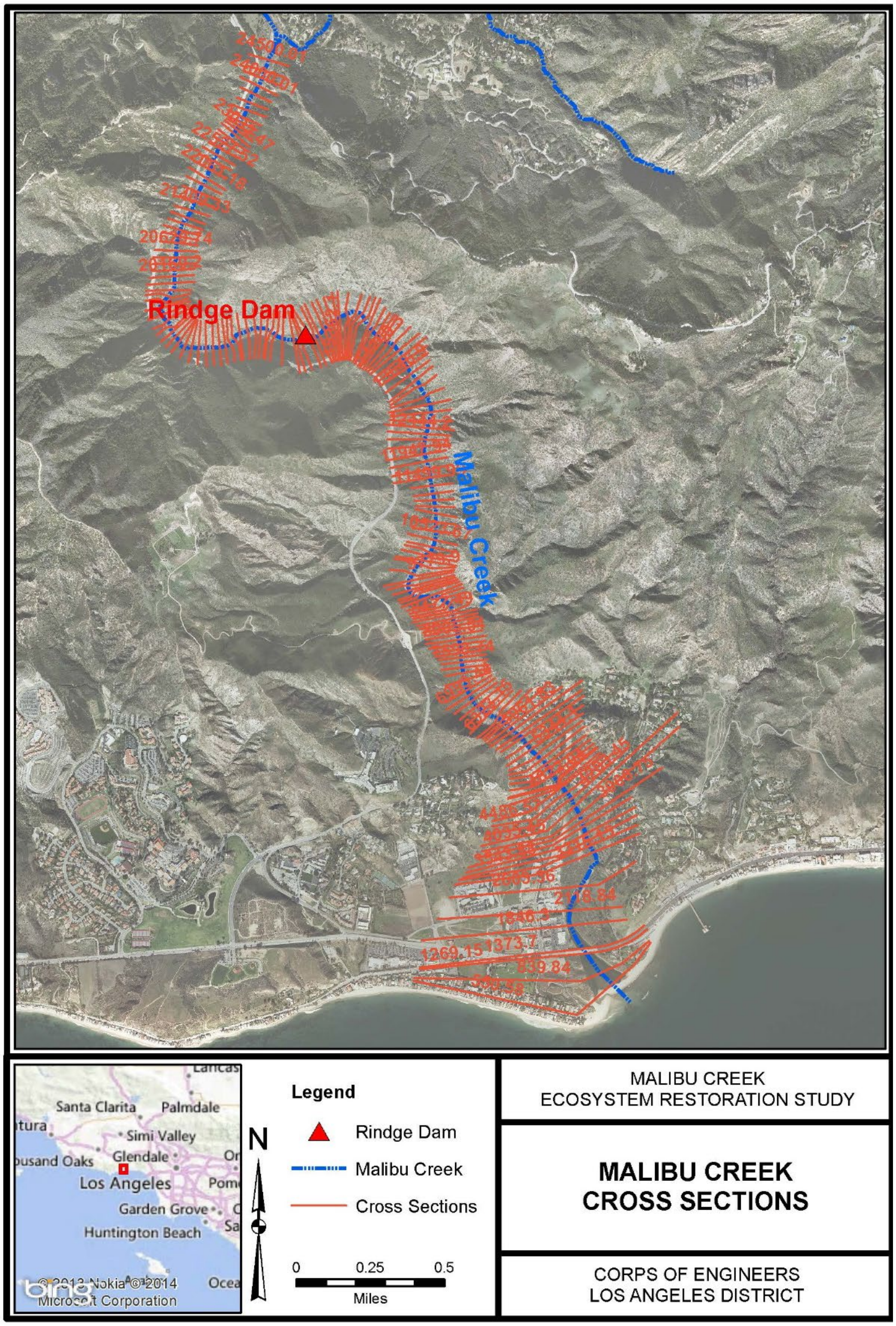


Plate 13-1 Malibu Creek Cross Sections

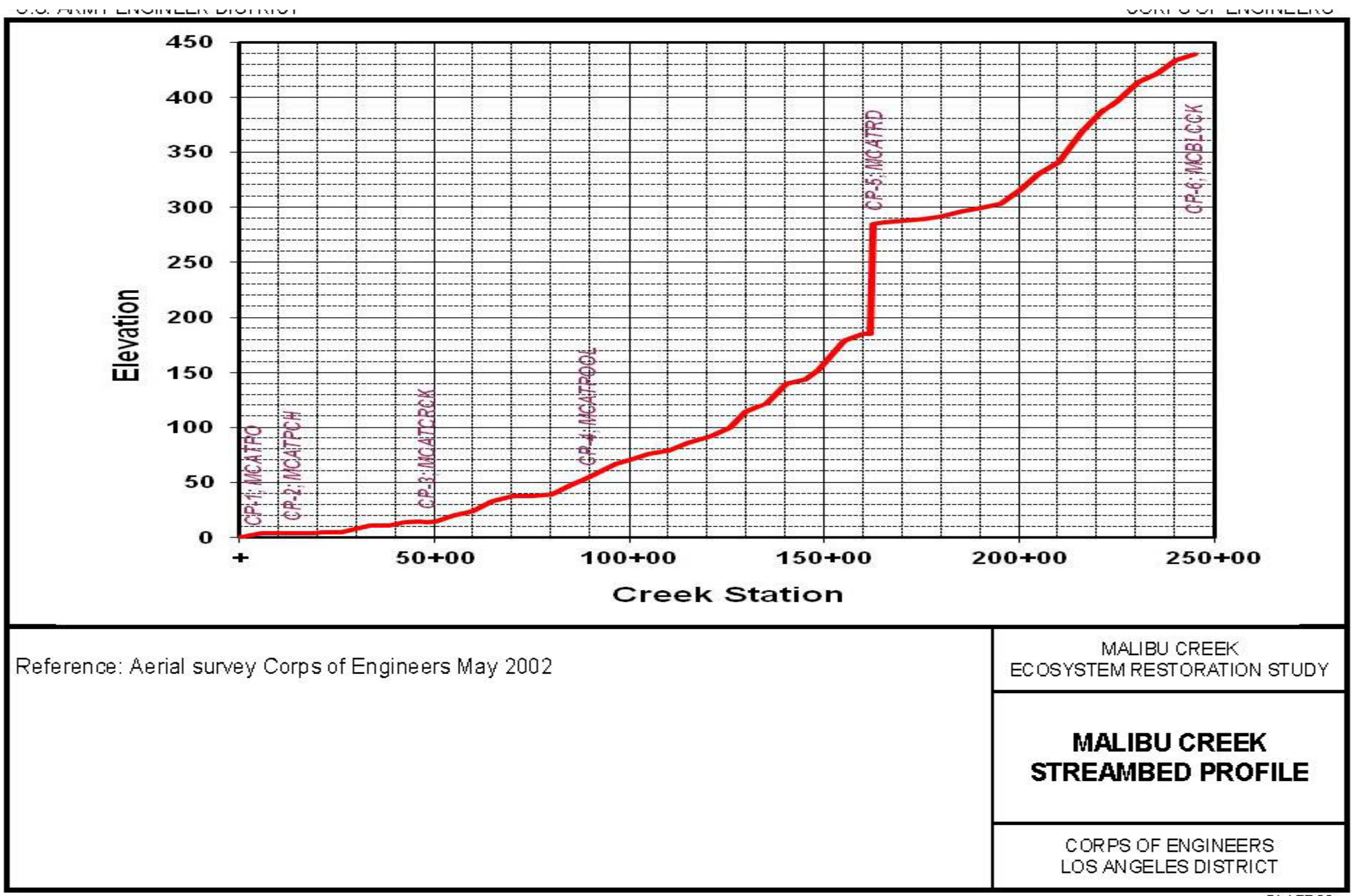


Plate 13-2 Malibu Creek Streambed Profile

Channel and overbank sections were determined using ArcGIS, HEC-GeoRAS, and a TIN based on aerial survey mapping at a scale of 1” = 200’ scale with 2- foot contour interval as well as field measurements. Bridge data for the Pacific Coast Highway bridge was acquired from CalTrans. Bridge data for the Cross Creek Road bridge was provided by a representative for the constructing authority. Photographs along Malibu Creek within the study area are shown in Exhibit A. Typical cross sections are included in Exhibit B.

The default contraction and expansion coefficients of 0.1 and 0.3 respectively were used for all open channel sections including upstream and downstream of the bridges. Bridge piers were modeled with 2-ft of debris on each side for both bridges. The Cross Creek Road bridge was designed to be overtopped during frequent events and plays little part in altering flows. It was determined during the initial analysis that flows in the right overbank are unconfined over a large area. An artificial boundary for ineffective flow was used in the right overbank based on an expansion ratio of 3 longitudinal to 1 horizontal for flows coming out of the canyon starting just below the Cross Creek Road bridge. The base conditions model input report is shown in Exhibit C.

The downstream boundary condition for all simulations was set to the estimated MHHW tide level of 5.5 ft. Steady flow conditions were simulated. Flow change locations were set at the river station closest to the CPs identified in the hydrologic analysis. Peak discharges for 8 frequency flood events were modeled.

13.3 Model Simulations

For much of the river, the flow nears a Froude number of 1. The modeling indicates that the water surface elevation is not as sensitive to changes in roughness as changes in cross sectional area at a given location, due to the steepness of the channel which causes the creek to flow near critical depth in many places (basically the backwater effect of downstream roughness changes is not propagating upstream of cross sections experiencing critical depth. Including additional cross sections was necessary to improve the accuracy and stability of the flow modeling. In some cases, the additional cross sections decreased the Froude number and shifted more water surface control to the roughness coefficient. Supercritical flow conditions can occur in some channel reaches, but typically cannot be sustained in natural creeks. The HEC-RAS program was set for subcritical analyses to determine flood elevations and energy grade lines. Results from the HEC-RAS computer runs are included in Exhibit D.

Based on the frequency discharges at the selected CP locations, inundation areas for existing conditions were generated for the 50% (2-yr), 20% (5-yr), 10% (10-yr), 5% (20-yr), 2% (50-yr), 1% (100-yr), 0.5% (200-yr), and 0.2% (500-yr) ACE events using the HEC-RAS hydraulic model. **Plate 13-3** and **Plate 13-4** show the inundation areas for the 10% (10-yr) and 1% (100-yr) ACE events under existing conditions (note: **Plate 13-4** includes the FEMA 100-yr floodplain for comparison). The inundation area maps for the remainder of the modeled events are presented in Exhibit E and show the overflow areas along Malibu Creek for the study reaches. The floodplains for the selected frequency events were delineated using ArcGIS, HEC-GeoRAS, and a TIN based on aerial survey mapping at a scale of 1” = 200’ scale with 2-foot contour interval.

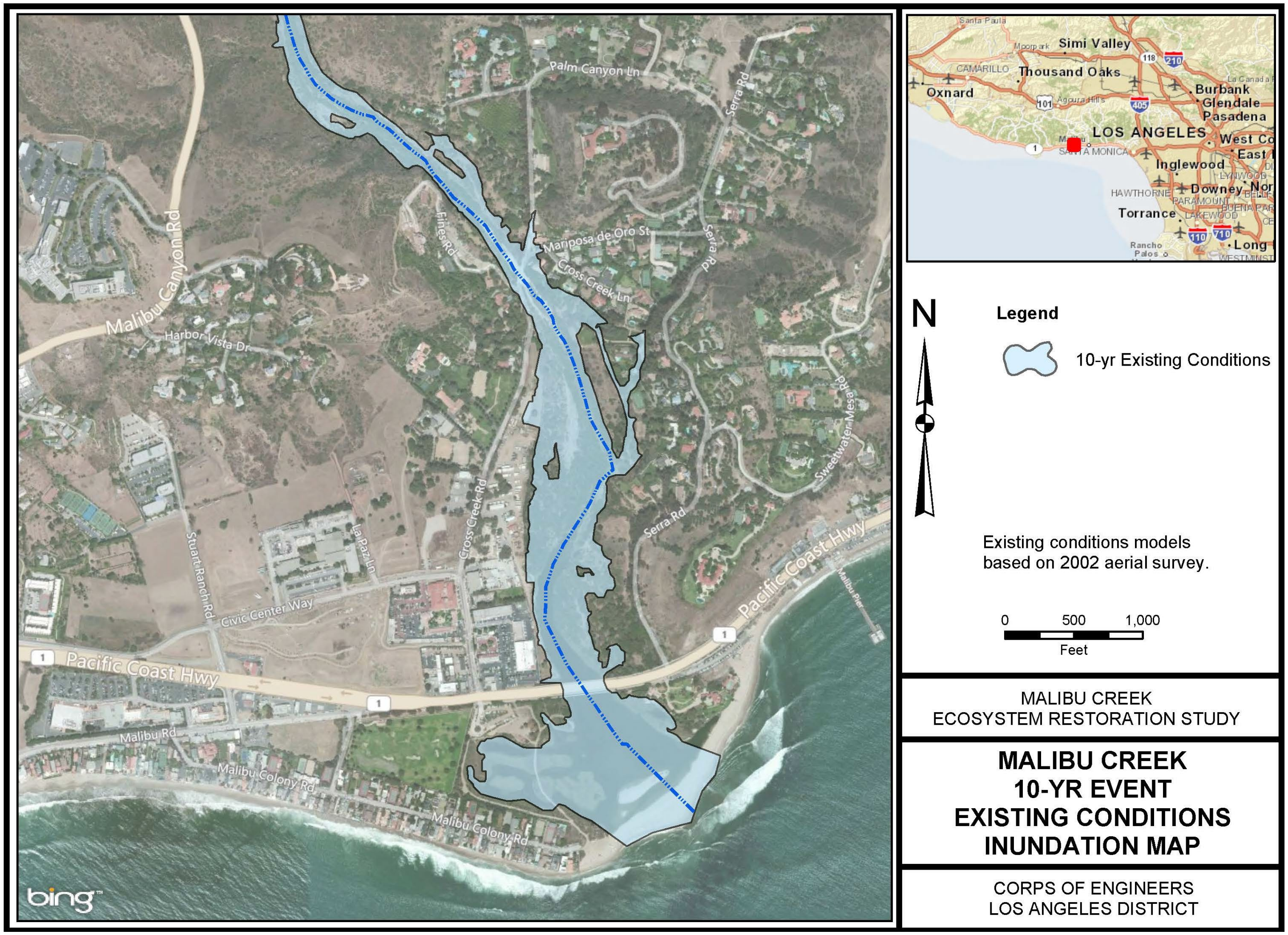


Plate 13-3 Malibu Creek 10-YR Event Existing Conditions Inundation Map

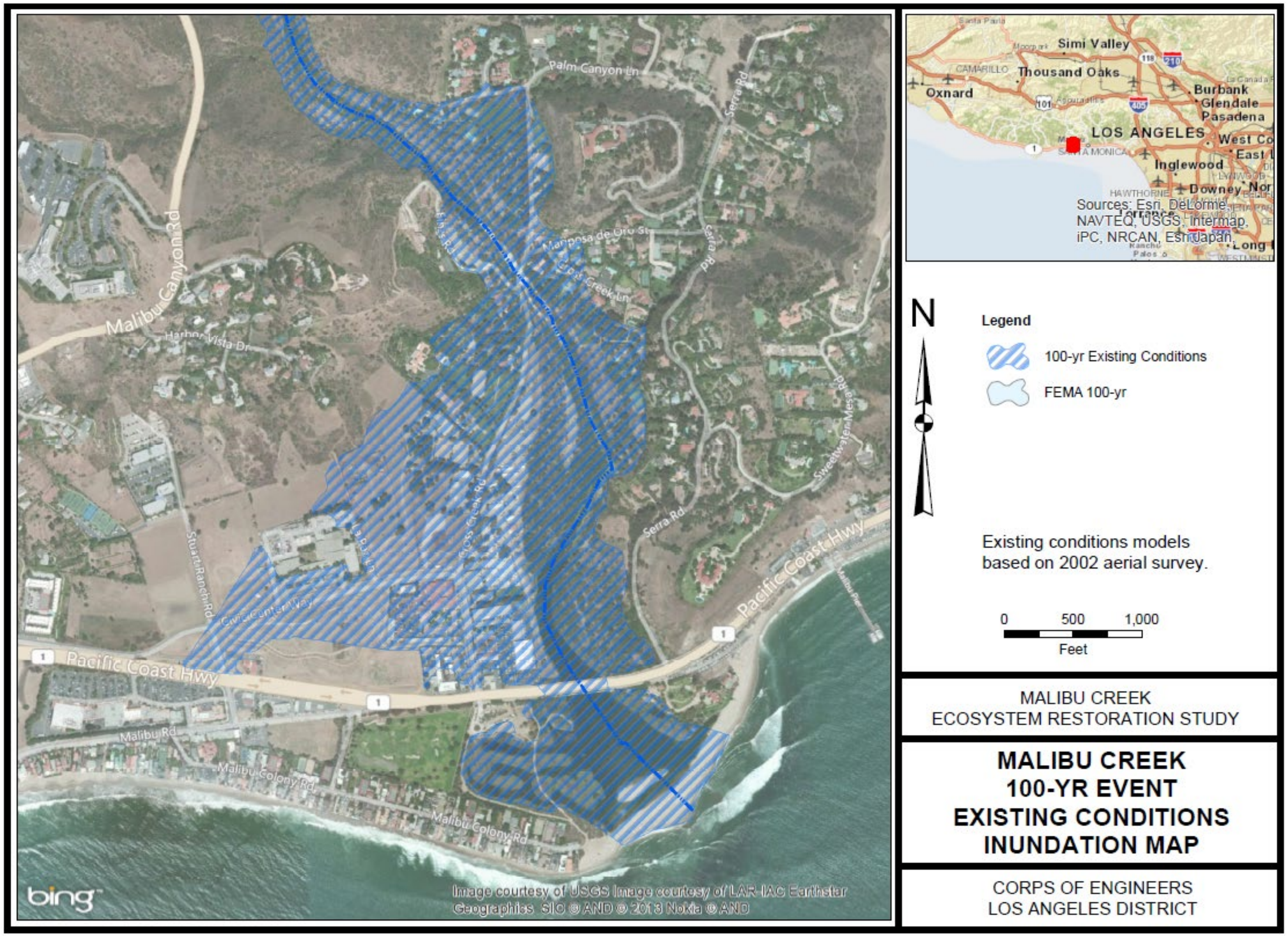


Plate 13-4 Malibu Creek 100-YR Event Existing Conditions Inundation Map

Flows in the Malibu Creek watershed are in typically well-incised streams with relatively high velocities. Flood profiles have been prepared for the project area for the selected frequencies. The resulting water surface profiles for the 50% (2-yr), 20% (5-yr), 10% (10-yr), 5% (20-yr), 2% (50-yr), 1% (100-yr), 0.5% (200-yr), and 0.2% (500-yr) ACE events are included in Exhibit F.

13.4 FEMA FIS Study

The latest FEMA hydraulic study is discussed here for comparison. The 1998 Flood Insurance Study models used Manning's "n" values ranging from 0.030 for the main channel and 0.050 for the overbanks. The values used for the Cross Creek Road bridge design were 0.040 for the channel and 0.065 for the overbanks. Field reconnaissance, reference material, and previous studies by the USACE indicated these values might be low, especially in the upper reaches of the project. Considering the amount of vegetation along and within the channel, as well as the size of the boulders present, one would expect higher roughness coefficients.

Reasonable estimates for the Manning's n-values for the Malibu Creek area influenced by the lagoon are 0.040 for the channel and 0.060 for the overbanks. For the area downstream from the canyon mouth to the upstream extent of the lagoon the roughness coefficients were set to 0.045 for the channel and 0.065 for the overbanks. The roughness values were increased to 0.065 for the channel and 0.080 for the overbanks in the canyon area to reflect the large boulders and amount of vegetation present. A sensitivity analysis was performed to evaluate the significance of using the higher roughness coefficients (than FEMA study) along the main channel and overbanks. **Table 13-1** shows the results of the Manning's n-value sensitivity analysis.

Table 13-1 Results of Manning's n Sensitivity Analysis

Reach	Representative Cross-section	1% Flood ΔWS (ft)	10% Flood ΔWS (ft)
5	217+73.7	1.28	1.26
4	116+47.8	2.35	1.82
3	74+04.4	2.17	2.23
2	26+03.4	0.09	0.01
1	8+39.8	0.01	0.00

1% (100-year) and 10% (10-year) refer to ACE event.
One cross section per reach is shown – results are typical of average change for the reach.
ΔWS (ft) is the difference in water surface elevation

The analysis indicated 0 to 3 ft of difference in computed water surface elevations for the 1% ACE event (100-year) and 0 to 2 ft of difference for the 10% ACE event (10-year). The larger differences were in the upper part of the study area (within the canyon) where the changes in n values were higher. Considering the total depth in the canyon reaches of 20-25 ft during the 1% ACE event (100-year), the small differences validate using the higher Manning's n values for this study.

14.0 RISK AND UNCERTAINTY

The USACE Engineering Manual EM 1110-2-1619, "Risk-Based Analysis for Flood Damage Reduction Studies" describes and provides procedures for risk and uncertainty for USACE flood risk management studies.

The Hydrologic Engineering Center's Flood Damage Analysis (HEC-FDA) computer program provides the capability to perform an integrated hydrologic and hydraulic engineering and economic analysis during the formulation and evaluation of flood risk management plans. The program methodologies quantify uncertainty in the discharge-exceedance probability and stage-discharge functions and incorporate it into the performance analysis. The program applies a Monte Carlo simulation, a numerical-analysis procedure that computes the expected value of performance while explicitly accounting for the uncertainties in the base values.

The HEC-FDA program requires the division of the channel system into separate damage reaches for computational purposes. The damage reaches are defined as a segment of the channel which is similar and can be well defined by one cross section (Index Location) in that reach. For this study it was determined that Malibu Creek could be divided into 7 damage reaches from the Cold Creek confluence to the Pacific Ocean. The reaches are described in **Table 2-1** and the Index Locations are presented in **Table 14-1** and shown on **Plate 14-1**.

Table 14-1 Index Locations

Reach	Index Location River Station	Equivalent Record (yrs)	Left Bank Elevation (ft)	Right Bank Elevation (ft)
5	204+98.7	68	339.0	339.0
4b	140+10.8	68	148.0	155.0
4a	108+39.2	68	88.2	88.0
3	68+81.4	68	47.0	53.0
2b	40+35.5	68	26.0	26.0
2a	21+18.8	68	15.0	17.0
1	8+39.8	68	8.0	7.0

The hydrologic inputs for the HEC-FDA program are the discharge-frequency relationships at each index location along with the equivalent years of record. The median probability frequency-discharges are shown in **Table 12-4** and the equivalent years of record are listed in **Table 14-1**. The equivalent years of record were set equal to the period of record for the Malibu Creek below Cold Creek stream gage.

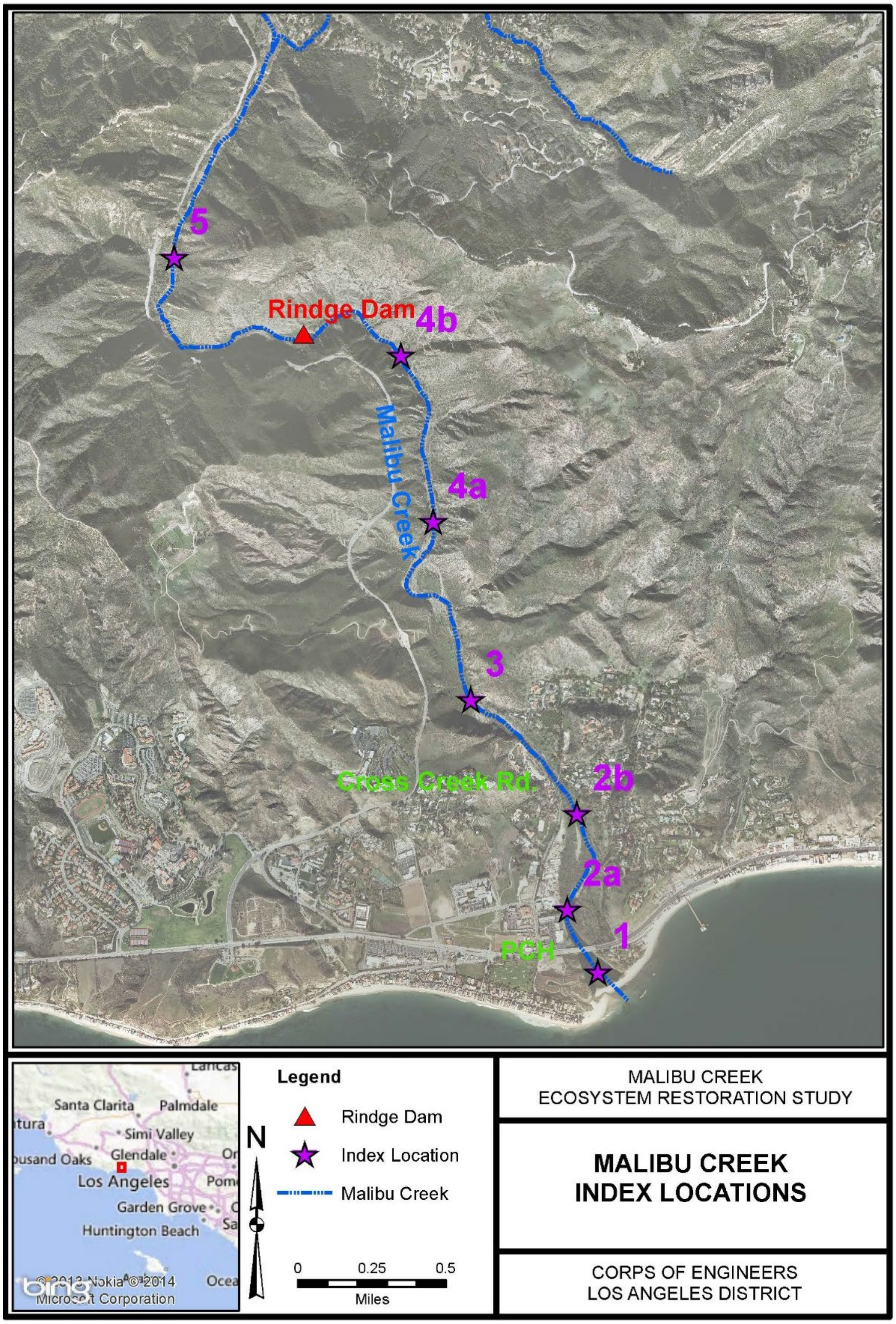


Plate 14-1 Malibu Creek Index Locations

The hydraulic inputs for the HEC-FDA program are the stage-frequency relationships based on the median probability discharges along with an estimate of the standard deviation. The gage rating data for the Malibu Creek stream gage was not available. Therefore, the procedure for ungaged locations from EM 1110-2-1619 was used. Uncertainty due to natural variations ($S_{natural}$) was combined with the values from modeling uncertainty (S_{model}) to obtain an estimate of total uncertainty (S_{total}) for each modeled reach. The modeling uncertainties for with-project condition did not take into account channel invert changes from the sediment transport analysis. The relative differences are not considered significant and alternative uncertainties are set equal to the without-project conditions.

Equation 5-5 from EM 1110-2-1619 was used to predict the uncertainty due to natural variations in river stages. The natural uncertainty is a function of the maximum expected or observed stage range, the basin area, the 100-yr discharge, and a stream bed identifier for the size bed material which controls flow in the reach of interest.

The procedure for estimating the uncertainty for numerical models is to estimate the reasonable upper and lower bounds for stage for a given discharge and converting the resulting range into the standard deviation of error in stage statistic. The computed water surface elevations using "best estimate" of Manning's n value and 2-foot debris on both sides of bridge piers were determined. An “upper” limit was determined by increasing Manning's n value by 25% and leaving 2-foot debris on both sides of bridge piers. The “lower” limit was determined by decreasing Manning's n value by 25% and removing debris from all bridge piers. The range between the upper and lower limit water stages is then used to estimate the standard deviation for models of stage uncertainty.

The total uncertainty is then calculated based on the following formula:

$$S_{total} = (S_{natural}^2 + S_{model}^2)^{0.5}$$

Results for hydraulic uncertainty are shown in Exhibit G.

15.0 SEDIMENT TRANSPORT ANALYSIS

15.1 General

The sediment transport capacity refers to the amount and size of sediment that the creek has the ability, or energy, to transport. The key components that control the sediment transport capacity are the velocity and depth of the water moving through the channel. Velocity and depth are controlled by the channel slope and dimensions, discharge (volume and magnitude of flow), and roughness of the channel. Changes in any of these parameters will result in a change in the sediment transport capacity of the creek. The specific characteristics of the sediment load are another key factor influencing channel form and process. The load is the total amount of sediment being transported. There are 3 types of sediment load in the creek: dissolved, suspended, and bed load. The dissolved load is made of the solutes that are generally derived from chemical weathering of bedrock and soils. Fine sands, clay, and silt are typically transported as suspended load. The suspended load is held aloft in the water column by turbulence. The bed load is made up of sands, gravels, cobbles, and boulders. Bed load is transported by rolling, sliding, and bouncing along the bed of the channel. While dissolved and suspended loads are important components of the total sediment load, in most river systems, the bed load is what influences the channel morphology and stability.

The objective of the sediment transport analysis is to identify baseline and future sediment conditions, which would be used with later alternative conditions studies to identify the preferred project alternative. The baseline conditions are with the dam in place and filled with sediment. A base conditions sediment transport model was created using the geometry from the existing conditions hydraulic models described in a previous section. The models are run using a period-of-record hydrograph consisting of historic flows between 1931 and 2005 was simulated. The results at the 50-year mark in the simulations are applicable for Future Conditions.

The computer program HEC-6T "Sedimentation in Stream Networks," version 5.13.20 of 10 February 2003 was used to conduct the numerical sediment transport modeling in this study. HEC-6T was developed by Mr. William A. Thomas of Mobile Boundary Hydraulics, Clinton, Mississippi.

15.2 <u>HEC-RAS Model Conversion</u>

15.2.1 Model Geometry

The computer program RAS2H6T was used to convert the HEC-RAS geometry (malibu3.g01) into a text file compatible with the HEC-6T program. Conveyance limits defined in HEC-RAS using ineffective flow boundaries were coded using XL records in HEC-6T. The advantage of using XL records is that they allow deposition to occur in the ineffective flow areas. The effect of bridges crossing the river in the study area was accounted for using a single cross-section with the pier geometry superimposed. Of the two bounding cross-sections used to define each bridge in HEC-RAS, only the upstream one was retained in HEC-6T.

15.2.2 Fixed Bed Simulation

A known water surface elevation of 5.5 ft was used as the downstream boundary condition for all discharges. This elevation corresponds to the MHHW.

Fixed bed simulations were conducted for the 50% (2-yr), 10% (10-yr), 1% (100-yr), and 0.2% (500-yr) ACE events to simulate a range of discharges that the sediment model would encounter during the movable bed simulations. The water surface elevations computed by HEC-6T for each of the simulated events were compared to the HEC-RAS results. The resulting water surfaces were on average less than 1 ft from the HEC-RAS water surfaces.

15.3 <u>Sediment Parameters</u>

The USACE computer program SAMAID was used to select the most appropriate sediment transport relationship. SAMAID results indicated that the Toffaleti-Schoklitch, Toffaleti and Meyer-Peter and Müller, and Laursen-Madden sediment transport functions were the first, second, and third best sediment transport relations for the hydraulic and bed material characteristics of the study reach. The Toffaleti-Schoklitch transport function was used for this study. The latter two transport functions were used in the numerical model and tested for sensitivity.

15.3.1 Bed Sediment Characteristics.

Seven locations were identified for sediment sampling and development of gradation curves. Sampling sites (**Plate 15-1**) were located approximately 0.25 to 0.75 mi apart along Malibu Creek, from RS 26+03.4 to RS 245+00.0 Samples were collected from 0 to 2 ft, and laboratory sieve analyses were performed on the samples. In addition, an in-situ particle count was performed for larger sized particles. The laboratory results and in-situ particle counts were then combined and the bed gradation data were entered in to HEC-6T input file using PF records. Sediment gradations for sample locations are shown on **Figure 15-1**.

Eight additional reservoir boring samples were used within the reservoir. In the fall of 2002, the USACE's' Geotechnical Branch from the Los Angeles District undertook drilling and sampling of impounded sediment behind Rindge dam to classify sediment grain size, allow estimating of sediment quantities by sediment type, and to assess whether any environmental contaminants are present in the sediment. The upper 0-3 ft of the data was used for the baseline conditions sediment transport model. Sediment gradations for sample locations at Rindge Dam are presented on **Figure 15-2**. Sample locations are shown in the Geotechnical Appendix.

15.3.2 Inflowing Sediment Rating Curve

Due to a lack of adequate data on inflowing sediment loads into the study reach, an equilibrium bed material load was assumed. The inflowing load at the upstream end of the model was determined on a reach approximately 0.25 mi long at the upstream end of the study reach (from RS 231+98 to RS 245+00) with the gradation information from the most upstream sediment sample location. Equilibrium sediment loads for this reach were determined for a range of discharges from 20 to 85,000 ft³/s. To determine the equilibrium load, HEC-6T was run using clear water inflow as the initial condition with the recirculation option turned on ($RE record). The recirculation option instructs the program to use the sediment discharge at the downstream end of the reach as the sediment inflow at the upstream end for the following time step. When equilibrium is attained, sediment load entering the reach is about equal to the load leaving the reach. For discharges between 20 and 100 ft³/s, the simulations were run typically for 10 days with a time step of 0.01 days. For larger discharges (500 to 85,000 ft³/s), typical durations were between 20 and 100 days with a time step of 0.001 days.

The inflowing sediment loads defined with Toffaleti-Schoklitch relationships are shown in **Figure 15-3**. The gradation of the inflowing load from the equilibrium analysis is shown in **Figure 15-4**. This information was entered into the HEC-6T input files using LQ, LT, and LF records.

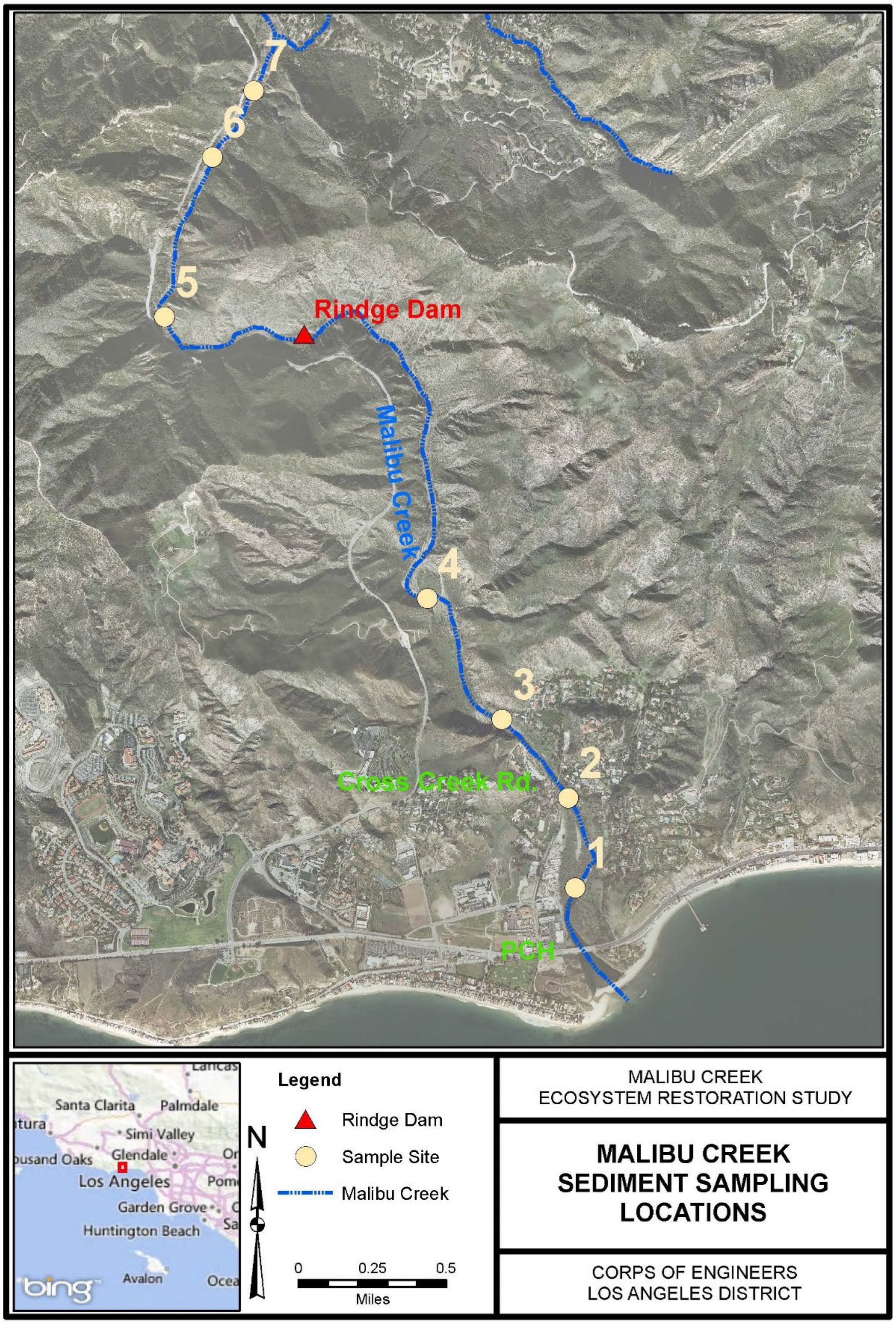


Plate 15-1 Malibu Creek, Sediment Sampling Locations

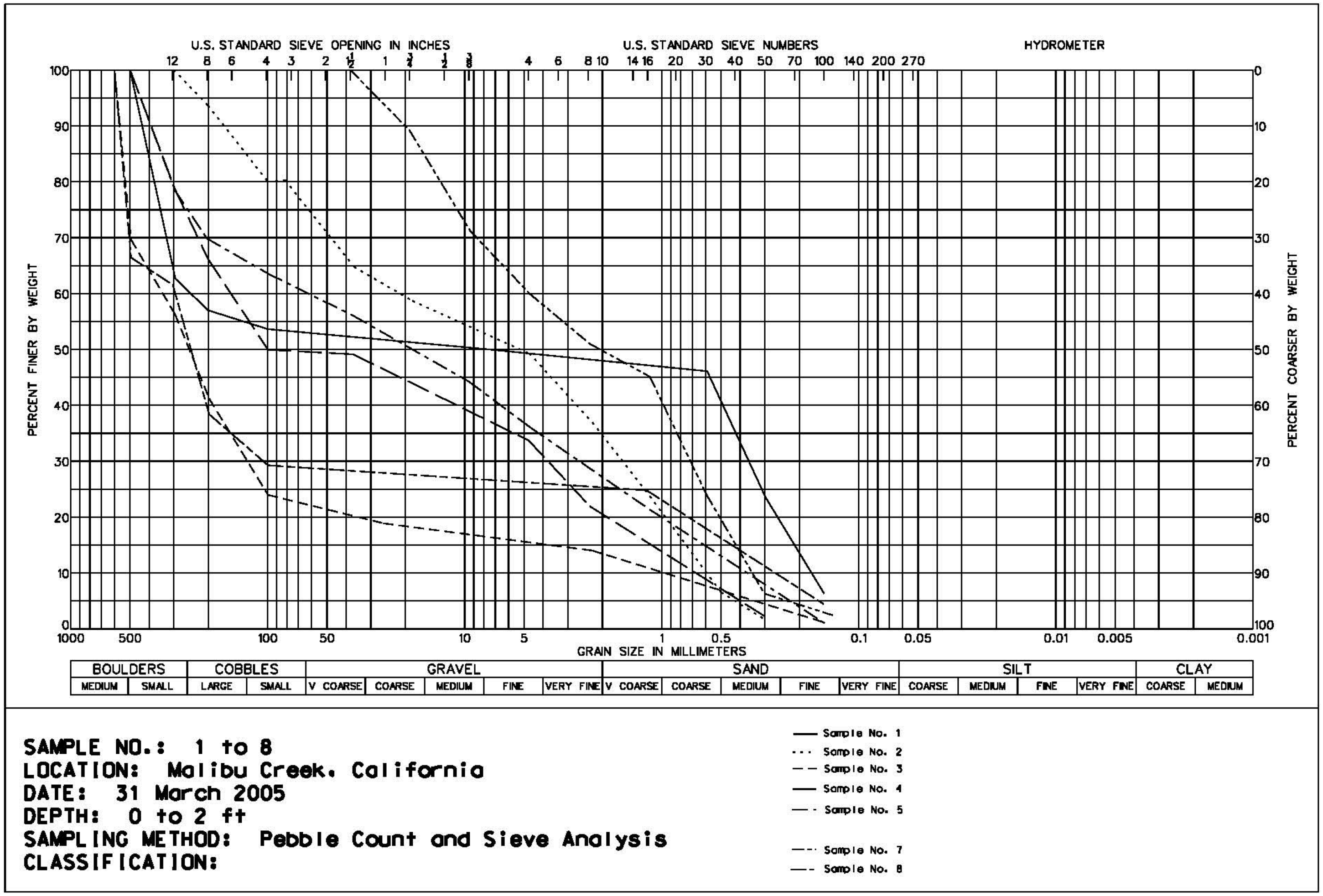


Figure 15-1 Sediment Gradations for Sample Locations

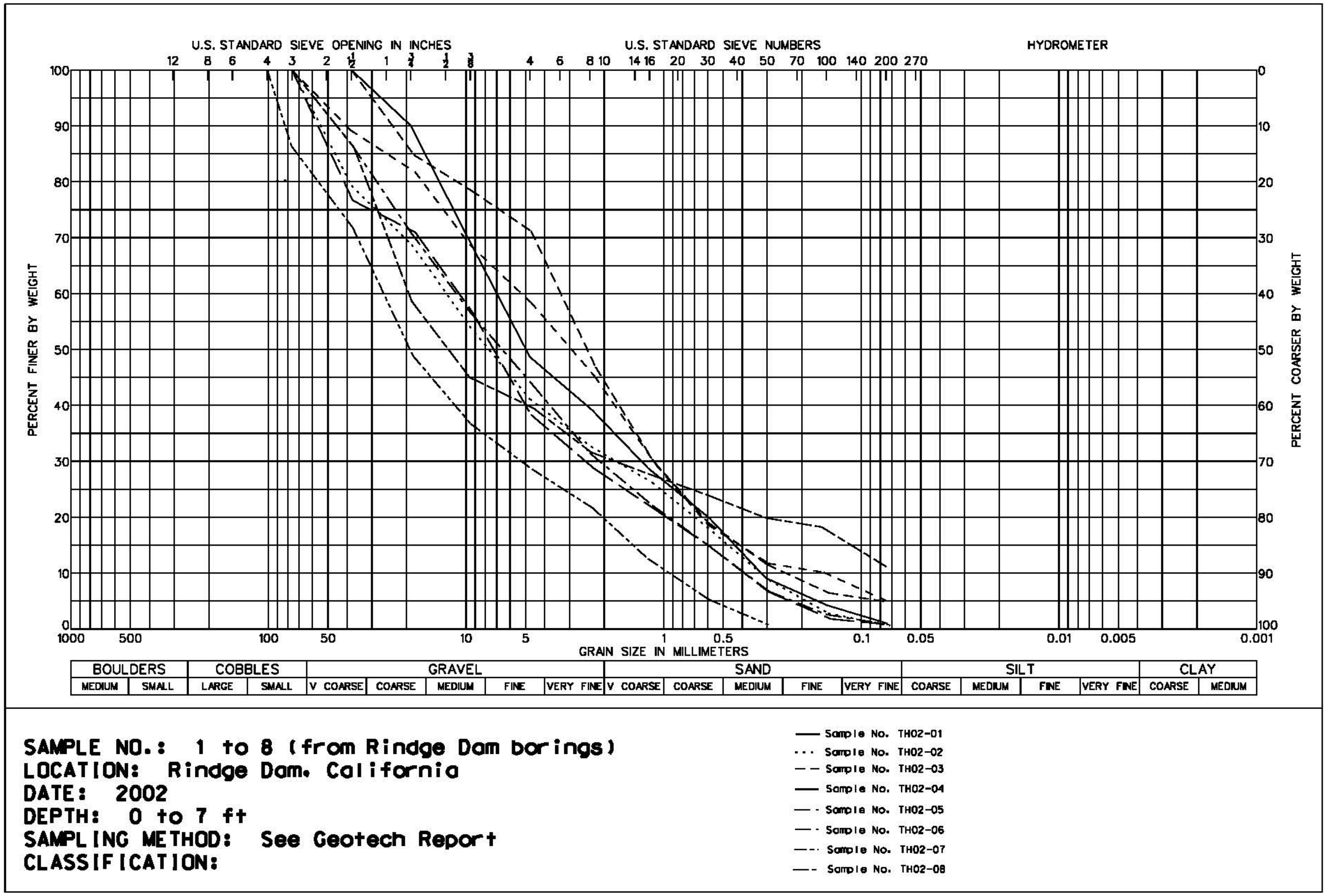


Figure 15-2 Sediment Gradations for Rindge Dam Sampling Locations

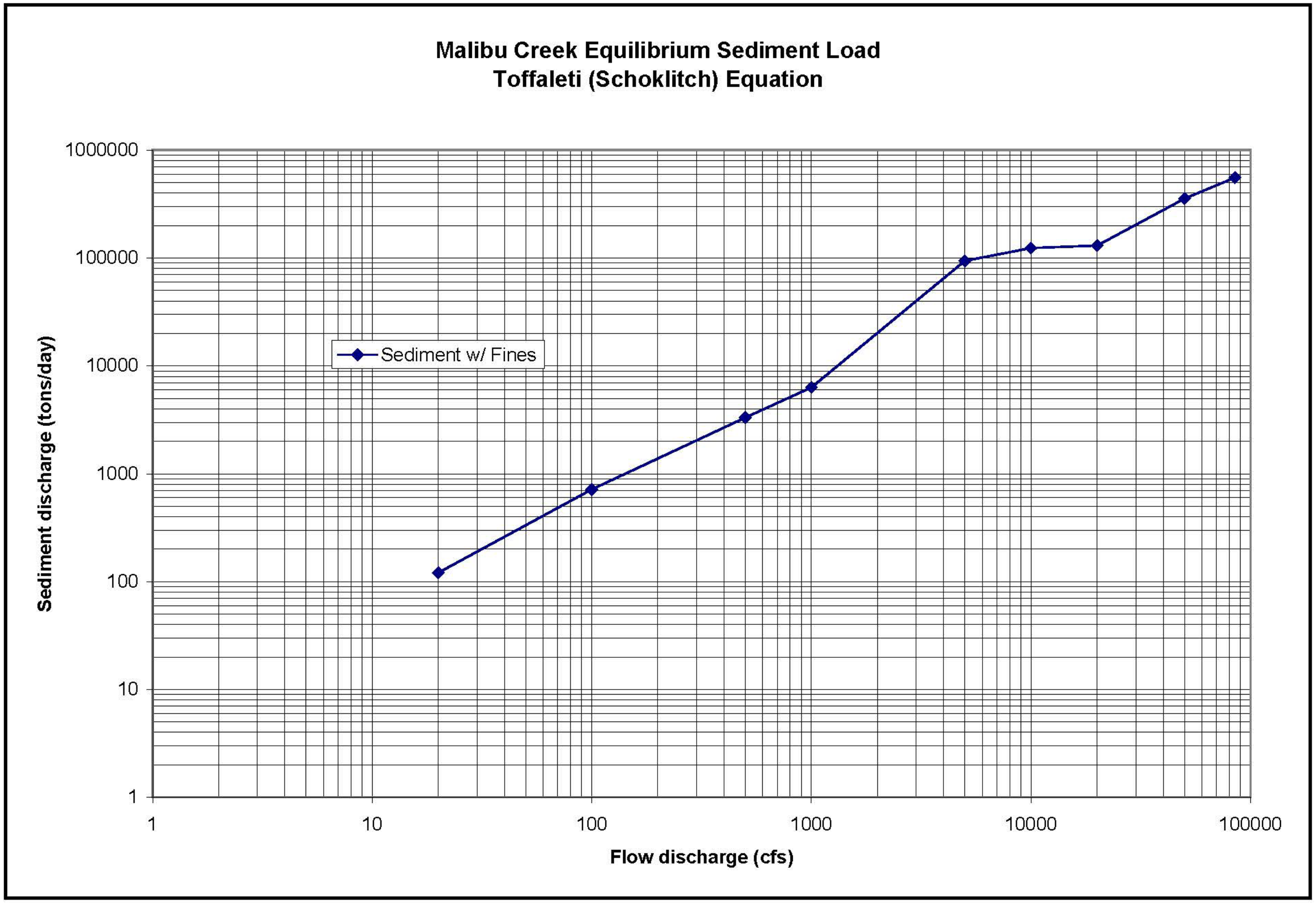


Figure 15-3 Equilibrium Sediment Load - Toffaleti (Schoklitch) Equation

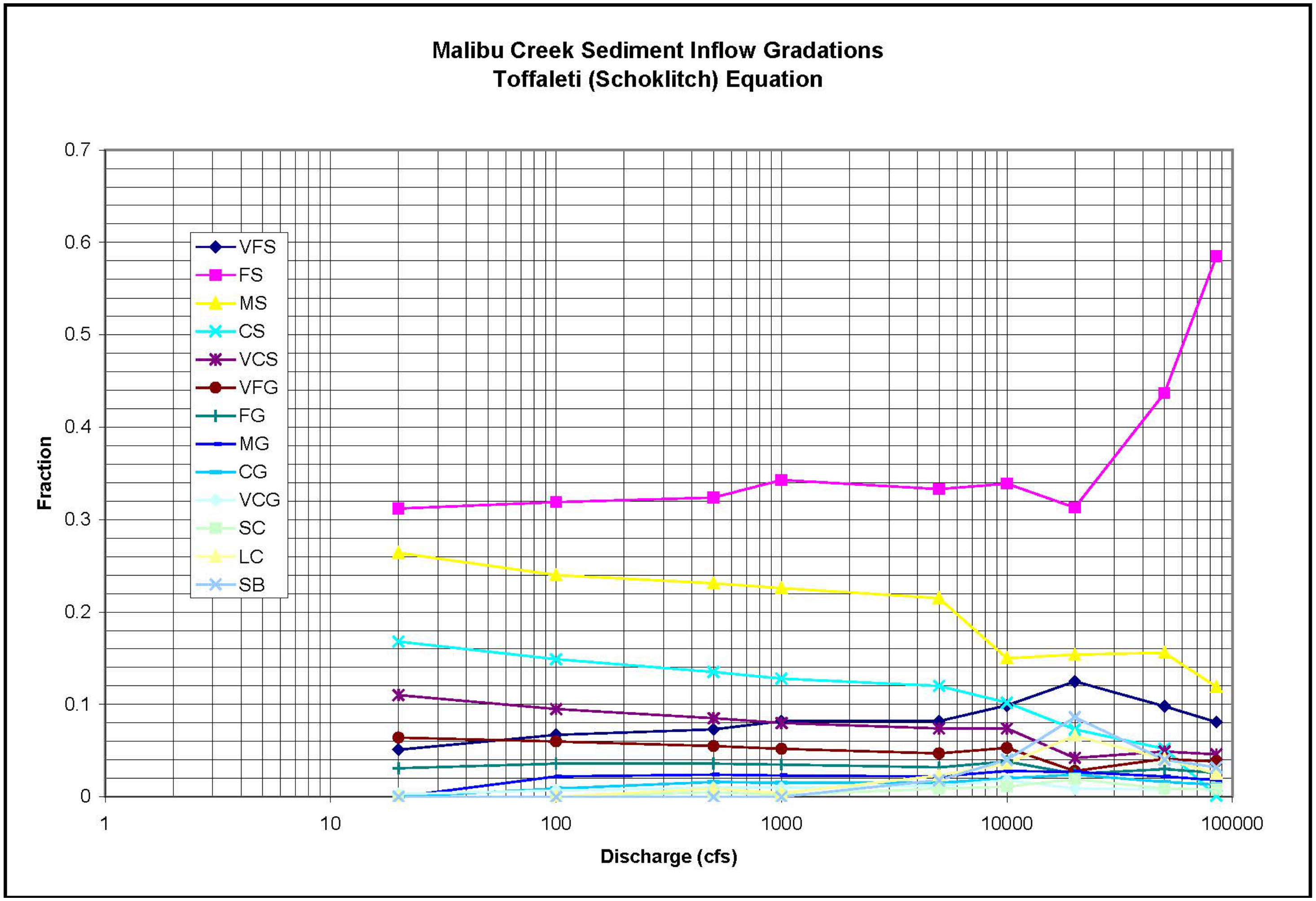


Figure 15-4 Sediment Inflow Gradation - Toffaleti (Schoklitch) Equation

15.3.3 Movable Bed Limits

In general, sediment dynamics tend to be more significant within the active channel, where the bed can either degrade or aggrade in response to erosion or deposition. The overbank areas tend to be more stable and normally are free of erosion, but can experience deposition. HD records were used to specify a bed sediment depth of 10 ft for most cross- sections, except at the dam embankment and bedrock outcrops, where the sediment depths were set to 0 ft. Movable bed limits were identified in the HD records. In addition, HE records were used to limit erosion within the channel bank stations.

15.4 Hydrologic Input

A period-of-record hydrograph consisting of historic flows between 1931 and 2005 was simulated. Discharges less than 200 ft^3/s were removed from the hydrograph since little sediment transport would occur for flows less than 200 ft^3/s.

Simulations were performed with the 75-year hydrograph, with simulation results reported by decade. **Plate 12-3** shows the complete 75-year period-of-record and identifies the end of each decade.

In addition, balanced hydrographs for the 50% (2-yr), 20% (5-yr), 10% (10-yr), 5% (20-yr), 2% (50-yr), 1% (100-yr), 0.5% (200-yr), and 0.2% (500-yr) events were simulated. The individual balanced hydrographs are shown in **Plate 12-5 through Plate 12-12**.

15.5 Calibration and Verification

Calibration and verification of the model is not typically possible due to lack of prototype data, e.g. suspended and bed material samples during flood events. This situation is common of ephemeral streams located in the Southwest.

However, survey information showing changes in channel geometry in the Malibu Lagoon is available. The resulting changes in geometry were compared and used to adjust the numerical model and decrease the uncertainty in the rates and volumes of sediment transport.

Surveys of the lagoon were taken in 2004 and 2005. The baseline conditions sediment model used the 2004 survey and a one year period-of-record hydrograph was simulated in the sediment model. The resulting geometry was then compared to the 2005 survey. The survey results show a net loss of 2,750 yd^3, or 0.13 ft, from the lagoon area between 2004 and 2005, while the model shows a net gain of 22,280 yd^3, or 1.1 ft.

The large difference in results may possibly be attributed to factors other than the sediment inflow from the creek to the lagoon. The long-shore drift of sediments, combined with the sediment brought down by the creek itself, cause the opening of the lagoon to fill in and close completely several times during the year. In order to more accurately evaluate the impacts at the lagoon, several iterations of the downstream boundary condition were simulated. Seasonal weighting factors were then applied to the results from each to reflect whether the opening to the ocean was closed or not.

Three cases of tidal of boundary conditions were analyzed. The first is a constant elevation of 5.5 ft, which corresponds to MHHW. This is the original model assumption discussed above. The second boundary condition analyzed is a weighted average to simulate a tidal variation. The third boundary condition analyzed is an hourly variation of the tidal boundary. As expected, the resulting volume differences varied with the different assumed boundary conditions. The MHHW boundary condition resulted in 22,280 yd³, or 1.1 ft, of deposition. The weighted average distribution boundary condition resulted in 53 yd³, or .003 ft, of deposition. Finally, the hourly tidal variation boundary condition resulted in 938 yd³, or 0.4 ft, of scour.

The calibration process using the model with the hourly variation of the tide closely replicates the survey results. The model with the weighted average tidal variation also yields reasonable results. More importantly, the above outcomes show that the differences in results are mainly due to the tidal boundary assumed, not the sediment parameters used in the numerical model. Therefore, no adjustments are necessary for the numerical model in the lagoon area and the model with the tide variation is sufficient for use for baseline conditions and as a tool for comparing alternatives.

15.6 Period-of-Record Simulation

The period-of-record simulation represents the future without-project conditions. Even though the simulations used a 75-year daily flow hydrograph for the period- of-record, for the most part, the results do not show significant changes after 50 years (Future Conditions). The results of the period-of-record simulation are shown in **Table 15-1** and **Plate 15-2 and Plate 15-3**. **Table 15-2** presents the accumulated sand delivery during the period of record.

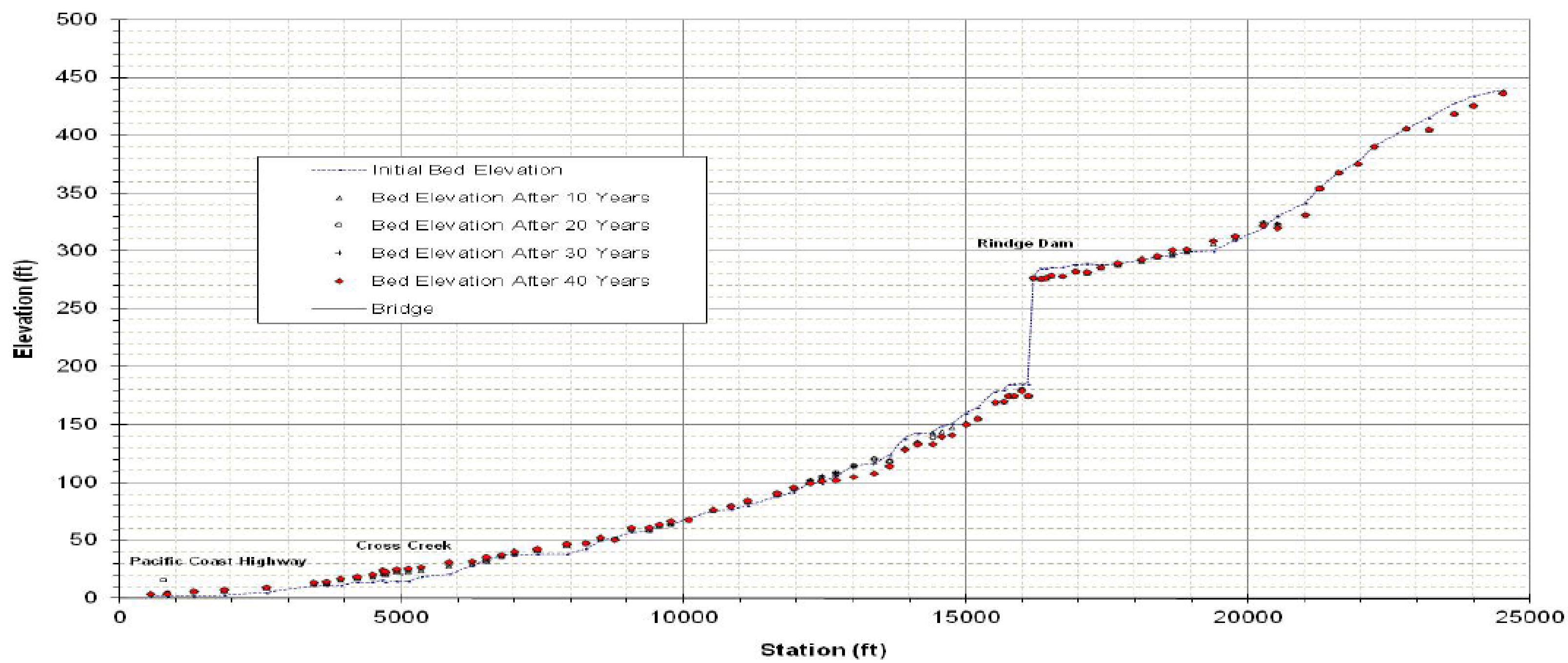
Table 15-1 Future Without-Project - Sediment Transport Results for Period of Record

Station	Initial Bed Elevation	Change in Bed Elevation After												Avg Annual Change
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	
550.6	2.2	0.0	0.5	0.8	0.7	0.8	2.1	2.1	2.1	1.9	2.0	1.9	2.1	0.3
839.8	1.7	0.0	0.9	1.5	1.7	1.7	3.0	2.9	2.9	2.6	2.7	2.8	2.7	0.4
1320.8	2.0	0.1	1.4	2.0	2.1	2.2	4.4	4.3	4.6	4.3	4.8	4.9	5.0	0.8
1846.3	3.0	0.3	0.4	1.3	1.5	1.7	4.3	4.4	4.9	4.6	5.2	5.4	6.1	1.0
2603.4	5.0	0.0	0.0	0.6	1.0	1.3	4.4	4.7	5.1	5.1	5.9	5.9	6.9	1.1
3445.8	11.0	-0.3	-1.0	-0.9	-0.9	-0.8	1.5	2.1	2.7	3.1	3.8	3.9	5.5	0.9
3670.5	11.0	0.0	-0.4	-0.3	0.0	-0.1	2.5	3.2	3.9	4.3	5.0	5.2	6.7	1.1
3906.8	11.0	0.0	1.6	2.1	2.4	2.3	4.8	5.7	6.5	6.5	7.5	7.7	9.5	1.5
4203.5	14.0	-0.3	-0.4	-0.1	0.2	0.2	3.5	4.5	5.5	5.5	6.5	6.8	8.6	1.4
4486.6	14.0	-0.1	1.0	1.4	1.9	1.8	4.2	5.4	6.4	6.6	7.5	7.6	9.6	1.5
4653.8	16.0	0.0	1.1	1.4	2.2	2.3	5.9	7.0	8.2	8.3	9.4	9.5	11.7	1.9
4705.1	14.0	0.6	3.1	2.3	3.6	3.3	6.5	7.7	8.8	9.0	10.0	10.1	12.3	2.0
4900.6	15.0	1.3	3.1	3.5	4.2	4.4	7.8	9.1	10.3	10.0	11.5	11.6	13.8	2.2
5117.6	15.0	0.1	2.6	3.0	4.0	4.2	8.0	9.4	10.5	10.9	11.8	11.8	14.1	2.3
5344.1	19.0	-0.2	0.8	1.5	2.2	2.4	5.5	7.0	8.1	7.5	9.2	9.4	11.6	1.9
5844.0	21.0	0.0	0.1	0.2	2.1	2.1	6.9	8.3	9.5	10.5	11.2	11.3	13.4	2.1
6237.3	28.0	-0.2	-0.3	-0.3	-0.3	-0.3	2.2	4.0	4.8	4.5	6.0	6.2	8.2	1.3
6490.1	33.0	-0.2	-0.3	-0.3	-0.5	-0.5	-0.8	0.3	1.7	2.8	3.5	3.5	5.8	0.9
6755.7	37.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.3	-0.2	0.2	1.0	1.6	1.6	3.5	0.6
6993.4	38.0	0.0	0.3	0.5	0.5	0.5	0.9	1.2	1.6	2.7	3.2	3.2	5.6	0.9
7404.4	38.0	0.5	1.9	2.5	2.9	3.0	3.8	3.9	4.3	4.7	5.4	5.4	6.1	1.0
7917.0	38.0	0.6	5.5	6.3	6.4	6.5	7.7	8.5	8.8	9.3	10.8	10.9	13.6	2.2
8262.6	43.0	-0.1	1.4	2.6	4.0	4.1	4.8	5.1	5.2	5.0	5.8	5.8	5.9	1.0
8533.1	50.0	-0.1	-0.2	-0.2	0.4	0.4	1.5	2.3	2.3	3.3	4.2	4.2	6.2	1.0
8770.2	53.0	0.0	-0.1	-0.2	-0.3	-0.3	-1.6	-1.7	-1.9	-2.8	-2.8	-2.7	-0.8	-0.1
9072.9	57.0	0.1	0.7	0.9	1.3	1.3	3.0	3.4	3.5	4.7	4.7	4.7	4.8	0.8
9385.9	58.0	-0.1	-0.3	-0.4	-0.4	-0.4	0.0	-0.5	0.8	2.8	3.6	3.6	4.7	0.8

Station	Initial Bed Elevation	Change in Bed Elevation After 1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	Avg Annual Change
9556.0	63.0	-0.1	-0.2	-0.2	-0.3	-0.3	-0.4	-0.2	-0.3	1.1	1.5	1.5	1.9	0.3
9779.9	64.0	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.3	0.0	1.5	1.9	1.9	2.9	0.5
10082.0	69.0	-0.1	0.0	-0.1	-0.1	-0.1	-0.8	-0.9	-1.0	-0.6	-0.6	-0.7	0.0	0.0
10524.0	76.0	0.0	0.1	0.1	0.2	0.2	0.0	0.1	0.2	-0.7	-0.7	-0.7	-0.9	-0.1
10839.0	77.0	1.2	2.9	2.9	3.0	3.0	3.2	3.3	3.0	2.7	2.8	2.8	2.9	0.5
11121.0	80.0	0.3	2.2	2.6	2.8	2.8	3.3	3.5	3.5	1.6	1.8	1.7	1.9	0.3
11648.0	88.0	0.1	0.7	0.5	0.8	0.8	0.9	0.9	1.4	0.6	0.3	0.3	0.7	0.1
11948.0	92.0	0.0	0.7	0.8	1.3	1.3	2.0	2.3	2.3	-3.9	-4.0	-4.0	-4.1	-0.7
12224.0	99.0	0.0	0.0	-0.3	0.1	0.1	0.6	1.2	0.6	-3.5	-3.7	-3.7	-3.8	-0.6
12444.0	99.0	0.2	2.2	2.3	3.4	3.4	3.3	4.2	3.0	-8.9	-8.9	-8.9	-8.9	-1.4
12689.0	106.0	-0.2	-1.6	-1.7	-1.9	-1.9	-2.7	-2.6	-2.7	-2.7	-2.7	-2.7	-2.7	-0.4
12999.0	114.0	0.1	-1.2	-1.5	-1.6	-1.6	-1.7	-2.5	-2.7	-2.7	-2.7	-2.7	-2.7	-0.4
13373.0	117.0	1.9	4.1	3.9	1.4	1.4	-1.5	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-0.4
13647.0	124.0	-1.6	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.4
13907.0	138.0	-0.9	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.4
14129.0	143.0	0.1	-0.3	-0.6	0.0	0.0	-1.5	-2.2	-2.4	-2.8	-2.8	-2.8	-2.8	-0.4
14394.0	143.0	0.4	3.4	3.5	3.4	3.4	2.2	-1.2	-2.8	-2.8	-2.8	-2.8	-2.8	-0.4
14559.0	149.0	0.0	0.7	0.5	1.9	1.9	-1.1	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.5
14747.0	151.0	0.1	2.4	2.7	-1.8	-1.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.5
14985.0	160.0	-0.5	-2.3	-2.7	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15196.0	165.0	-0.3	-0.4	-1.4	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15512.0	179.0	-0.4	-2.8	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15662.0	180.0	-0.4	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15764.0	185.0	-0.2	-2.6	-2.6	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15859.0	185.0	-0.1	-2.4	-2.5	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15990.0	185.0	5.6	3.3	3.0	2.2	2.2	1.7	1.6	1.7	0.6	0.6	0.8	0.8	0.1
16092.0	185.0	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
16201.0	277.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16326.0	285.0	-5.7	-8.4	-8.6	-8.7	-8.9	-8.5	-8.4	-8.7	-9.0	-8.0	-8.1	-7.0	-1.1

Station	Initial Bed Elevation	Change in Bed Elevation After 1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	Avg Annual Change
16409.0	285.0	-5.3	-7.6	-7.8	-8.1	-8.1	-8.2	-8.0	-8.0	-7.7	-7.7	-7.7	-7.5	-1.2
16503.0	286.0	-3.6	-7.2	-7.4	-8.0	-7.8	-7.4	-7.2	-7.0	-7.2	-6.7	-6.8	-5.6	-0.9
16704.0	286.0	-0.8	-5.2	-5.9	-6.2	-6.2	-7.4	-7.3	-7.5	-7.1	-7.1	-7.2	-7.1	-1.1
16943.0	288.0	-0.4	-4.6	-4.9	-5.5	-5.3	-5.6	-5.1	-5.2	-5.1	-4.7	-4.7	-3.5	-0.6
17143.0	289.0	-0.3	-4.3	-5.2	-5.9	-6.0	-7.6	-7.8	-8.0	-6.9	-7.1	-7.1	-6.3	-1.0
17389.0	288.0	1.0	0.0	-0.6	-0.9	-0.9	-2.4	-1.8	-1.8	-1.4	-1.2	-1.2	-0.1	0.0
17674.0	289.0	1.0	0.8	0.2	0.6	0.3	-1.0	-0.6	-0.8	0.7	-0.1	-0.1	1.8	0.3
18118.0	292.0	0.7	1.4	0.9	1.4	1.2	-0.6	0.1	0.5	1.4	1.4	1.4	4.2	0.7
18376.0	295.0	0.1	1.5	1.1	1.4	1.3	0.3	0.5	1.0	1.7	1.5	1.5	2.0	0.3
18648.0	296.0	0.2	0.7	0.5	0.7	0.6	1.0	2.5	3.4	4.8	4.4	4.3	5.5	0.9
18901.0	299.0	0.9	2.5	2.0	2.1	2.0	1.0	1.4	1.7	2.7	2.8	2.8	2.7	0.4
19374.0	300.0	2.3	4.7	4.3	5.1	5.0	6.9	8.5	10.0	8.5	10.5	10.5	12.2	2.0
19769.0	309.0	0.8	2.5	2.5	2.6	2.6	2.9	4.3	4.9	4.3	3.7	3.7	5.8	0.9
20271.0	320.0	0.1	-0.6	-0.5	1.0	1.0	2.9	3.9	5.0	2.3	5.8	5.8	5.6	0.9
20499.0	330.0	0.1	-4.6	-5.4	-6.6	-6.6	-7.8	-6.9	-6.5	-9.8	-7.6	-7.5	-3.5	-0.6
21000.0	341.0	-2.4	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-1.6
21256.0	355.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21588.0	368.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21928.0	376.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22233.0	391.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22781.0	405.0	0.4	0.3	0.4	1.1	1.1	1.6	1.5	0.5	1.2	0.4	0.5	0.8	0.1
23198.0	415.0	-3.8	-5.3	-5.4	-5.8	-5.9	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-1.6
23661.0	428.0	-2.1	-8.7	-8.7	-8.6	-8.6	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-1.4
24000.0	434.0	-0.5	-4.3	-4.4	-6.9	-6.9	-7.9	-7.9	-7.9	-7.6	-7.8	-7.8	-7.9	-1.3
24500.0	439.0	-0.2	-0.3	-0.2	-1.0	-1.2	-1.0	-2.5	-2.0	-2.5	-1.6	-1.6	-3.0	-0.5

Initial bed elevations in feet NGVD
Change in bed elevations in feet
Average annual change in inches



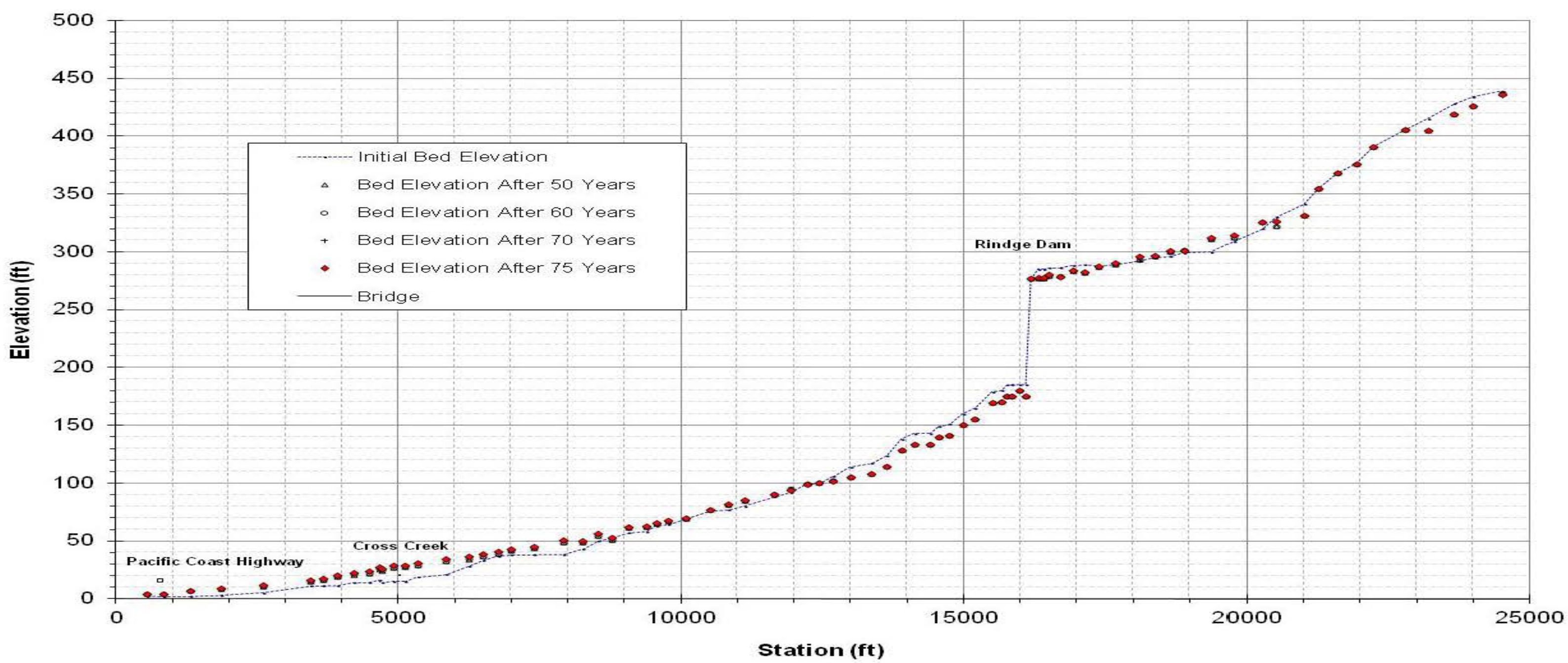
Results from HEC-6T simulations.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK STREAMBED PROFILE WITHOUT-PROJECT

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 15-2 Malibu Creek Streambed Profile Without Project



Results from HEC-6T simulations.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

**MALIBU CREEK
STREAMBED PROFILE
WITHOUT-PROJECT**

CORPS OF ENGINEERS
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Plate 15-3 Malibu Creek Streambed Profile Without-Project

Table 15-2 Accumulated Sand Delivery during Period of Record

River Station (ft)	Accumulated Sand Delivery (tons)	Accumulated Sand Delivery (tons/year)	Accumulated Sand Delivery (cy/year)	Accumulated Sand Delivery (ac-ft/year)
550.6	2952223	39363	24347	15.1
839.8	2938988	39187	24238	15.0
1320.8	2968966	39586	24485	15.2
1846.3	2989580	39861	24655	15.3
2603.4	2996006	39947	24708	15.3
3445.8	3063148	40842	25262	15.7
3670.5	3105277	41404	25609	15.9
3906.8	3143331	41911	25923	16.1
4203.5	3221209	42949	26565	16.5
4486.6	3284062	43787	27083	16.8
4653.8	3334398	44459	27498	17.0
4705.1	3367027	44894	27768	17.2
4900.6	3387036	45160	27933	17.3
5117.6	3414996	45533	28163	17.5
5344.1	3450806	46011	28458	17.6
5844.0	3499338	46658	28859	17.9
6237.3	3577623	47702	29504	18.3
6490.1	3597385	47965	29667	18.4
6755.7	3616856	48225	29828	18.5
6993.4	3631016	48414	29945	18.6
7404.4	3643081	48574	30044	18.6
7917.0	3660271	48804	30186	18.7
8262.6	3684248	49123	30384	18.8
8533.1	3699133	49322	30506	18.9
8770.2	3708748	49450	30586	19.0
9072.9	3714453	49526	30633	19.0
9385.9	3738517	49847	30831	19.1
9556.0	3741326	49884	30854	19.1
9779.9	3745807	49944	30891	19.1
10082.0	3753111	50041	30952	19.2
10524.0	3761085	50148	31017	19.2
10839.0	3772815	50304	31114	19.3
11121.0	3781154	50415	31183	19.3
11648.0	3795721	50610	31303	19.4
11948.0	3806564	50754	31392	19.5
12224.0	3813063	50841	31446	19.5
12444.0	3817926	50906	31486	19.5
12689.0	3821087	50948	31512	19.5
12999.0	3814157	50855	31455	19.5
13373.0	3805300	50737	31382	19.5
13647.0	3794415	50592	31292	19.4
13907.0	3796906	50625	31313	19.4

River Station (ft)	Accumulated Sand Delivery (tons)	Accumulated Sand Delivery (tons/year)	Accumulated Sand Delivery (cy/year)	Accumulated Sand Delivery (ac-ft/year)
14129.0	3790774	50544	31262	19.4
14394.0	3783975	50453	31206	19.3
14559.0	3775636	50342	31137	19.3
14747.0	3770402	50272	31094	19.3
14985.0	3762794	50171	31031	19.2
15196.0	3755483	50073	30971	19.2
15512.0	3744937	49932	30884	19.1
15662.0	3735537	49807	30807	19.1
15764.0	3732998	49773	30786	19.1
15859.0	3729713	49730	30759	19.1
15990.0	3725331	49671	30722	19.0
16092.0	3722542	49634	30699	19.0
16201.0	3717499	49567	30658	19.0
16326.0	3717821	49571	30661	19.0
16409.0	3714651	49529	30634	19.0
16503.0	3710565	49474	30601	19.0
16704.0	3706380	49418	30566	18.9
16943.0	3704040	49387	30547	18.9
17143.0	3696838	49291	30487	18.9
17389.0	3693566	49248	30461	18.9
17674.0	3703281	49377	30541	18.9
18118.0	3715318	49538	30640	19.0
18376.0	3728144	49709	30746	19.1
18648.0	3739845	49865	30842	19.1
18901.0	3751936	50026	30942	19.2
19374.0	3768276	50244	31077	19.3
19769.0	3802721	50703	31361	19.4
20271.0	3826337	51018	31555	19.6
20499.0	3843962	51253	31701	19.6
21000.0	3838420	51179	31655	19.6
21256.0	3834463	51126	31622	19.6
21588.0	3838824	51184	31658	19.6
21928.0	3850523	51340	31755	19.7
22233.0	3873307	51644	31943	19.8
22781.0	3881197	51749	32008	19.8
23198.0	3889004	51853	32072	19.9
23661.0	3885080	51801	32040	19.9
24000.0	3884151	51789	32032	19.9
24500.0	3873995	51653.3	31948	19.8

15.7 Average Annual Results

The average annual results were obtained by dividing the period-of-record simulation by the number of years of record, i.e., 75 years. Results are included in **Table 15-1**.

15.8 Balanced Hydrograph Simulations

Discrete flood events represented by the balanced hydrographs were used as input to the sediment transport models. Initial geometry was based on the 2002 survey data. Selected results of the balanced hydrograph simulations are shown in **Table 15-3 through Table 15-5** and **Plate 15-4 through Plate 15-11.** The scour and deposition trends are generally similar to the period-of-record results except at the lagoon, where scour would occur in the balanced hydrograph simulation.

The average sediment deposition/scour by reach for the period-of-record simulation is shown in **Table 15-6**. The average sediment deposition/scour by reach for frequency flood events is shown in **Table 15-7**.

15.9 Sensitivity Analysis

A sensitivity analysis of the sediment transport model is necessary due to the number of unknown variables and complex nature of sediment transport in general. The sensitivity of the sediment transport models were tested by modifying the: 1) sediment transport function, 2) hydraulic roughness, 3) inflowing sediment load, and 4) bed material gradation. See **Table 15-8 through Table 15-11** for the sensitivity analysis results for selected simulations.

15.9.1 Sediment Transport Function

The Toffaleti and Meyer-Peter and Müller, and Laursen-Madden sediment transport functions were substituted for the sediment transport function to test the sensitivity of the model. As expected, different results were obtained from using the different transport functions. However, the trends in aggradation and degradation locations remained the same.

The sediment transport model is only somewhat sensitive to the sediment transport function used. The average bed elevation difference from the Toffaleti and Meyer-Peter and Müller, and Laursen-Madden sediment transport functions was between 0.1 to 1.4 ft and -0.1 to 2.6 ft, respectively.

15.9.2 Hydraulic Roughness

The sensitivity of the sediment transport model to the hydraulic roughness coefficients was examined. The base conditions sediment transport model results were compared to simulation outputs resulting from increasing and reducing all Manning's roughness coefficients in the input file by 25%.

The sediment transport model is not sensitive to changes in Manning's roughness coefficients. The average bed elevation difference from increasing and decreasing the Manning's roughness coefficients was between -0.1 to 0.1 ft and -0.7 to 0.5 ft, respectively.

15.9.3 Inflowing Sediment Load.

Because of the lack of prototype sediment inflow data, it was especially important to determine the sensitivity of the HEC-6T numerical models to sediment inflow. The effect of the inflowing sediment load was determined by comparing the base conditions sediment transport model with simulation results after increasing and reducing the sediment discharge to twice and half the equilibrium load determined with the Toffaleti-Schoklitch function.

The model is marginally sensitive to doubling the sediment load after 75 yrs of simulated sediment transport. The average bed elevation difference is 4.8 ft. However, this number is misleading because this difference is after 75 yrs of simulation; the annualized difference is 0.8 ft (4.8 ft/75 yrs). The average bed elevation difference from the balanced hydrograph simulations varies from 0.1 to 1.1 ft.

In contrast, the model is not sensitive to reducing the sediment load by half. The average bed elevation difference is between -2.4 to 0.0 ft.

The sediment inflow was also tested for its sensitivity to the sediment transport function used. Sediment inflow curves for the total sediment load using the Toffaleti-Schoklitch, Toffaleti and Meyer-Peter and Müller, and Laursen-Madden sediment transport functions are shown in **Plate 15-12**. As illustrated in **Plate 15-12**, the Laursen-Madden function tends to move the largest amount of coarse material, while the Toffaleti and Meyer-Peter and Müller function moves the least amount of coarse material. The sediment inflow calculated by the Toffaleti-Schoklitch function is in between the two previous functions.

15.9.4 Bed Material Gradation

Since a backhoe was not used to collect the bed material samples for Malibu Creek (due to difficulty in accessing the streambed), in-situ particle counts and grab samples were combined to determine the gradation of the streambed. As a result, the resulting bed material gradation depended on the depth of fines assumed. Therefore, a sensitivity analysis that varied the depth of fines was simulated. The depth of fines was doubled (from 1 ft to 2 ft) and the resulting bed material gradations were used in the model. Note that reservoir bed material samples were not modified since these were from boring samples.

The sediment transport model is not sensitive to changes in bed material gradation. The average bed elevation difference from doubling the depth of fines was between -0.1 to 0.1 ft. Results are presented on **Plate 15-3.**

15.10 Modeling Recommendations

Because the models are somewhat sensitive to the amount of inflowing sediment load, it is recommended that monitoring programs be established in Malibu Creek and similar watersheds to help determine the inflowing sediment load for projects of this type. This would consist of taking suspended and bed load samples for a range of flows throughout the study reach. It is also recommended that new topography be obtained prior to the design phase of this study and at set intervals or after major flood events to compare with the sediment model. The sediment model could then be adjusted/calibrated based on the additional data.

The sediment transport results presented in this Appendix are appropriate for a feasibility level study to distinguish differences between alternatives. The parameters are reasonable and applied equally for all plans. It is understood there is some inherent uncertainty with sediment transport modeling and predictions and use of these results should be limited to the applications in this study.

Table 15-3 Sediment Transport Results for 10% ACE Event (10-Year)

Station (ft)	Initial Bed Elev. (ft)	Peak		End Bed Elev. (ft)	Maximum Change (ft)
		Bed Elev. (ft)	WSEL (ft)		
550.6	2.2	1.9	5.5	2.9	0.7
839.8	1.7	2.1	7.7	2.8	1.1
1320.8	2.0	1.8	9.4	3.3	1.3
1846.3	3.0	2.1	12.8	3.3	-0.9
2603.4	5.0	5.0	16.8	5.1	0.1
3445.8	11.0	10.0	20.1	10.0	-1.0
3670.5	11.0	10.8	21.8	10.7	-0.3
3906.8	11.0	11.3	23.8	12.8	1.8
4203.5	14.0	13.6	25.8	14.1	-0.4
4486.6	14.0	14.7	26.6	15.8	1.8
4653.8	16.0	16.9	29.0	18.3	2.3
4705.1	14.0	16.3	29.8	19.0	5.0
4900.6	15.0	17.2	30.1	19.4	4.4
5117.6	15.0	17.3	31.0	19.4	4.4
5344.1	19.0	21.0	32.2	21.2	2.2
5844.0	21.0	22.8	35.7	24.2	3.2
6237.3	28.0	27.3	36.9	27.4	-0.7
6490.1	33.0	32.6	42.2	32.3	-0.7
6755.7	37.0	36.9	45.5	36.8	-0.2
6993.4	38.0	37.9	48.1	38.4	0.4
7404.4	38.0	38.6	52.3	40.8	2.8
7917.0	38.0	42.1	56.4	44.1	6.1
8262.6	43.0	44.9	59.6	46.7	3.7
8533.1	50.0	50.0	61.6	50.4	0.4
8770.2	53.0	52.8	64.2	52.5	-0.5
9072.9	57.0	58.8	67.9	58.4	1.8
9385.9	58.0	58.1	70.5	58.5	0.5
9556.0	63.0	62.4	74.1	62.5	-0.6
9779.9	64.0	63.9	77.0	63.7	-0.3
10082.0	69.0	69.3	80.9	68.9	0.3
10524.0	76.0	76.1	86.4	76.0	0.1
10839.0	77.0	79.0	90.5	79.9	2.9
11121.0	80.0	81.5	94.0	82.6	2.6
11648.0	88.0	88.6	100.3	89.1	1.1
11948.0	92.0	92.8	105.1	93.8	1.8
12224.0	99.0	100.0	109.1	100.0	1.0
12444.0	99.0	100.9	113.3	103.0	4.0
12689.0	106.0	105.6	118.0	105.5	-0.5

Station (ft)	Initial Bed Elev. (ft)	Peak Bed Elev. (ft)	Peak WSEL (ft)	End Bed Elev. (ft)	Maximum Change (ft)
12999.0	114.0	113.4	125.5	114.1	-0.6
13373.0	117.0	120.7	133.2	121.8	4.8
13647.0	124.0	123.0	140.7	124.3	-1.0
13907.0	138.0	133.7	146.6	132.3	-5.7
14129.0	143.0	142.8	151.1	141.1	-1.9
14394.0	143.0	145.5	157.5	145.6	2.6
14559.0	149.0	151.5	160.2	150.9	2.5
14747.0	151.0	149.4	164.3	151.7	-1.6
14985.0	160.0	159.0	170.5	157.4	-2.6
15196.0	165.0	163.1	174.2	160.7	-4.3
15512.0	179.0	174.7	183.4	173.0	-6.0
15662.0	180.0	173.0	188.1	170.3	-9.7
15764.0	185.0	178.9	189.2	175.9	-9.1
15859.0	185.0	176.6	192.5	175.2	-9.8
15990.0	185.0	184.4	193.5	180.8	-4.2
16092.0	185.0	175.2	196.9	175.2	-9.8
16201.0	277.0	277.0	290.8	277.0	0.0
16326.0	285.0	275.4	297.3	276.8	-9.6
16409.0	285.0	276.4	297.9	278.1	-8.6
16503.0	286.0	280.7	298.4	279.5	-6.5
16704.0	286.0	283.1	299.4	281.0	-5.0
16943.0	288.0	282.6	301.1	284.1	-5.4
17143.0	289.0	286.6	303.3	285.1	-3.9
17389.0	288.0	290.9	304.7	288.8	2.9
17674.0	289.0	292.0	305.9	291.0	3.0
18118.0	292.0	294.8	308.9	294.7	2.8
18376.0	295.0	297.6	310.8	297.9	2.9
18648.0	296.0	297.3	312.6	298.1	2.1
18901.0	299.0	302.1	314.5	302.2	3.2
19374.0	300.0	305.3	318.7	306.2	6.2
19769.0	309.0	314.0	323.3	313.6	5.0
20271.0	320.0	320.5	333.1	321.1	1.1
20499.0	330.0	323.9	336.9	324.1	-6.1
21000.0	341.0	331.2	350.8	331.2	-9.8
21256.0	355.0	355.0	369.2	355.0	0.0
21588.0	368.0	368.0	380.4	368.0	0.0
21928.0	376.0	376.0	392.0	376.0	0.0
22233.0	391.0	391.0	402.3	391.0	0.0
22781.0	405.0	405.3	416.6	405.9	0.9
23198.0	415.0	405.3	424.0	405.3	-9.7
23661.0	428.0	419.4	435.0	419.3	-8.7
24000.0	434.0	430.7	444.0	428.1	-5.9
24500.0	439.0	439.9	450.4	439.7	0.9

Table 15-4 Sediment Transport Results for 2% ACE Event (50-Year)

Station (ft)	Initial Bed Elev. (ft)	Peak		End Bed Elev. (ft)	Maximum Change (ft)
		Bed Elev. (ft)	WSEL (ft)		
550.6	2.2	0.3	5.5	2.3	-1.9
839.8	1.7	1.3	8.7	2.2	0.5
1320.8	2.0	0.8	11.5	2.4	-1.2
1846.3	3.0	1.8	16.7	2.7	-1.2
2603.4	5.0	5.0	20.3	5.1	0.1
3445.8	11.0	10.1	23.7	10.2	-0.9
3670.5	11.0	10.3	24.4	10.7	-0.7
3906.8	11.0	11.8	28.0	13.3	2.3
4203.5	14.0	13.9	29.8	14.4	0.4
4486.6	14.0	14.6	30.9	16.2	2.2
4653.8	16.0	17.0	33.4	18.2	2.2
4705.1	14.0	15.7	34.9	19.1	5.1
4900.6	15.0	18.1	34.5	19.2	4.2
5117.6	15.0	17.3	37.2	19.5	4.5
5344.1	19.0	20.7	37.7	21.2	2.2
5844.0	21.0	23.5	40.5	25.3	4.3
6237.3	28.0	27.2	41.7	27.7	-0.8
6490.1	33.0	32.9	49.1	32.0	-1.0
6755.7	37.0	37.1	50.6	36.9	-0.1
6993.4	38.0	37.0	53.0	37.9	-1.0
7404.4	38.0	37.9	57.7	39.9	1.9
7917.0	38.0	41.7	62.6	43.3	5.3
8262.6	43.0	44.7	66.3	45.8	2.8
8533.1	50.0	50.0	68.0	50.7	0.7
8770.2	53.0	52.7	70.2	51.5	-1.5
9072.9	57.0	59.9	73.7	59.9	2.9
9385.9	58.0	58.0	76.6	58.6	0.6
9556.0	63.0	62.7	79.0	63.0	-0.3
9779.9	64.0	64.1	81.3	63.6	-0.4
10082.0	69.0	69.4	84.8	69.1	0.4
10524.0	76.0	75.9	91.2	76.5	0.5
10839.0	77.0	77.3	95.0	79.5	2.5
11121.0	80.0	82.3	99.9	83.3	3.3
11648.0	88.0	88.6	107.1	90.6	2.6
11948.0	92.0	94.5	111.7	96.0	4.0
12224.0	99.0	101.3	116.1	102.1	3.1
12444.0	99.0	103.8	119.4	105.5	6.5
12689.0	106.0	105.1	125.1	106.4	-0.9
12999.0	114.0	111.3	129.6	115.9	-2.7
13373.0	117.0	117.0	139.5	119.3	2.3
13647.0	124.0	126.1	144.9	125.2	2.1
13907.0	138.0	134.5	152.9	130.6	-7.4

Station (ft)	Initial Bed Elev. (ft)	Peak Bed Elev. (ft)	Peak WSEL (ft)	End Bed Elev. (ft)	Maximum Change (ft)
14129.0	143.0	140.8	155.2	139.7	-3.3
14394.0	143.0	143.8	161.9	140.1	-2.9
14559.0	149.0	151.4	166.9	145.4	-3.6
14747.0	151.0	143.9	168.5	141.5	-9.5
14985.0	160.0	160.1	177.6	150.5	-9.5
15196.0	165.0	161.3	179.7	155.4	-9.6
15512.0	179.0	169.3	187.4	169.3	-9.7
15662.0	180.0	170.3	189.0	170.3	-9.7
15764.0	185.0	175.3	192.7	175.3	-9.7
15859.0	185.0	175.3	196.3	175.2	-9.8
15990.0	185.0	177.2	201.2	179.4	-7.8
16092.0	185.0	175.2	202.9	175.2	-9.8
16201.0	277.0	277.0	298.7	277.0	0.0
16326.0	285.0	275.4	303.6	276.5	-9.6
16409.0	285.0	277.3	304.0	278.2	-7.7
16503.0	286.0	281.6	304.5	279.0	-7.0
16704.0	286.0	283.5	305.4	282.0	-4.0
16943.0	288.0	281.0	307.3	283.4	-7.0
17143.0	289.0	286.3	308.8	284.8	-4.2
17389.0	288.0	290.9	310.5	288.6	2.9
17674.0	289.0	291.4	312.0	291.3	2.4
18118.0	292.0	292.9	315.0	293.9	1.9
18376.0	295.0	297.2	317.3	298.3	3.3
18648.0	296.0	296.6	319.3	297.9	1.9
18901.0	299.0	301.7	321.2	303.2	4.2
19374.0	300.0	305.4	325.8	306.5	6.5
19769.0	309.0	313.3	331.2	313.4	4.4
20271.0	320.0	317.0	336.9	321.1	-3.0
20499.0	330.0	320.1	341.5	320.5	-9.9
21000.0	341.0	331.2	362.2	331.2	-9.8
21256.0	355.0	355.0	377.8	355.0	0.0
21588.0	368.0	368.0	389.6	368.0	0.0
21928.0	376.0	376.0	399.7	376.0	0.0
22233.0	391.0	391.0	408.6	391.0	0.0
22781.0	405.0	405.0	422.4	405.8	0.8
23198.0	415.0	405.3	429.3	405.7	-9.7
23661.0	428.0	419.3	443.7	419.3	-8.7
24000.0	434.0	429.3	453.9	427.9	-6.1
24500.0	439.0	441.0	457.1	440.1	2.0

Table 15-5 Sediment Transport Results for 1% ACE Event (100-Year)

Station (ft)	Initial Bed Elev. (ft)	Peak		End Bed Elev. (ft)	Maximum Change (ft)
		Bed Elev. (ft)	WSEL (ft)		
550.6	2.2	-0.5	5.5	2.5	-2.7
839.8	1.7	1.1	9.0	2.0	-0.6
1320.8	2.0	0.5	12.7	2.3	-1.5
1846.3	3.0	1.5	17.9	2.2	-1.5
2603.4	5.0	5.0	21.1	5.0	0.0
3445.8	11.0	10.1	24.9	10.1	-0.9
3670.5	11.0	10.0	25.3	10.5	-1.0
3906.8	11.0	11.9	28.6	12.0	1.0
4203.5	14.0	14.0	30.7	14.1	0.1
4486.6	14.0	14.3	32.0	15.1	1.1
4653.8	16.0	16.3	34.3	17.5	1.5
4705.1	14.0	13.6	36.4	18.0	4.0
4900.6	15.0	16.9	35.5	18.2	3.2
5117.6	15.0	17.2	38.8	18.5	3.5
5344.1	19.0	20.5	39.2	20.5	1.5
5844.0	21.0	23.4	42.1	25.2	4.2
6237.3	28.0	26.8	43.7	27.2	-1.2
6490.1	33.0	33.2	51.8	32.2	-0.8
6755.7	37.0	37.3	53.0	36.9	0.3
6993.4	38.0	36.6	55.1	37.8	-1.4
7404.4	38.0	37.7	59.6	39.6	1.6
7917.0	38.0	41.2	64.9	42.8	4.8
8262.6	43.0	45.2	68.5	45.5	2.5
8533.1	50.0	50.0	70.4	50.7	0.7
8770.2	53.0	52.8	72.2	51.1	-1.9
9072.9	57.0	60.1	75.9	60.1	3.1
9385.9	58.0	58.2	78.4	58.6	0.6
9556.0	63.0	63.0	80.4	63.1	0.1
9779.9	64.0	64.3	82.7	63.9	0.3
10082.0	69.0	69.4	86.1	69.3	0.4
10524.0	76.0	75.7	93.0	76.7	0.7
10839.0	77.0	75.7	96.6	79.4	2.4
11121.0	80.0	82.2	101.2	83.5	3.5
11648.0	88.0	88.5	110.1	90.8	2.8
11948.0	92.0	95.8	114.3	96.0	4.0
12224.0	99.0	102.1	119.6	102.5	3.5
12444.0	99.0	104.4	122.2	105.1	6.1
12689.0	106.0	105.8	128.4	106.7	0.7
12999.0	114.0	110.4	132.1	114.6	-3.6
13373.0	117.0	115.8	141.9	118.1	-1.2
13647.0	124.0	125.7	147.0	122.4	1.7
13907.0	138.0	134.8	155.3	129.4	-8.6

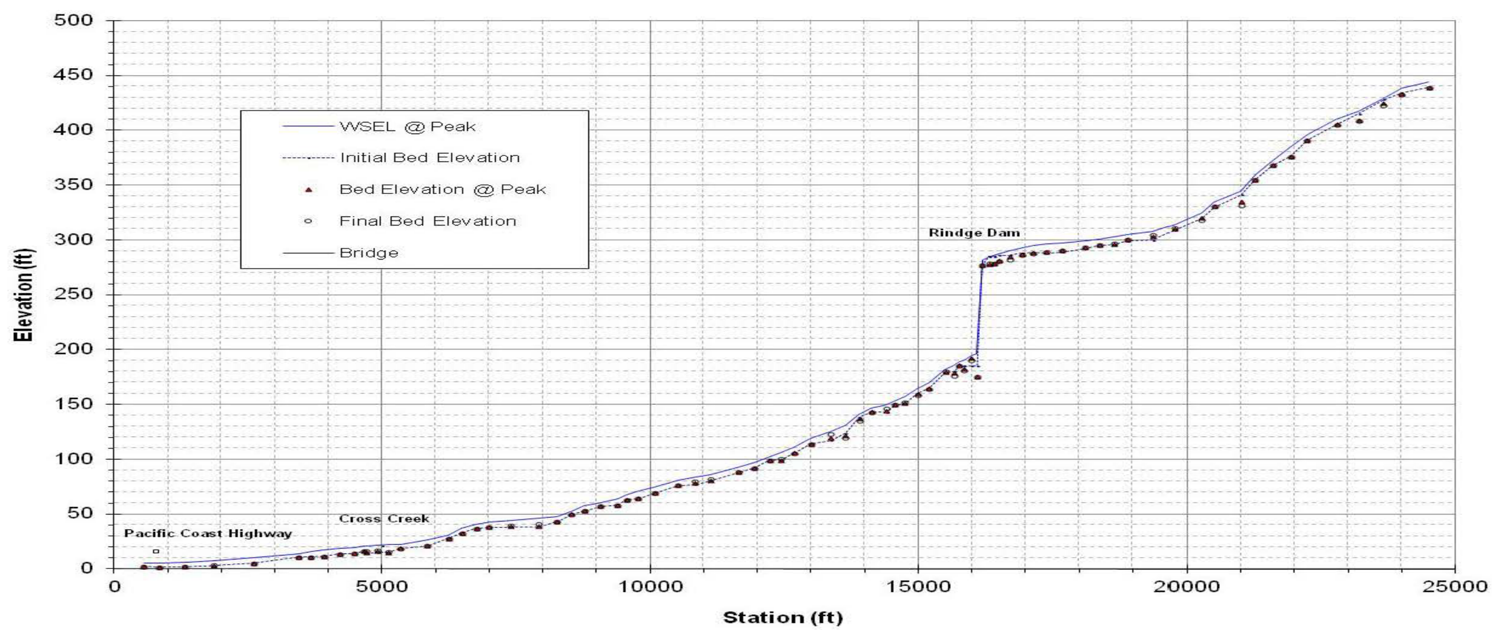
Station (ft)	Initial Bed Elev. (ft)	Peak Bed Elev. (ft)	Peak WSEL (ft)	End Bed Elev. (ft)	Maximum Change (ft)
14129.0	143.0	139.9	157.4	136.2	-6.8
14394.0	143.0	142.6	163.2	138.7	-4.3
14559.0	149.0	149.2	169.8	141.7	-7.3
14747.0	151.0	141.6	168.4	141.5	-9.5
14985.0	160.0	160.7	181.0	150.5	-9.5
15196.0	165.0	156.9	183.3	155.4	-9.6
15512.0	179.0	169.3	187.2	169.3	-9.7
15662.0	180.0	170.3	192.2	170.3	-9.7
15764.0	185.0	175.3	195.7	175.3	-9.7
15859.0	185.0	175.2	198.4	175.2	-9.8
15990.0	185.0	175.2	205.6	179.0	-9.8
16092.0	185.0	175.2	206.9	175.2	-9.8
16201.0	277.0	277.0	300.6	277.0	0.0
16326.0	285.0	275.4	306.0	276.4	-9.6
16409.0	285.0	277.6	306.2	278.4	-7.4
16503.0	286.0	282.4	306.8	278.6	-7.4
16704.0	286.0	282.8	307.6	282.9	-3.2
16943.0	288.0	280.4	309.6	283.2	-7.6
17143.0	289.0	286.5	310.9	285.5	-3.5
17389.0	288.0	290.6	312.9	289.3	2.6
17674.0	289.0	291.4	314.4	291.9	2.9
18118.0	292.0	292.1	317.4	293.8	1.8
18376.0	295.0	296.9	319.8	299.8	4.8
18648.0	296.0	296.7	321.9	297.3	1.3
18901.0	299.0	301.8	323.9	306.4	7.4
19374.0	300.0	305.0	328.6	304.0	5.0
19769.0	309.0	313.7	334.2	316.5	7.5
20271.0	320.0	313.5	339.5	310.1	-9.9
20499.0	330.0	320.1	341.7	320.1	-9.9
21000.0	341.0	331.2	366.8	331.2	-9.8
21256.0	355.0	355.0	381.6	355.0	0.0
21588.0	368.0	368.0	393.4	368.0	0.0
21928.0	376.0	376.0	403.6	376.0	0.0
22233.0	391.0	391.0	411.3	391.0	0.0
22781.0	405.0	405.0	424.9	405.5	0.5
23198.0	415.0	405.3	432.0	405.6	-9.7
23661.0	428.0	419.3	447.8	419.3	-8.7
24000.0	434.0	428.6	458.5	428.3	-5.7
24500.0	439.0	441.6	460.7	439.9	2.6

Table 15-6 Future Without-Project Conditions - Sediment Transport Summary

Reach	After 5 years	After 10 years	After 20 years	After 30 years	After 40 years	After 50 years
5	2.6 -2.7	2.9 -2.9	4.3 -2.8	5.0 -2.6	4.3 -3.1	5.8 -2.7
4b	3.4 -1.3	2.2 -1.9	1.6 -2.4	1.7 -2.5	0.6 -2.6	0.6 -2.6
4a	3.4 0.7	3.3 0.8	4.2 0.9	3.5 0.9	2.8 -0.8	3.6 -0.7
3	6.5 2.0	8.0 3.5	9.4 4.3	10.5 4.9	10.9 5.3	11.8 6.1
2b	3.3 1.3	6.5 4.1	7.7 5.1	8.8 6.0	9.0 6.2	10.0 7.1
2a	1.7 1.5	4.4 4.4	4.7 4.5	5.1 5.0	5.1 4.8	5.9 5.6
1	2.2 1.2	4.4 2.4	4.3 2.3	4.6 2.4	4.3 2.2	4.8 2.4
	Values in feet Top value in cell is maximum within reach; bottom number is average					

Table 15-7 Average Sediment Deposition/Scour by Reach for Frequency Events

	ACE Event							
Reach	50% (2-yr)	20% (5-yr)	10% (10-yr)	5% (20-yr)	2% (50-yr)	1% (100-yr)	0.5% (200-yr)	0.2% (500-yr)
5	-1.4	-1.9	-1.8	-1.8	-2.1	-2.1	-2.2	-2.7
4	-0.1	-0.7	-1.4	-1.6	-2.6	-3.1	-3.8	-4.1
3	0.5	1.4	2.0	2.0	1.7	1.3	1.0	0.4
2	0.2	0.8	0.9	1.1	1.1	0.5	0.2	-0.1
1	0.2	0.9	1.0	0.3	-0.9	-1.6	-2.0	-2.6
Values in feet Computer runs for frequency events were performed prior to subdivision of Reaches 2a & 2b and 4a & 4b								



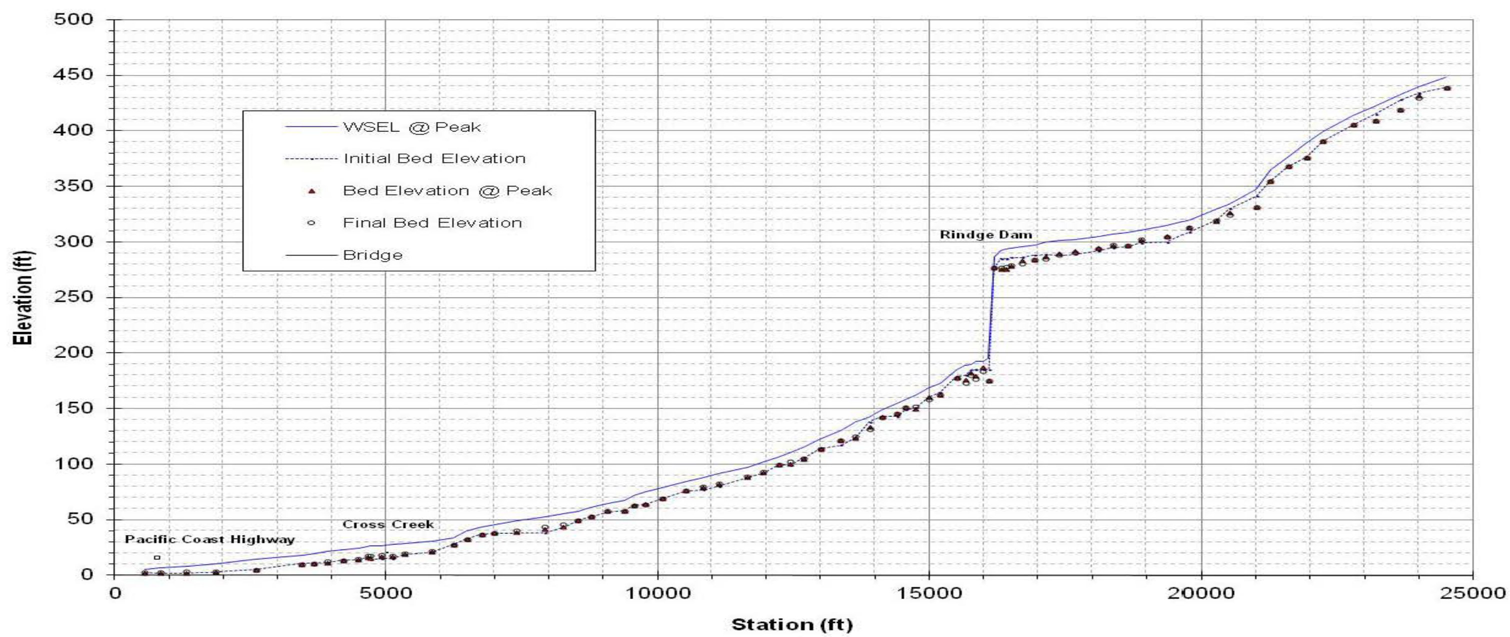
Results from HEC-6T simulations.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK STREAMBED PROFILE AFTER 50% CHANCE EVENT

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 15-4 Malibu Creek Streambed Profile After 50% Chance Event (2-Year)



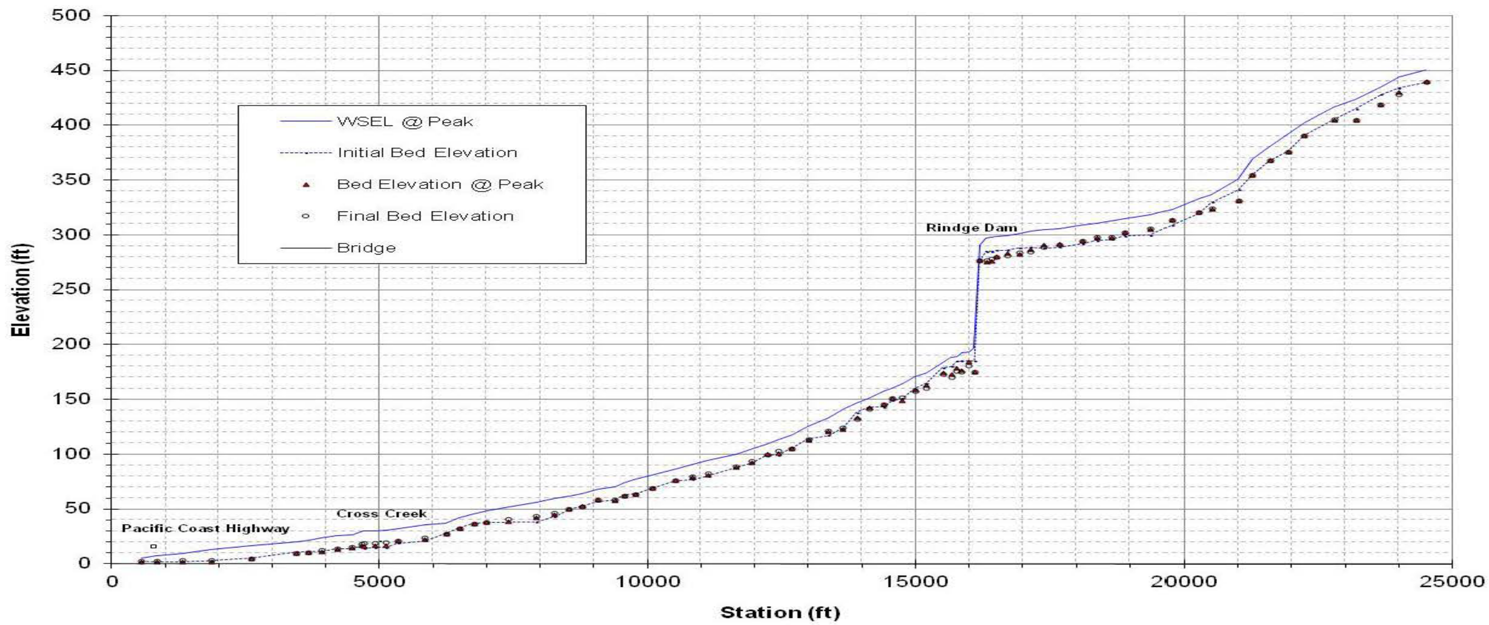
Results from HEC-6T simulations.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK STREAMBED PROFILE AFTER 20% CHANCE EVENT

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 15-5 Malibu Creek Streambed Profile After 20% Chance Event (5-Year)



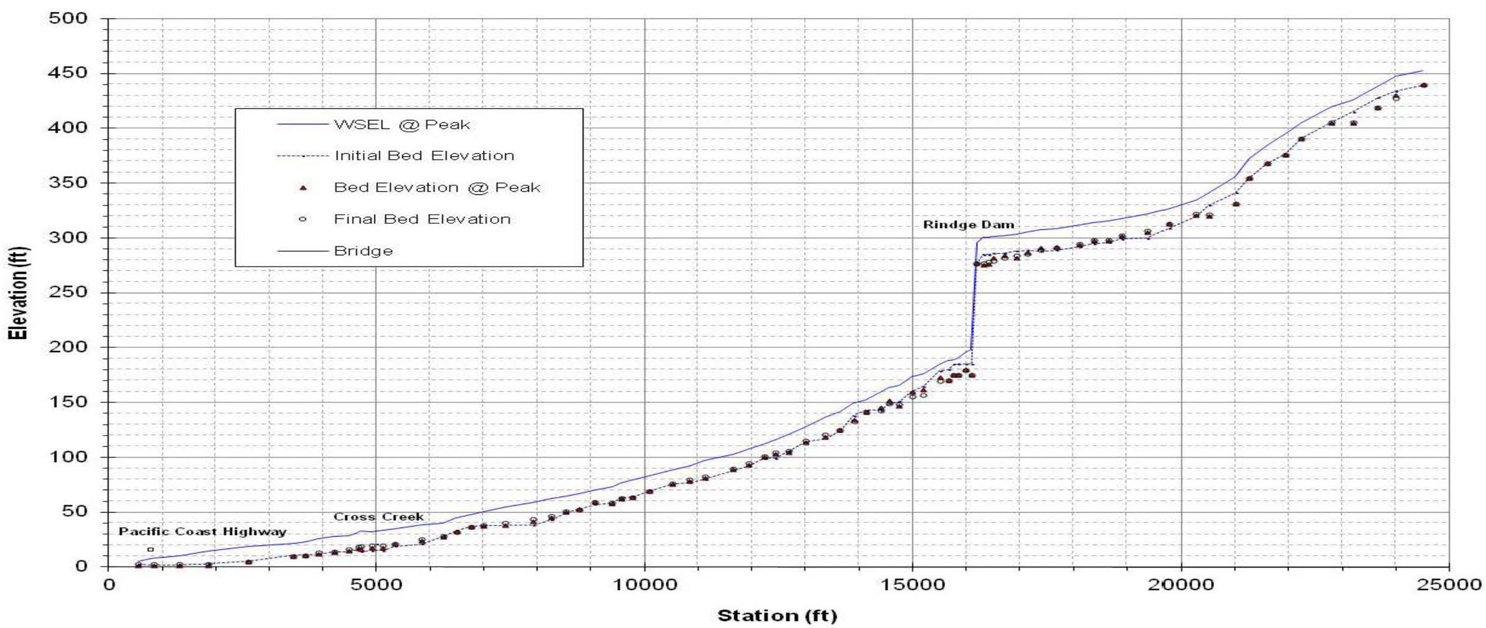
Results from HEC-6T simulations.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK STREAMBED PROFILE AFTER 10% CHANCE EVENT

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 15-6 Malibu Creek Streambed Profile After 10% Chance Event (10-Year)



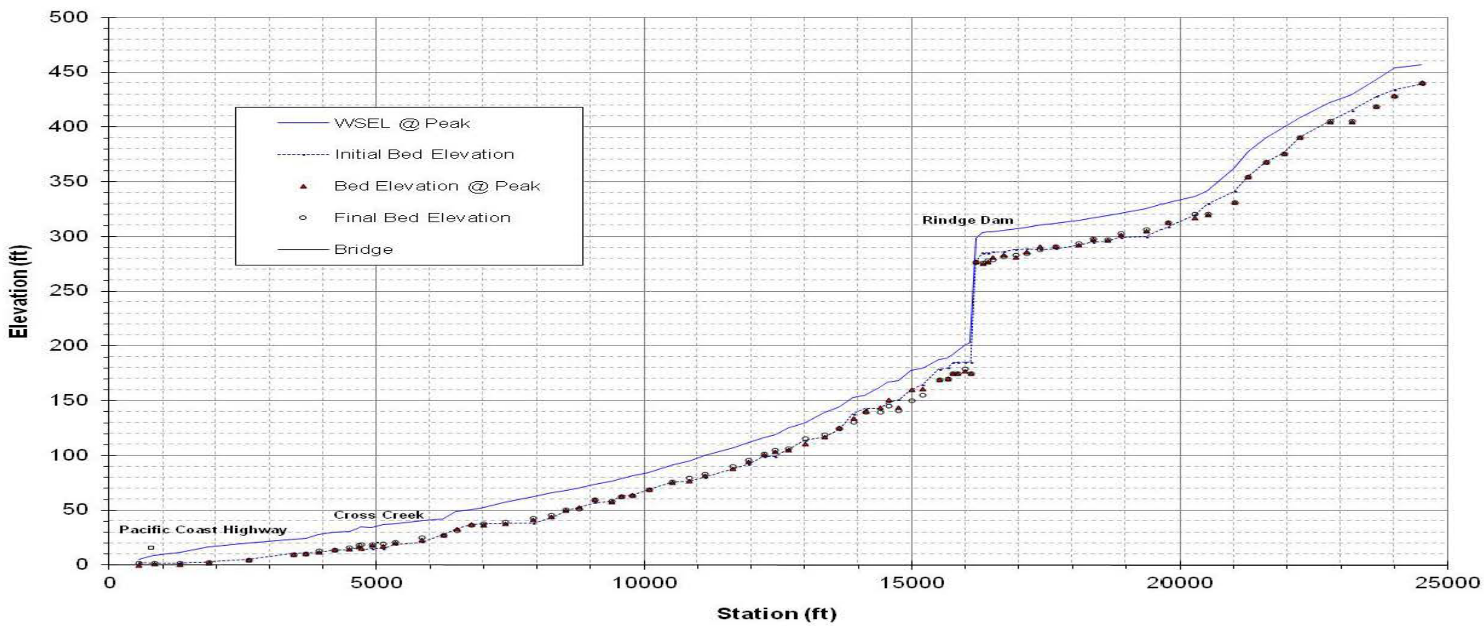
Results from HEC-6T simulations.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK STREAMBED PROFILE AFTER 5% CHANCE EVENT

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 15-7 Malibu Creek Streambed Profile After 5% Chance Event (20-Year)



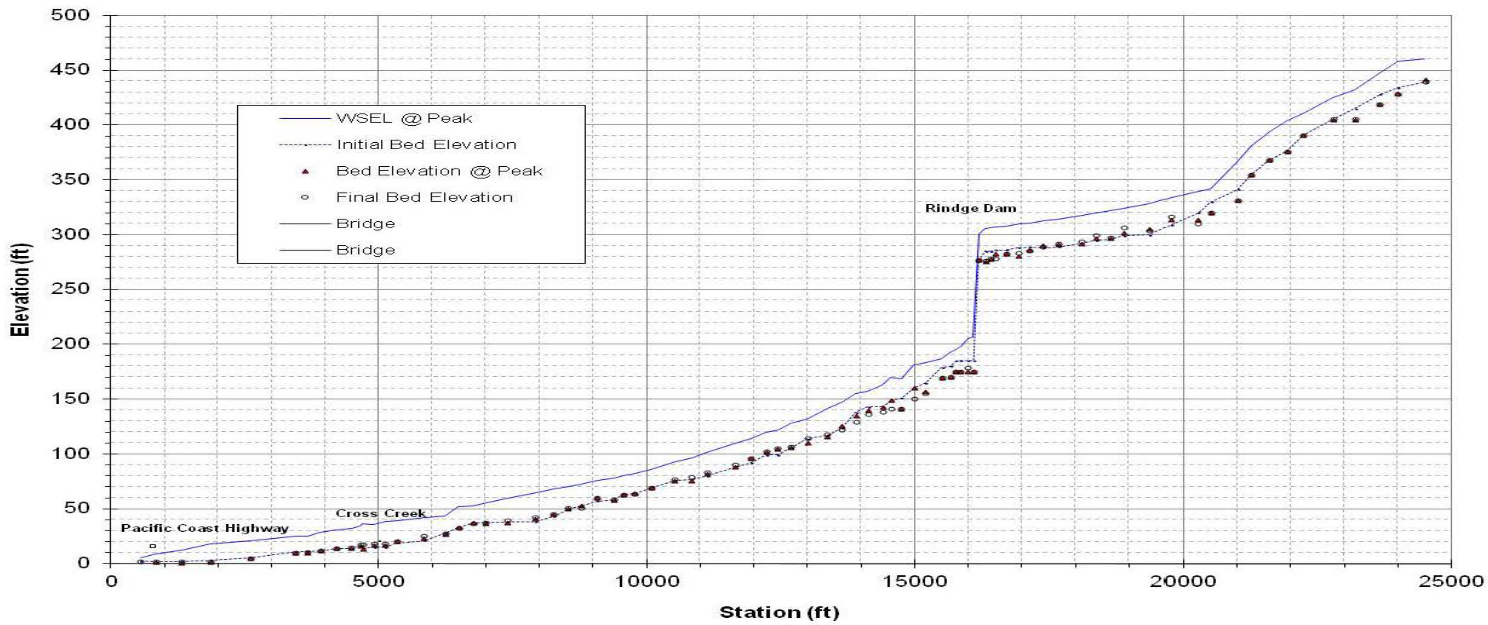
Results from HEC-6T simulations.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK
STREAMBED PROFILE
AFTER 2% CHANCE
EVENT

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 15-8 Malibu Streambed Profile After 2% Chance Event (50-Year)



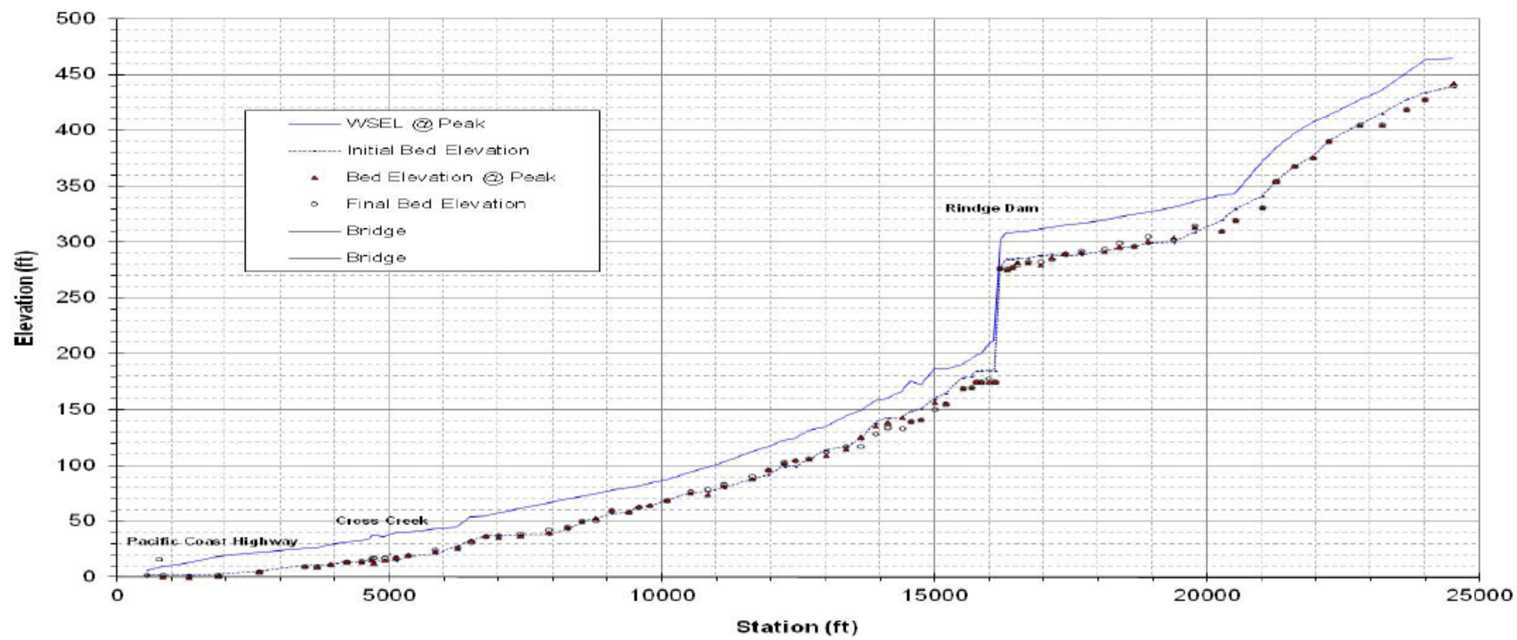
Results from HEC-6T simulations.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK STREAMBED PROFILE AFTER 1% CHANCE EVENT

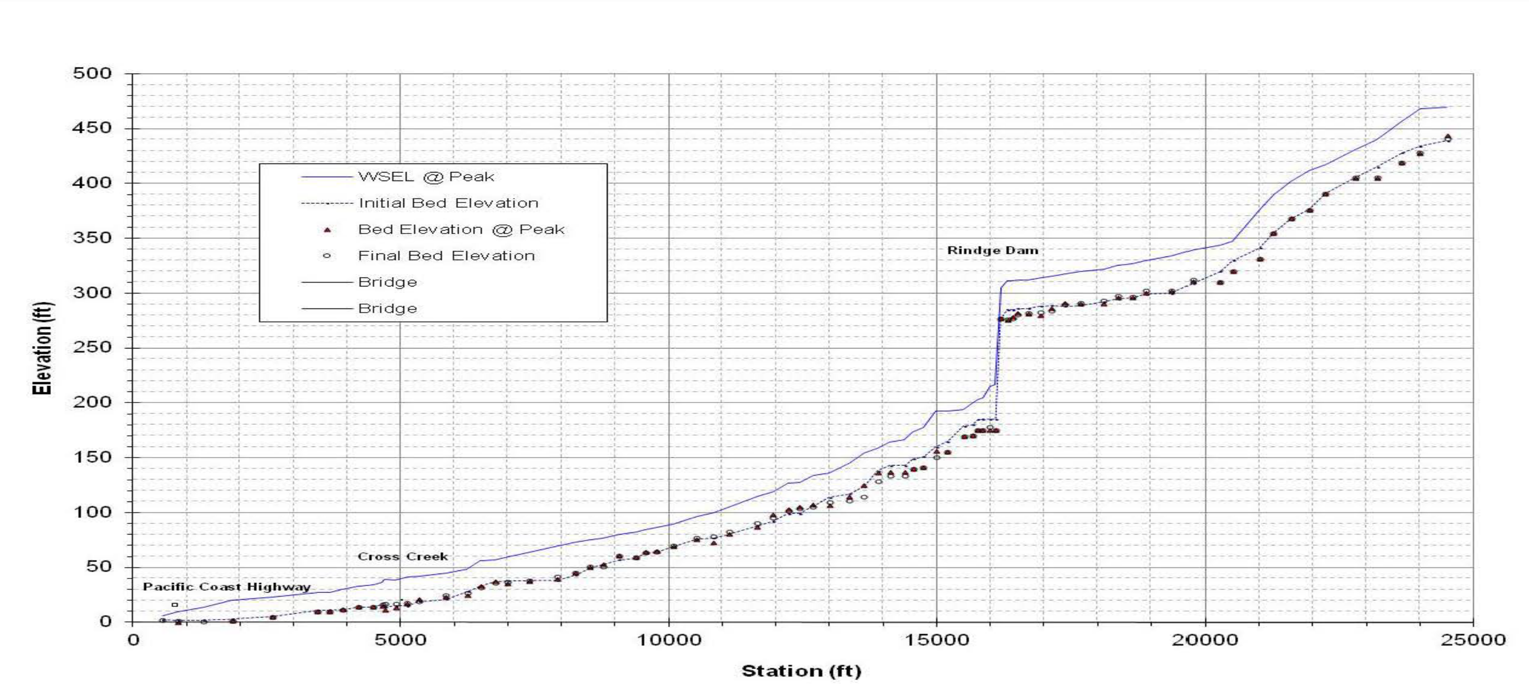
CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 15-9 Malibu Streambed Profile After 1% Chance Event (100-Year)



Results from HEC-6T simulations.	MALIBU CREEK ECOSYSTEM RESTORATION STUDY
	MALIBU CREEK STREAMBED PROFILE AFTER 0.5% CHANCE EVENT
	CORPS OF ENGINEERS LOS ANGELES DISTRICT

Plate 15-10 Malibu Streambed Profile After 0.5% Chance Event (200-Year)



Results from HEC-6T simulations.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK STREAMBED PROFILE AFTER 0.2% CHANCE EVENT

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 15-11 Malibu Creek Streambed Profile After 0.2% Chance Event (500-Year)

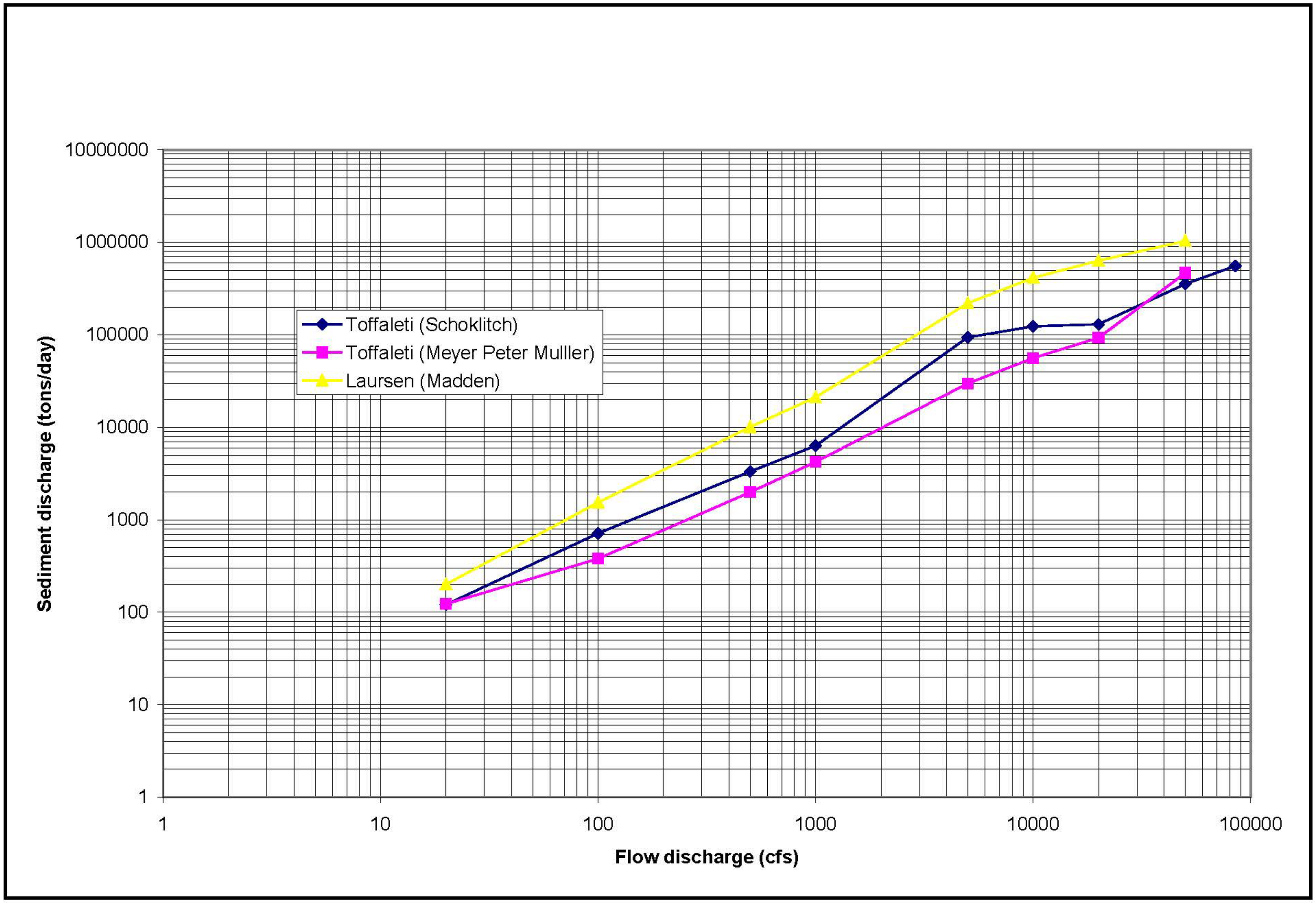


Plate 15-12 Equilibrium Sediment Load - Sensitivity Analysis - Sediment Transport Equation

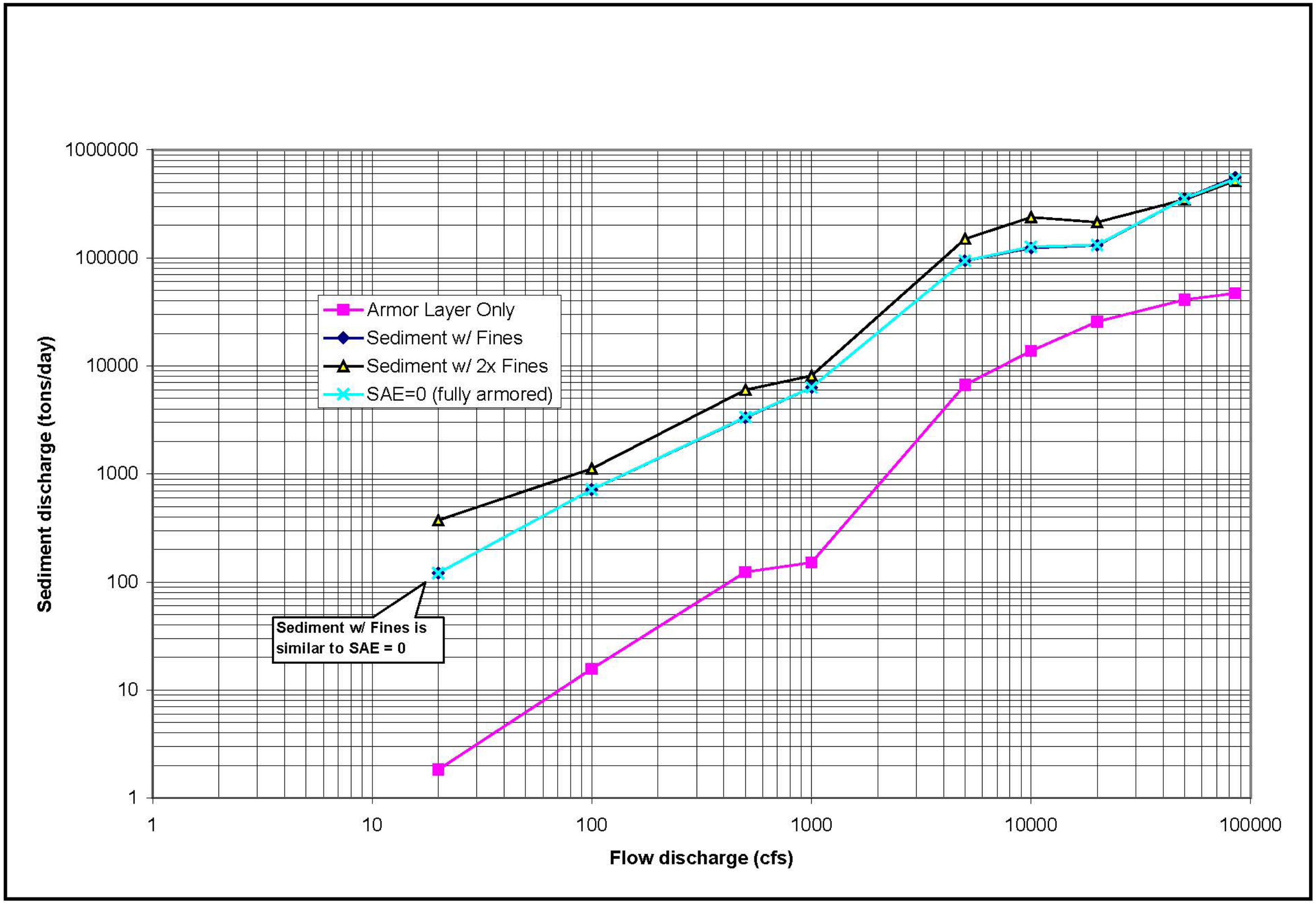


Plate 15-13 Equilibrium Sediment Load - Toffaleti (Scholkitch) Equation - Sensitivity Analysis Additional Fines

Table 15-8 Sensitivity Analysis Results for Period of Simulation

River Station (ft)	Toffaleti (MPM) (ft)	Laursen (Madden) (ft)	Increase n Value (ft)	Decrease n Value (ft)	2x Sediment Load (ft)	0.5x Sediment Load (ft)	2x Fines in Bed Material (ft)
550.6	-0.2	0.1	-0.1	0.2	0.1	-0.2	0.1
839.8	-0.2	-1.1	-0.2	0.4	-0.1	-0.1	0.0
1320.8	0.0	-1.2	-0.2	0.5	0.4	-0.9	0.3
1846.3	0.2	-1.1	-0.2	0.4	0.7	-1.8	0.4
2603.4	-0.2	-1.0	-0.1	0.5	2.0	-2.3	0.3
3445.8	-2.3	-1.1	0.0	0.4	3.0	-3.4	0.3
3670.5	-2.9	-1.0	0.0	0.5	3.2	-3.5	0.2
3906.8	-3.0	-1.3	0.0	0.4	3.3	-4.2	0.2
4203.5	-3.4	-1.5	-0.3	0.9	3.2	-4.7	-0.2
4486.6	-3.0	-1.2	0.4	1.1	3.0	-4.5	0.4
4653.8	-3.3	-2.1	0.2	0.8	3.3	-4.8	0.2
4705.1	-2.1	-1.3	0.3	1.2	3.3	-5.0	0.4
4900.6	-3.0	-1.4	0.2	0.0	3.3	-4.9	0.2
5117.6	-2.8	-1.5	0.3	1.7	3.1	-5.1	0.3
5344.1	-2.7	-1.3	0.3	-3.3	3.0	-5.1	0.1
5844.0	-3.6	-1.6	0.5	3.0	3.4	-5.4	0.6
6237.3	-3.3	-1.8	-0.1	-5.4	3.8	-5.2	-0.3
6490.1	-1.8	-1.6	0.3	0.4	3.0	-6.0	0.5
6755.7	-2.0	-1.1	0.3	-3.6	4.2	-4.5	-0.5
6993.4	-1.7	-1.2	0.2	0.8	3.0	-4.5	0.4
7404.4	0.7	0.3	0.7	-5.4	5.4	-4.1	-1.3
7917.0	-1.6	-1.5	-0.2	1.2	3.3	-3.8	1.3
8262.6	4.0	2.5	1.3	-3.1	-5.6	-3.8	-2.2
8533.1	0.9	-0.5	-0.1	-0.9	10.6	-3.4	0.0
8770.2	6.6	5.7	1.1	-6.1	17.5	-4.2	-1.4
9072.9	1.7	0.8	-0.1	-3.1	12.6	-1.8	-0.3
9385.9	0.4	0.8	-0.5	-2.4	11.7	-2.8	-0.4
9556.0	-0.1	0.8	-0.1	-2.9	11.9	-2.8	-0.4
9779.9	-1.6	0.7	-0.1	-2.7	9.1	-2.5	-0.8
10082.0	0.0	1.9	0.2	-2.8	17.6	-3.4	-0.3
10524.0	1.4	1.5	0.2	-2.9	13.7	-1.2	-1.0
10839.0	1.0	0.7	-0.1	-2.0	9.3	-1.8	-1.9
11121.0	0.1	0.3	-0.4	-1.5	9.6	-1.4	-1.6
11648.0	0.3	1.0	0.5	-0.3	8.2	-1.5	-0.6
11948.0	0.7	2.2	0.9	-1.5	13.2	-2.1	-1.1
12224.0	1.0	-0.6	0.6	-1.2	11.1	-2.2	-0.3
12444.0	0.8	-0.8	0.9	-0.8	11.7	-2.9	-0.3
12689.0	1.6	0.9	1.3	0.0	12.4	-4.2	-0.2

River Station (ft)	Toffaleti (MPM) (ft)	Laursen (Madden) (ft)	Increase n Value (ft)	Decrease n Value (ft)	2x Sediment Load (ft)	0.5x Sediment Load (ft)	2x Fines in Bed Material (ft)
12999.0	3.9	4.2	0.8	0.0	12.8	0.0	0.5
13373.0	4.3	5.9	0.0	0.0	13.7	0.0	0.5
13647.0	3.7	5.3	0.0	0.0	0.0	0.0	0.5
13907.0	1.8	3.0	0.0	0.0	0.0	0.0	0.5
14129.0	3.3	3.6	0.0	0.1	0.1	0.0	0.5
14394.0	7.9	7.9	0.0	0.0	0.0	0.0	0.5
14559.0	6.1	5.0	0.0	0.0	0.0	0.0	0.5
14747.0	4.2	5.0	0.0	0.0	0.0	0.0	0.5
14985.0	0.4	2.0	0.0	0.0	0.0	0.0	0.5
15196.0	2.1	5.1	0.0	0.0	0.0	0.0	0.5
15512.0	0.0	2.1	0.0	0.0	0.0	0.0	0.5
15662.0	0.6	3.0	0.0	0.0	0.0	0.0	0.5
15764.0	0.0	3.0	0.0	0.0	0.0	0.0	0.5
15859.0	2.1	4.6	0.0	0.0	0.0	0.0	0.4
15990.0	0.1	1.6	0.5	-0.2	1.2	-0.7	0.6
16092.0	3.8	5.9	0.0	0.0	0.0	0.0	0.5
16201.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16326.0	1.7	1.9	-1.2	3.5	2.1	-2.1	-0.1
16409.0	2.0	2.1	-0.3	-0.1	1.9	-1.1	-0.2
16503.0	1.3	1.7	-0.6	1.6	2.3	-1.4	0.2
16704.0	3.8	4.2	-0.2	-0.2	3.4	-1.7	-0.6
16943.0	1.6	2.3	-0.2	1.9	4.0	-2.8	0.4
17143.0	4.9	5.7	-0.1	-2.2	5.1	-3.2	-0.9
17389.0	3.3	4.3	-0.1	0.6	5.9	-2.5	0.6
17674.0	3.1	4.8	0.3	-2.5	8.1	-2.5	-0.2
18118.0	3.3	5.4	-0.2	2.0	4.3	-3.3	0.0
18376.0	5.8	8.4	0.6	-1.2	11.4	-3.4	0.6
18648.0	4.9	7.5	1.0	2.1	5.9	-4.1	0.6
18901.0	9.2	10.9	2.4	-8.1	14.3	-2.3	-1.6
19374.0	3.8	6.7	0.6	-2.1	4.9	-8.5	0.3
19769.0	4.4	8.8	1.2	-3.8	19.0	-2.9	0.4
20271.0	4.4	12.7	-1.1	-2.0	6.2	-15.6	0.0
20499.0	4.3	13.6	-0.1	-4.2	17.4	-6.2	1.0
21000.0	1.4	15.7	0.0	0.0	0.0	0.0	0.3
21256.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21588.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21928.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22233.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22781.0	0.2	1.8	-0.4	-0.6	0.4	-0.8	0.0
23198.0	5.7	9.7	0.0	0.0	6.8	0.0	0.0
23661.0	1.1	4.7	0.0	0.0	0.4	0.0	0.1
24000.0	4.6	6.8	0.0	0.0	1.2	0.0	0.2
24500.0	15.0	15.0	0.4	-1.8	1.8	-0.5	0.1
Average	1.4	2.6	0.1	-0.7	4.8	-2.4	0.0

Table 15-9 Sensitivity Analysis Results for 10% ACE Event (10-Year) Change from Original Model

River Station (ft)	Toffaleti (MPM) (ft)	Laursen (Madden) (ft)	Increase n Value (ft)	Decrease n Value (ft)	2x Sediment Load (ft)	0.5x Sediment Load (ft)	2x Fines in Bed Material (ft)
550.6	-1.2	0.1	-1.0	0.2	0.3	-0.4	-0.1
839.8	-0.9	0.1	-0.3	0.2	0.3	-0.3	-0.1
1320.8	-0.2	0.7	-0.2	-2.3	0.5	-0.2	0.1
1846.3	-0.4	-0.8	-0.3	0.2	-0.3	0.0	1.4
2603.4	-0.6	0.5	-0.1	0.4	0.2	0.0	0.1
3445.8	-0.2	-0.8	0.3	0.7	-0.1	0.0	0.7
3670.5	-0.4	-1.0	0.1	-0.2	-0.2	0.0	0.5
3906.8	-0.7	-0.9	0.3	0.1	0.6	-0.4	0.5
4203.5	-0.4	-0.3	0.6	1.3	1.3	0.0	0.9
4486.6	-1.1	-1.0	0.0	0.2	0.6	-0.7	0.3
4653.8	-1.7	-1.4	-0.2	0.0	0.9	-0.8	0.3
4705.1	-1.5	-1.4	-0.2	-2.0	1.0	-0.8	0.3
4900.6	-1.6	-1.7	-0.4	-2.0	0.8	-0.8	0.3
5117.6	-1.4	-1.6	-0.3	0.2	1.3	-1.0	0.4
5344.1	-2.7	-2.8	-0.2	0.6	1.2	-0.4	0.4
5844.0	-2.1	-1.8	-0.4	1.1	1.8	-0.7	0.7
6237.3	-1.2	-0.8	0.3	0.0	0.1	0.0	0.1
6490.1	-0.4	-0.4	0.1	-0.2	0.0	-0.1	-0.8
6755.7	-0.2	-0.3	0.1	0.3	0.0	0.0	-0.4
6993.4	-0.6	-1.0	-0.2	0.0	0.3	-0.3	-0.7
7404.4	-0.9	-1.2	-0.2	-1.6	0.4	-0.5	-0.2
7917.0	-1.0	-2.2	-0.4	-3.6	0.4	-0.7	-0.1
8262.6	0.4	-1.3	-0.3	0.2	0.6	-0.8	0.1
8533.1	-0.8	-1.2	-0.2	0.2	0.4	-0.4	0.0
8770.2	-0.2	-0.6	0.1	0.0	0.1	-0.2	-0.1
9072.9	-0.9	-0.2	-0.1	-0.4	0.2	-0.1	-0.1
9385.9	-0.9	-1.2	-0.1	0.0	0.8	-0.2	-0.1
9556.0	-0.4	-0.5	0.1	0.1	0.0	0.0	-0.3
9779.9	0.4	-0.1	0.1	-0.2	0.1	-0.1	-0.5
10082.0	-0.5	-0.9	0.0	0.1	0.0	-0.6	-0.8
10524.0	-0.5	-0.8	0.0	-0.1	0.0	0.0	0.0
10839.0	-0.1	-1.1	0.0	-3.4	0.1	-0.1	-0.1
11121.0	1.1	-0.5	-0.2	-1.8	0.4	-0.4	-0.2
11648.0	-1.4	-1.5	0.0	-0.1	0.1	-0.2	-0.2
11948.0	-0.1	-0.5	0.2	0.3	0.6	-0.1	-0.2
12224.0	-1.4	-1.8	0.1	-0.6	0.3	0.0	0.0
12444.0	-0.8	-1.6	0.0	-1.3	0.1	0.0	-0.2
12689.0	-0.4	-1.3	-0.3	-0.1	-0.2	0.0	-0.2
12999.0	-1.6	-0.9	-0.8	0.0	0.1	0.1	-0.2
13373.0	-3.6	-4.4	-0.6	-7.6	0.4	0.0	-0.2
13647.0	1.2	-0.7	-0.8	6.1	-0.3	1.8	-0.7
13907.0	1.7	2.4	0.1	1.6	0.4	-0.1	-0.2

River Station (ft)	Toffaleti (MPM) (ft)	Laursen (Madden) (ft)	Increase n Value (ft)	Decrease n Value (ft)	2x Sediment Load (ft)	0.5x Sediment Load (ft)	2x Fines in Bed Material (ft)
14129.0	-0.2	0.0	0.5	1.1	-0.1	1.1	0.1
14394.0	0.2	0.2	0.1	-3.2	0.1	0.1	0.0
14559.0	-1.9	-3.1	1.0	-1.1	0.0	0.0	-0.2
14747.0	-0.4	-0.3	-0.4	-1.4	0.0	-0.4	-0.4
14985.0	-1.5	-2.1	0.6	1.3	-0.2	0.0	-0.1
15196.0	1.7	3.4	0.4	0.7	0.0	0.0	0.5
15512.0	-0.9	0.8	0.6	-0.5	-0.1	-0.1	0.7
15662.0	4.3	6.0	0.0	4.4	0.0	0.0	0.5
15764.0	3.3	4.5	1.8	-0.5	0.0	0.0	0.8
15859.0	4.8	6.3	0.0	4.4	0.0	0.0	0.4
15990.0	1.3	7.2	2.1	-6.2	0.0	0.0	0.5
16092.0	6.3	6.3	0.0	9.8	0.0	0.0	0.4
16201.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16326.0	0.0	0.9	0.0	6.1	0.0	0.0	0.0
16409.0	1.1	1.3	-0.9	6.2	0.2	-0.3	0.1
16503.0	0.6	1.5	-0.4	5.4	0.6	-0.4	-0.1
16704.0	1.2	3.0	0.3	3.7	0.4	-0.2	0.1
16943.0	0.4	2.1	0.3	1.7	0.3	-0.2	0.1
17143.0	1.4	1.2	0.3	1.4	1.0	-0.6	0.1
17389.0	-1.0	-0.6	-0.2	-1.0	0.8	-0.8	-0.1
17674.0	0.1	-0.6	-0.1	-1.3	0.7	-0.7	-0.1
18118.0	2.4	-0.2	-0.1	-1.2	2.0	-0.7	-0.1
18376.0	2.3	-0.7	0.1	0.4	1.9	-0.6	0.1
18648.0	3.9	-0.2	0.1	-1.9	3.2	-1.5	0.0
18901.0	2.1	-1.0	0.4	-0.2	2.7	-0.6	0.7
19374.0	4.8	1.3	0.1	-4.1	4.1	-1.4	0.2
19769.0	0.4	-2.9	0.1	-3.3	1.3	-0.4	0.2
20271.0	-0.2	0.6	0.1	3.3	1.3	-0.4	0.4
20499.0	2.9	1.8	0.5	-2.1	0.5	-0.4	0.8
21000.0	0.1	1.4	0.0	9.8	0.0	0.0	0.3
21256.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21588.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21928.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22233.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22781.0	-0.4	0.4	-0.1	0.1	-0.1	-0.6	-0.4
23198.0	1.6	3.3	0.0	6.5	1.3	0.0	0.0
23661.0	0.5	1.1	0.0	6.1	0.0	0.0	0.1
24000.0	2.9	2.8	0.1	1.1	0.9	-0.6	-0.6
24500.0	2.2	4.3	0.1	-0.4	3.6	-1.8	-0.4
Average	0.2	0.1	0.0	0.4	0.5	-0.3	0.1

Table 15-10 Sensitivity Analysis Results for 2% ACE Event (50-Year) Change from Original Model

River Station (ft)	Toffaleti (MPM) (ft)	Laursen (Madden) (ft)	Increase n Value (ft)	Decrease n Value (ft)	2x Sediment Load (ft)	0.5x Sediment Load (ft)	2x Fines in Bed Material (ft)
550.6	-0.2	-0.5	-0.4	0.4	0.1	-0.1	0.5
839.8	-1.3	0.4	-1.0	0.1	0.3	-1.0	0.3
1320.8	-0.1	-1.3	0.3	-0.7	-0.1	0.0	2.2
1846.3	-0.5	-2.0	0.1	-1.3	-0.4	0.0	0.9
2603.4	-0.8	0.5	-0.1	0.2	0.0	0.0	0.1
3445.8	-0.7	-1.1	0.2	0.8	-0.3	0.1	0.6
3670.5	-1.1	-1.3	-0.3	0.2	-0.7	0.3	0.2
3906.8	-0.4	-1.4	-0.7	0.4	0.5	-1.3	0.4
4203.5	-0.4	-1.3	0.0	1.0	1.5	-0.2	0.4
4486.6	-0.7	-1.4	-0.3	0.4	1.2	-1.1	0.4
4653.8	-0.6	-2.9	-0.5	0.2	2.4	-0.8	0.4
4705.1	-0.8	-1.7	-0.4	-1.7	2.0	-1.3	0.6
4900.6	-0.8	-1.9	-0.6	-1.9	2.3	-1.1	0.4
5117.6	-1.0	-1.8	-0.4	0.4	2.4	-1.1	0.7
5344.1	-1.0	-3.5	-0.5	0.7	2.3	-1.0	0.6
5844.0	-2.0	-1.9	-0.2	0.4	2.0	-0.4	0.7
6237.3	-1.5	-1.5	0.2	0.1	1.6	-0.1	-0.3
6490.1	-1.0	-0.4	0.4	0.2	0.6	0.0	-0.4
6755.7	0.0	-0.6	0.3	0.0	0.3	0.0	-0.5
6993.4	0.2	-0.7	-0.1	-0.2	0.1	0.0	-0.6
7404.4	-0.7	-1.2	-0.1	-3.5	0.8	-0.5	-0.3
7917.0	-1.1	-1.9	-0.4	-1.5	0.7	-0.4	-0.1
8262.6	0.6	-0.1	-0.1	-0.2	1.1	-0.5	-0.4
8533.1	-1.3	-1.6	-0.2	1.6	0.4	-0.2	-0.1
8770.2	0.0	0.4	0.1	-0.8	0.7	-0.3	-1.1
9072.9	0.2	0.4	-0.1	-0.1	0.1	0.0	0.1
9385.9	0.6	-1.0	-0.2	-0.1	0.9	-0.4	-0.5
9556.0	-0.5	-0.6	0.1	0.0	0.8	0.0	-0.2
9779.9	1.5	0.2	0.7	-0.6	0.6	-0.2	-0.6
10082.0	0.8	-0.1	0.0	0.1	0.0	0.0	-0.1
10524.0	0.1	-0.9	0.0	-0.1	0.2	-0.1	-1.1
10839.0	0.2	-1.2	-0.3	-5.3	0.3	-0.2	-0.4
11121.0	-1.6	-2.0	-0.2	-1.7	0.2	-0.1	-0.4
11648.0	-3.6	-3.1	-0.3	-0.9	0.2	-0.4	-0.5
11948.0	-2.0	-2.9	-0.5	-0.3	0.1	-0.2	-0.5
12224.0	-1.1	-3.5	0.0	-1.3	0.0	-0.1	-0.4
12444.0	-1.3	-3.5	-0.7	-0.9	-0.1	0.0	-0.4
12689.0	1.8	-0.6	0.3	-0.6	0.1	-0.1	-0.3
12999.0	-0.9	-1.6	-0.5	5.0	-0.4	4.9	-0.1
13373.0	-3.9	-4.7	-0.2	-6.2	0.5	-0.4	-0.2
13647.0	-4.8	-4.8	-0.2	4.2	0.4	-0.4	-0.7
13907.0	1.6	3.2	0.7	3.3	0.6	-0.2	0.1

River Station (ft)	Toffaleti (MPM) (ft)	Laursen (Madden) (ft)	Increase n Value (ft)	Decrease n Value (ft)	2x Sediment Load (ft)	0.5x Sediment Load (ft)	2x Fines in Bed Material (ft)
14129.0	-0.7	-0.4	0.9	-1.0	0.1	-0.3	0.2
14394.0	1.5	3.6	0.6	-2.8	1.0	-0.1	0.3
14559.0	0.8	1.9	7.3	-2.3	1.2	-0.6	0.2
14747.0	0.0	2.5	2.1	-0.7	2.5	0.0	0.5
14985.0	3.2	3.5	0.7	0.9	0.0	0.0	0.5
15196.0	4.8	6.9	0.0	1.5	0.0	0.0	0.5
15512.0	0.0	2.2	0.0	-0.9	0.0	0.0	0.5
15662.0	2.0	4.6	0.0	4.3	0.0	0.0	0.5
15764.0	0.0	2.3	0.0	-0.1	0.0	0.0	0.5
15859.0	0.2	3.2	0.0	4.4	0.0	0.0	0.4
15990.0	2.3	3.7	-1.6	-3.8	0.5	-0.7	0.1
16092.0	3.0	5.1	0.0	9.8	0.0	0.0	0.4
16201.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16326.0	1.5	1.4	0.0	6.1	0.0	0.0	0.0
16409.0	1.0	1.0	-0.2	6.8	0.0	0.0	0.0
16503.0	1.8	2.1	0.3	4.7	0.9	-0.8	-0.2
16704.0	1.3	2.1	0.8	5.5	0.7	-0.2	0.1
16943.0	0.4	2.3	-0.2	1.6	1.2	-0.5	0.0
17143.0	2.3	1.3	0.6	1.7	1.6	-0.3	0.2
17389.0	1.5	-0.1	-0.3	-0.8	1.3	-1.2	-0.1
17674.0	1.8	-0.3	0.0	-1.3	0.8	0.0	0.2
18118.0	3.4	0.8	0.2	-2.3	3.6	-1.4	0.0
18376.0	1.3	-0.7	-0.5	-0.2	2.0	-1.3	0.0
18648.0	3.3	0.4	-0.1	-1.1	3.6	-1.3	-0.1
18901.0	0.3	-1.2	-0.2	-1.2	2.0	-0.7	0.0
19374.0	2.5	1.2	0.2	-4.7	4.1	-2.0	-0.1
19769.0	-1.1	-1.8	0.4	-2.8	1.7	-0.3	0.5
20271.0	0.6	4.0	4.7	5.8	6.2	-1.4	0.6
20499.0	1.6	3.6	0.0	-0.3	0.0	0.0	0.4
21000.0	0.0	0.0	0.0	9.8	0.0	0.0	0.3
21256.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21588.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21928.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
22233.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22781.0	-0.5	-0.5	-0.2	0.4	-0.1	-0.7	-0.2
23198.0	0.0	0.2	0.0	6.5	0.0	0.0	0.0
23661.0	0.0	0.0	0.0	6.1	0.0	0.0	0.1
24000.0	4.1	2.7	-0.2	1.2	3.0	-1.2	0.1
24500.0	6.2	7.1	0.0	-0.8	4.4	-3.3	-0.8
Average	0.3	0.1	0.1	0.5	0.9	-0.3	0.1

Table 15-11 Sensitivity Analysis Results for 1% ACE Event (100-Year) Change from Original Model

River Station (ft)	Toffaleti (MPM) (ft)	Laursen (Madden) (ft)	Increase n Value (ft)	Decrease n Value (ft)	2x Sediment Load (ft)	0.5x Sediment Load (ft)	2x Fines in Bed Material (ft)
550.6	-0.2	-0.4	-0.5	0.7	0.1	-0.1	0.6
839.8	-0.5	0.9	-0.1	-0.2	-0.4	-0.1	1.0
1320.8	0.0	-1.5	0.3	-1.1	-0.3	-0.1	0.6
1846.3	-0.4	-2.0	0.2	-0.7	-0.4	0.1	1.1
2603.4	-0.8	-0.9	0.0	0.3	0.1	0.0	0.1
3445.8	-0.7	-1.0	0.2	0.9	-0.3	0.2	0.6
3670.5	-1.2	-1.5	-0.2	-0.1	-0.8	0.5	0.3
3906.8	0.8	-0.8	-0.2	1.3	1.7	-0.4	1.3
4203.5	-0.1	-0.4	0.2	0.9	0.5	0.0	0.6
4486.6	0.3	-0.5	-0.1	1.1	2.3	-0.4	1.0
4653.8	0.0	-2.3	-0.2	0.3	3.0	-0.3	0.7
4705.1	-0.1	-0.8	-0.1	-1.2	3.5	-0.8	0.9
4900.6	-0.1	-1.1	-0.2	-5.1	3.2	-0.4	0.9
5117.6	-0.5	-1.1	0.0	0.5	2.9	-0.5	0.9
5344.1	-2.9	-2.5	-0.4	1.0	2.4	-0.6	0.9
5844.0	-2.1	-2.1	0.0	-0.1	1.6	-0.3	0.4
6237.3	-2.8	-1.9	0.0	0.5	0.3	-0.1	-0.6
6490.1	-1.7	-0.9	0.1	1.9	1.3	-0.2	-0.4
6755.7	-0.8	-1.1	0.0	0.1	0.0	0.0	-0.9
6993.4	0.3	-0.5	0.0	-0.2	0.1	0.0	-0.6
7404.4	-0.8	-2.5	-0.1	-3.6	0.9	-0.3	-0.5
7917.0	-0.4	-1.9	-0.3	-0.9	0.8	-0.2	-0.1
8262.6	1.2	0.0	-0.2	-0.1	0.8	-0.2	-0.6
8533.1	-0.9	-1.8	-0.2	1.6	0.2	-0.1	-0.2
8770.2	0.8	0.4	0.2	-0.5	0.7	-0.1	-1.2
9072.9	0.6	0.3	-0.2	0.0	0.1	0.0	0.1
9385.9	0.5	-1.5	-0.2	0.2	0.9	-0.1	-0.4
9556.0	-0.9	-1.0	0.0	0.1	0.4	0.0	-0.2
9779.9	1.0	-1.0	0.2	-1.2	0.1	0.0	-1.3
10082.0	0.6	0.0	0.1	0.1	0.0	0.0	-0.1
10524.0	-0.2	-2.8	0.0	-0.1	0.4	0.0	-1.6
10839.0	-0.9	-1.9	-0.6	-6.3	0.8	-0.2	-0.4
11121.0	-1.4	-2.5	-0.2	-2.2	0.4	-0.1	-0.8
11648.0	-2.1	-3.7	-0.3	-0.4	0.5	-0.2	-0.6
11948.0	-0.2	-2.9	-0.2	-0.4	0.3	-0.1	-0.6
12224.0	0.0	-2.7	0.2	-1.3	0.2	-0.1	-0.5
12444.0	-0.3	-2.7	-0.4	-1.7	0.2	-0.1	-0.5
12689.0	1.2	-2.2	0.2	0.2	0.4	-0.1	-0.2
12999.0	-1.7	-1.5	-0.5	1.3	-0.7	-0.5	-0.6
13373.0	-2.7	-1.6	0.0	-4.5	2.6	2.2	-0.3
13647.0	-5.9	-4.9	0.9	4.7	0.8	0.2	-3.4
13907.0	2.7	4.2	0.5	2.6	0.6	-0.1	0.1

River Station (ft)	Toffaleti (MPM) (ft)	Laursen (Madden) (ft)	Increase n Value (ft)	Decrease n Value (ft)	2x Sediment Load (ft)	0.5x Sediment Load (ft)	2x Fines in Bed Material (ft)
14129.0	1.1	2.6	1.0	-0.8	0.4	-0.4	0.4
14394.0	-0.1	2.2	0.2	-2.8	0.6	-0.2	0.4
14559.0	1.9	5.0	1.0	-1.1	0.9	-0.6	0.5
14747.0	0.0	0.0	0.0	-0.7	0.0	0.0	0.5
14985.0	2.2	3.3	0.0	0.9	0.0	0.0	0.5
15196.0	2.5	6.2	0.0	1.5	0.0	0.0	0.5
15512.0	0.0	1.7	0.0	-0.9	0.0	0.0	0.5
15662.0	1.8	3.8	0.0	4.3	0.0	0.0	0.5
15764.0	0.0	1.0	0.0	-0.1	0.0	0.0	0.5
15859.0	1.4	1.6	0.0	4.4	0.0	0.0	0.5
15990.0	3.9	4.6	0.0	-3.6	0.8	0.0	0.4
16092.0	3.1	4.4	0.0	9.8	0.0	0.0	0.4
16201.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16326.0	2.2	1.2	0.0	6.1	0.0	0.0	0.0
16409.0	1.0	0.9	-0.6	6.8	0.4	0.0	0.1
16503.0	2.2	2.8	0.7	5.0	1.0	-0.1	-0.2
16704.0	-0.3	-0.4	-0.5	4.3	0.2	-0.3	0.1
16943.0	1.8	2.9	-0.1	2.3	1.2	-0.5	0.2
17143.0	1.4	0.4	-0.8	1.8	0.8	-1.0	0.1
17389.0	2.1	0.1	-0.1	-0.6	1.7	0.0	0.3
17674.0	1.5	-0.8	-0.6	-0.6	0.9	-1.7	0.1
18118.0	3.4	0.7	0.3	-2.7	3.4	-0.8	-0.2
18376.0	-0.9	-2.2	-1.7	-0.8	0.5	-2.2	-0.2
18648.0	2.7	0.8	0.4	-1.5	4.1	-0.9	-0.1
18901.0	-4.0	-4.5	-3.1	-3.3	-1.3	-2.2	-0.5
19374.0	2.1	2.1	1.1	-6.5	5.4	-0.8	-0.5
19769.0	-5.1	-4.8	-2.5	-4.2	-1.8	-3.1	0.0
20271.0	5.6	7.1	4.9	2.0	13.4	0.0	0.4
20499.0	0.0	2.1	0.0	-0.3	0.0	0.0	0.4
21000.0	0.0	0.0	0.0	9.8	0.0	0.0	0.3
21256.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21588.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21928.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22233.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22781.0	-0.5	-0.3	-0.1	0.4	0.3	-0.5	0.0
23198.0	0.0	0.0	0.0	6.5	0.0	0.0	0.0
23661.0	0.0	0.0	0.0	6.1	0.0	0.0	0.1
24000.0	4.1	2.4	-0.3	1.4	3.2	-1.9	-0.3
24500.0	7.0	8.0	0.0	-0.6	6.2	-4.4	-0.7
Average	0.3	0.0	0.0	0.4	0.9	-0.3	0.0

16.0 ALTERNATIVE ANALYSES

16.1 General

The focus of the alternative analyses is removal of Rindge Dam. In addition, the study also includes removal or modification to other barriers to aquatic species along Malibu Creek and tributaries. These barriers include culverts, stream crossings, impaired channel sections, abandoned pipes, etc. No specific hydraulic or sediment transport modeling was performed to address barrier removals.

An initial array of alternatives was determined by the PDT during the plan formulation phase of this study. The initial array consisted of a number of versions of mechanical removal of sediments and natural sediment transport. Several mechanical removal scenarios were developed that involved slurrying, conveyors, or truck removal. The assumption for the mechanical removal alternatives was that the sediment would be removed from behind the dam prior to the start of the simulations. Trucking was the only mechanical removal option that persisted into the final array.

The natural sediment removal alternatives from the initial array included full-dam removal and the natural disposition of sediments downstream, and half-dam removal, in which half the dam is removed at the start of the simulation and the remainder of the dam is removed as soon as half the volume of sediment has been removed by natural transport.

The hydrologic and hydraulic analyses for the alternatives consisted of determining the short- and long-term impacts along Malibu Creek from Rindge Dam to the Pacific Ocean. In addition, the changes in water surface elevation and extent for discrete flood events were computed. The future condition impacts under the No Action alternative are used as a basis for alternative comparison.

There are numerous factors which are vital to determining the ecosystem assessment of the selected alternatives. These factors are used in the habitat evaluation process and allow better understanding and communication about the creek system. To assist in the evaluation of the alternatives from the ecosystem perspective the width-to-depth ratios were determined for each of the initial alternatives. These results are shown in **Table 16-1**. In addition, the average bankfull width-to-depth ratios and the entrenchment ratios were determined for each reach under each of the initial alternative scenarios. The results are presented in **Table 16-2**.

A detailed discussion of the cumulative volumetric data and gradation for the deposited material behind the dam can be found in the Geotechnical Appendix. This is important for sediment management considerations in selecting alternatives. The sediments behind the dam range from very small particle sizes to very large boulders. Because of the steepness of the canyon, even the large size material can make its way to the ocean during larger events. The number of the large boulders is not high and some can be left in place without causing adverse problems downstream. This will be further defined during the design phase of the study.

Table 16-1 Width-to-Depth Ratios for Malibu Creek

Existing Conditions Without Project							
Event	Reach 1	Reach 2a	Reach 2b	Reach 3	Reach 4a	Reach 4b	Reach 5
50%*	268	70	45	42	43	32	29
20%	264	57	184	30	37	24	21
10%	288	184	476	30	35	20	19
4%	236	427	513	38	37	17	16
2%	202	462	449	60	39	14	14
1%	189	384	401	58	35	13	12
Future Conditions Without Project							
Event	Reach 1	Reach 2a	Reach 2b	Reach 3	Reach 4a	Reach 4b	Reach 5
50%	975	199	177	70	46	19	22
20%	449	139	232	61	51	12	18
10%	331	236	244	57	42	13	16
4%	270	260	298	52	46	13	14
2%	345	301	275	45	38	11	12
1%	352	281	251	42	33	10	11
Future Conditions Mechanical Removal							
Event	Reach 1	Reach 2a	Reach 2b	Reach 3	Reach 4a	Reach 4b	Reach 5
50%	957	199	149	66	49	20	31
20%	445	136	218	59	50	13	17
10%	330	262	208	57	49	14	13
4%	271	268	292	53	51	13	11
2%	346	297	241	46	39	11	9
1%	347	282	244	42	33	10	8
Future Conditions Natural Transport Full-Dam Removal							
Event	Reach 1	Reach 2a	Reach 2b	Reach 3	Reach 4a	Reach 4b	Reach 5
50%	1025	220	198	70	100	26	30
20%	463	180	221	46	93	13	17
10%	352	285	354	61	71	11	13
4%	293	349	329	54	55	12	11
2%	365	327	287	47	43	10	9
1%	375	293	263	42	37	9	8
Future Conditions Natural Transport Half-Dam Removal							
Event	Reach 1	Reach 2a	Reach 2b	Reach 3	Reach 4a	Reach 4b	Reach 5
50%	789	264	220	87	126	31	30
20%	502	207	537	97	99	13	17
10%	373	334	468	80	71	11	13
4%	311	371	396	68	55	11	11
2%	372	342	337	56	42	10	9
1%	376	313	303	50	36	9	8

*50% ACE = 2-yr, 20% ACE = 5-yr, 10% ACE = 10-yr, 5% ACE = 20-yr, 2% ACE = 50-yr, 1% ACE = 100-yr, 0.5% ACE = 200-yr, 0.2% ACE = 500-yr

Table 16-2 Average Riverine Entrenchment Ratios by Reach

Existing Conditions Without Project							
Q	Reach 1	Reach 2a	Reach 2b	Reach 3	Reach 4a	Reach 4b	Reach 5
Bankfull w/d	264	57	184	30	37	24	21
avg ER	1.27	7.95	2.96	1.70	1.35	1.21	1.29
Future Conditions Without Project							
Q	Reach 1	Reach 2a	Reach 2b	Reach 3	Reach 4a	Reach 4b	Reach 5
Bankfull w/d	449	139	232	61	51	12	18
avg ER	1.09	1.88	2.28	1.56	1.26	1.74	1.44
Future Conditions Mechanical Removal							
Q	Reach 1	Reach 2a	Reach 2b	Reach 3	Reach 4a	Reach 4b	Reach 5
Bankfull w/d	445	136	218	59	50	13	17
avg ER	1.26	0.00	2.75	1.64	1.39	1.69	1.24
Future Conditions Natural Transport Full-Dam Removal							
Q	Reach 1	Reach 2a	Reach 2b	Reach 3	Reach 4a	Reach 4b	Reach 5
Bankfull w/d	463	180	221	46	93	13	17
avg ER	1.06	0.00	3.33	2.43	1.15	1.77	1.34
Future Conditions Natural Transport Half-Dam Removal							
Q	Reach 1	Reach 2a	Reach 2b	Reach 3	Reach 4a	Reach 4b	Reach 5
Bankfull w/d	502	207	537	97	99	13	17
avg ER	1.08	0.00	0.27	1.04	1.17	2.06	1.41

Bankfull Depth = stage at which the channel begins to spill onto its floodplain
Bankfull w/d = width-to-depth ratio at bankfull depth
Flood Prone Depth = double the bankfull depth
Flood Prone Width = width of channel at flood prone depth
Entrenchment ratio (ER) = flood prone width divided by bankfull width

Subsequent to the hydraulic analyses of the initial array of alternatives, the PDT reviewed the results and concluded there was a significant flood risk downstream even under the No Action alternative. Therefore, natural transport was not considered a viable alternative because it would only exacerbate the downstream flood risks. Therefore, it was concluded the recommended plan should be based on mechanical removal of sediments. However, disposal areas for the sediment proved hard to find and expensive. The study experienced a significant gap in funding and after several years the PDT and TAC members changed. The new members of the PDT and TAC wanted to re-visit natural transport combined with smaller 'notching' of the dam over several years. A 'hybrid' alternative that included mechanical removal plus 5-ft notches at the end of each year's construction season was included in the mix. The results for the alternatives are summarized in the following sections.

16.2 <u>Alternative 1 - No Action</u>

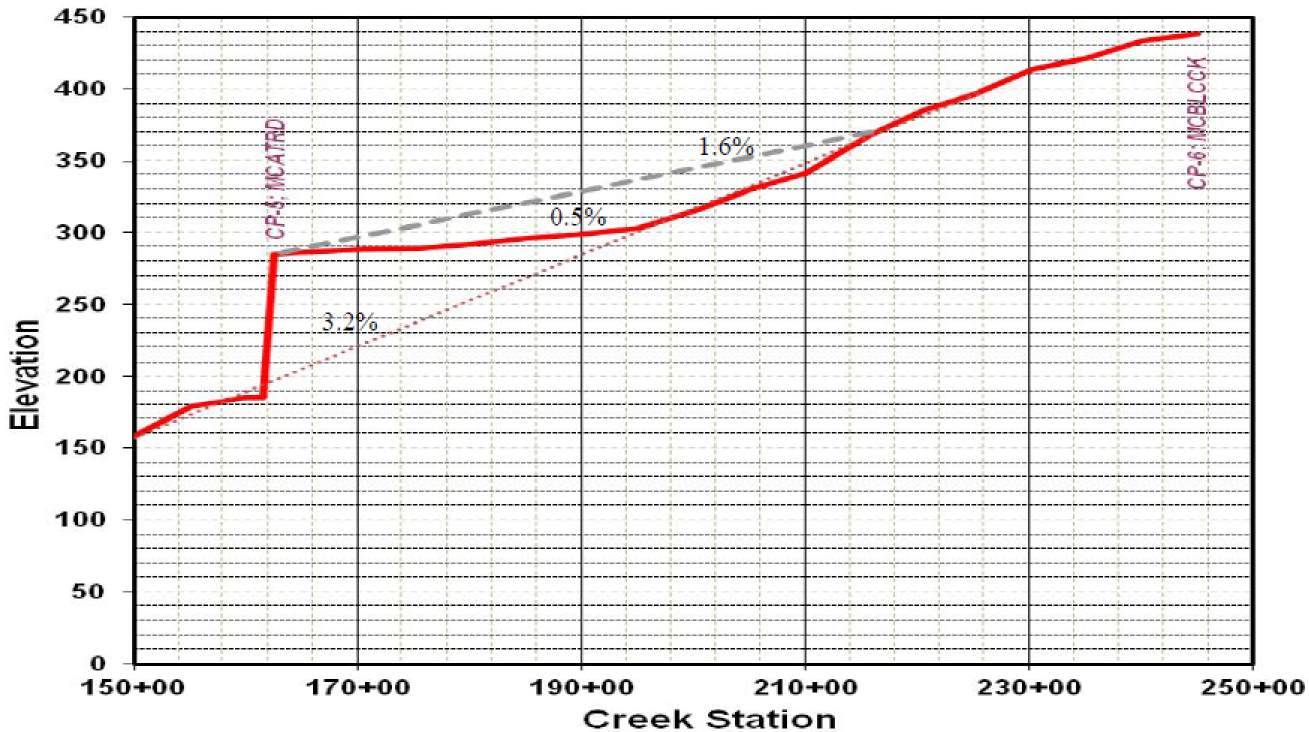
16.2.1 General

Rindge Dam is effectively “full”. The natural slope of the channel invert along the Rindge Dam area is 3.2%. The current depositional slope of sediments behind the dam is about 0.5%. However, under the No Action Alternative and 'optimal' hydrologic conditions (a number of years with smaller magnitude events) some deposition could still occur behind Rindge Dam. The depositional slope behind the dam would approach 1.6% which is one-half of the natural slope of Malibu Creek in this vicinity. This hypothetical slope is shown on **Plate 16-1**.

Under 'optimal' hydrologic conditions, in approximately 17 years all sediment, including sand and gravel sized sediment would pass over the dam crest, at which time it is estimated that over 1.3 million yd^3 of sediment could be stored behind the dam. The approximately 780,000 yd^3 of sediment that is presently trapped behind the dam would not be supplied to the beach and an additional 530,000 yd^3 of sediment could be trapped behind the dam for a total of 1.3 million yd^3. It is important to note that Malibu Creek has only gone 10 straight years once (based on recorded flows at the stream gage) where there wasn’t at least one 20% ACE flood event (5-year). Which means, 'optimal' hydrologic conditions for deposition are not expected to occur.

It is expected that in approximately 100 years, without human intervention, Malibu Creek could be in approximate equilibrium, meaning that sediment load entering the system would be in approximate balance with the sediment load exiting the system.

Presently, the majority of the silt and clay carried along Malibu Creek passes over the top of Rindge Dam. However, the decrease in slope caused by the dam allows some sand and larger sizes to deposit. Because the dam is continuing to trap some coarse sediment, there would be some continued degradation in the reach immediately downstream of the dam. Based on data from other reports and information provided by members of the TAC, the maximum scour in Reach 4b below the dam was limited to 3 ft in the models. The expected degradation in 50 years under the No Action Alternative would be about 2.5 ft in this reach.



Elevations (ft NGVD) based on May 2002 survey.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

**MALIBU CREEK
DEPOSITIONAL SLOPES
VICINITY RINDGE DAM**

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 16-1 Malibu Creek Depositional Slopes Vicinity Rindge Dam

16.2.2 Period-of-Record Simulation.

There are flood concerns along lower Malibu Creek even under current conditions. Several residential and commercial areas downstream of the canyon mouth are at risk of flooding during events more frequent than the 1% ACE event (100-year). Significant deposition would be expected in these reaches even if the dam is not removed which will increase the flood risk. Up to 12 ft of deposition in some locations could be expected in the lower reaches over the next 50 years. The results of the period-of-record simulation for without-project conditions were shown in **Table 15-1**.

Under the No Action alternative, the dam is continuing to trap some coarse sediment and there will be some continued degradation in the reach immediately downstream of the dam. The expected degradation for Future Conditions under the No Action Alternative would vary from 0-10 ft in this reach after 5 years. The sediment loads downstream of the dam would then increase slightly. Just downstream of the canyon, where the floodplain widens, up to 7 ft of deposition would occur after 5 years. From Cross Creek Road bridge to PCH, an average of about 3 ft of deposition would take place. In the lagoon, about 2 ft of deposition would occur.

The hydraulic models were adjusted to include the geometry after 5 years under No Action. The HEC-6T models were stopped at each specific time step and the cross sections were manually then input into HEC-RAS using the graphical cross section editor and merging cross sections. The resulting inundation areas were mapped to show the increase in flood risk for the lower portions of Malibu Creek. Even though there was an increase in water surface elevation for the 50% ACE event (2-year), the flow was still contained within the banks. However, events larger than the 50% ACE event (2-year) all showed flow exceeding the channel capacity and increasing the flood risks. **Plate 16-2 through Plate 16-4** show the inundation areas for the 20% (5-yr), 10% (10-yr), and 5% (20-yr) ACE events Without-Project at 5 yrs after construction. The larger events were not plotted since the increase in inundation areas was not discernible.

About 50 yrs after construction, one can expect up to 12 ft of deposition in certain locations from the “Big Bend” to Malibu Lagoon under the Future No Action Alternative. The impacts of which may be offset by removal and maintenance at key locations. However, there is no guarantee all or any sediment would be removed prior to any given flood event and permits are difficult to attain. **Plate 16-5** shows the Future (50-years) Without-Project inundation areas for the 2% (50-yr), 1% (100-yr), 0.5% (200-yr), and 0.2% (500-yr) ACE events.

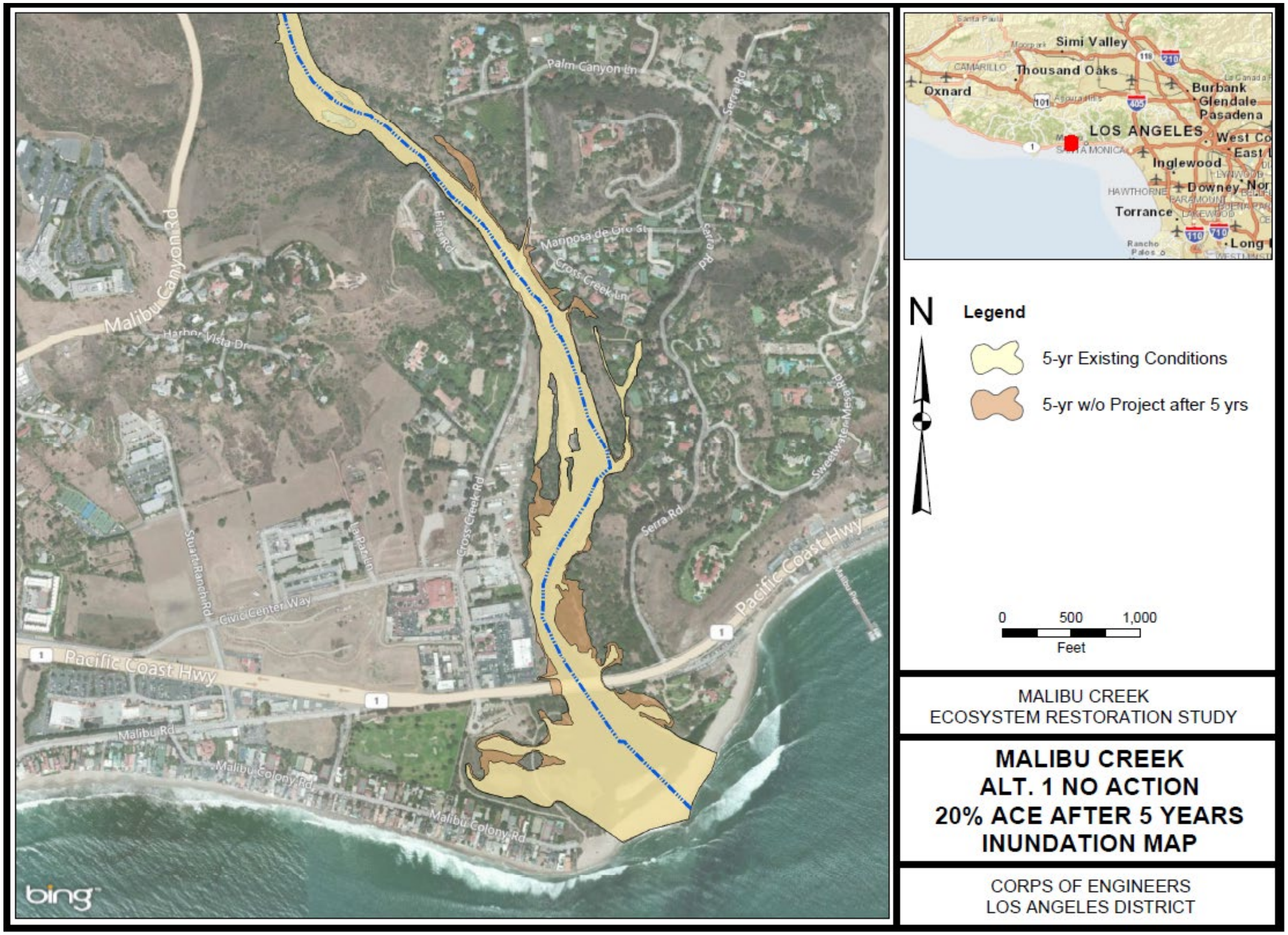


Plate 16-2 Malibu Creek Alt. 1 No Action - 20% ACE (5-Year) after 5 Years Inundation Map

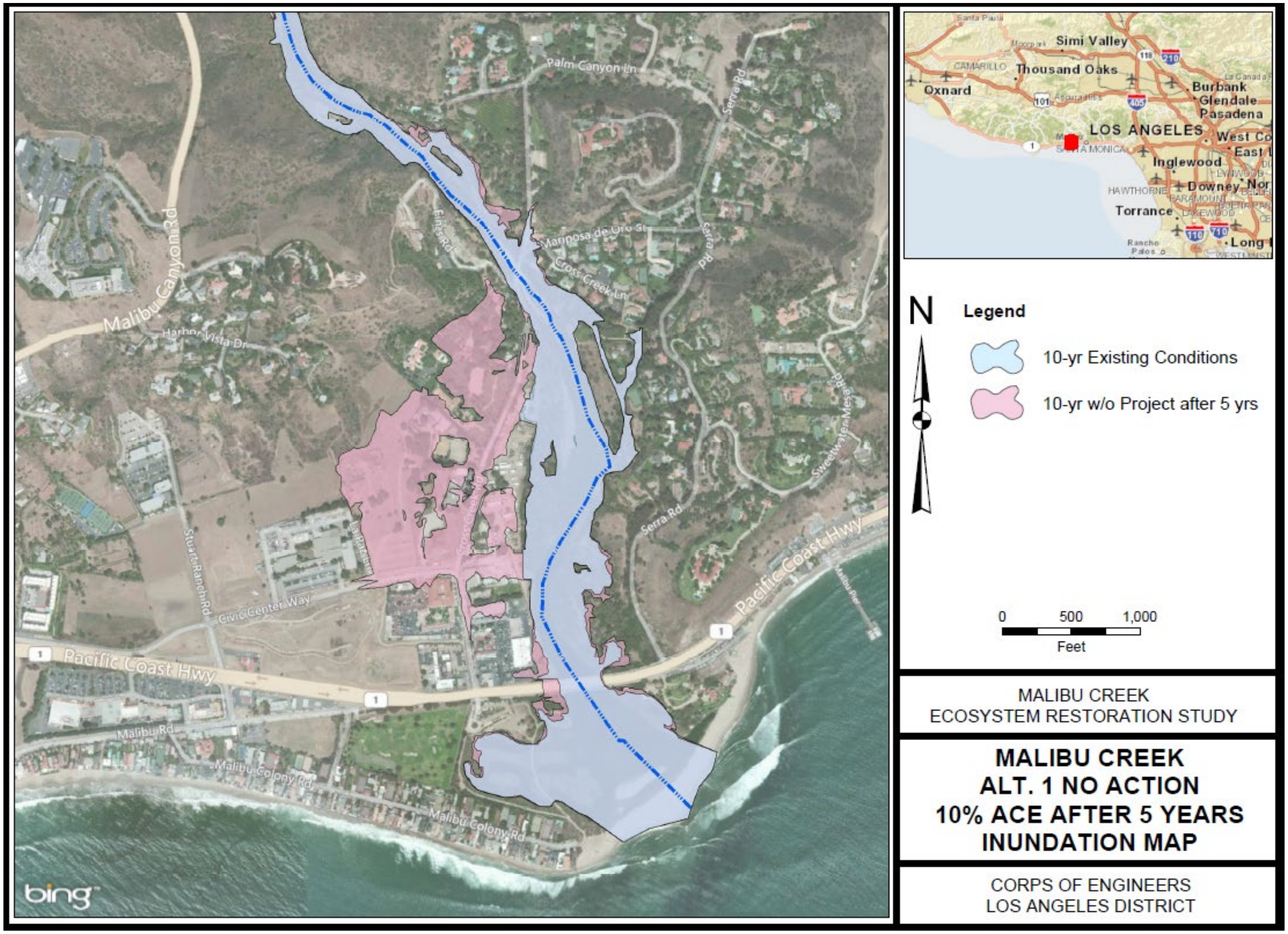


Plate 16-3 Malibu Creek Alt. 1 No Action - 10% ACE (10-Year) after 5 Years Inundation Map

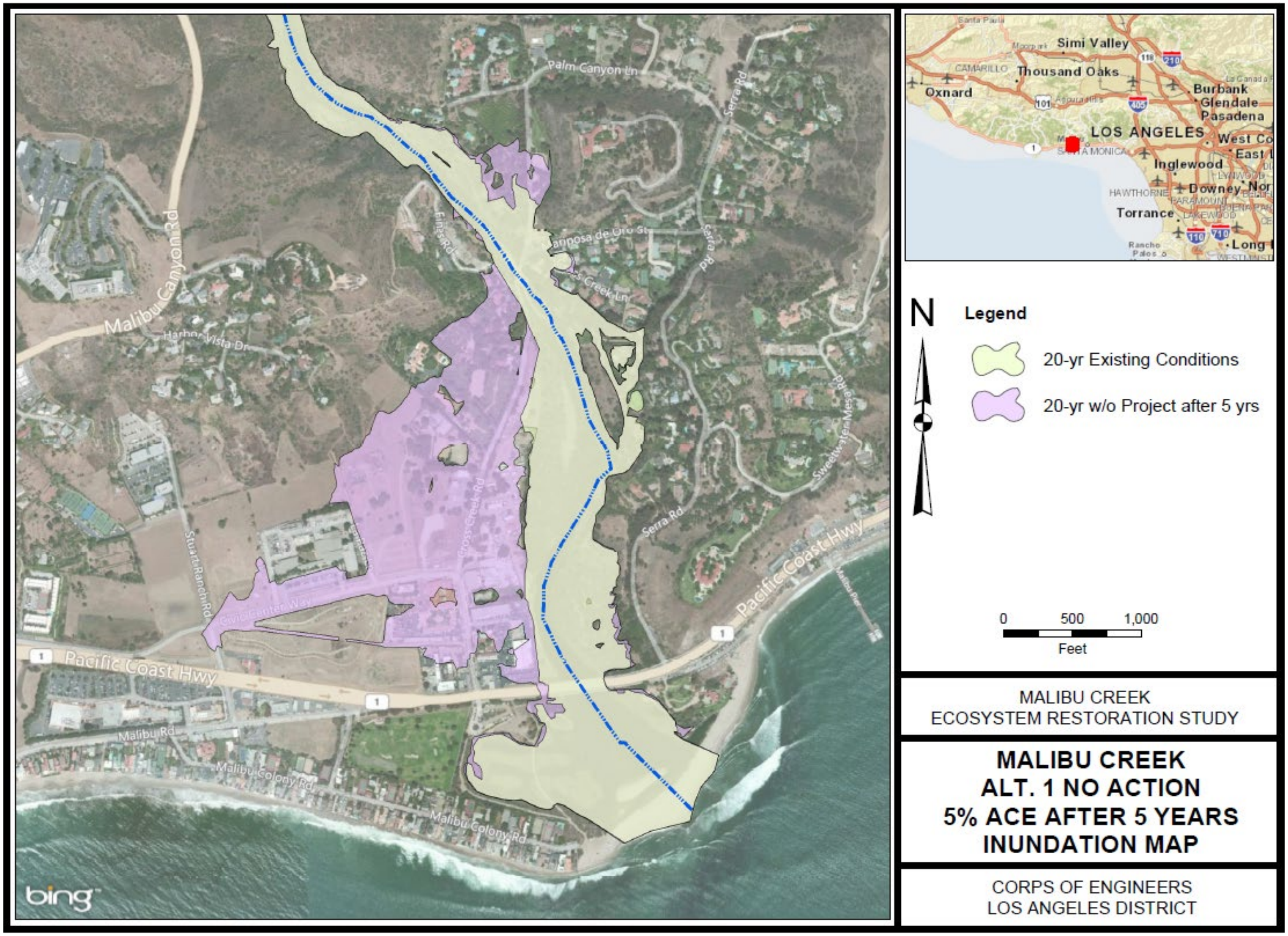


Plate 16-4 Malibu Creek Alt. 1 No Action - 5% ACE (20-Year) after 5 Years Inundation Map

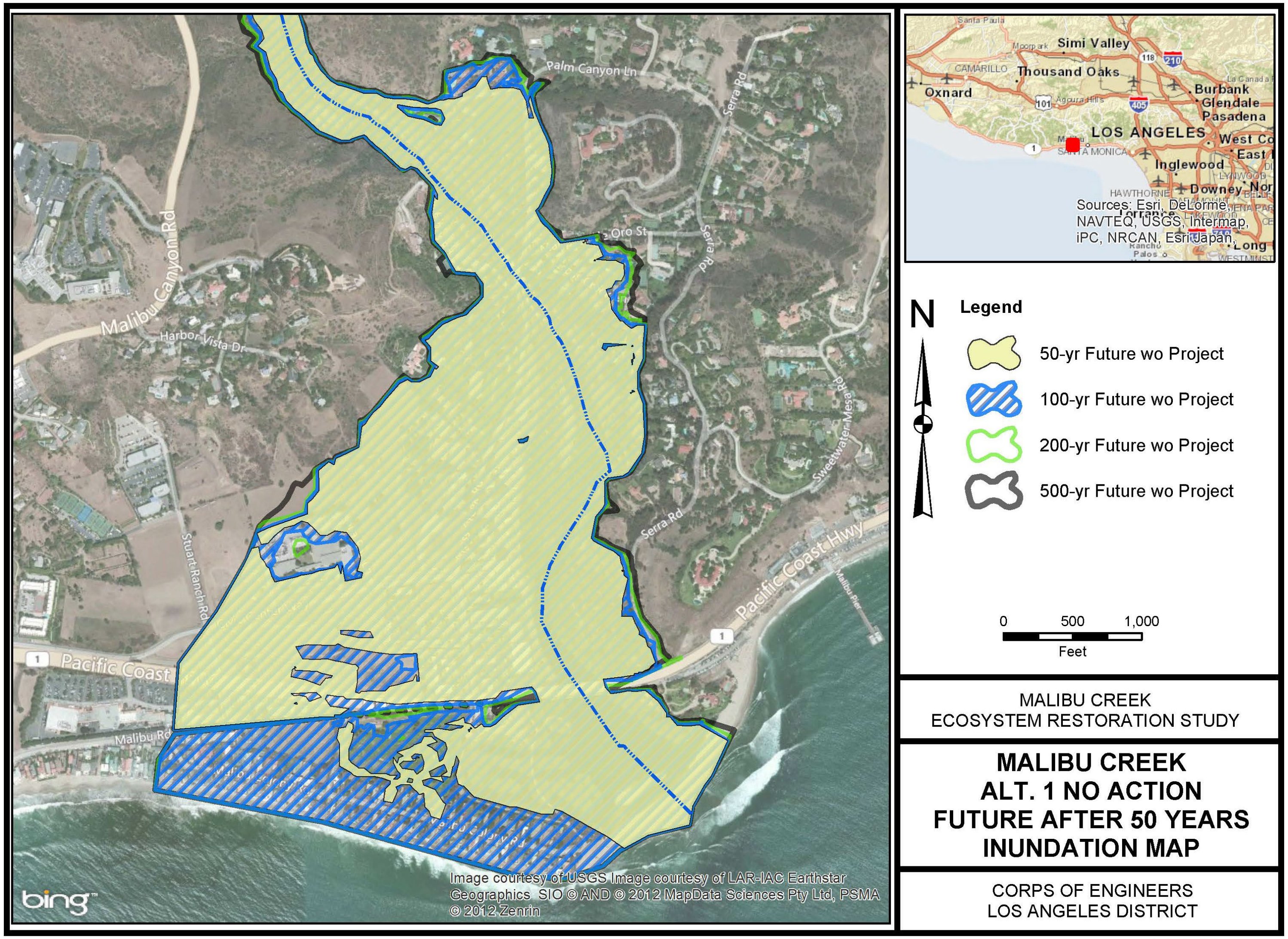


Plate 16-5 Malibu Creek Alt. 1 No Action - Future after 50 Years Inundation Map

16.2.3 Frequency Event Simulations

The 1% (100-year) and 2% (50-year) ACE events were also simulated for the No Action alternative. The following summary is for the 1% ACE event (100-year); results for other flood events are proportionally similar. The upstream end of the study reach (Reach 5) would experience up to 9 ft of local degradation. Bedrock outcrops exist between RS 212+56 and RS 227+81; therefore, this reach would remain relatively stable. Up to 7 ft of deposition would occur downstream from RS 176+74 to RS 202+71. The reservoir immediately upstream of the dam could experience up to 10 ft of local scour. Similarly, up to 2.5 ft of degradation could occur immediately downstream of the dam (Reach 4b). Downstream of the canyon, where the floodplain widens, up to 4 ft of deposition would occur (Reach 3). From Cross Creek Road bridge to the Pacific Coast Highway bridge (Reaches 2b and 2a) about 1.5 ft of scour would occur. The results of the 1% (100-year) and 2% (50-year) ACE events for without-project conditions are shown in **Table 16-3 and Table 16-4**.

Table 16-3 Alt. 1 Future w/o Project - Sediment Transport Results for 1% ACE (100-Year) Event

Station	Initial Bed Elevation	End Hydrograph 100-yr	Change in Bed Elevation After (values in ft)												
			1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	70 Years	75 Years
550.6	2.2	0.2	0.6	1.0	0.8	0.9	1.9	2.2	1.8	2.1	1.9	2.0	1.9	2.1	2.1
839.8	1.7	0.3	1.1	1.6	1.9	1.9	2.4	2.9	2.3	2.8	2.6	2.8	2.9	2.6	2.7
1320.8	2.0	0.2	1.4	2.0	2.2	2.4	3.3	4.3	3.9	4.4	4.1	4.8	4.9	5.0	5.0
1846.3	3.0	-0.9	1.0	1.7	2.2	2.2	3.1	4.3	4.3	4.8	4.5	5.4	5.5	6.2	6.2
2603.4	5.0	0.0	0.4	0.7	1.5	1.6	2.7	4.3	4.8	5.2	5.0	5.8	5.9	6.8	6.9
3445.8	11.0	-0.9	-0.9	-0.9	-0.8	-0.7	-0.3	1.5	2.4	3.1	3.2	3.9	4.1	5.2	5.5
3670.5	11.0	-0.5	-0.5	-0.5	-0.3	-0.3	0.4	2.4	3.5	4.1	4.3	5.0	5.1	6.2	6.5
3906.8	11.0	1.0	1.4	1.7	1.9	2.0	2.7	4.9	6.3	6.9	6.8	7.9	8.0	9.3	9.7
4203.5	14.0	0.1	0.1	0.2	0.4	0.4	0.8	3.3	5.0	5.6	5.7	6.6	6.8	8.1	8.4
4486.6	14.0	1.1	1.6	1.8	2.2	2.2	2.3	4.6	6.4	7.0	7.4	8.1	8.3	9.6	9.9
4653.8	16.0	1.5	2.0	2.3	2.7	2.7	3.3	5.9	7.9	8.6	8.7	9.8	9.9	11.4	11.9
4705.1	14.0	4.0	4.1	3.5	4.0	3.8	4.4	6.8	8.8	9.4	9.7	10.5	10.5	12.2	12.7
4900.6	15.0	3.2	3.8	4.1	4.5	4.6	5.3	7.9	10.1	10.8	10.7	11.9	12.0	13.5	14.1
5117.6	15.0	3.5	4.1	4.5	4.9	5.1	5.6	8.1	10.3	11.0	11.4	12.4	12.4	14.0	14.4
5344.1	19.0	1.5	1.7	1.8	2.4	2.4	2.9	5.6	7.9	8.6	8.5	9.9	10.0	11.5	12.1
5844.0	21.0	4.3	4.3	4.3	4.8	4.8	4.9	6.7	9.1	9.8	10.7	11.6	11.6	13.2	13.6
6237.3	28.0	-0.8	-0.6	-0.6	0.0	-0.1	-0.2	2.5	4.4	5.0	5.0	6.3	6.4	7.9	8.5
6490.1	33.0	-0.9	-1.0	-1.1	-1.1	-1.1	-1.2	-1.1	1.2	2.0	3.0	4.0	4.0	5.3	5.9
6755.7	37.0	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.6	-0.2	0.1	1.2	1.6	1.7	3.2	3.9
6993.4	38.0	-0.3	0.1	0.3	0.3	0.4	0.7	0.8	1.6	1.9	3.0	3.5	3.6	4.8	5.4
7404.4	38.0	1.5	2.2	2.4	2.4	2.5	2.9	3.2	3.5	3.9	4.4	5.0	5.0	6.7	7.7
7917.0	38.0	4.7	5.4	5.7	5.9	6.1	6.8	8.1	9.1	9.6	10.3	11.3	11.3	12.1	12.6
8262.6	43.0	2.5	2.6	2.6	3.0	2.9	3.1	3.8	4.2	4.3	4.6	5.4	5.6	7.0	8.3
8533.1	50.0	0.7	0.8	0.8	1.3	1.2	1.2	1.9	2.8	3.0	3.9	4.3	4.3	5.3	5.9
8770.2	53.0	-2.0	-2.2	-2.2	-2.3	-2.3	-2.4	-2.5	-2.2	-2.3	-1.9	0.6	0.5	1.1	1.6
9072.9	57.0	3.1	3.1	3.1	3.2	3.2	3.3	3.3	3.5	3.5	4.1	3.6	3.6	4.2	4.4
9385.9	58.0	0.5	0.8	1.0	0.8	0.8	1.0	1.8	2.2	2.8	3.9	4.1	4.1	4.7	5.1

Station	Initial Bed Elevation	End Hydrograph 100-yr	Change in Bed Elevation After (values in ft)												
			1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	70 Years	75 Years
9556.0	63.0	0.1	0.2	0.3	0.4	0.4	0.5	0.5	0.6	0.6	1.3	1.6	1.6	2.2	2.9
9779.9	64.0	-0.1	-0.2	-0.1	-0.1	-0.1	-0.1	0.2	1.2	1.5	3.1	3.2	3.2	3.6	3.7
10082.0	69.0	0.3	0.3	0.2	0.3	0.2	0.1	-0.1	-0.1	-0.1	0.3	0.5	0.5	0.8	1.2
10524.0	76.0	0.7	0.8	0.9	1.0	1.0	0.9	0.9	1.2	1.0	1.5	1.5	1.5	1.5	1.4
10839.0	77.0	2.3	2.7	2.9	3.1	3.1	3.5	3.7	4.5	4.6	3.7	4.5	4.6	5.3	5.2
11121.0	80.0	3.4	3.6	3.7	3.9	3.9	4.0	4.6	5.2	5.1	5.4	5.5	5.5	5.6	5.7
11648.0	88.0	2.7	2.8	2.8	3.1	3.1	2.9	3.1	3.6	3.5	2.7	2.8	2.7	3.1	2.9
11948.0	92.0	3.9	4.1	4.0	4.0	4.0	4.2	4.2	4.4	4.3	3.8	2.5	2.5	2.1	2.0
12224.0	99.0	3.4	3.4	3.4	3.4	3.4	3.3	3.4	3.8	3.6	0.9	0.8	0.8	0.3	-0.1
12444.0	99.0	6.0	6.0	5.9	6.2	6.2	6.1	6.1	6.7	6.6	2.7	2.1	2.1	1.4	1.5
12689.0	106.0	0.6	0.6	0.7	0.4	0.5	0.4	0.8	0.5	0.2	-3.3	-3.3	-3.3	-3.6	-3.9
12999.0	114.0	0.5	0.4	0.3	0.2	0.2	0.0	-1.3	-1.8	-1.8	-8.8	-9.0	-9.0	-8.3	-8.8
13373.0	117.0	1.1	1.1	1.2	1.2	1.2	1.1	2.6	-2.8	-3.3	-9.1	-9.1	-9.1	-9.1	-9.1
13647.0	124.0	-1.7	-3.0	-3.6	-3.6	-3.6	-4.1	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2
13907.0	138.0	-8.7	-8.8	-8.8	-9.2	-9.2	-9.2	-9.3	-9.3	-9.3	-9.3	-9.3	-9.3	-9.3	-9.3
14129.0	143.0	-6.8	-6.9	-7.0	-7.5	-7.5	-7.7	-8.4	-8.9	-8.1	-9.3	-9.3	-9.3	-9.3	-9.3
14394.0	143.0	-4.4	-4.5	-4.5	-4.9	-5.0	-5.2	-5.8	-8.5	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4
14559.0	149.0	-7.4	-7.6	-7.6	-7.6	-7.7	-7.7	-8.9	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4
14747.0	151.0	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5
14985.0	160.0	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5
15196.0	165.0	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6
15512.0	179.0	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7
15662.0	180.0	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7
15764.0	185.0	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7
15859.0	185.0	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8
15990.0	185.0	-6.1	-6.1	-6.1	-6.8	-6.5	-6.1	-6.1	-6.6	-6.5	-6.0	-6.0	-6.0	-5.6	-5.5
16092.0	185.0	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8
16201.0	277.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16326.0	285.0	-8.8	-8.9	-9.0	-8.4	-8.8	-8.0	-8.4	-7.8	-8.0	-7.7	-7.2	-7.1	-6.4	-6.1

Station	Initial Bed Elevation	End Hydrograph 100-yr	Change in Bed Elevation After (values in ft)												
			1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	70 Years	75 Years
16409.0	285.0	-6.7	-7.4	-7.5	-7.5	-7.5	-7.3	-7.5	-7.5	-7.8	-7.8	-7.8	-7.9	-7.5	-7.7
16503.0	286.0	-7.6	-7.3	-7.3	-7.1	-7.3	-7.3	-7.5	-6.3	-6.4	-5.8	-5.6	-5.5	-4.8	-4.6
16704.0	286.0	-3.1	-4.7	-4.9	-4.8	-4.8	-5.4	-5.8	-6.3	-6.9	-8.0	-8.0	-8.0	-7.4	-7.5
16943.0	288.0	-5.0	-5.6	-5.5	-5.8	-5.8	-5.3	-5.5	-4.5	-4.4	-3.4	-3.2	-3.2	-2.7	-2.2
17143.0	289.0	-3.7	-4.2	-4.4	-4.4	-4.4	-4.7	-5.4	-5.9	-6.4	-7.5	-7.4	-7.3	-6.1	-6.3
17389.0	288.0	1.1	-0.1	-0.4	-0.6	-0.6	-0.7	-1.1	-0.5	-0.3	0.4	0.2	0.1	1.2	1.4
17674.0	289.0	2.6	2.3	2.2	2.2	2.1	1.9	0.9	1.1	0.8	0.9	0.9	0.9	2.1	2.2
18118.0	292.0	2.1	1.8	1.6	1.6	1.5	0.3	0.8	2.7	3.0	3.8	4.1	4.2	5.0	5.4
18376.0	295.0	3.6	3.6	3.5	3.6	3.6	3.3	1.3	1.9	1.9	1.3	1.5	1.5	2.2	3.5
18648.0	296.0	1.6	1.5	1.4	1.4	1.4	1.4	1.7	4.0	4.2	5.1	5.4	5.4	6.0	6.4
18901.0	299.0	4.7	4.6	4.5	4.7	4.6	4.4	3.8	3.9	3.6	1.8	2.3	2.2	3.3	4.5
19374.0	300.0	5.8	5.8	5.7	5.8	5.8	5.9	7.0	10.5	10.9	12.1	11.1	11.1	12.6	12.9
19769.0	309.0	4.7	4.7	4.6	4.6	4.6	4.4	4.0	5.4	4.7	4.4	4.7	4.7	6.9	8.8
20271.0	320.0	-0.5	-0.3	-0.2	1.3	1.3	1.5	2.4	3.9	3.5	4.8	4.9	4.9	3.6	3.8
20499.0	330.0	-9.7	-9.5	-9.5	-9.3	-9.3	-9.0	-6.8	-3.8	-3.7	-6.4	-3.5	-3.4	-0.9	-0.1
21000.0	341.0	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8
21256.0	355.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21588.0	368.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21928.0	376.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22233.0	391.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22781.0	405.0	0.5	0.6	0.7	1.1	1.0	1.2	1.8	1.6	1.6	1.0	1.2	1.2	1.4	0.8
23198.0	415.0	-9.4	-9.5	-9.5	-9.4	-9.4	-9.4	-9.6	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7
23661.0	428.0	-8.7	-8.7	-8.7	-8.6	-8.6	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7
24000.0	434.0	-5.7	-5.9	-5.9	-6.7	-6.7	-6.8	-6.8	-7.5	-7.5	-6.9	-7.3	-7.3	-7.7	-7.7
24500.0	439.0	0.9	0.3	0.3	-0.2	-0.2	-0.6	-0.5	-2.2	-2.9	-2.0	-2.1	-2.0	-4.1	-3.3

Table 16-4 Alt. 1 Future w/o project - Sediment Transport Results for 2% ACE (50-year) Event

Station	Initial Bed Elevation	End Hydrograph 50-yr	Change in Bed Elevation After (values in ft)												
			1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	70 Years	75 Years
550.6	2.2	0.1	0.8	1.3	0.8	0.9	2.0	2.0	1.9	2.0	1.8	1.9	1.8	2.2	2.2
839.8	1.7	0.6	1.3	1.7	1.8	1.9	2.5	2.9	2.5	2.8	2.8	2.8	2.9	2.7	2.9
1320.8	2.0	0.4	1.8	2.3	2.5	2.7	3.5	4.3	3.8	4.5	3.7	4.6	4.7	4.9	4.9
1846.3	3.0	-0.3	1.4	2.0	2.6	2.4	3.3	4.3	4.3	5.0	4.5	5.3	5.4	6.1	6.2
2603.4	5.0	0.0	0.7	1.2	2.0	2.2	3.0	.4	5.1	5.3	5.2	6.0	6.1	7.1	7.3
3445.8	11.0	-0.8	-0.7	-0.7	-0.5	-0.4	0.0	1.7	2.6	3.2	3.4	4.0	4.2	5.4	5.7
3670.5	11.0	-0.3	-0.2	-0.1	0.2	0.3	0.9	2.7	3.7	4.3	4.4	5.0	5.2	6.3	6.7
3906.8	11.0	2.3	2.2	2.4	2.4	2.5	3.1	5.2	6.4	7.0	7.1	7.9	8.2	9.4	9.8
4203.5	14.0	0.4	0.6	0.8	1.0	1.0	1.3	3.6	5.1	5.8	5.7	6.6	6.8	8.1	8.6
4486.6	14.0	2.2	2.4	2.5	2.8	2.8	2.8	5.0	6.5	7.1	7.5	8.1	8.3	9.6	10.0
4653.8	16.0	2.2	2.8	3.1	3.4	3.4	3.9	6.4	8.1	8.8	8.9	10.0	10.0	11.5	12.0
4705.1	14.0	5.1	4.2	3.7	4.2	4.1	4.8	7.0	8.9	9.4	9.7	10.5	10.5	12.3	12.7
4900.6	15.0	4.2	4.7	5.0	5.3	5.3	5.9	8.4	10.3	10.9	11.0	12.1	12.1	13.7	14.2
5117.6	15.0	4.5	5.1	5.4	5.7	5.8	6.2	8.5	10.6	11.1	11.6	12.5	12.5	14.1	14.5
5344.1	19.0	2.2	2.5	2.8	3.2	3.3	3.6	6.2	8.2	8.7	8.7	9.9	10.0	11.7	12.2
5844.0	21.0	4.3	4.6	4.6	5.3	5.2	5.4	7.1	9.5	10.0	11.0	11.6	11.7	13.2	13.8
6237.3	28.0	-0.3	-0.2	-0.1	0.6	0.5	0.5	3.0	4.6	5.1	5.1	6.4	6.6	8.0	8.6
6490.1	33.0	-1.0	-1.1	-1.2	-1.2	-1.2	-1.2	-0.9	1.6	2.3	3.2	4.0	4.0	5.4	6.2
6755.7	37.0	-0.1	-0.2	-0.2	-0.2	-0.2	-0.3	-0.6	0.1	0.4	1.3	1.8	1.9	3.1	3.8
6993.4	38.0	-0.1	0.2	0.4	0.3	0.3	0.6	0.8	1.8	2.1	3.1	3.7	3.7	5.0	5.9
7404.4	38.0	1.9	2.4	2.7	2.6	2.7	3.1	3.4	4.0	4.3	4.6	5.2	5.2	6.0	6.8
7917.0	38.0	5.3	6.0	6.3	6.4	6.5	7.1	8.1	9.6	9.9	10.4	11.6	11.6	12.9	13.5
8262.6	43.0	2.8	3.0	3.1	3.4	3.4	3.6	4.3	4.8	4.7	4.7	5.2	5.4	6.7	7.2
8533.1	50.0	0.7	0.8	0.7	1.4	1.3	1.3	2.0	3.2	3.2	4.0	4.8	4.8	5.8	6.3
8770.2	53.0	-1.5	-1.6	-1.6	-1.7	-1.7	-1.9	-2.3	-2.3	-2.3	-2.1	-1.9	-1.8	0.1	0.5
9072.9	57.0	2.9	3.0	3.0	3.1	3.1	3.2	3.4	3.9	3.8	4.4	4.5	4.5	4.7	4.9
9385.9	58.0	0.6	0.8	0.9	0.7	0.7	0.9	1.6	2.6	3.0	4.0	4.5	4.6	5.0	5.3

Station	Initial Bed Elevation	End Hydrograph 50-yr	Change in Bed Elevation After (values in ft)												
			1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	70 Years	75 Years
9556.0	63.0	0.0	0.2	0.3	0.4	0.4	0.5	0.7	0.6	0.8	1.6	2.0	2.0	2.5	3.0
9779.9	64.0	-0.4	-0.4	-0.4	-0.3	-0.3	-0.3	0.3	1.5	1.9	3.2	3.4	3.4	3.8	3.9
10082.0	69.0	0.1	0.1	0.1	0.1	0.0	-0.1	-0.4	-0.2	-0.2	0.6	1.0	1.0	1.6	2.2
10524.0	76.0	0.5	0.6	0.6	0.8	0.7	0.7	0.8	1.1	0.8	1.2	1.2	1.2	1.2	1.1
10839.0	77.0	2.6	2.9	3.1	3.2	3.3	3.6	3.8	4.4	4.5	3.8	4.1	4.1	4.7	4.7
11121.0	80.0	3.3	3.6	3.7	3.9	3.9	4.1	4.9	5.3	5.3	5.2	5.4	5.4	5.6	5.5
11648.0	88.0	2.6	2.8	2.6	3.2	3.2	3.0	3.0	3.6	3.7	2.5	2.6	2.6	2.9	2.6
11948.0	92.0	4.0	4.2	4.1	4.1	4.2	4.5	5.0	5.0	4.9	3.5	2.4	2.4	2.1	2.1
12224.0	99.0	3.1	3.2	3.3	3.4	3.4	3.3	2.9	4.0	3.9	1.0	0.6	0.5	0.0	-0.1
12444.0	99.0	6.4	6.5	6.4	6.6	6.6	6.7	6.3	6.9	6.7	2.0	1.7	1.7	1.6	1.5
12689.0	106.0	0.4	0.5	0.7	0.8	0.8	0.9	1.7	1.3	0.9	-3.3	-3.7	-3.7	-3.8	-4.1
12999.0	114.0	1.8	1.4	1.2	1.4	1.3	1.1	-1.1	-1.1	-1.6	-8.8	-9.0	-9.0	-8.3	-9.0
13373.0	117.0	2.3	2.7	2.8	2.9	2.9	3.2	4.8	-1.2	-1.4	-9.1	-9.1	-9.1	-9.1	-9.1
13647.0	124.0	1.2	0.0	-0.7	-1.1	-1.1	-3.1	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2	-9.2
13907.0	138.0	-7.4	-7.8	-7.8	-8.0	-8.0	-8.1	-9.3	-9.3	-9.3	-9.3	-9.3	-9.3	-9.3	-9.3
14129.0	143.0	-3.3	-3.7	-4.0	-5.4	-5.4	-5.8	-7.4	-8.2	-8.3	-9.3	-9.3	-9.3	-9.3	-9.3
14394.0	143.0	-2.9	-3.0	-3.0	-3.7	-3.8	-4.1	-4.7	-9.1	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4
14559.0	149.0	-3.7	-4.1	-4.2	-4.8	-4.9	-5.2	-7.7	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4
14747.0	151.0	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5
14985.0	160.0	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5	-9.5
15196.0	165.0	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6	-9.6
15512.0	179.0	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7
15662.0	180.0	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7
15764.0	185.0	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7
15859.0	185.0	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8
15990.0	185.0	-5.6	-5.7	-5.7	-6.2	-6.0	-5.7	-5.8	-6.3	-6.1	-6.0	-6.0	-5.9	-5.7	-5.8
16092.0	185.0	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8
16201.0	277.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16326.0	285.0	-8.5	-8.9	-9.0	-8.3	-8.9	-7.9	-8.0	-7.9	-8.0	-7.7	-7.2	-7.2	-6.4	-6.1

Station	Initial Bed Elevation	End Hydrograph 50-yr	Change in Bed Elevation After (values in ft)												
			1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	70 Years	75 Years
16409.0	285.0	-6.8	-7.2	-7.4	-7.5	-7.4	-7.5	-7.8	-7.7	-7.9	-7.8	-7.8	-7.9	-7.7	-7.8
16503.0	286.0	-7.0	-7.3	-7.2	-7.1	-7.1	-6.9	-6.6	-6.4	-6.4	-5.7	-5.7	-5.6	-4.8	-4.6
16704.0	286.0	-4.0	-4.9	-5.1	-5.0	-5.1	-6.2	-7.2	-6.9	-7.1	-7.5	-8.0	-7.9	-7.9	-7.7
16943.0	288.0	-4.6	-5.4	-5.4	-5.4	-5.4	-5.2	-4.9	-4.5	-4.5	-3.5	-3.3	-3.2	-2.7	-2.2
17143.0	289.0	-4.2	-4.5	-4.9	-5.0	-5.0	-5.9	-6.9	-6.6	-7.0	-6.9	-7.6	-7.6	-6.5	-6.4
17389.0	288.0	0.6	-0.6	-0.7	-1.0	-0.9	-1.3	-1.5	-0.4	-0.3	0.5	0.2	0.2	1.2	1.5
17674.0	289.0	2.3	1.8	1.2	1.2	1.1	0.7	0.0	0.6	0.4	1.1	1.0	0.9	2.0	2.2
18118.0	292.0	1.9	1.5	1.2	1.2	1.2	1.0	1.1	2.4	2.3	3.3	3.5	3.5	4.4	5.3
18376.0	295.0	3.3	3.1	2.9	3.1	2.9	2.7	1.6	1.7	1.6	1.5	1.8	1.9	2.3	3.2
18648.0	296.0	1.9	1.7	1.7	1.8	1.6	1.8	2.3	4.6	4.6	4.4	4.7	4.7	5.7	6.6
18901.0	299.0	4.2	4.1	3.7	3.9	3.8	3.7	3.1	3.7	3.5	2.3	2.2	2.2	2.3	2.8
19374.0	300.0	6.5	6.4	6.3	6.7	6.6	6.6	8.3	10.7	11.0	10.4	11.3	11.3	12.4	12.6
19769.0	309.0	4.4	4.3	4.3	4.3	4.3	4.2	4.1	5.1	5.3	3.4	3.7	3.7	5.7	7.4
20271.0	320.0	1.1	1.0	1.0	1.7	1.7	1.8	2.5	3.6	3.4	3.0	4.3	4.3	3.9	4.3
20499.0	330.0	-9.5	-9.3	-9.2	-8.8	-8.8	-8.4	-6.7	-4.2	-3.9	-8.5	-5.7	-5.6	-2.9	-2.0
21000.0	341.0	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8
21256.0	355.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21588.0	368.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21928.0	376.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22233.0	391.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22781.0	405.0	0.8	1.0	1.0	1.4	1.3	1.5	2.1	1.8	1.8	1.1	1.3	1.3	1.4	0.9
23198.0	415.0	-9.3	-9.5	-9.4	-9.4	-9.4	-9.4	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7
23661.0	428.0	-8.7	-8.7	-8.7	-8.6	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7
24000.0	434.0	-6.1	-6.2	-6.2	-6.7	-6.7	-6.8	-6.7	-7.3	-7.4	-7.0	-7.3	-7.3	-7.8	-7.7
24500.0	439.0	1.1	0.3	0.2	-0.4	-0.4	-0.7	-0.6	-2.2	-3.0	-1.9	-2.1	-2.0	-4.1	-3.0

16.3 Alternative 2 - Mechanical Sediment Removal

16.3.1 General

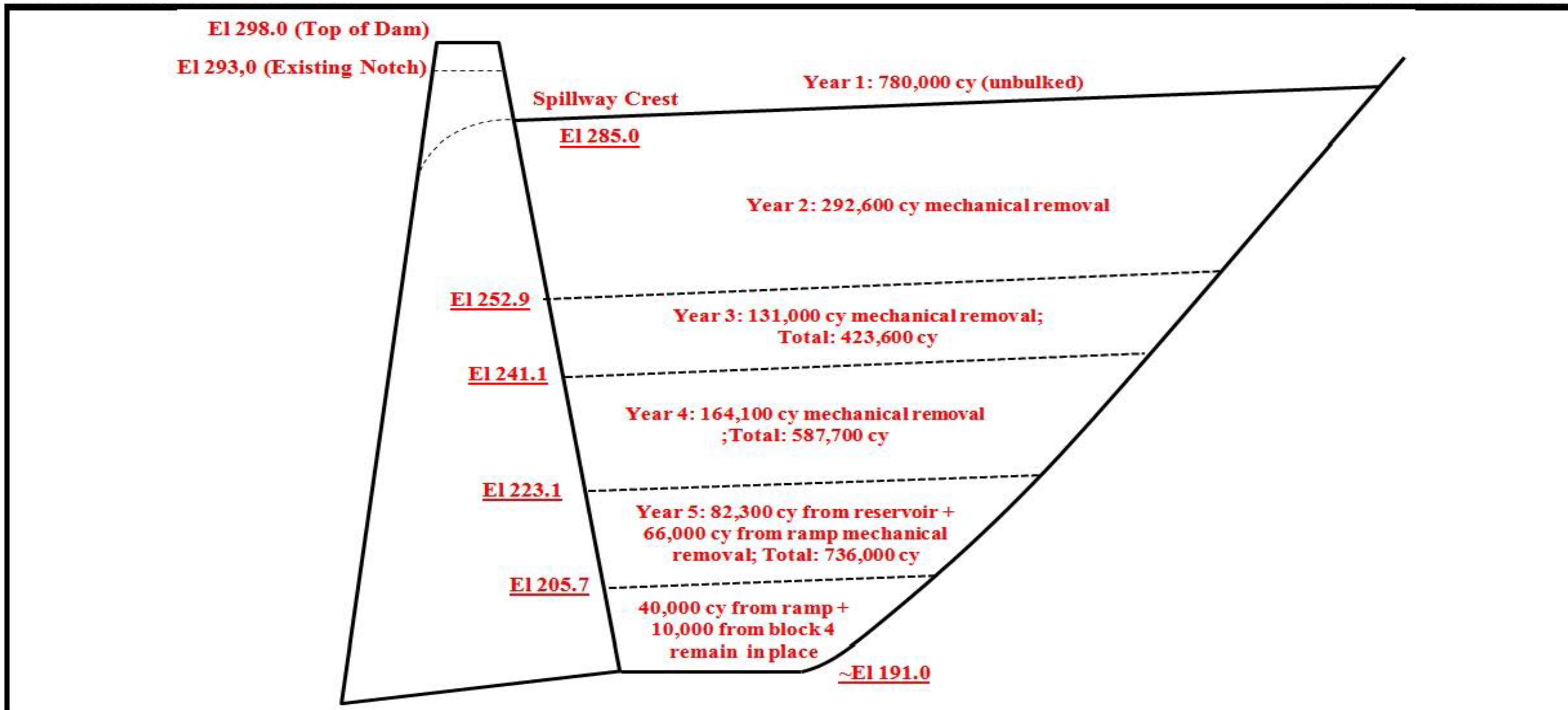
This alternative entails removal of the bulk of the sediment behind the dam by mechanical means down almost to the existing bedrock. The total volume of sediment behind the dam is estimated to be about 780,000 yd^3. The disposition of the excavated sediment includes a local landfill as well as beach replenishment. **Plate 16-6** shows the approximate sediment volumes removed based on a 5-yr construction schedule. Per this 5-yr construction schedule, the first year of construction would consist of clearing and grubbing and ramp building. Sediment removal would commence in the second year and continue through year 5. However, additional considerations regarding daily truck hauling hours of operation along Malibu Canyon Road and Las Virgenes Road may extend the construction schedule up to 8 yrs. The sediment removed each year would be excavated on a slope to minimize the amount of sediment re-deposited during each ensuing flood season during construction. Removal of the dam itself would occur concurrent with sediment removal down to the elevations determined from the Sediment Removal Plan.

The sediment transport models had to be stopped and restarted for each construction year and also as each major gradation change occurred during the simulation.

16.3.2 Period-of-Record Simulation

Reaches 4b would experience an average about 2 ft of scour in some local areas showing up to 2 ft of deposition during the first 5 years. Reach 4a would average about 3 ft of scour. In Reach 3 there would be about 2½ ft of deposition with highs up over 7 ft. Reach 2b would average about 3 ft of deposition with local areas seeing about 5½ ft and Reach 2a would average about 3 ft of deposition. In the lagoon below PCH (Reach 1), up to 3¼ ft of deposition would occur.

After 50 years of simulation, the invert slope would be evening out. Reach 4b would vary from about 2 ft of scour to 2 ft of deposition. Within Reach 4a the average scour would be about ¼ ft. Reach 3 would see between 7- 13 ft of deposition. Reach 2b shows about 8-11 ft of deposition and Reach 2a would average 6 ft of deposition. Reach 1 in the lagoon would see between 2-5 ft of deposition. The results of the period-of-record simulation for Alt. 2 are shown in **Table 16-5** and **Plate 16-7** shows the inundation areas for the 2% (50-yr), 1% (100-yr), 0.5% (200-yr), and 0.2% (500-yr) ACE events for the Mechanical Removal alternative under Future Conditions.



Elevations in ft NGVD based on May 2002 Survey

Elevations and volumes shown above are approximate

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

RINDGE DAM
ALT. 2 SCHEMATIC
SEDIMENT REMOVAL PLAN

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 16-6 Rindge Dam - Alt. 2 Schematic Sediment Removal Plan

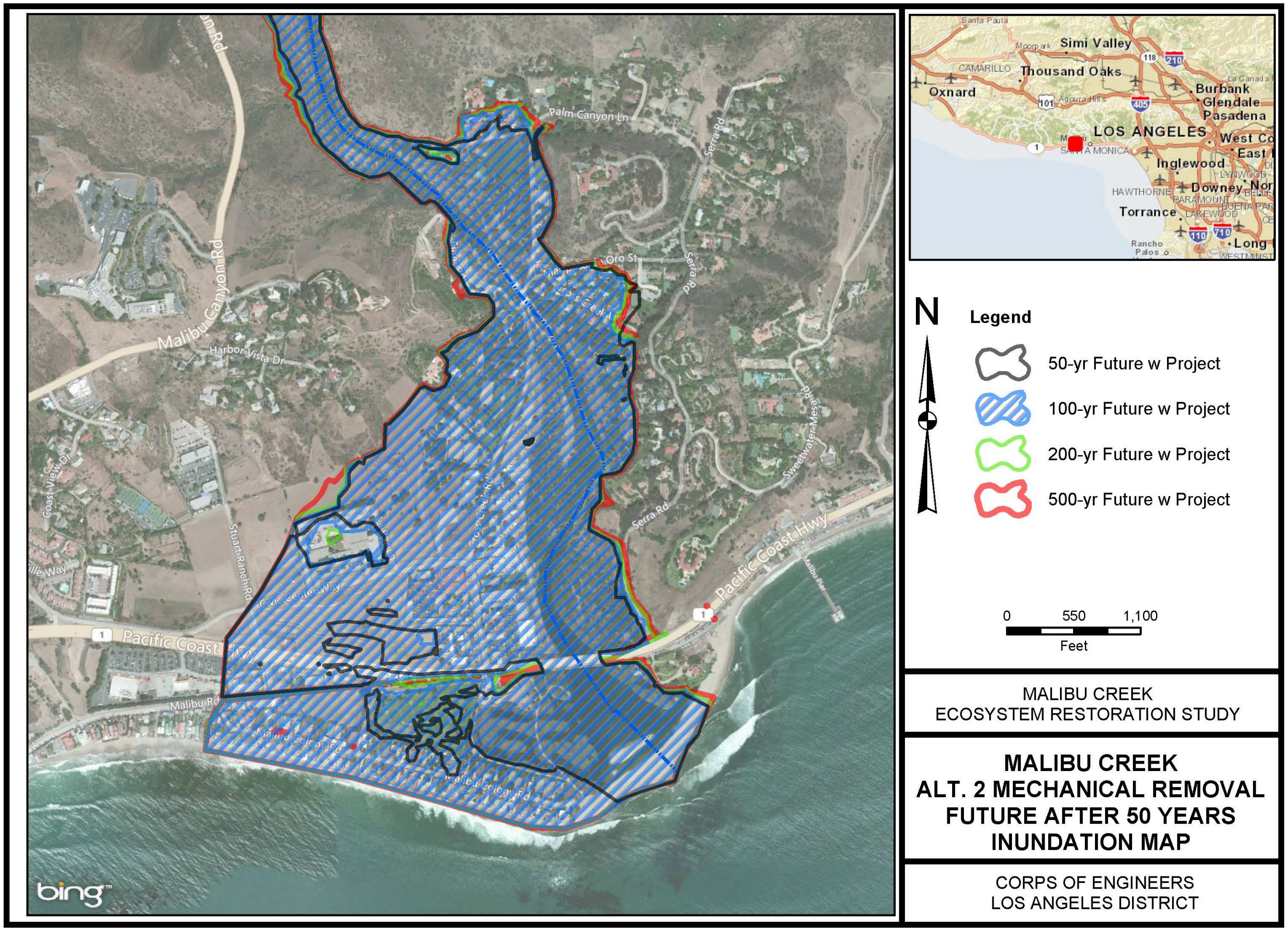


Plate 16-7 Malibu Creek - Alt. 2 Mechanical Removal Future after 50 Years - Inundation Map

Table 16-5 Alt. 2 Mechanical Removal - Sediment Transport Results for Period of Record

Station	Initial Bed Elevation	Change in Bed Elevation After												Avg Annual Change
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	
550.6	2.2	0.0	0.6	1.0	0.8	0.9	2.1	2.1	2.1	1.9	2.0	1.9	2.2	0.4
839.8	1.7	0.0	0.9	1.5	1.9	1.9	3.0	3.0	3.0	2.6	2.8	2.8	2.3	0.4
1320.8	2.0	0.1	1.3	2.3	2.3	2.4	4.5	4.5	4.7	4.3	4.9	5.0	4.8	0.8
1846.3	3.0	0.3	0.5	1.0	1.3	1.6	4.4	4.6	5.1	4.7	5.4	5.6	6.3	1.0
2603.4	5.0	0.0	0.0	0.8	1.1	1.7	4.5	4.8	5.2	5.1	5.9	6.0	7.2	1.1
3445.8	11.0	-0.3	-1.1	-1.1	-1.1	-1.1	1.8	2.3	3.0	3.1	4.0	4.1	5.6	0.9
3670.5	11.0	0.0	-0.6	-0.6	-0.3	0.0	2.7	3.4	3.9	4.3	5.0	5.2	6.8	1.1
3906.8	11.0	0.0	0.8	1.6	2.3	2.6	5.3	6.2	6.9	7.0	7.9	8.0	9.6	1.5
4203.5	14.0	-0.3	-0.7	-0.5	0.2	1.1	3.6	4.7	5.5	5.6	6.9	7.0	9.0	1.4
4486.6	14.0	-0.1	0.3	1.4	2.0	2.8	4.9	6.0	6.9	7.2	7.8	7.9	9.9	1.6
4653.8	16.0	0.0	0.3	0.8	2.7	3.8	6.2	7.4	8.5	8.7	9.8	9.9	12.0	1.9
4705.1	14.0	0.7	2.8	2.6	4.7	5.2	7.1	8.3	9.4	9.6	10.5	10.5	12.8	2.0
4900.6	15.0	1.3	1.9	2.8	4.9	5.9	8.1	9.5	10.6	10.9	11.9	11.9	14.1	2.3
5117.6	15.0	0.0	1.1	3.1	4.8	6.0	8.4	9.8	10.9	11.4	12.3	12.4	14.5	2.3
5344.1	19.0	-0.2	-0.1	0.8	2.6	3.5	5.8	7.3	8.4	8.7	9.9	10.0	12.0	1.9
5844.0	21.0	0.0	0.0	0.3	2.2	2.5	7.2	8.5	9.6	11.1	11.5	11.5	13.6	2.2
6237.3	28.0	-0.2	-0.3	-0.3	-0.4	-0.4	2.4	4.1	4.9	5.0	6.3	6.4	8.5	1.4
6490.1	33.0	-0.2	-0.3	-0.4	-0.5	-0.5	-0.7	0.5	1.8	3.0	3.8	3.8	6.1	1.0
6755.7	37.0	-0.1	-0.2	-0.1	-0.2	-0.2	-0.3	-0.2	0.3	1.5	1.8	1.8	3.7	0.6
6993.4	38.0	0.0	0.1	0.2	0.4	1.0	0.8	1.2	1.7	3.0	3.3	3.4	5.9	0.9
7404.4	38.0	0.5	1.3	1.8	2.6	4.0	4.0	4.0	4.4	5.1	5.6	5.7	6.4	1.0
7917.0	38.0	0.6	3.4	4.6	5.9	7.3	7.8	8.5	8.7	9.5	10.4	10.5	14.0	2.2
8262.6	43.0	-0.1	0.2	0.9	2.9	5.0	4.9	5.1	5.7	5.8	6.0	6.1	6.6	1.1
8533.1	50.0	-0.1	-0.7	-0.7	-0.4	0.5	1.5	2.3	2.5	3.5	4.1	4.1	7.2	1.1
8770.2	53.0	0.0	-0.4	-0.7	-0.9	-0.8	-1.2	-1.2	-1.5	-1.8	-1.8	-1.8	0.5	0.1
9072.9	57.0	0.1	0.3	0.4	0.6	0.5	2.5	3.0	3.7	4.7	4.8	4.8	5.8	0.9
9385.9	58.0	-0.1	-0.3	-0.5	-0.4	1.4	0.8	1.1	2.5	3.9	4.8	4.8	5.8	0.9

Station	Initial Bed Elevation	Change in Bed Elevation After												Avg Annual Change
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	
9556.0	63.0	-0.1	-0.3	-0.4	-0.5	-0.2	-0.1	0.0	0.2	1.8	2.2	2.2	3.6	0.6
9779.9	64.0	0.0	-0.3	-0.6	-0.7	-0.5	-0.3	-0.1	0.6	2.9	3.2	3.3	4.5	0.7
10082.0	69.0	-0.1	-0.4	-0.5	-0.5	-0.5	-1.0	-1.0	-1.0	0.0	0.7	0.6	2.8	0.5
10524.0	76.0	0.0	-0.1	-0.2	-0.2	-0.1	-0.1	0.1	0.3	0.4	0.5	0.5	2.2	0.3
10839.0	77.0	1.1	1.2	1.3	2.2	2.5	2.7	3.1	3.2	4.3	4.6	4.6	5.2	0.8
11121.0	80.0	0.2	0.5	1.0	1.8	2.2	3.1	3.7	4.3	2.9	4.1	4.2	6.7	1.1
11648.0	88.0	0.1	-0.9	-1.3	-0.8	-0.4	-0.1	0.8	1.8	5.3	3.4	3.4	4.0	0.6
11948.0	92.0	0.0	0.3	0.8	0.8	1.1	1.5	2.1	2.8	-0.8	1.6	1.6	4.3	0.7
12224.0	99.0	0.0	-1.4	-1.5	-1.0	-0.8	-0.5	0.6	1.0	1.4	0.8	0.7	1.7	0.3
12444.0	99.0	0.1	1.6	1.8	2.4	2.7	2.6	2.9	3.7	-5.2	2.8	2.8	5.5	0.9
12689.0	106.0	-0.3	-2.4	-2.4	-2.6	-2.6	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.0	-0.3
12999.0	114.0	0.1	-1.9	-2.4	-2.0	-1.9	-1.7	-2.6	-2.7	-2.7	-2.7	-2.7	-2.0	-0.3
13373.0	117.0	1.6	2.8	2.4	0.2	0.3	-2.2	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-0.4
13647.0	124.0	-1.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.4
13907.0	138.0	-1.1	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.4
14129.0	143.0	0.0	-0.8	-1.0	-0.2	0.1	-1.3	-2.0	-2.4	-1.4	-2.8	-2.8	-2.8	-0.4
14394.0	143.0	0.2	1.9	2.1	2.3	3.6	2.3	2.0	2.4	1.0	1.6	1.5	1.5	0.2
14559.0	149.0	-0.3	-0.4	0.0	0.8	1.1	-1.3	-2.6	-2.2	-1.1	-2.4	-2.4	-1.3	-0.2
14747.0	151.0	0.0	1.2	0.0	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.5
14985.0	160.0	-0.8	-2.8	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15196.0	165.0	-0.6	-2.3	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15512.0	179.0	-0.8	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15662.0	180.0	-0.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15764.0	185.0	-0.8	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.8	-2.9	-2.9	-2.9	-2.9	-0.5
15859.0	185.0	-0.6	-1.8	-2.0	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15990.0	185.0	2.9	1.4	1.3	1.1	2.5	2.6	1.1	2.8	3.4	2.9	2.9	3.1	0.5
16092.0	185.0	-2.9	-2.9	-2.9	-2.9	2.4	-2.9	1.6	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
16201.0	277.0	-19.2	-31.9	-51.3	-70.1	-85.9	-86.0	-86.0	-86.0	-85.5	-84.4	-84.4	-85.2	-13.6
16326.0	285.0	-27.2	-40.4	-59.8	-76.7	-90.3	-89.0	-88.0	-89.4	-88.8	-88.6	-88.7	-89.3	-14.3

Station	Initial Bed Elevation	Change in Bed Elevation After 1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	Avg Annual Change
16409.0	285.0	-27.2	-39.5	-58.3	-76.6	-89.7	-88.3	-89.2	-86.7	-85.6	-86.2	-86.1	-85.9	-13.7
16503.0	286.0	-28.2	-40.7	-60.1	-74.7	-86.0	-86.0	-86.0	-86.0	-85.9	-85.9	-85.9	-85.8	-13.7
16704.0	286.0	-28.2	-39.6	-57.1	-77.3	-77.7	-78.0	-78.0	-78.0	-78.0	-78.0	-78.0	-78.0	-12.5
16943.0	288.0	-30.2	-41.3	-60.4	-69.7	-69.8	-73.0	-72.8	-72.9	-73.0	-72.9	-72.9	-72.9	-11.7
17143.0	289.0	-30.6	-40.2	-56.5	-66.6	-66.6	-67.0	-66.9	-66.9	-66.9	-67.0	-67.0	-66.9	-10.7
17389.0	288.0	-29.6	-39.4	-57.3	-57.5	-57.5	-58.0	-58.0	-58.0	-58.0	-58.0	-58.0	-58.0	-9.3
17674.0	289.0	-27.2	-34.5	-48.4	-48.9	-48.9	-48.9	-48.9	-48.9	-48.9	-48.9	-48.9	-48.9	-7.8
18118.0	292.0	-36.2	-35.8	-36.2	-36.2	-36.2	-36.2	-36.2	-36.2	-36.2	-36.2	-36.2	-36.2	-5.8
18376.0	295.0	-17.5	-21.6	-22.0	-22.0	-22.0	-22.0	-22.0	-22.0	-22.0	-22.0	-22.0	-22.0	-3.5
18648.0	296.0	-18.0	-17.5	-17.9	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-2.9
18901.0	299.0	-3.4	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-1.5
19374.0	300.0	1.7	0.3	0.0	0.7	0.7	2.9	4.1	4.0	-0.1	-0.1	-0.1	-0.3	0.0
19769.0	309.0	0.7	0.5	0.2	-0.3	-0.6	-2.9	-2.2	-2.0	-3.8	-2.1	-2.2	-2.8	-0.4
20271.0	320.0	0.0	-0.8	-0.4	0.6	0.5	-0.3	-1.0	-1.7	-9.9	-9.9	-9.9	-9.9	-1.6
20499.0	330.0	0.1	-4.8	-6.3	-7.3	-7.4	-9.8	-9.9	-9.9	-9.9	-9.9	-9.9	-9.9	-1.6
21000.0	341.0	-2.5	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-1.6
21256.0	355.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21588.0	368.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21928.0	376.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22233.0	391.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22781.0	405.0	0.4	0.3	0.5	1.1	1.1	1.6	1.5	0.5	1.2	0.4	0.5	0.8	0.1
23198.0	415.0	-4.0	-5.3	-5.6	-5.8	-5.9	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-1.6
23661.0	428.0	-2.1	-8.7	-8.7	-8.6	-8.6	-8.7	-8.7	-8.7	-8.7	-8.6	-8.6	-8.6	-1.4
24000.0	434.0	-0.5	-4.3	-4.8	-6.9	-6.9	-7.9	-7.9	-7.9	-7.6	-7.8	-7.8	-7.9	-1.3
24500.0	439.0	-0.2	-0.3	-0.1	-1.0	-1.1	-1.0	-2.6	-1.9	-2.4	-1.6	-1.6	-3.0	-0.5

Initial bed elevations in feet NGVD
Change in bed elevations in feet
Average annual change in inches

16.4 Alternative 3 - Natural Sediment Transport

16.4.1 General

Generation of this alternative was very dynamic throughout the plan formulation and analysis process. The intent is to remove a portion of the dam and let the confined sediment disperse downstream through natural processes. Once the reservoir surface eroded to the notched elevation, another notch would be cut and natural sediment dispersal would commence again. This would continue until the entire 780,000 yd^3, or close to it, was evacuated.

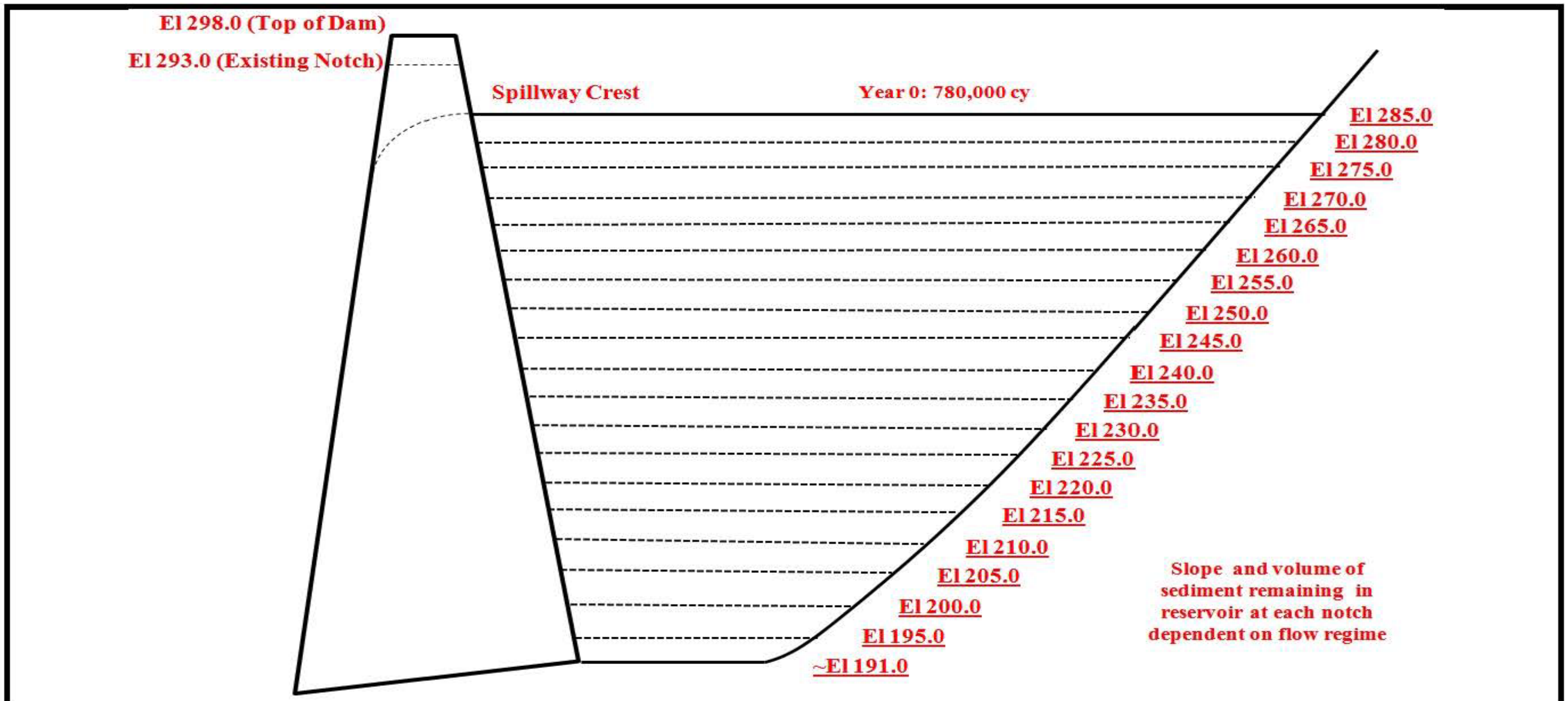
Initially two natural sediment transport scenarios were analyzed. The first scenario assumes all of the concrete arch dam would be removed at one time and the sediment behind the dam would then move by natural sediment transport. The second scenario assumes the top half of the concrete arch dam would be removed (to elevation 255.0[3] ft) first and the sediment allowed to erode to that elevation through natural sediment transport, at which point the lower half of the dam would be removed. There would be a construction period which could take as little as one year depending on the non-flood season flows in the creek. After completion of removal of the rest of the dam, the remainder of the sediment would then be allowed to erode by natural sediment transport.

Results from these two initial scenarios showed there would be a significant increase in flood risk downstream. In addition, leaving this much sediment exposed presents an unacceptable situation. A significant flood event could trigger a slug of sediment moving downstream. This would be very difficult to predict or model.

Several additional notching scenarios were then evaluated to see if the impacts downstream could be managed without additional downstream flood risk management measures such as levees or flood walls. Notches at 5 ft, 10 ft, and 20 ft were modeled. The sediment transport simulations for these scenarios was limited to a single notch and the first 5 years of simulation to determine if there was any significant reduction in flood risks. Further modeling was not warranted at this time. Again, the results indicate once the volume of sediment is made available for transport, the bulk of the material would be moved within the 1-5 years. All of these alternatives also showed significant impacts due to downstream deposition.

The version of the alternative that went into the environmental documents consists of 5-ft notches followed by natural sediment transport. This would require about 21 notches to remove the 108-ft high dam. This could happen in as few as 21 years if the hydrologic conditions were conducive to moving the sediment every year, but based on the period of record, it is more likely each cut may take up to 5 years to evacuate the sediment and the total time could exceed 100 years. This combination of cuts and natural transport was not modeled specifically, but the results from the other natural transport simulations were used to estimate downstream impacts. A schematic dam profile showing the excavation levels for Alt. 3 is shown on **Plate 16-8**.

1



Elevations in ft NGVD based on May 2002 Survey

All sediment removed by natural transport

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

RINDGE DAM
ALT. 3 SCHEMATIC
SEDIMENT REMOVAL PLAN

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 16-8 Rindge Dam - Alt. 3 Schematic, Sediment Removal Plan

16.4.2 Natural Transport - Full-Dam Removal

After the first 5 years, up to 10 ft of local scour could occur in Reach 5 from Cold Creek to Rindge Dam (Reach 5). From Rindge Dam to RM 2.4 (Reach 4b), up to 20 ft of deposition would occur. Up to 13 ft of deposition would occur from the RM 2.4 to the “Big Bend” (Reach 4a). From the “Big Bend” to the Cross Creek Road bridge (Reach 3), up to 12 ft of deposition would occur. In Reach 2b about 10.0 ft of deposition would occur. Up to 4 ft of deposition would occur within Reach 2a. In the lagoon below PCH up to 4 ft of deposition would occur. After 5 years, the total volume of sediment removed from the reservoir behind the dam would be 581,000 yd^3. Similarly, the volume of sediment that would deposit in the lagoon would be 23,500 yd^3 and the volume of sediment that would go to the ocean would be 10,700 yd^3.

After 50 years of simulation, the bulk of the sediment would have moved further downstream. The total volume of sediment removed from behind the dam would be 772,500 yd^3. The results of the period-of-record simulation for this alternative are shown in **Table 16-6**.

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Table 16-6 Alt. 3 Natural Transport Full-Dam Removal - Sediment Transport Results for Period of Record

Station	Initial Bed Elevation	Change in Bed Elevation After												Avg Annual Change
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	
550.6	2.2	0.0	1.2	1.1	1.9	1.8	2.2	2.1	2.1	2.0	2.1	2.0	2.2	0.4
839.8	1.7	0.0	2.6	2.3	2.5	2.7	3.3	3.2	3.2	2.6	2.8	2.6	2.4	0.4
1320.8	2.0	0.9	4.1	3.8	3.8	3.9	5.2	5.0	5.2	4.5	5.3	5.3	4.9	0.8
1846.3	3.0	0.5	2.7	2.8	3.4	3.4	5.7	5.7	6.1	5.8	6.4	6.5	6.4	1.0
2603.4	5.0	0.0	3.3	2.9	3.4	3.8	6.3	6.2	6.5	6.0	6.6	6.8	7.7	1.2
3445.8	11.0	-0.9	0.3	1.1	1.7	2.0	4.5	4.9	5.3	4.6	5.1	5.4	6.5	1.0
3670.5	11.0	-0.3	1.6	2.2	2.9	3.2	5.7	6.0	6.4	5.3	6.2	6.3	7.8	1.3
3906.8	11.0	0.8	4.5	5.6	6.1	6.5	8.8	9.1	9.5	8.2	9.3	9.3	11.0	1.8
4203.5	14.0	-0.6	3.9	4.6	5.4	6.0	7.8	8.1	8.6	6.9	8.0	8.3	9.9	1.6
4486.6	14.0	0.2	6.0	6.4	7.3	7.9	9.3	9.6	10.1	8.8	9.6	9.8	11.4	1.8
4653.8	16.0	0.1	7.1	8.1	8.4	8.8	11.3	11.6	12.4	10.5	11.8	11.8	13.8	2.2
4705.1	14.0	2.8	8.9	9.5	9.8	10.5	12.0	12.5	13.1	11.3	12.5	12.4	14.6	2.3
4900.6	15.0	2.1	9.1	10.8	10.8	11.1	13.5	14.0	14.6	12.5	14.1	14.1	16.0	2.6
5117.6	15.0	1.8	10.6	11.4	11.5	11.7	13.9	14.5	15.2	12.9	14.4	14.5	16.4	2.6
5344.1	19.0	-0.2	8.1	8.9	8.8	9.0	11.6	12.2	12.9	10.4	12.3	12.4	13.9	2.2
5844.0	21.0	0.0	10.5	11.5	11.5	11.5	13.3	14.0	14.7	12.1	13.5	13.5	15.9	2.5
6237.3	28.0	-0.5	5.5	7.1	7.2	7.1	8.6	9.3	9.9	6.7	9.4	9.4	11.1	1.8
6490.1	33.0	-0.4	3.0	4.3	4.4	4.3	6.2	6.7	7.5	4.4	5.7	5.8	8.7	1.4
6755.7	37.0	-0.3	1.9	2.6	2.7	2.8	4.6	5.4	6.1	5.5	5.5	5.5	6.3	1.0
6993.4	38.0	0.3	3.1	4.0	4.1	4.4	6.2	7.0	7.4	6.9	6.9	6.9	7.9	1.3
7404.4	38.0	2.0	6.5	7.2	7.4	7.3	9.7	10.0	10.8	10.6	10.4	10.4	12.4	2.0
7917.0	38.0	5.8	10.8	11.4	11.5	11.7	14.4	14.9	15.2	14.9	15.0	14.9	13.7	2.2
8262.6	43.0	1.4	9.3	9.8	9.7	9.8	11.8	12.2	12.8	13.0	13.1	13.1	15.8	2.5
8533.1	50.0	-0.1	5.3	6.1	6.2	6.1	8.7	9.5	9.1	9.8	9.6	9.6	2.9	0.5
8770.2	53.0	0.1	4.7	4.6	4.4	4.6	5.9	6.3	6.5	9.2	8.6	8.6	15.8	2.5
9072.9	57.0	0.2	4.9	5.7	5.7	5.7	7.3	8.4	8.5	9.4	9.5	9.6	11.9	1.9
9385.9	58.0	0.0	5.1	6.1	6.5	6.4	8.2	8.8	8.9	10.2	10.1	10.1	10.8	1.7

Station	Initial Bed Elevation	Change in Bed Elevation After												Avg Annual Change
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	
9556.0	63.0	-0.3	3.0	3.9	4.4	4.6	6.5	6.9	7.3	8.1	7.9	7.9	8.5	1.4
9779.9	64.0	0.2	3.5	4.3	5.0	5.0	7.6	8.2	8.5	9.6	9.5	9.4	9.7	1.6
10082.0	69.0	-0.1	3.0	3.7	4.0	4.1	6.3	7.1	7.5	6.6	6.6	6.5	6.1	1.0
10524.0	76.0	0.2	3.2	4.3	4.2	4.3	5.4	5.9	6.2	5.8	6.2	6.3	8.2	1.3
10839.0	77.0	3.1	7.1	8.0	8.3	8.4	10.0	10.3	10.0	5.8	5.7	5.7	5.1	0.8
11121.0	80.0	2.7	8.3	9.2	9.0	9.0	10.5	10.5	11.4	7.8	8.3	8.3	10.1	1.6
11648.0	88.0	1.5	8.3	8.4	9.0	9.3	10.0	9.9	8.3	1.5	-1.8	-1.9	-0.5	-0.1
11948.0	92.0	1.6	10.3	11.5	10.3	10.2	14.1	13.9	12.3	7.3	7.0	7.0	7.6	1.2
12224.0	99.0	0.1	8.4	10.1	9.7	9.6	12.9	12.8	12.2	5.8	4.8	4.8	5.3	0.8
12444.0	99.0	2.9	11.9	13.1	13.0	12.9	15.3	15.2	14.9	6.8	7.3	7.2	6.7	1.1
12689.0	106.0	0.0	8.5	9.3	9.8	9.8	10.7	10.7	8.6	0.2	1.0	1.3	1.4	0.2
12999.0	114.0	0.0	8.0	8.0	7.6	7.3	8.0	7.7	6.1	-3.6	-3.5	-3.5	-3.4	-0.6
13373.0	117.0	6.5	11.9	11.7	11.7	11.4	10.2	9.3	6.2	-2.7	-2.7	-2.7	-2.7	-0.4
13647.0	124.0	-1.5	10.1	11.5	8.6	7.4	0.0	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.4
13907.0	138.0	-1.2	2.7	2.4	0.4	-0.2	-2.1	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.4
14129.0	143.0	0.4	8.0	7.4	4.9	3.8	-0.3	-2.8	-2.7	-2.8	-2.8	-2.8	-2.8	-0.4
14394.0	143.0	6.8	9.3	7.5	4.5	3.2	-2.4	-2.3	-2.1	0.8	-0.3	-0.3	0.1	0.0
14559.0	149.0	4.1	9.0	9.0	9.0	9.0	1.2	-0.8	-0.2	-1.1	1.4	1.4	-1.6	-0.2
14747.0	151.0	7.0	14.8	14.8	14.9	14.9	-1.4	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.5
14985.0	160.0	3.6	10.7	8.4	9.3	10.2	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15196.0	165.0	6.4	17.1	14.2	14.5	15.0	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15512.0	179.0	5.1	5.4	5.6	5.0	5.2	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15662.0	180.0	6.4	11.5	12.6	12.6	12.9	3.0	3.3	3.5	1.1	1.0	1.0	0.9	0.2
15764.0	185.0	13.3	10.8	8.6	8.0	8.0	-2.4	-2.6	-1.8	-1.8	-1.4	-1.5	-1.9	-0.3
15859.0	185.0	17.0	14.1	12.7	13.1	13.2	1.6	1.5	2.2	-2.9	-2.9	-2.9	-2.9	-0.5
15990.0	185.0	24.7	17.8	13.9	13.5	13.5	2.8	2.8	4.4	2.7	3.1	3.1	2.6	0.4
16092.0	185.0	32.1	22.6	19.9	20.4	20.1	7.3	7.5	8.8	-3.0	-3.0	-3.0	-3.0	-0.5
16201.0	277.0	-55.1	-70.7	-74.2	-73.5	-73.6	-83.5	-83.3	-82.6	-87.0	-87.0	-87.0	-87.0	-13.9
16326.0	285.0	-50.4	-72.4	-74.5	-72.3	-73.1	-88.7	-87.6	-87.1	-92.5	-92.3	-92.3	-92.3	-14.8

Station	Initial Bed Elevation	Change in Bed Elevation After												Avg Annual Change
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	
16409.0	285.0	-39.6	-79.6	-76.1	-78.5	-78.2	-86.9	-85.8	-86.1	-91.8	-91.2	-91.2	-91.7	-14.7
16503.0	286.0	-28.8	-72.8	-69.5	-69.6	-72.1	-85.2	-84.1	-84.2	-89.4	-89.4	-89.4	-89.4	-14.3
16704.0	286.0	-16.9	-61.6	-79.9	-79.8	-80.4	-79.8	-79.0	-81.2	-82.2	-82.2	-82.2	-82.2	-13.2
16943.0	288.0	-4.9	-55.7	-56.0	-60.1	-62.0	-74.1	-74.8	-75.9	-75.9	-75.9	-75.9	-75.9	-12.1
17143.0	289.0	-1.0	-47.3	-62.2	-60.6	-60.5	-68.8	-69.8	-69.8	-69.8	-69.8	-69.8	-69.8	-11.2
17389.0	288.0	0.9	-35.6	-44.5	-44.9	-47.4	-59.5	-60.1	-60.1	-60.1	-60.1	-60.1	-60.1	-9.6
17674.0	289.0	1.6	-21.0	-26.5	-28.9	-35.2	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0	-8.2
18118.0	292.0	0.7	-11.4	-14.4	-31.1	-28.7	-38.3	-38.3	-38.3	-38.3	-38.3	-38.3	-38.3	-6.1
18376.0	295.0	0.3	-8.6	-10.8	-13.8	-22.7	-32.2	-32.2	-32.2	-32.2	-32.2	-32.2	-32.2	-5.2
18648.0	296.0	0.8	-2.7	-6.4	-6.5	-10.5	-20.6	-20.6	-20.6	-20.6	-20.6	-20.6	-20.6	-3.3
18901.0	299.0	1.1	-0.2	-3.1	-3.2	-3.4	-15.9	-16.0	-16.1	-16.1	-16.1	-16.1	-16.1	-2.6
19374.0	300.0	3.2	4.3	4.0	4.0	3.8	-2.4	-5.9	-9.9	-9.9	-9.8	-9.8	-9.9	-1.6
19769.0	309.0	1.5	0.9	0.9	0.9	0.8	-5.4	-9.7	-9.9	-9.9	-9.9	-9.9	-9.9	-1.6
20271.0	320.0	-0.6	-0.3	0.8	0.8	0.7	-3.7	-9.9	-9.9	-9.9	-9.9	-9.9	-9.9	-1.6
20499.0	330.0	1.1	-6.2	-7.4	-7.5	-7.5	-9.9	-9.9	-9.9	-9.9	-9.9	-9.9	-9.9	-1.6
21000.0	341.0	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-1.6
21256.0	355.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21588.0	368.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21928.0	376.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22233.0	391.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22781.0	405.0	0.2	0.5	1.1	1.0	1.0	1.6	1.5	0.5	1.2	0.4	0.5	0.8	0.1
23198.0	415.0	-5.5	-5.6	-5.8	-5.9	-6.0	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-1.6
23661.0	428.0	-5.3	-8.6	-8.6	-8.6	-8.6	-8.6	-8.6	-8.6	-8.6	-8.6	-8.6	-8.6	-1.4
24000.0	434.0	-1.1	-4.8	-6.9	-7.0	-7.0	-7.9	-7.9	-7.9	-7.6	-7.8	-7.8	-7.9	-1.3
24500.0	439.0	-0.2	-0.1	-1.0	-1.1	-1.3	-1.0	-2.5	-1.9	-2.5	-1.5	-1.5	-3.0	-0.5

Initial bed elevations in feet NGVD
Change in bed elevations in feet
Average annual change in inches

16.4.3 Natural Transport - Half-Dam Removal

The half-dam removal scenario was evaluated in which half the dam is removed at the start of the simulation and the remainder of the dam is removed as soon as half the volume of sediment has been removed. The elevation used for half the volume is 255 ft. Based on a similar hydrologic pattern as has occurred in the past, it would take approximately 5 years for the existing sediment behind the dam to scour to elevation 255.0 ft.

At the end of this 5-year period, about 9 ft of deposition would occur from the "Big Bend" to the Cross Creek Road bridge. From Cross Creek Road bridge to the Malibu Lagoon, up to 7 ft of deposition would occur. Up to 4 ft of deposition would occur within Reach 2a. And in the lagoon below PCH, up to 4 ft of deposition would occur.

Similarly, it would take another 5 years of the same flow pattern in Malibu Creek to remove the MAJORITY of the remaining volume. A small volume of sediment would be "caught" in irregularities in the streambed and canyon walls. For Future Conditions, the streambed through the reservoir area of Rindge Dam would have scoured almost to pre-dam conditions. Reach 4b would see areas of scour and areas of deposition with the average about 7 ft of deposition. In Reach 4a, there would be between 9- 14 ft of deposition. From the "Big Bend" to the Cross Creek Road bridge, up to 14 ft of deposition would occur. From Cross Creek Road bridge to the Malibu Lagoon, about 12 ft of deposition would occur. Up to 6 ft of deposition would occur within Reach 2a. In the lagoon below PCH, up to 5 ft of deposition would occur. The results of the period-of-record simulation for Alt. 3 are shown in **Table 16-7**.

The 5 year estimates are reasonable based on the period of record for flows measured at the stream gage on Malibu Creek. It was observed that Malibu Creek has only gone 10 straight years once where there wasn't at least one 20% ACE event (5-year).

Regardless of the notching scenario, the results indicate once the volume of sediment is made available for transport, the bulk of the material would be moved within the 1-5 years. The bulk of the sediment depositing in the reaches downstream from the dam occurs because Malibu Creek is a high-production watershed even under the No Action alternative. The contribution from the dam only exacerbates the problem. The deposition in the channel increased by up to 4 ft for the smallest notching scenario (5-ft), but once flow exceeds channel capacity, it spreads out into a relatively wide and flat floodplain. The additional flood depth and added extent of flood inundation for the three notching scenarios did not change significantly from the No Action alternative, but the increase over Existing Conditions is significant.

Streambed profiles at selected time intervals for Malibu Creek under the Rindge Dam with 5-ft notch scenario are presented on **Plate 16-9** for the downstream portion of Malibu Creek. Streambed profiles for Malibu Creek under the Rindge Dam with 5-, 10-, and 20-ft notching scenarios at 5 years after notching are shown on **Plate 16-10**.

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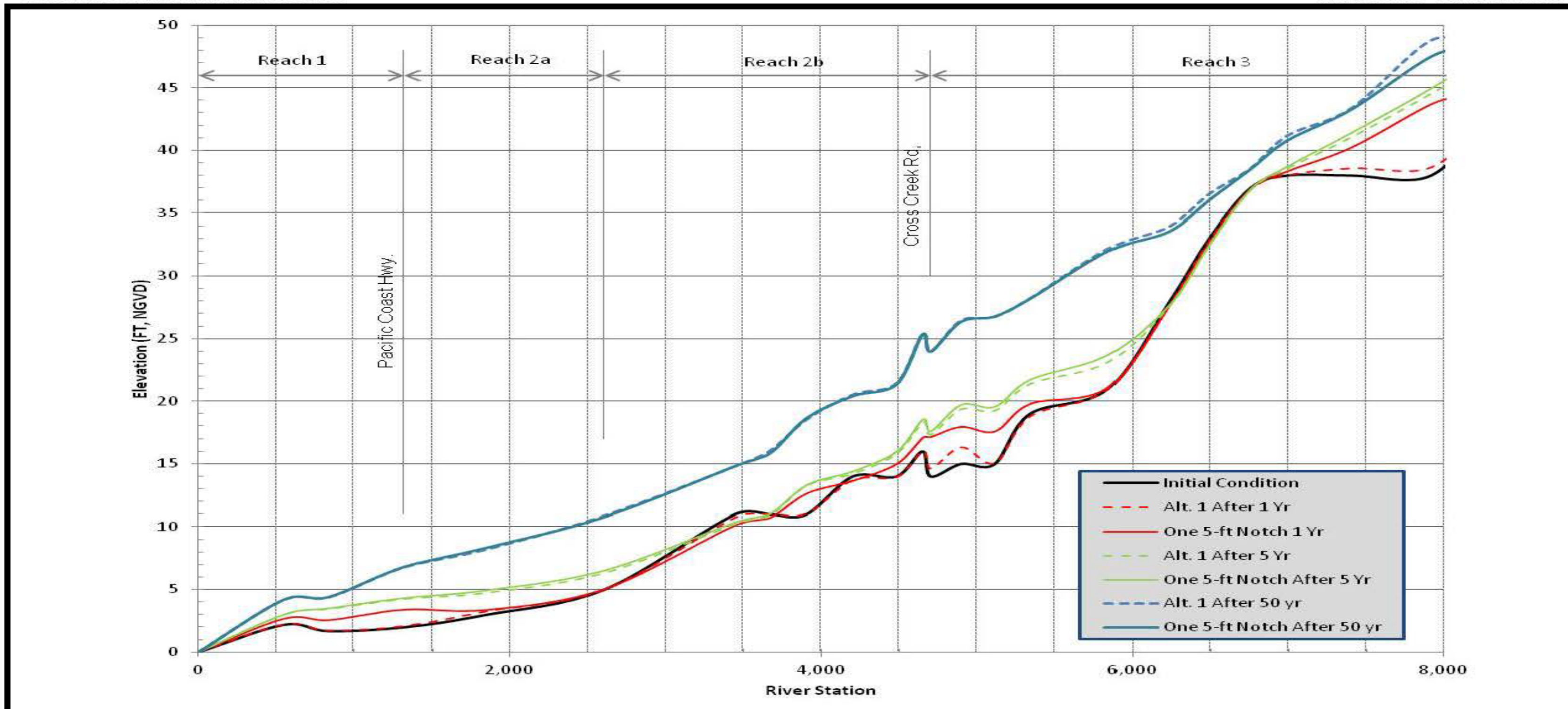
Table 16-7 Alt. 3 Natural Transport Half-Dam Removal - Sediment Transport Results for Period of Record

Station	Initial Bed Elevation	Change in Bed Elevation After												Avg Annual Change
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	
550.6	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
839.8	1.7	0.0	0.8	1.1	1.0	1.9	2.0	2.1	2.0	2.0	2.1	2.0	2.2	0.5
1320.8	2.0	0.0	1.1	1.8	2.1	2.6	3.2	3.3	2.4	2.4	3.1	3.0	3.4	0.9
1846.3	3.0	0.7	1.6	2.7	3.0	3.8	5.0	5.2	4.7	4.7	5.4	5.4	5.8	1.1
2603.4	5.0	0.4	0.7	1.3	2.7	3.6	5.4	6.2	6.1	6.1	6.7	6.7	7.0	1.3
3445.8	11.0	0.0	0.2	2.3	2.8	3.7	6.2	6.7	6.4	6.4	7.1	7.2	8.1	1.1
3670.5	11.0	-0.8	-1.2	-1.2	0.4	1.6	4.9	5.3	4.8	4.8	5.6	5.8	6.7	1.3
3906.8	11.0	-0.3	-0.7	0.3	1.4	2.6	6.1	6.4	6.0	6.0	6.7	6.8	8.0	1.8
4203.5	14.0	0.7	1.4	3.0	3.7	5.0	9.2	9.7	9.2	9.2	9.8	9.8	11.3	1.6
4486.6	14.0	-0.6	-0.5	1.7	1.9	3.4	8.1	8.7	8.5	8.5	8.8	8.9	10.1	1.9
4653.8	16.0	0.0	1.3	3.4	3.8	4.8	9.7	10.2	9.7	9.7	10.1	10.6	11.6	2.2
4705.1	14.0	0.0	1.9	3.8	4.9	5.9	11.0	12.3	11.0	11.0	12.1	12.2	13.7	2.4
4900.6	15.0	2.8	2.7	5.7	6.4	7.1	12.4	13.4	11.9	11.9	13.1	13.2	14.8	2.6
5117.6	15.0	1.9	4.6	5.5	7.2	8.1	13.6	14.6	13.0	13.0	14.4	14.4	16.0	2.6
5344.1	19.0	0.8	3.4	6.5	7.5	8.5	13.9	15.0	13.2	13.2	14.7	14.7	16.4	2.2
5844.0	21.0	-0.3	2.7	3.8	5.2	6.3	11.7	12.8	10.7	10.7	12.5	12.6	14.0	2.5
6237.3	28.0	0.0	2.3	5.5	6.8	7.9	13.2	14.8	12.2	12.2	13.9	13.9	15.8	1.7
6490.1	33.0	-0.4	-0.5	0.0	2.2	3.4	8.2	10.1	7.0	7.0	9.4	9.5	10.6	1.3
6755.7	37.0	-0.4	-0.6	-0.7	-0.5	0.5	5.8	7.8	4.5	4.5	6.1	6.1	8.2	1.0
6993.4	38.0	-0.3	-0.2	-0.2	-0.3	-0.1	4.2	6.2	5.7	5.7	5.7	5.7	6.4	1.2
7404.4	38.0	0.1	0.6	1.0	1.3	1.4	5.9	7.8	6.8	6.8	7.0	7.0	7.8	1.8
7917.0	38.0	1.8	3.3	4.3	4.5	4.8	9.0	11.1	11.4	11.4	10.4	10.5	11.4	2.5
8262.6	43.0	5.0	7.0	8.5	9.2	9.7	13.6	15.3	15.2	15.2	14.6	14.7	15.8	2.1
8533.1	50.0	0.6	4.9	6.6	7.1	7.7	11.9	13.2	13.9	13.9	13.0	13.0	13.2	1.6
8770.2	53.0	-0.2	1.0	2.7	3.5	4.1	8.1	9.8	9.5	9.5	9.2	9.1	10.2	1.1
9072.9	57.0	0.1	0.3	1.6	2.2	2.6	7.2	7.8	8.3	8.3	7.1	7.1	6.7	1.6
9385.9	58.0	0.2	1.0	2.4	2.9	3.4	8.2	9.8	10.0	10.0	9.7	9.7	9.9	1.7

Station	Initial Bed Elevation	Change in Bed Elevation After												Avg Annual Change
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	
9556.0	63.0	-0.2	-0.2	0.4	1.2	2.1	6.4	8.4	8.7	8.7	8.6	8.5	8.3	1.3
9779.9	64.0	0.1	0.1	0.7	2.1	2.7	7.2	9.7	10.9	10.9	10.4	10.2	10.8	1.7
10082.0	69.0	-0.1	0.1	0.5	1.0	1.6	5.5	7.5	5.6	5.6	5.1	5.0	0.1	0.0
10524.0	76.0	0.2	0.2	0.8	1.1	1.6	5.7	7.7	10.4	10.4	12.0	12.4	15.5	2.5
10839.0	77.0	2.9	4.1	4.9	5.3	6.1	9.3	9.9	0.9	0.9	0.6	0.1	-0.1	0.0
11121.0	80.0	2.2	4.1	5.5	6.2	6.8	11.6	12.6	12.6	12.6	13.0	12.7	12.1	1.9
11648.0	88.0	0.9	2.8	5.2	6.4	7.1	10.3	7.5	-2.8	-2.8	-1.0	-1.1	-0.6	-0.1
11948.0	92.0	0.5	3.9	6.2	6.9	7.3	13.7	13.0	7.5	7.5	9.8	9.8	10.3	1.6
12224.0	99.0	0.1	1.9	5.2	6.3	6.5	11.2	10.0	4.0	4.0	4.9	5.0	5.7	0.9
12444.0	99.0	1.4	4.7	7.6	9.0	9.3	13.4	9.4	5.0	5.0	6.0	6.0	8.2	1.3
12689.0	106.0	-0.2	2.2	5.8	6.4	6.2	10.3	6.4	-1.0	-1.0	0.2	0.2	0.8	0.1
12999.0	114.0	0.0	0.1	2.8	4.4	4.5	6.3	-1.0	-3.8	-3.8	-4.0	-4.0	-0.2	0.0
13373.0	117.0	5.5	8.5	9.2	8.5	8.3	17.4	6.1	1.4	1.4	1.6	1.7	1.5	0.2
13647.0	124.0	-2.6	1.8	3.9	4.2	3.2	14.5	-2.7	-2.8	-2.8	-2.8	-2.8	-2.8	-0.4
13907.0	138.0	-1.4	-1.5	0.5	-2.0	-2.4	4.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.4
14129.0	143.0	0.1	-1.3	-0.5	-0.5	-1.1	7.1	-2.2	-2.8	-2.8	-2.8	-2.8	-2.8	-0.4
14394.0	143.0	6.5	11.3	9.1	6.1	6.1	13.9	-0.1	2.3	2.3	2.6	2.5	1.1	0.2
14559.0	149.0	2.6	5.1	5.3	4.8	4.1	11.6	1.9	2.5	2.5	3.5	3.5	1.8	0.3
14747.0	151.0	7.4	13.1	9.8	5.7	7.0	14.9	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.5
14985.0	160.0	0.2	1.7	1.5	0.5	-2.0	2.4	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15196.0	165.0	8.3	10.5	7.5	4.5	2.7	5.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15512.0	179.0	-2.0	-2.9	-2.9	-2.9	-2.9	-2.1	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15662.0	180.0	10.1	3.4	2.1	2.0	1.2	1.6	1.8	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15764.0	185.0	0.3	-1.1	-1.8	-2.9	-2.9	-1.7	-1.8	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15859.0	185.0	9.6	3.9	2.4	1.1	0.4	1.3	0.6	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15990.0	185.0	6.7	4.7	3.0	1.4	1.5	3.8	4.0	2.6	2.6	2.7	2.7	2.6	0.4
16092.0	185.0	15.5	9.8	7.8	6.2	4.5	6.2	6.1	-3.0	-3.0	-3.0	-3.0	-3.0	-0.5
16201.0	277.0	-87.0	-87.0	-87.0	-87.0	-87.0	-83.8	-83.9	-87.0	-87.0	-87.0	-87.0	-87.0	-13.9
16326.0	285.0	-29.4	-29.4	-29.4	-29.4	-29.4	-88.8	-88.5	-89.4	-89.4	-89.4	-89.4	-89.4	-14.3

Station	Initial Bed Elevation	Change in Bed Elevation After												Avg Annual Change
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	
16409.0	285.0	-18.3	-21.7	-27.2	-28.6	-30.0	-85.8	-86.6	-88.1	-88.1	-88.4	-88.4	-88.3	-14.1
16503.0	286.0	-15.2	-19.6	-24.9	-27.0	-27.4	-84.8	-85.2	-88.4	-88.4	-87.7	-87.7	-88.0	-14.1
16704.0	286.0	-6.0	-14.6	-21.9	-22.0	-25.8	-78.6	-79.8	-83.2	-83.2	-83.1	-83.1	-83.2	-13.3
16943.0	288.0	-1.3	-10.8	-16.8	-19.5	-22.2	-74.8	-75.9	-75.9	-75.9	-75.9	-75.9	-75.9	-12.1
17143.0	289.0	-0.3	-7.7	-14.5	-16.2	-21.2	-69.7	-69.8	-69.8	-69.8	-69.8	-69.8	-69.8	-11.2
17389.0	288.0	1.0	-2.1	-8.6	-10.2	-14.2	-60.1	-60.1	-60.1	-60.1	-60.1	-60.1	-60.1	-9.6
17674.0	289.0	1.6	0.2	-5.1	-6.6	-9.5	-50.9	-51.0	-51.0	-51.0	-51.0	-51.0	-51.0	-8.2
18118.0	292.0	0.7	0.9	-1.4	-4.1	-6.8	-37.5	-38.3	-38.3	-38.3	-38.3	-38.3	-38.3	-6.1
18376.0	295.0	0.3	0.6	-0.8	-2.5	-4.8	-30.8	-32.2	-32.2	-32.2	-32.2	-32.2	-32.2	-5.2
18648.0	296.0	0.8	1.6	0.8	0.1	-2.3	-20.0	-20.6	-20.6	-20.6	-20.6	-20.6	-20.6	-3.3
18901.0	299.0	1.1	1.8	1.0	0.6	0.1	-10.5	-16.0	-16.1	-16.1	-16.1	-16.1	-16.1	-2.6
19374.0	300.0	3.1	4.6	4.4	5.0	5.1	4.3	-5.0	-9.9	-9.9	-9.8	-9.8	-9.9	-1.6
19769.0	309.0	1.5	1.1	0.9	1.0	0.9	0.7	-8.3	-9.9	-9.9	-9.9	-9.9	-9.9	-1.6
20271.0	320.0	-0.5	-0.6	-0.3	0.8	0.9	2.0	-9.9	-9.9	-9.9	-9.9	-9.9	-9.9	-1.6
20499.0	330.0	1.2	-4.6	-6.2	-7.5	-7.5	-9.0	-9.9	-9.9	-9.9	-9.9	-9.9	-9.9	-1.6
21000.0	341.0	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-1.6
21256.0	355.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21588.0	368.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21928.0	376.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22233.0	391.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22781.0	405.0	0.2	0.3	0.5	1.0	1.3	1.3	1.5	1.2	1.2	0.5	0.5	1.0	0.2
23198.0	415.0	-5.5	-5.2	-5.6	-5.9	-8.0	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-1.6
23661.0	428.0	-5.3	-8.6	-8.6	-8.6	-8.6	-8.6	-8.6	-8.6	-8.6	-8.6	-8.6	-8.6	-1.4
24000.0	434.0	-1.1	-4.3	-4.8	-6.9	-7.1	-7.6	-7.9	-7.6	-7.6	-7.8	-7.8	-7.9	-1.3
24500.0	439.0	-0.2	-0.3	-0.1	-1.1	-1.7	-1.0	-2.5	-2.5	-2.5	-1.7	-1.7	-4.0	-0.6

Initial bed elevations in feet NGVD
Change in bed elevations in feet
Average annual change in inches



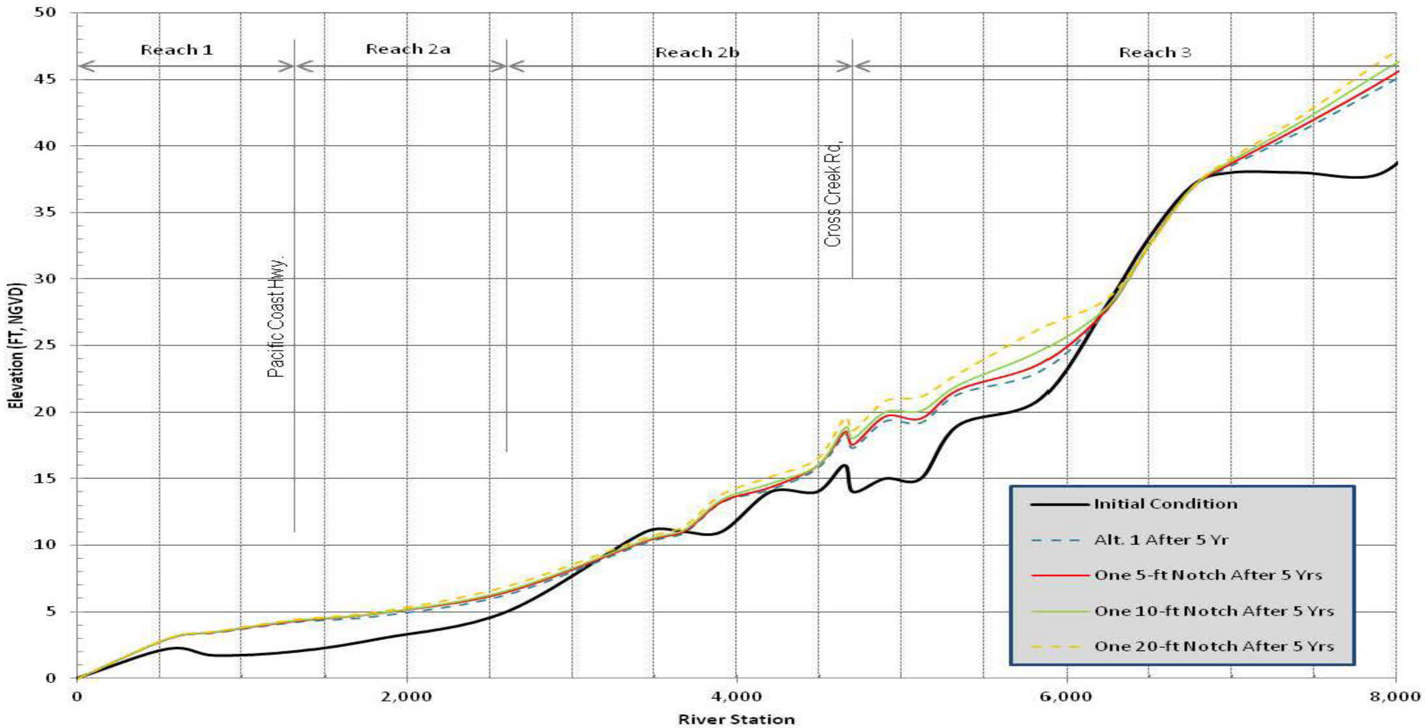
Streambed elevations based on lowest elevation in cross section from sediment transport models after shown period of time.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK
STREAMBED PROFILES
W/ 5-FT NOTCH

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 16-9 Malibu Creek Streambed Profiles with 5-ft Notch



Streambed elevations based on lowest elevation in cross section from sediment transport models after shown period of time.	MALIBU CREEK ECOSYSTEM RESTORATION STUDY **MALIBU CREEK STREAMBED PROFILES NOTCH COMPARISON** CORPS OF ENGINEERS LOS ANGELES DISTRICT

Plate 16-10 Malibu Creek Streambed Profiles Notch Comparison

16.5 Alternative 4 - Hybrid

16.5.1 General

The Hybrid Alternative is a combination of Alt. 2 Mechanical Transport and Alt. 3 Natural Transport. The hybrid alternative came about after review of the results from the natural transport alternatives. The main gist of the hybrid is to notch the dam at the end of each construction season and allow natural processes to move the portion of the impounded sediment from the notched section downstream. For the Hybrid Alternative the construction and excavation would occur over a 5-year period. The first year of construction would consist of clearing and grubbing and ramp building. Sediment removal would commence in the second year and continue through year 5. The volume of sediment removed each year is dependent on the number of days allowed for construction and the delivery location for the removed material. The Sediment Removal Plan prepared for Alt.2 Mechanical Removal was used to estimate elevations for each year. The annual volumes mechanically removed for Alt. 2 were maintained into this alternative. The sediment removed each year would be excavated at a level grade. Removal of the dam itself would occur concurrent with sediment removal down to the elevations determined. At the end of each construction season, an additional 5-ft notch would be cut into the dam and the exposed sediment would be allowed to disperse downstream through natural processes. Excavation during the ensuing years would commence at the notch elevation and the volumes from the Sediment Removal Plan would be maintained with the elevations adjusted accordingly. A schematic dam profile showing the excavation levels for Alt. 4 is shown on **Plate 16-11**.

The sediment transport models had to be stopped and restarted for each construction year and also as each major gradation change occurred during the simulation. The hydrograph for 1969, which is the largest within the period record, was used successively for each of the first 4 years to ensure the greatest volume of sediment would be evacuated. This was followed by the period of record hydrograph. This was done to determine the maximum impacts downstream from the natural transport portion of the sediment.

16.5.2 Period-of-Record Simulation.

Reaches 4b would experience an average of about 2 ft of scour with local scour up to 3 ft during the first 5 years. Reach 4a would average about ½ ft of scour with some local areas up to 7 ft. In Reach 3 there would be about 4 ft of deposition with highs up over 8 ft. Reach 2b would average about 4 of deposition with local areas seeing about 7 ft and Reach 2a would average about 3 ft of deposition. In the lagoon below PCH (Reach 1), up to 3½ ft of deposition would occur.

After 50 years of simulation, the invert slope would be evening out. Reach 4b would vary from about 2 ft of scour to 3 ft of deposition. Within Reach 4a the average deposition would be about 1½ ft with local areas up to 6 ft. Reach 3 would see between 7-13 ft of deposition. Reach 2b shows about 8-12 ft of deposition and Reach 2a would average 6 ft of deposition. Reach 1 in the lagoon would average about 3 ft of deposition. The results of the period-of-record simulation for Alt. 4 are shown in **Table 16-8**. The inundation areas for the Hybrid alternative were not mapped separately, but are consistent with the 20-ft notch shown on **Plate 16-12**.

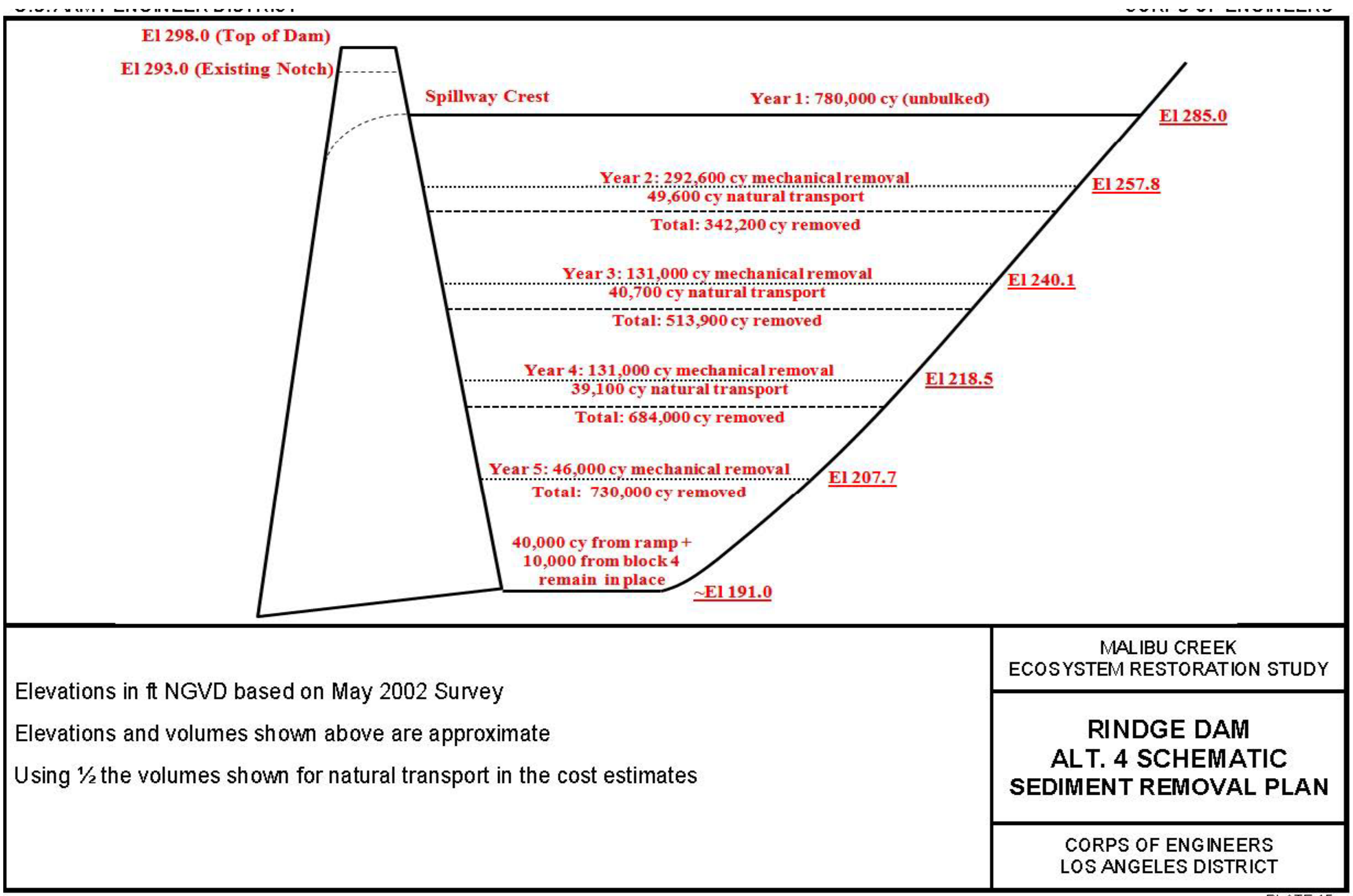


Plate 16-11 Rindge Dam, Alt. 4 Schematic Sediment Removal Plan

Table 16-8 Alt. 4 Hybrid - Sediment Transport Results for Period of Record

Station	Initial Bed Elevation	Change in Bed Elevation After												Avg Annual Change
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	
550.6	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
839.8	1.7	0.4	0.8	1.1	1.4	1.7	2.1	2.1	2.1	1.9	2.0	1.9	2.2	0.4
1320.8	2.0	0.9	2.1	1.9	2.1	2.2	3.2	3.1	3.1	2.6	2.7	2.8	2.2	0.7
1846.3	3.0	2.0	2.5	2.8	3.0	3.1	4.8	4.7	4.9	4.4	5.1	5.2	4.6	1.0
2603.4	5.0	0.7	2.4	2.5	2.9	3.1	5.0	5.2	5.5	4.9	5.9	6.0	6.4	1.2
3445.8	11.0	0.3	1.4	2.2	2.9	3.3	5.2	5.6	6.1	5.9	6.4	6.6	7.5	1.0
3670.5	11.0	-0.9	-0.6	0.1	0.7	1.0	2.9	3.4	4.0	4.4	4.9	5.0	6.3	1.2
3906.8	11.0	-0.5	0.1	0.8	1.4	2.0	4.0	4.6	5.2	5.5	5.9	6.0	7.4	1.7
4203.5	14.0	2.2	2.4	4.1	4.4	4.8	6.7	7.2	8.0	8.1	8.7	8.7	10.5	1.5
4486.6	14.0	0.7	0.7	2.1	2.5	3.1	5.5	6.3	6.9	7.0	7.6	7.8	9.4	1.7
4653.8	16.0	2.8	2.3	4.1	4.3	4.8	6.5	7.4	8.1	8.1	8.7	8.8	10.6	2.0
4705.1	14.0	2.4	2.6	4.5	5.2	6.0	8.3	9.1	9.8	9.4	10.5	10.6	12.5	2.2
4900.6	15.0	5.8	5.5	7.0	7.3	7.6	9.3	10.1	10.9	10.6	11.6	11.7	13.6	2.4
5117.6	15.0	3.6	4.5	6.6	7.3	8.2	10.7	11.3	12.1	11.5	12.7	12.8	14.8	2.4
5344.1	19.0	5.7	4.7	7.0	7.8	8.6	10.4	11.3	12.1	11.7	12.8	12.8	14.9	2.0
5844.0	21.0	1.2	2.4	4.4	5.3	6.2	8.4	9.1	9.8	8.9	10.4	10.5	12.6	2.3
6237.3	28.0	4.6	4.7	6.0	6.9	7.8	9.4	10.3	11.4	11.0	12.0	12.1	14.5	1.4
6490.1	33.0	-0.2	-0.1	1.4	2.4	3.5	4.8	5.3	6.0	5.1	6.6	6.8	9.0	1.1
6755.7	37.0	-1.4	-1.9	-1.6	-1.1	0.0	1.4	2.5	3.8	3.5	4.4	4.4	7.1	0.7
6993.4	38.0	-1.1	-0.9	-0.7	-0.8	-0.4	0.1	0.5	1.0	1.6	2.0	2.1	4.5	1.1
7404.4	38.0	-0.2	0.5	0.8	1.0	1.5	1.9	2.5	3.2	3.9	4.5	4.6	6.6	1.2
7917.0	38.0	1.6	1.2	1.7	2.2	2.8	3.4	4.0	4.2	3.7	4.2	4.3	7.4	2.2
8262.6	43.0	5.6	7.0	8.0	8.8	9.8	10.2	11.0	11.5	12.0	12.3	12.3	13.6	1.2
8533.1	50.0	2.2	1.8	2.0	2.5	3.4	3.6	4.1	4.2	4.7	5.1	5.3	7.7	1.0
8770.2	53.0	0.9	2.3	2.7	2.8	3.4	3.4	4.2	4.4	5.3	5.5	5.6	6.5	0.3
9072.9	57.0	-2.4	-3.0	-2.9	-3.0	-3.0	-3.1	-3.0	-2.8	-2.1	-1.1	-1.1	1.7	0.8
9385.9	58.0	3.3	3.2	3.2	3.2	3.5	3.6	3.8	4.1	4.5	4.6	4.6	5.2	1.0

Station	Initial Bed Elevation	Change in Bed Elevation After												Avg Annual Change
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	
9556.0	63.0	-0.7	-0.2	0.3	0.2	1.2	1.0	1.0	1.4	2.7	3.1	3.0	3.9	0.6
9779.9	64.0	-1.3	-0.6	-0.2	0.5	1.1	1.4	1.7	1.9	3.6	3.7	3.8	5.0	0.8
10082.0	69.0	-2.4	-1.9	-2.2	-1.6	-0.8	-0.9	-0.5	0.0	1.5	1.9	1.9	2.9	0.5
10524.0	76.0	-1.6	-2.1	-2.3	-2.1	-1.4	-1.5	-1.5	-0.7	-0.7	-0.3	-0.3	1.9	0.3
10839.0	77.0	1.9	0.8	0.3	1.5	1.8	2.3	3.5	4.2	4.2	4.1	4.1	4.2	0.7
11121.0	80.0	0.3	-2.7	-0.4	-0.3	0.1	0.8	1.2	1.6	0.2	1.1	1.1	5.6	0.9
11648.0	88.0	1.1	-1.5	0.3	1.5	1.8	2.9	4.5	6.3	5.6	4.1	4.1	2.4	0.4
11948.0	92.0	-4.4	-6.5	-6.3	-4.9	-5.1	-4.3	-3.8	-3.1	-4.2	-1.9	-1.9	3.0	0.5
12224.0	99.0	-2.6	-4.5	-4.2	-2.3	-1.7	-1.3	0.1	1.0	0.7	1.7	1.7	2.1	0.3
12444.0	99.0	-8.1	-8.9	-8.9	-8.6	-8.6	-8.7	-8.1	-8.5	-7.0	0.8	0.9	6.2	1.0
12689.0	106.0	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-1.0	-0.2
12999.0	114.0	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.6	-2.7	-2.7	-2.0	-0.3
13373.0	117.0	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-2.7	-0.4
13647.0	124.0	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.4
13907.0	138.0	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.4
14129.0	143.0	-2.8	-2.8	-1.6	-2.1	-2.5	-2.1	-2.0	-2.4	-1.4	-2.8	-2.8	-2.8	-0.4
14394.0	143.0	-2.8	-2.8	-2.8	0.2	1.0	1.4	1.5	0.8	0.9	0.9	0.8	1.5	0.2
14559.0	149.0	-2.8	-2.8	-2.8	-2.8	-1.3	-2.1	-1.9	-2.5	-0.9	-2.8	-2.8	-1.8	-0.3
14747.0	151.0	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-2.8	-0.5
14985.0	160.0	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15196.0	165.0	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15512.0	179.0	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15662.0	180.0	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15764.0	185.0	-2.9	-2.9	-2.9	-2.9	-2.8	-2.8	-2.4	-2.0	-2.0	-2.7	-2.7	-2.1	-0.3
15859.0	185.0	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
15990.0	185.0	-2.9	-1.0	-1.4	-0.9	0.9	3.1	3.1	3.5	3.8	3.1	3.1	4.1	0.7
16092.0	185.0	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-2.9	-0.5
16201.0	277.0	-24.2	-41.9	-63.5	-74.3	-85.9	-86.0	-85.9	-85.9	-85.7	-84.4	-84.4	-85.3	-13.7
16326.0	285.0	-41.5	-49.0	-71.0	-81.1	-88.9	-89.7	-90.0	-89.4	-89.0	-88.6	-88.7	-89.5	-14.3

Station	Initial Bed Elevation	Change in Bed Elevation After												Avg Annual Change
		1 Year	2 Years	3 Years	4 Years	5 Years	10 Years	20 Years	30 Years	40 Years	50 Years	60 Years	75 Years	
16409.0	285.0	-32.2	-48.3	-70.6	-80.6	-87.3	-86.3	-86.4	-86.3	-85.8	-86.4	-86.3	-86.0	-13.8
16503.0	286.0	-33.6	-48.4	-70.7	-79.9	-85.9	-85.9	-85.8	-86.0	-85.9	-85.9	-85.9	-85.9	-13.7
16704.0	286.0	-32.2	-47.3	-69.7	-77.9	-78.3	-78.3	-78.3	-78.3	-78.3	-78.3	-78.3	-78.3	-12.5
16943.0	288.0	-34.8	-45.6	-67.6	-72.8	-72.8	-72.9	-72.6	-72.9	-73.0	-72.9	-72.9	-72.9	-11.7
17143.0	289.0	-32.8	-45.7	-66.4	-66.8	-66.8	-66.9	-66.8	-66.9	-66.9	-66.9	-66.9	-66.8	-10.7
17389.0	288.0	-33.7	-39.8	-57.9	-57.9	-57.9	-57.9	-57.9	-57.9	-57.9	-57.9	-57.9	-57.9	-9.3
17674.0	289.0	-28.3	-44.5	-48.9	-48.9	-48.9	-48.9	-48.9	-48.9	-48.9	-48.9	-48.9	-48.9	-7.8
18118.0	292.0	-36.2	-36.2	-36.2	-36.2	-36.2	-36.2	-36.2	-36.2	-36.2	-36.2	-36.2	-36.2	-5.8
18376.0	295.0	-22.0	-22.3	-22.3	-22.3	-22.3	-22.3	-22.3	-22.3	-22.3	-22.3	-22.3	-22.3	-3.6
18648.0	296.0	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-2.9
18901.0	299.0	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-9.1	-1.5
19374.0	300.0	-1.8	-1.1	-1.3	-1.1	-1.2	-0.4	-0.8	-0.8	-1.2	-0.8	-0.8	-1.2	-0.2
19769.0	309.0	-1.7	-2.4	-2.4	-2.6	-2.8	-2.0	-1.7	-2.0	-4.0	-2.3	-2.3	-2.7	-0.4
20271.0	320.0	-9.8	-9.8	-9.9	-9.9	-9.9	-9.9	-9.9	-9.9	-9.9	-9.9	-9.9	-9.9	-1.6
20499.0	330.0	-9.8	-9.8	-9.8	-9.8	-9.8	-9.9	-9.9	-9.9	-9.9	-9.9	-9.9	-9.9	-1.6
21000.0	341.0	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-9.8	-1.6
21256.0	355.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21588.0	368.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
21928.0	376.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22233.0	391.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22781.0	405.0	1.2	1.2	1.1	0.9	1.1	2.0	2.1	1.4	1.2	0.8	0.8	0.7	0.1
23198.0	415.0	-9.5	-9.6	-9.5	-9.6	-9.6	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-9.7	-1.6
23661.0	428.0	-8.6	-8.6	-8.6	-8.7	-8.6	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-8.7	-1.4
24000.0	434.0	-6.4	-7.1	-7.0	-7.2	-7.3	-7.6	-7.7	-7.9	-7.6	-7.8	-7.8	-7.9	-1.3
24500.0	439.0	-0.5	-0.6	-1.4	-1.0	-1.7	-2.3	-3.4	-2.6	-2.7	-2.2	-2.1	-3.3	-0.5

Initial bed elevations in feet NGVD
Change in bed elevations in feet
Average annual change in inches

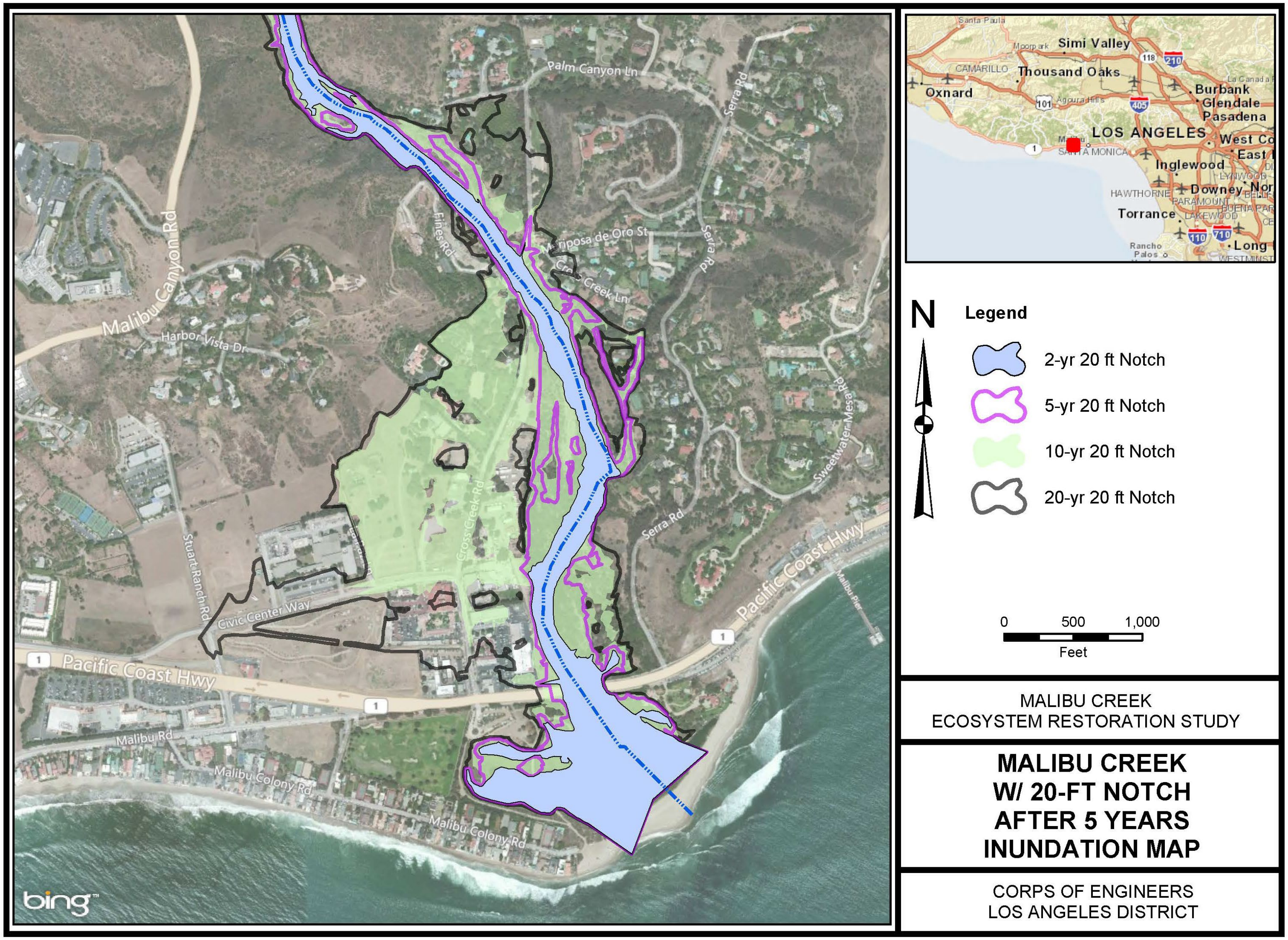


Plate 16-12 Malibu Creek with 20-ft Notch after 5 Years Inundation Map

17.0 SUMMARY

This Hydrology, Hydraulics, and Sedimentation Appendix is in support of the Main Feasibility Report for the Malibu Creek Watershed Study and other associated Appendices. The results presented herein are meant to be used, along with other factors, to select the recommended plan.

The Malibu Creek watershed is very dynamic. The flow in Malibu Creek and its tributaries can vary rapidly. Portions of the upper watershed are highly urbanized. Runoff from urban watersheds is characterized by high flood peaks of short duration that result from high-intensity rainfall on watersheds that have a high percentage of impervious cover. Malibu Creek has not been channelized, but short reaches along some of the tributaries have been improved. Runoff originating in the upper watershed flows at high velocities. Where Malibu Creek emerges from the canyon, the bed slope decreases and the overbank area increases. Flow velocities decrease and the potential for sediment deposition increases. The soils in the Malibu Creek watershed are susceptible to high erosion rates.

Removal of Rindge Dam would meet the goal of ecosystem restoration and enhance the passage of the endangered steelhead trout and other aquatic and terrestrial species. Many additional miles of upstream habitat will become available to these species. Once the dam has been removed the creek will attempt to reach an equilibrium slope. Since the upstream watershed is developed and there are several other dams and lakes which were constructed for water supply and recreation, the creek will not achieve a perfect balance. There will be local areas of slope discontinuities. The pools and riffles that currently exist along the creek are expected to remain; however, the exact locations could change depending on flow conditions and the geologic conditions along the creek.

Rindge Dam is effectively “full” (estimated at 780,000 yd^3 of sediment and debris). This means most of the sediment and debris that comes into the reservoir during larger flood events flows through the reservoir and right over the spillway or top of the dam. Malibu Creek is a high-production watershed as far as sediment is concerned. The model results indicate that in as few as 5 years under similar hydrologic conditions as have occurred in the past, the level of protection along the lower portions of Malibu Creek could be severely reduced. Any release of sediment by removal of the dam would only increase the flood risk downstream. The flood risk varies depending on the flood event and volume of sediment allowed to transport naturally.

There is extensive development along the lower portions of Malibu Creek with several businesses and communities located in areas where flooding has previously occurred. Many of these developments are within the existing FEMA 100-year (1% ACE event) floodplain. Malibu Creek does not have a high level of protection. Model results indicate there are risks of flooding for events larger than the 5% ACE event (20-year) for existing conditions. There are existing block walls and fences along Malibu Creek which have served to divert flows in the past. These are not considered structurally sound for flood control purposes and are not included in the models. Rocks have been dumped at several locations at different times along the lower reaches to prevent lateral channel erosion. These have had varied levels of success.

The hydraulic and sediment transport modeling and analyses focused on the removal of Rindge Dam and the initial array of alternatives. Along with the No-Action alternative, these included mechanical removal of sediments and natural sediment transport. The natural sediment transport was originally combined with full-dam removal and half-dam removal. Several constraints and limitations were identified for the initial array; thus a "hybrid" of mechanical removal combined with natural sediment transport was added to the alternative array. This included notching the dam at the end of each year of excavation and letting the impounded sediment transport downstream through natural processes.

Regardless of the notching scenario, the results indicate once the volume of sediment is made available for transport, the bulk of the material would be moved within the 1-5 years. Malibu Creek is a high-production watershed and significant deposition in the downstream reaches especially where below the canyon where the slope decreases significantly. The contribution from the dam only exacerbates the problem. The results indicate there is a significant flood risk downstream even under the No Action alternative. The natural transport and the hybrid alternatives were not considered viable alternatives because they add to the downstream flood risks. Therefore, it was concluded the recommended plan should be based on mechanical removal of sediments. **Table 17-1 through Table 17-4** present summaries of the sediment transport results for Alts. 2, 3, and 4. The values in the tables represent the maximum and average changes in invert elevations compared to Existing Conditions. **Plate 17-1 through Plate 17-6** present streambed profile comparisons for the alternatives in relation to time; 5 yrs after, 10 yrs after, and 50 yrs after construction.

Table 17-1 Alt. 2 Mechanical Removal - Sediment Transport Summary

Reach	After 5 years	After 10 years	After 20 years	After 30 years	After 40 years	After 50 years
5	1.1 -3.0	1.6 -3.7	1.5 -3.9	0.5 -3.9	1.2 -4.7	0.4 -4.5
4b	3.6 -1.1	2.6 -1.9	2.0 -1.9	2.8 -2.1	3.4 -2.0	2.9 -2.2
4a	2.7 0.4	3.1 0.5	3.7 0.9	4.3 1.4	5.3 1.2	4.8 2.2
3	7.3 2.5	8.4 3.7	9.8 4.4	10.9 5.1	11.4 5.8	12.3 6.4
2b	5.2 2.1	7.1 4.5	8.3 5.5	9.4 6.3	9.6 6.5	10.5 7.4
2a	1.7 1.7	4.5 4.5	4.8 4.7	5.2 5.1	5.1 4.9	5.9 5.7
1	2.4 1.3	4.5 2.4	4.5 2.4	4.7 2.4	4.3 2.2	4.9 2.4
	Values in feet Top value in cell is maximum within reach; bottom number is average					

Table 17-2 Alt. 3 Natural Transport Full-Dam Removal - Sediment Transport Summary

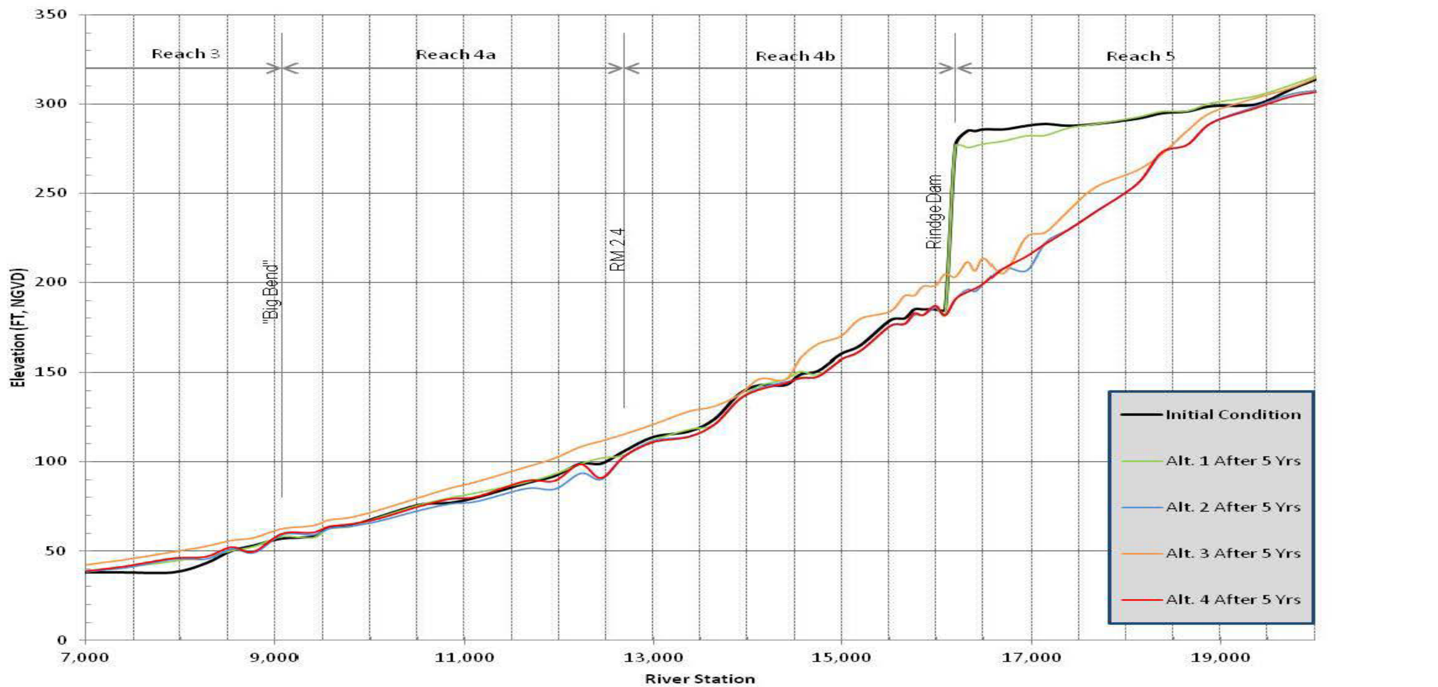
Reach	After 5 years	After 10 years	After 20 years	After 30 years	After 40 years	After 50 years
5	1.0 -2.9	1.6 -4.2	1.5 -5.1	0.5 -5.2	1.2 -5.1	0.4 -5.1
4b	20.1 9.7	10.2 1.1	9.3 0.4	8.8 0.5	2.7 -1.9	3.1 -1.8
4a	12.9 7.8	15.3 9.8	15.2 10.0	14.9 9.7	10.2 6.3	10.1 6.0
3	11.7 7.7	14.4 9.7	14.9 10.3	15.2 10.8	14.9 9.9	15.0 10.6
2b	10.5 6.4	12.0 8.5	12.5 8.9	13.1 9.3	11.3 7.9	12.5 8.9
2a	3.8 3.6	6.3 6.0	6.2 6.0	6.5 6.3	6.0 5.9	6.6 6.5
1	3.9 2.1	5.2 2.7	5.0 2.6	5.2 2.6	4.5 2.3	5.3 2.6
	Values in feet Top value in cell is maximum within reach; bottom number is average					

Table 17-3 Alt. 3 Natural Transport Half-Dam Removal - Sediment Transport Summary

Reach	After 5 years	After 10 years	After 20 years	After 30 years	After 40 years	After 50 years
5	1.3 -3.1	2.0 -3.2	1.5 -5.0	1.2 -5.1	1.2 -5.1	0.5 -5.1
4b	8.3 2.0	17.4 6.7	6.1 -0.1	2.6 -1.7	2.6 -1.7	3.5 -1.6
4a	9.3 5.1	13,7 9.4	13.0 9.4	12.6 6.0	12.6 6.0	13.0 6.7
3	9.7 4.9	13.9 9.6	15.3 11.1	15.2 10.1	15.2 10.1	14.7 10.5
2b	7.1 4.3	12.4 8.8	13.4 9.4	11.9 8.7	11.9 8.7	13.1 9.5
2a	3.7 3.6	6.2 5.8	6.7 6.4	6.4 6.3	6.4 6.3	7.1 6.9
1	3.8 2.1	5.0 2.5	5.2 2.7	4.7 2.3	4.7 2.3	5.4 2.6
	Values in feet Top value in cell is maximum within reach; bottom number is average					

Table 17-4 Alt. 4 Hybrid - Sediment Transport Summary

Reach	After 5 years	After 10 Years	After 20 Years	After 30 Years	After 40 Years	After 50 years
5	1.1 -4.5	2.0 -4.4	2.1 -4.5	1.4 -4.5	1.2 -4.7	0.8 -4.6
4b	1.0 -2.2	3.1 -2.1	3.1 -2.1	3.5 -2.1	3.8 -1.9	3.1 -2.2
4a	2.3 -1.0	2.9 -0.7	4.5 -0.1	6.3 0.4	5.7 0.8	5.8 1.8
3	9.8 4.0	10.7 4.9	11.3 5.5	12.1 6.1	12.0 6.1	12.8 6.9
2b	7.6 4.2	9.3 6.2	10.1 6.9	10.9 7.5	10.6 7.6	11.6 8.3
2a	3.3 3.2	5.2 5.1	5.6 5.4	6.1 5.8	5.9 5.4	6.4 6.2
1	3.1 1.8	4.8 2.5	4.7 2.5	4.9 2.5	4.4 2.2	5.1 2.5
	Values in feet Top value in cell is maximum within reach; bottom number is average					



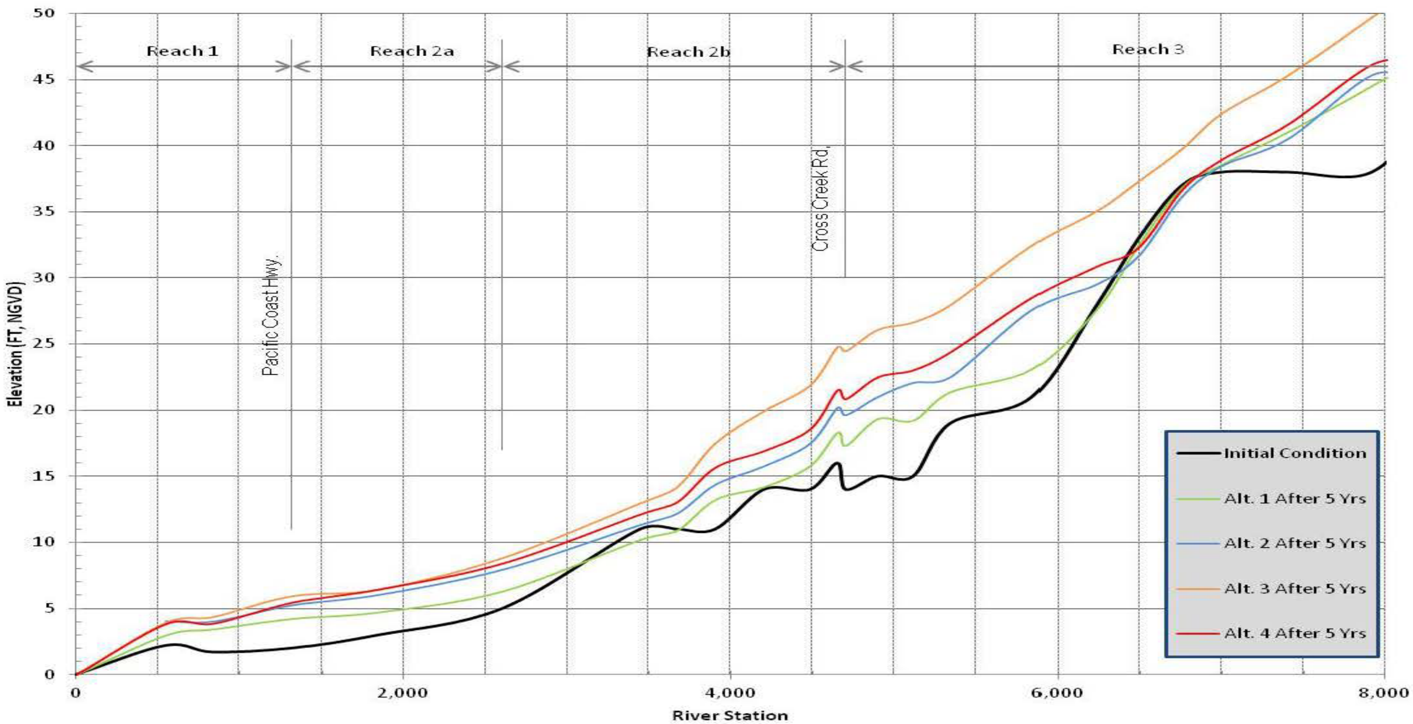
Streambed elevations based on lowest elevation in cross section from sediment transport models for shown alternative after 5 years of time.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK STREAMBED PROFILES AFTER 5 YEARS

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 17-1 Malibu Creek Streambed Profiles after 5 Years, Upper Reaches



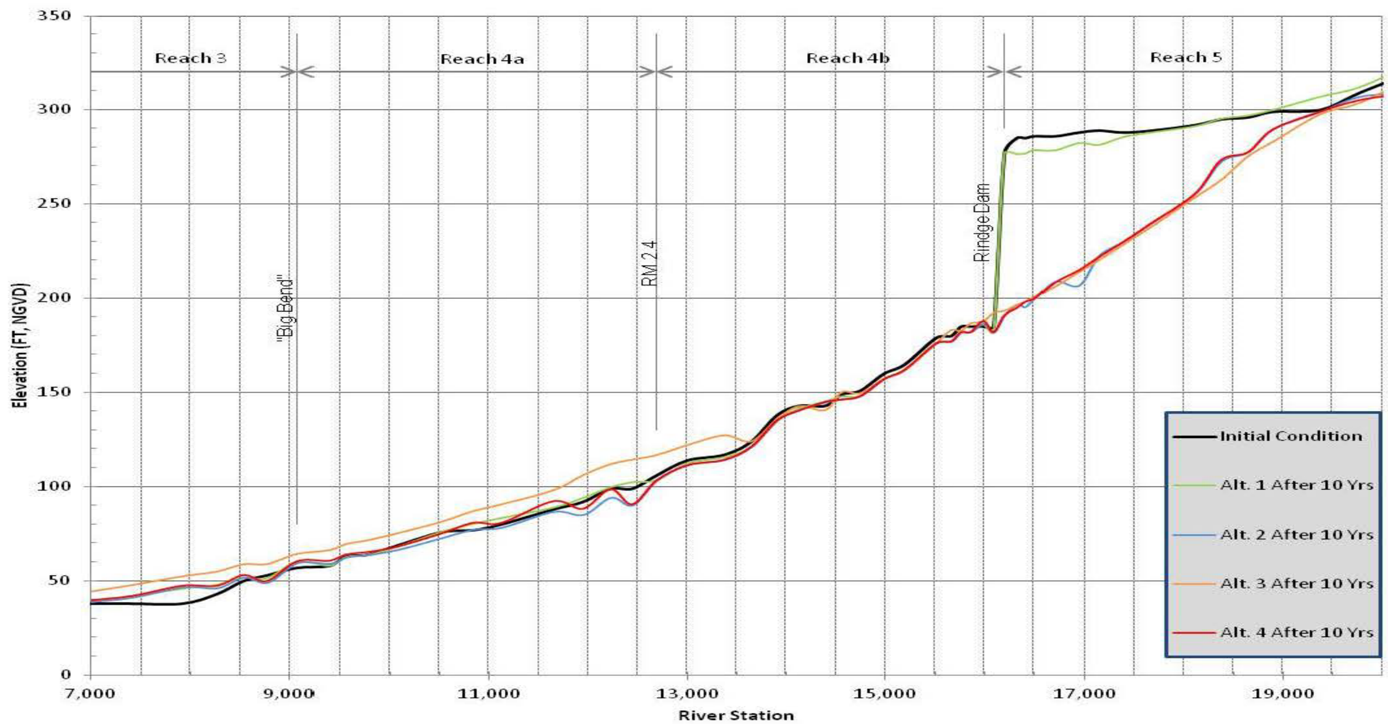
Streambed elevations based on lowest elevation in cross section from sediment transport models for shown alternative after 5 years of time.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK STREAMBED PROFILES AFTER 5 YEARS

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 17-2 Malibu Creek Streambed Profiles after 5 Years, Lower Reaches



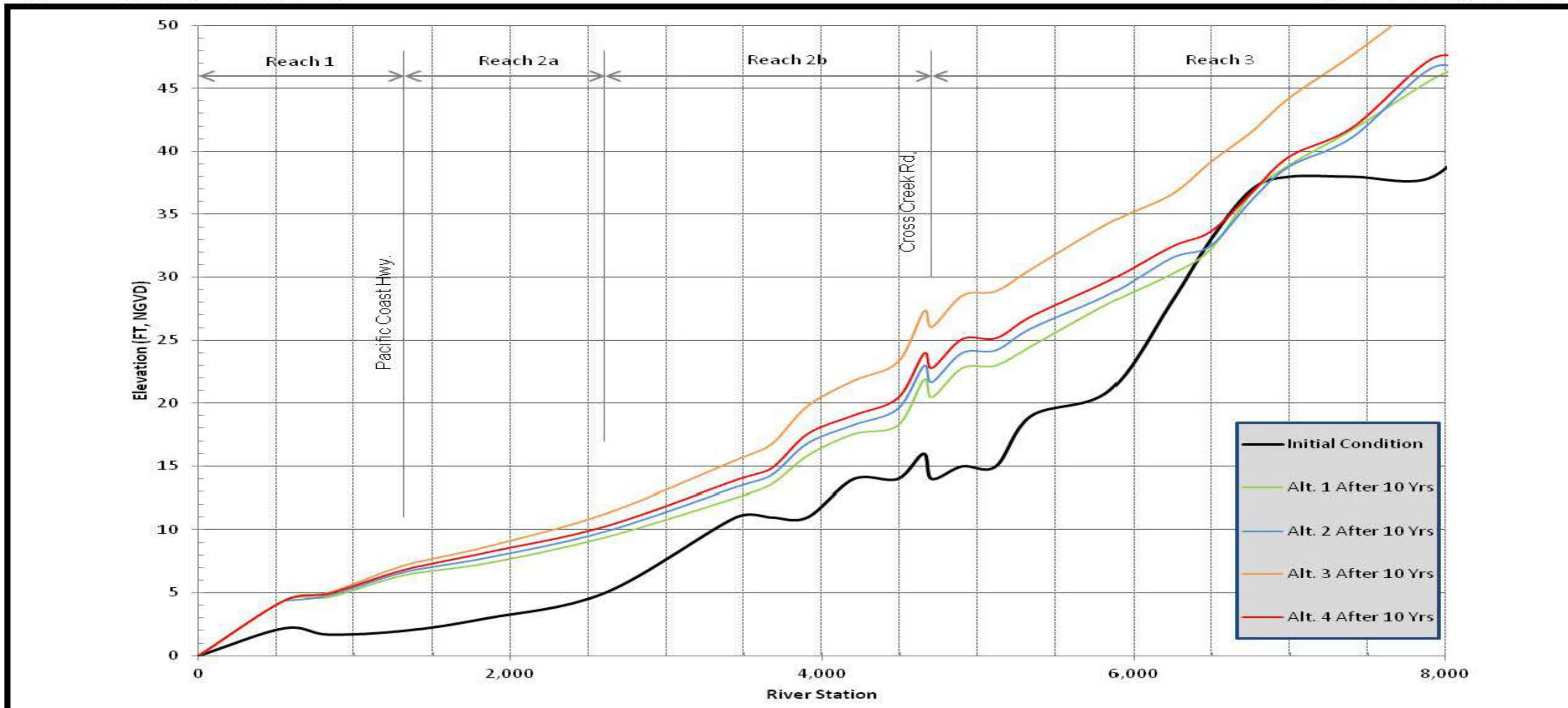
Streambed elevations based on lowest elevation in cross section from sediment transport models for shown alternative after 5 years of time.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK STREAMBED PROFILES AFTER 10 YEARS

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 17-3 Malibu Creek Streambed Profiles after 10 Years, Upper Reaches



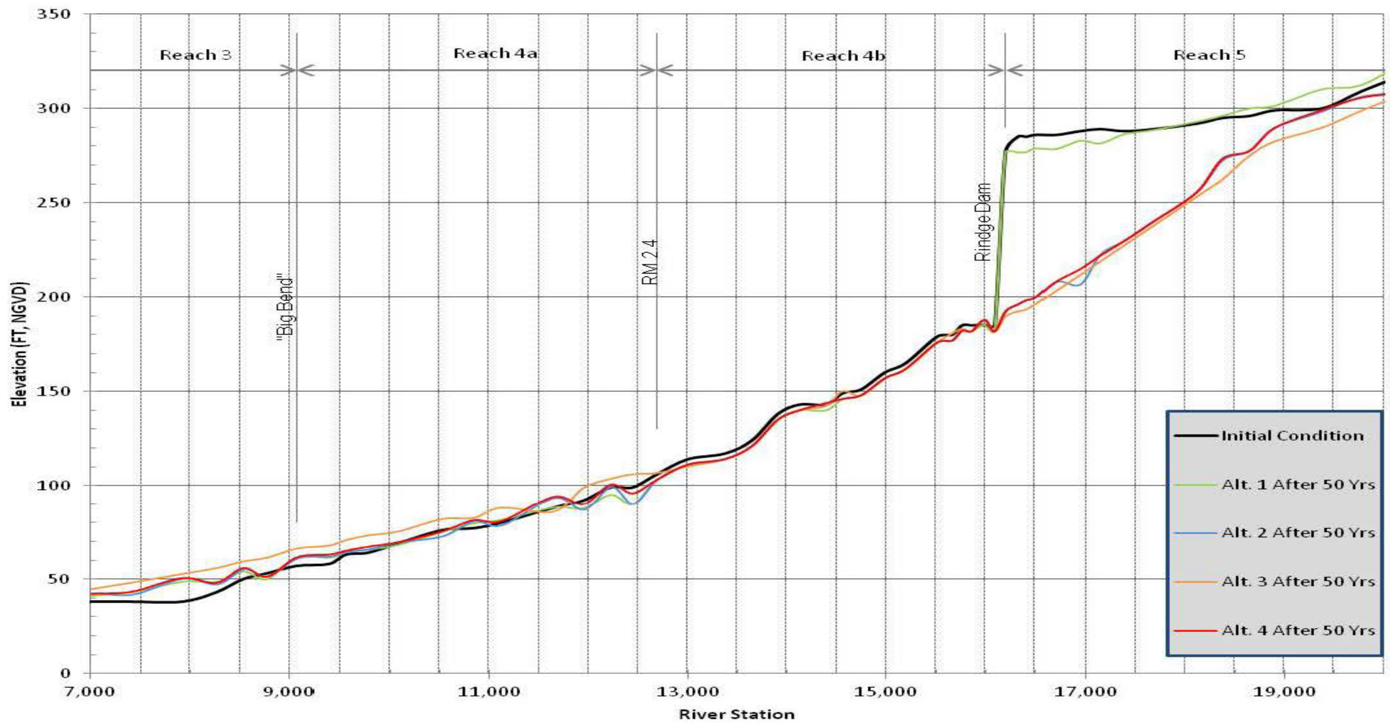
Streambed elevations based on lowest elevation in cross section from sediment transport models for shown alternative after 5 years of time.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK
STREAMBED PROFILES
AFTER 10 YEARS

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 17-4 Malibu Creek Streambed Profiles after 10 Years, Lower Reaches



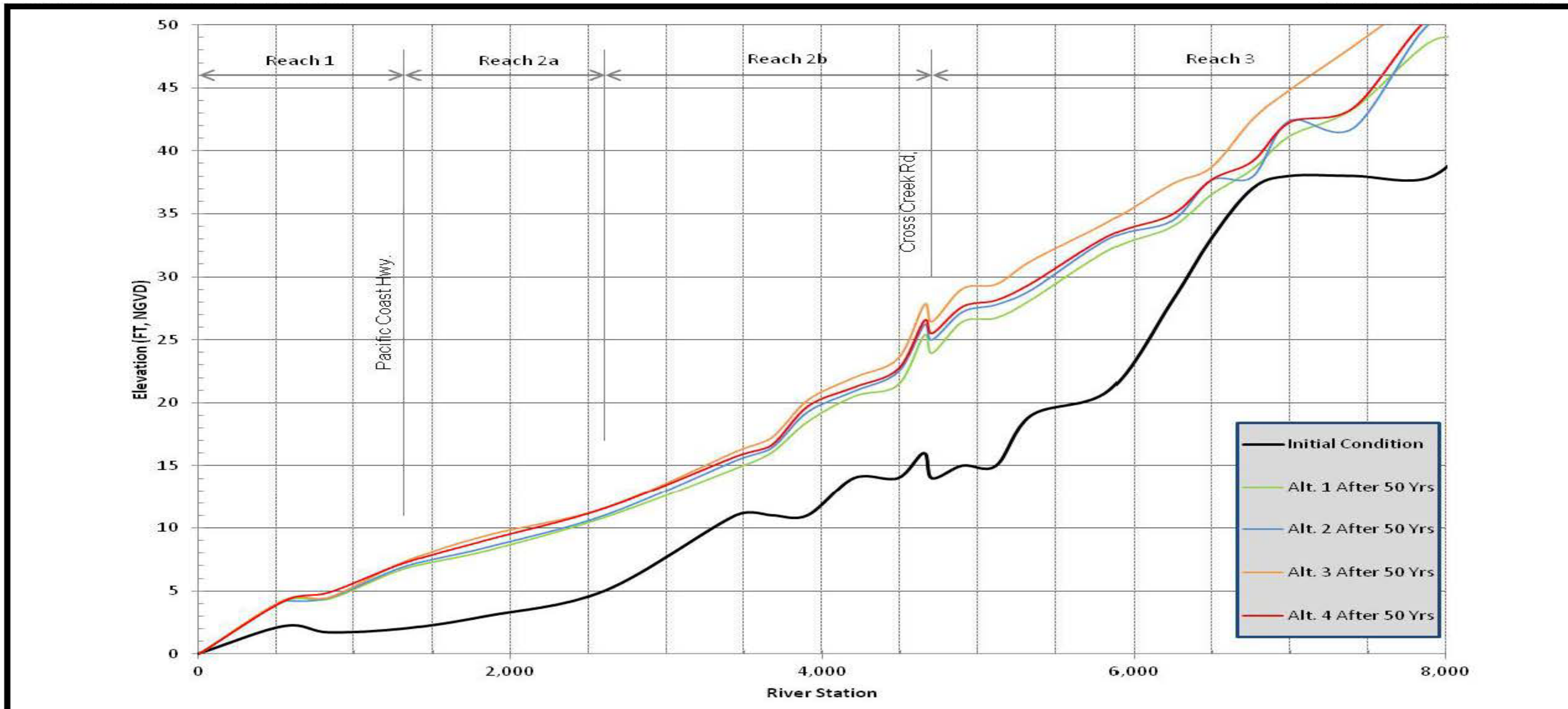
Streambed elevations based on lowest elevation in cross section from sediment transport models for shown alternative after 5 years of time.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK STREAMBED PROFILES AFTER 50 YEARS

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 17-5 Malibu Creek Streambed Profiles after 50 Years, Upper Reaches



Streambed elevations based on lowest elevation in cross section from sediment transport models for shown alternative after 5 years of time.

MALIBU CREEK
ECOSYSTEM RESTORATION STUDY

MALIBU CREEK STREAMBED PROFILES AFTER 50 YEARS

CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Plate 17-6 Malibu Creek Streambed Profiles after 50 Years, Lower Reaches

18.0 RECOMMENDED PLAN

Selection of the recommended plan was based on input from criteria in addition to the hydraulic and sediment model results including acceptability, economics, geotechnical, and environmental. The recommended plan was selected as Alt. 2 Mechanical Removal. This alternative entails Dam Removal along with Sediment Removal by Mechanical Means over 5 years - Impounded sediment is removed from behind the dam using mechanical means (excavators, bulldozers, trucks, etc.). The period of removal may be extended depending on final sediment removal plan to be updated during the detailed design phase.

The recommended plan consists of incremental notching of the dam concurrent with mechanical sediment removal to occur over 5 years. The intent is to de- construct the dam at the same rate as sediment is removed. If the dam is not removed concurrently with sediment removal, a flood event could potentially fill the reservoir back up and if the dam is notched greater than the expected annual sediment removal volume, a flood event could flush the "available" sediment out of the reservoir and increase the downstream flood risk. The preponderance of the sediment removal activities would take place during the non-flood season and would factor in the ecosystem concerns. The first year would focus on site preparation and other pre- construction activities. Sediment removal and dam de-construction would start in the 2nd year and continue until completion of the project. At the end of construction activities each year, the site will be prepped for the upcoming winter flood season.

The recommended plan also includes removal or reconfiguring of upstream barriers. No detailed hydrologic or hydraulic modeling was done for this aspect of the recommended alternative.

The level of hydraulic and sediment modeling is commensurate with a planning feasibility study. Additional sediment and floodplain modeling may be required in the next phase of this study.

19.0 FLOOD RISK COMPARISON BETWEEN ALT. 1 (NO ACTION) AND ALT. 2 (MECHANICAL REMOVAL)

As described in Section 16.2, presently, the majority of the sediment and debris carried along Malibu Creek passes over the top of Rindge Dam without any significant deposition, because the dam impoundment is almost full with sediment. Malibu Creek is a high-production watershed and significant deposition is predicted in the downstream reaches of Malibu Creek, especially below the canyon where the slope decreases significantly. Under the No Action Alternative (Alt. 1), in 50 years, one can expect up to 12 ft of deposition in certain locations from the “Big Bend” to Malibu Lagoon. The No Action Alternative analysis reveals that flood concerns exist along lower Malibu Creek even under current conditions. However, it should be noted that the sediment deposition predicted by the sediment transport model was based on a conservative assumption for the downstream boundary condition. As described in Section 8, the downstream boundary condition for all simulations was set to the estimated MHHW (mean higher high water) tide level of 5.5 ft. This conservative boundary was selected for the modeling because more detailed data was not available for the full period of record of the sediment transport model and because the conservative boundary condition captures a worst-case deposition scenario. A variable downstream boundary condition based on time (i.e., hourly varied tide level) would yield less sediment deposition than using a constant tide level (the MHHW) as the boundary condition. Therefore, the simulated results presented in this report should be considered to be conservative in terms of sediment deposition.

Plate 19-1 presents the 100-yr floodplain boundary after 50 years of Alt. 1 (No Action) compared to the current FEMA 100-yr floodplain boundary (Effective Date: September 26, 2008). This plate shows the increased floodplain boundary due to future sediment accumulation along lower Malibu Creek. It should be noted that the 100-yr peak discharge used in the FEMA FIS (Flood Insurance Study) is 40,544 cfs, while 49,200 cfs was used in this study. Even considering the increased 100-yr peak discharge, it is clear that the 100-yr floodplain boundary will increase along lower Malibu Creek after 50 years due to the sedimentation along lower Malibu Creek under the No Action Alternative.

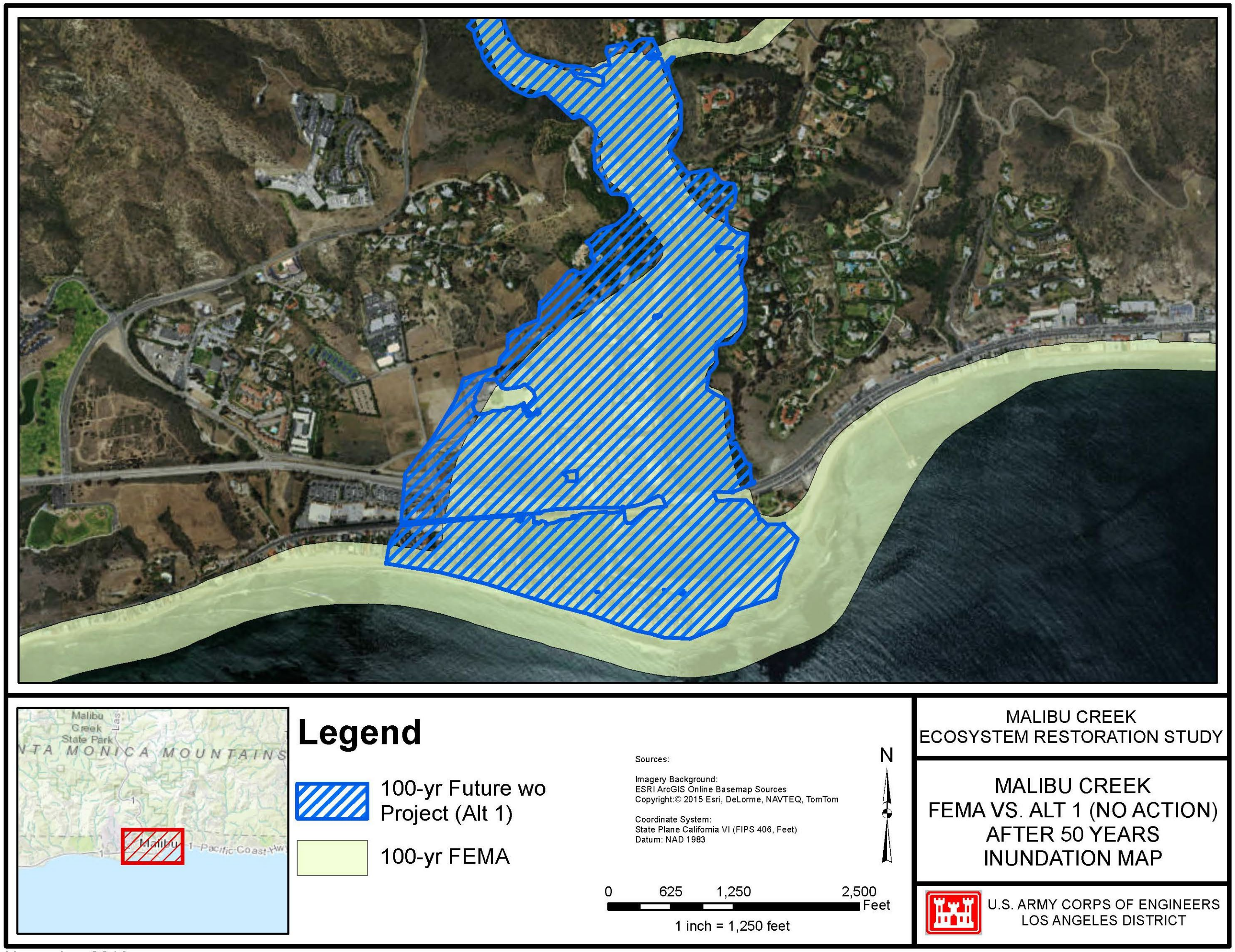


Plate 19-1 Malibu Creek FEMA vs. Alt. 1 (No Action) after 50 Years Inundation Map (100-year Floodplain)

19.1 Comparison of the Results after 50 Years.

To evaluate the impact of the Mechanical Removal Alternative (Alt. 2) on the flood risk compared to No Action (Alt. 1), the simulated streambed elevations of these two alternatives were compared. **Table 19-1** presents the comparison of the streambed elevations of Alt. 1 and Alt. 2 after 50 years. **Table 19-1** also presents the comparison of the 100-yr water surface elevations, which were based on the simulated cross section geometry after 50 years. **Plate 19-2** shows the streambed and 100-yr water surface profiles after 50 years within the reaches downstream of the canyon mouth (i.e., Reaches 1, 2a, 2b, and the lower 15,000 ft of Reach 3), where commercial and residential areas are located. In these reaches, the increases in streambed elevation are very small at most locations (0 to 0.3 ft) with the maximum increase in streambed elevation of 1.0 ft. The increases in water surface elevation are lesser than those in streambed elevation at most cross sections with the exception of the cross sections within lower portion of Reach 3. **Plate 19-4** compares the 100-yr floodplain boundaries of Alt. 1 and Alt. 2. Even though up to 1.2 ft increase in water surface elevation of Alt. 2 is predicted compared to Alt. 1, no discernable increase in 100-yr floodplain boundary is shown in this **Plate 19-4**.

In addition to the 100-yr floodplain boundary comparison, to evaluate the impact of the increased water surface elevation on the structures located within the reaches downstream of the canyon mouth in detail, simulated cross sections after 50 years were compared. **Plate 19-5** is a location map of the structures located near the cross sections of the Alt. 2 model which have an increase in water surface elevation of 0.5 ft or greater compared to Alt. 1. The analysis assumes that a water surface elevation increase of less than or equal to 0.5 ft is insignificant, considering the level of accuracy of the sediment transport model and uncertainties of the input data of the model. **Plate 19-6** shows the simulated cross sections of Alt. 1 and Alt. 2 after 50 years with the 100-yr water surface elevations and locations of the inhabited and uninhabited structures. **Plate 19-6** shows that under Alt. 2, no additional structures are subject to flooding after 50 years, compared to Alt. 1; i.e., structures at risk of flooding under Alt. 1 remain at risk under Alt. 2. Also, the plate shows that at cross sections 4653.8 and 4203.5, the increase in flood depth is less than or equal to 0.5 ft (insignificant change); therefore, under Alt. 2, the 100-year flood depth increases greater than 0.5 ft are near a total of 13 inhabitable structures only, compared to Alt. 1. The plate shows that the water depth increases up to 1.2 ft are insignificant relative to the 100-year flood depths around those 13 structures of Alt. 1.

The bulk of the sediment accumulated behind the dam will be removed by mechanical means in Alt. 2 which will result in a markedly different channel slope in the vicinity of the dam as compared to Alt. 1. The current depositional slope of the sediment behind Rindge Dam is approximately 0.5% whereas the invert channel slope of the same area after mechanical sediment removal (Alt. 2) will be approximately 3.2% (**Plate 16-1**). This increase in slope may increase fluvial sediment transport downstream. However, an evaluation of the potential for increased sediment deposition downstream shows that the differences between Alt. 1 (No Action) and Alt. 2 is insubstantial. First, the probable additional sediment storage behind the dam due to the milder slope (0.5%) was investigated. **Plate 19-3** shows the streambed profile changes of Alt. 1 after 50 yrs. Even though the depositional slope behind the dam would approach 1.6% (**Plate 16-1), Plate 19-3** shows that the amount of the sedimentation behind the dam after 50 years will be very small. Therefore, it is predicted that no additional sediment storage volume behind the dam will be provided by Alt.1 compared to Alt. 2. Second, to see the impact of the invert slope change on the sediment volume entering the ocean, cumulative volumes of the sediment leaving the downstream boundary of both models were compared. In both models, the cumulative sediment volume entering the upstream boundary of the model is 1,306.2 ac-ft during 50 yrs. The cumulative sediment volume leaving the downstream boundary of Alt. 1 model is 986.8 ac-ft during 50 years. Thus, the sediment trap efficiency of the modeled reaches of Alt. 1 is 24.45%. The cumulative sediment volume leaving the downstream boundary of Alt. 2 model is 991.4 ac-ft during 50 years. Thus, the sediment trap efficiency of Alt. 2 is also 24.10%. Even though the cumulative sediment volume from Malibu Creek to the ocean of Alt. 2 (991.4 ac-ft) is slightly greater than that of Alt. 1 (986.8 ac-ft), the percent increase in volume is less than half a percent. Considering that the total length of the modeled reaches is 4.7 mi, it can be concluded that the impact of the invert slope change on the sediment volume to be transported through Malibu Creek to the ocean will be insignificant.

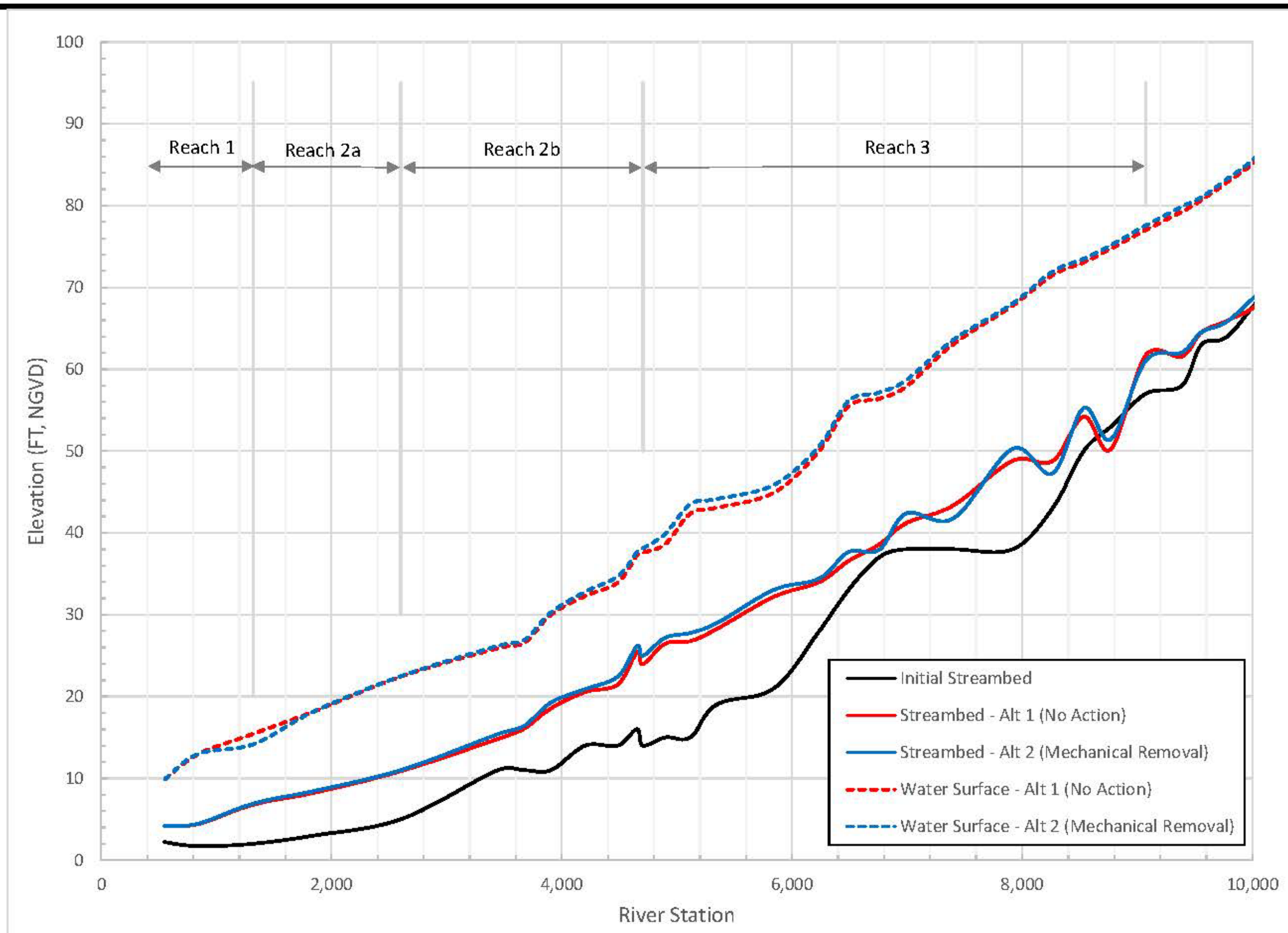
Table 19-1 Comparison of Sediment Transport Results between Alt 1 (No Action) and Alt 2 (Mechanical Removal)

Reach	Station	Initial Streambed Elevation (ft)	Streambed Elevation after 50 Years (ft)			100-yr Water Surface Elevation Based on Streambed after 50 Years (ft)		
			Alt 1 - No Action (a)	Alt 2 - Mechanical Removal (b)	Increase in Streambed (b) – (a)	Alt 1 - No Action (c)	Alt 2 - Mechanical Removal (d)	Increase in WSE (d) – (c)
Reach 1	550.58	2.2	4.2	4.2	0.0	9.9	9.9	0.0
	839.84	1.7	4.4	4.4	0.1	12.9	13.0	0.0
Reach 2a	1320.8	2	6.8	6.9	0.1	15.4	14.15	-1.3
	1846.3	3	8.2	8.4	0.2	18.2	18.2	0.0
Reach 2b	2603.4	5	10.9	11.0	0.1	22.5	22.5	0.0
	3445.8	11	14.8	15.4	0.6	25.9	26.2	0.3
	3670.5	11	16.0	16.4	0.3	26.5	26.8	0.3
	3906.8	11	18.5	19.3	0.7	30.0	30.3	0.3
	4203.5	14	20.5	20.9	0.3	32.3	32.8	0.5
	4486.6	14	21.5	22.4	1.0	33.9	34.7	0.7
	4653.8	16	25.4	26.1	0.8	37.3	37.6	0.3
Reach 3	4705.1	14	24.0	25.0	1.0	37.6	38.1	0.5
	4900.6	15	26.5	27.2	0.7	38.7	39.9	1.2
	5117.6	15	26.8	27.8	1.0	42.4	43.5	1.1
	5344.1	19	28.2	29.0	0.7	43.1	44.1	1.0
	5844	21	32.2	33.0	0.8	44.9	45.9	0.9
	6237.3	28	34.0	34.4	0.4	50.1	50.6	0.6
	6490.1	33	36.5	37.6	1.1	55.5	56.1	0.6
	6755.7	37	38.6	37.9	-0.7	56.4	57.1	0.7
	6993.4	38	41.2	42.4	1.2	57.9	58.7	0.8
	7404.4	38	43.4	41.8	-1.6	63.1	63.6	0.5
	7917	38	48.8	50.3	1.5	67.8	68.0	0.2
	8262.6	43	48.8	47.3	-1.5	71.5	71.9	0.4
	8533.1	50	54.2	55.2	1.1	73.1	73.5	0.4
	8770.2	53	50.2	51.5	1.2	74.8	75.1	0.4

Reach	Station	Initial Streambed Elevation (ft)	Streambed Elevation after 50 Years (ft)			100-yr Water Surface Elevation Based on Streambed after 50 Years (ft)		
			Alt 1 - No Action (a)	Alt 2 - Mechanical Removal (b)	Increase in Streambed (b) – (a)	Alt 1 - No Action (c)	Alt 2 - Mechanical Removal (d)	Increase in Streambed (d) – (c)
Reach 4a	9072.9	57	61.7	61.0	-0.7	77.0	77.6	0.5
	9385.9	58	61.6	62.1	0.5	79.3	79.9	0.6
	9556	63	64.5	64.5	0.0	80.7	81.0	0.3
	9779.9	64	65.9	65.8	-0.1	82.9	83.3	0.4
	10082	69	68.4	69.5	1.1	86.3	86.7	0.4
	10524	76	75.3	72.8	-2.5	94.2	94.6	0.4
	10839	77	79.8	80.8	1.0	97.5	100.4	2.9
	11121	80	81.8	78.7	-3.1	105.0	108.0	3.0
	11648	88	88.3	93.4	5.0	109.3	111.7	2.3
	11948	92	88.0	87.0	-1.0	115.5	119.0	3.5
	12224	99	95.3	99.4	4.1	116.9	119.3	2.4
	12444	99	90.1	90.2	0.1	119.3	121.6	2.3
Reach 4b	12689	106	103.3	103.3	0.0	124.5	124.4	-0.1
	12999	114	111.3	111.3	0.0	134.5	134.5	0.0
	13373	117	114.3	114.3	0.0	144.2	144.6	0.4
	13647	124	121.2	121.2	0.0	146.5	147.0	0.5
	13907	138	135.2	135.2	0.0	153.6	154.2	0.6
	14129	143	140.2	140.2	0.0	158.0	158.6	0.6
	14394	143	140.2	143.7	3.5	164.4	165.7	1.3
	14559	149	146.2	146.2	0.1	168.4	171.3	2.9
	14747	151	148.2	148.2	0.0	176.0	174.7	-1.3
	14985	160	157.1	157.1	0.0	188.9	186.6	-2.3
	15196	165	162.1	162.1	0.0	188.5	186.4	-2.1
	15512	179	176.1	176.1	0.0	195.6	194.0	-1.5
	15662	180	177.1	177.1	0.0	200.8	199.3	-1.5
	15764	185	182.1	182.7	0.6	203.2	203.1	-0.1

Reach	Station	Initial Streambed Elevation (ft)	Streambed Elevation after 50 Years (ft)			100-yr Water Surface Elevation Based on Streambed after 50 Years (ft)		
			Alt 1 - No Action (a)	Alt 2 - Mechanical Removal (b)	Increase in Streambed (b) – (a)	Alt 1 - No Action (c)	Alt 2 - Mechanical Removal (d)	Increase in Streambed (d) – (c)
	15859	185	182.1	182.1	0.0	205.2	205.9	0.7
	15990	185	185.6	188.0	2.4	210.7	211.9	1.2
	16092	185	182.1	182.1	0.0	213.9	213.9	-0.1
Reach 5	16201	277	277.0	192.5	-84.5	300.7	216.4	-84.3
	16326	285	277.0	196.3	-80.7	306.0	216.5	-89.5
	16409	285	277.3	198.5	-78.7	306.2	216.4	-89.9
	16503	286	279.3	200.0	-79.2	306.6	216.6	-90.0
	16704	286	278.9	208.3	-70.6	307.0	220.1	-86.9
	16943	288	283.3	206.9	-76.4	309.7	226.9	-82.8
	17143	289	281.9	222.7	-59.2	311.7	234.0	-77.6
	17389	288	286.8	230.1	-56.6	313.2	242.0	-71.1
	17674	289	288.9	240.1	-48.8	314.7	255.3	-59.4
	18118	292	293.4	255.8	-37.6	317.3	273.0	-44.4
	18376	295	296.5	272.7	-23.8	322.6	288.7	-33.9
	18648	296	300.4	277.7	-22.7	324.3	296.6	-27.6
	18901	299	301.8	289.9	-11.9	326.9	315.3	-11.6
	19374	300	310.5	298.5	-12.0	331.4	325.6	-5.7
	19769	309	312.7	306.4	-6.3	338.8	330.1	-8.7
	20271	320	325.8	310.1	-15.6	344.4	336.3	-8.0
	20499	330	322.4	320.1	-2.2	351.7	340.6	-11.1
	21000	341	331.2	331.2	0.0	368.4	367.6	-0.8
	21256	355	355.0	355.0	0.0	382.0	381.5	-0.5
	21588	368	368.0	368.0	0.0	393.5	393.2	-0.3
	21928	376	376.0	376.0	0.0	403.4	403.4	0.1
	22233	391	391.0	391.0	0.0	411.6	411.5	-0.1
	22781	405	405.4	405.7	0.3	424.7	425.2	0.5

Reach	Station	Initial Streambed Elevation (ft)	Streambed Elevation after 50 Years (ft)			100-yr Water Surface Elevation Based on Streambed after 50 Years (ft)		
			Alt 1 - No Action (a)	Alt 2 - Mechanical Removal (b)	Increase in Streambed (b) – (a)	Alt 1 - No Action (c)	Alt 2 - Mechanical Removal (d)	Increase in Streambed (d) – (c)
	23198	415	405.3	405.3	0.0	435.4	434.5	-0.9
	23661	428	419.3	419.3	0.0	450.3	448.6	-1.7
	24000	434	426.2	426.2	0.0	461.1	459.3	-1.8
	24500	439	437.4	436.8	-0.6	462.9	462.3	-0.6

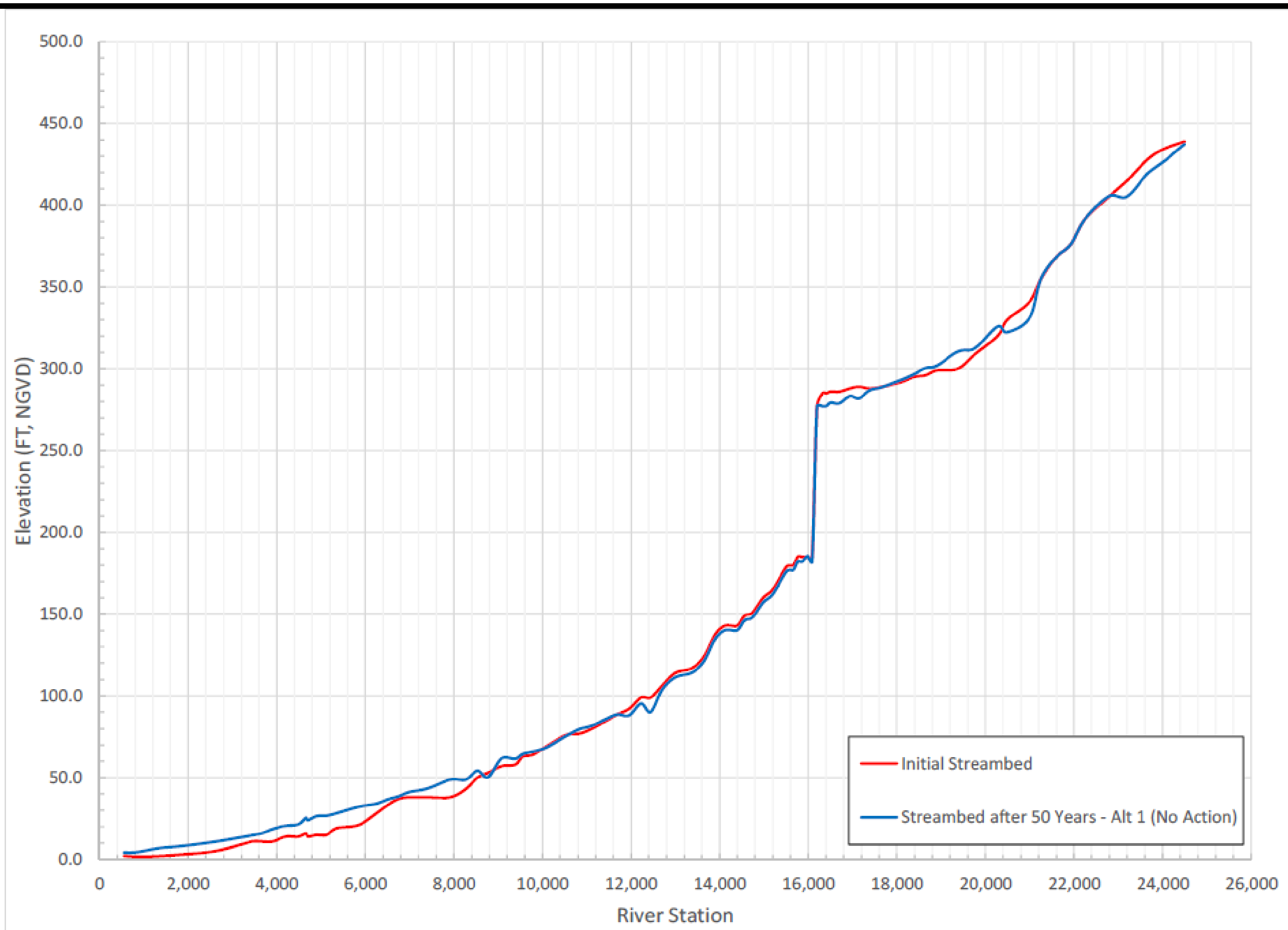


Notes: Not to Scale

Malibu Creek Ecosystem Restoration Study	**Malibu Creek Streambed and 100-yr Water Surface Profiles After 50 Years**		U.S. ARMY CORPS OF ENGINEERS LOS ANGELES DISTRICT

Plate 56

Plate 19-2 Malibu Creek Streambed and 100-yr Water Surface Profiles after 50 Years



Notes: Not to Scale

Malibu Creek Ecosystem Restoration Study	**Malibu Creek Streambed Profiles After 50 Years**		U.S. ARMY CORPS OF ENGINEERS LOS ANGELES DISTRICT

Plate 19-3 Malibu Creek Streambed Profiles after 50 Years

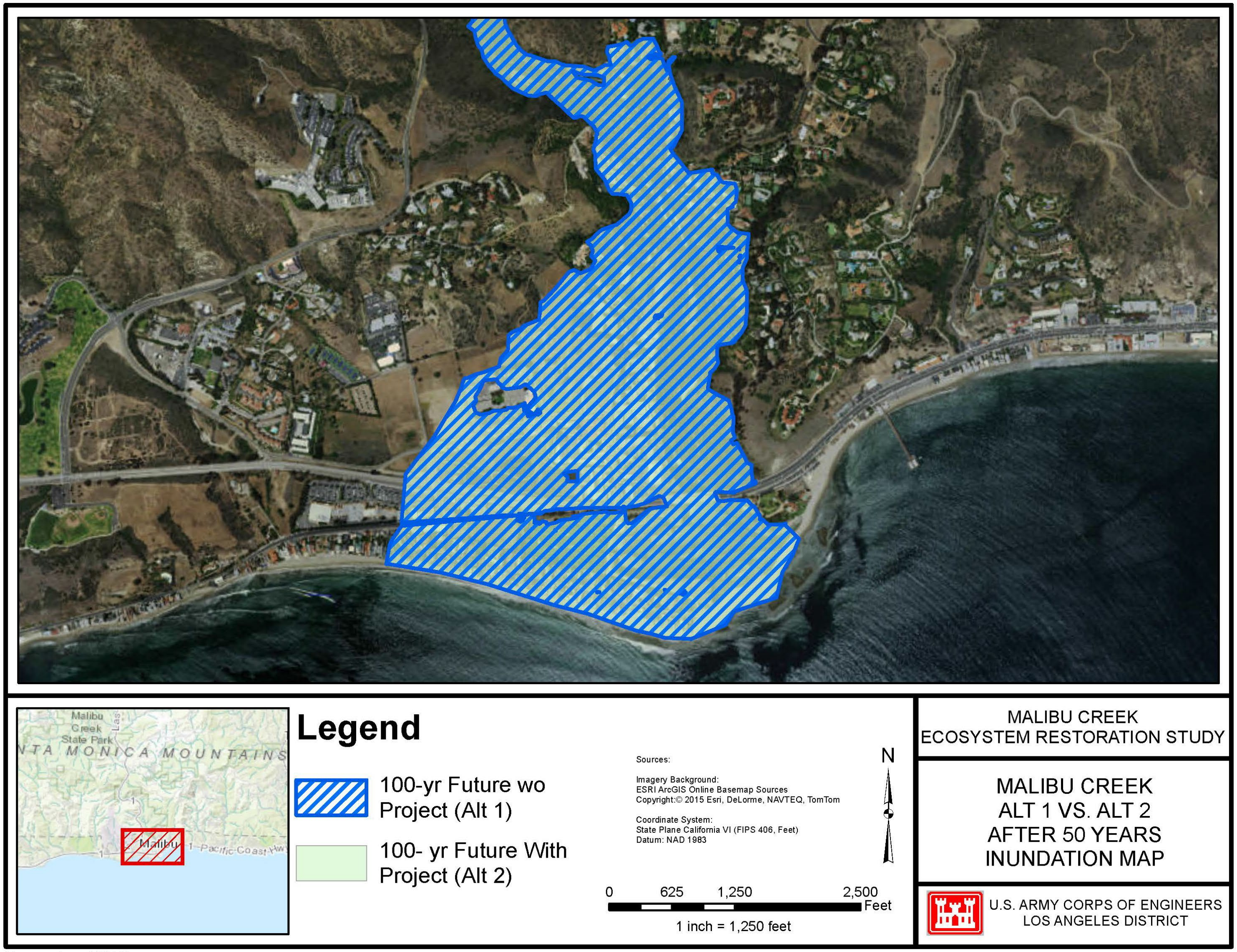


Plate 19-4 Malibu Creek Alt. 1 vs. Alt. 2 Inundation Map after 50 Years (100-yr Floodplain)

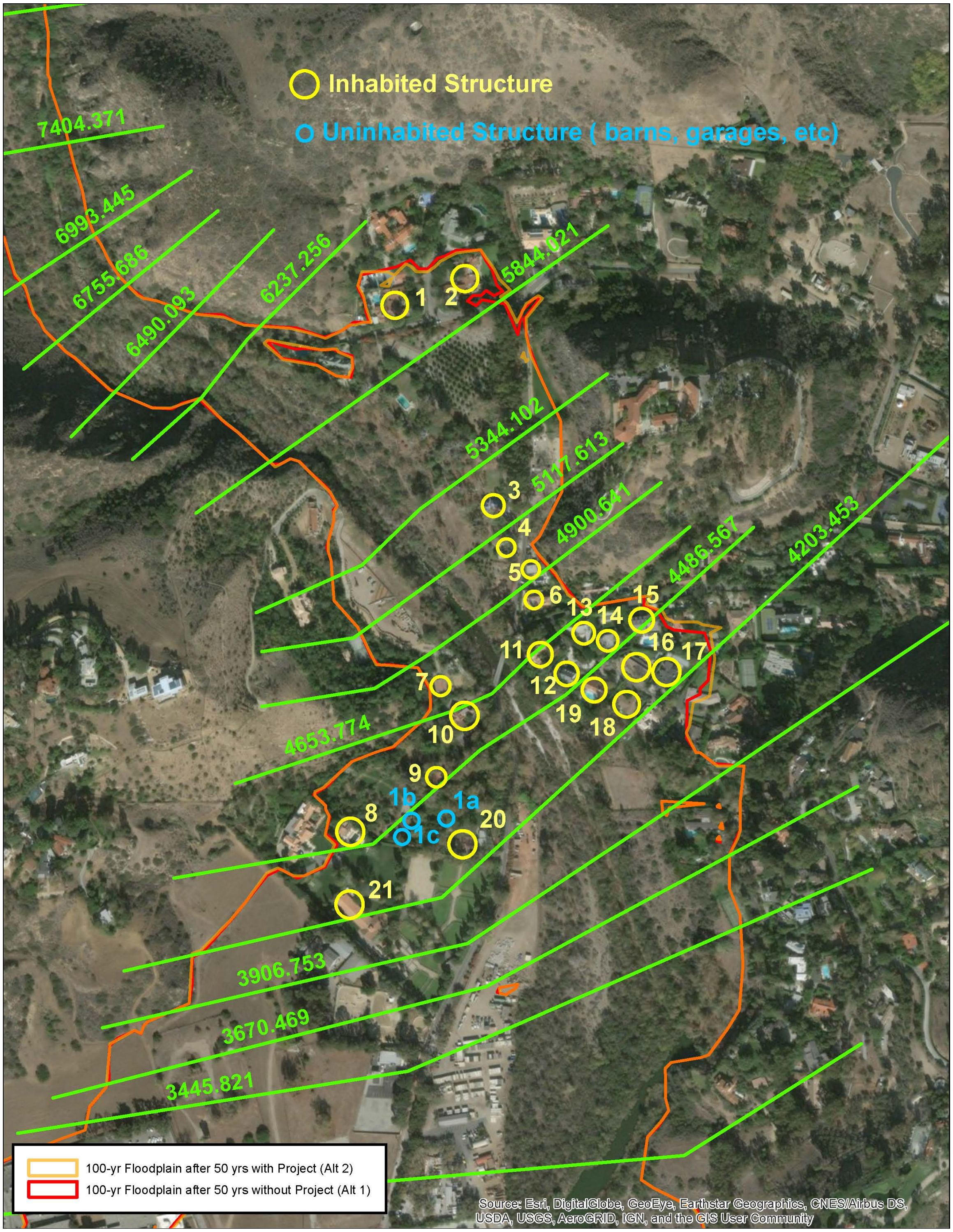
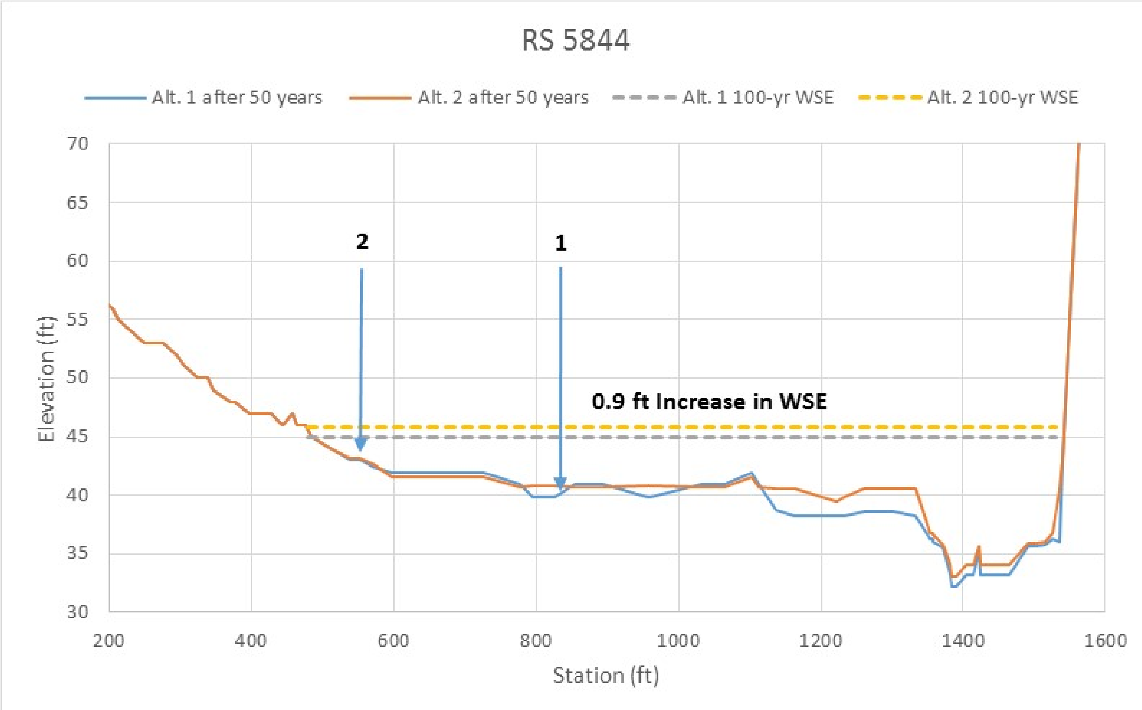
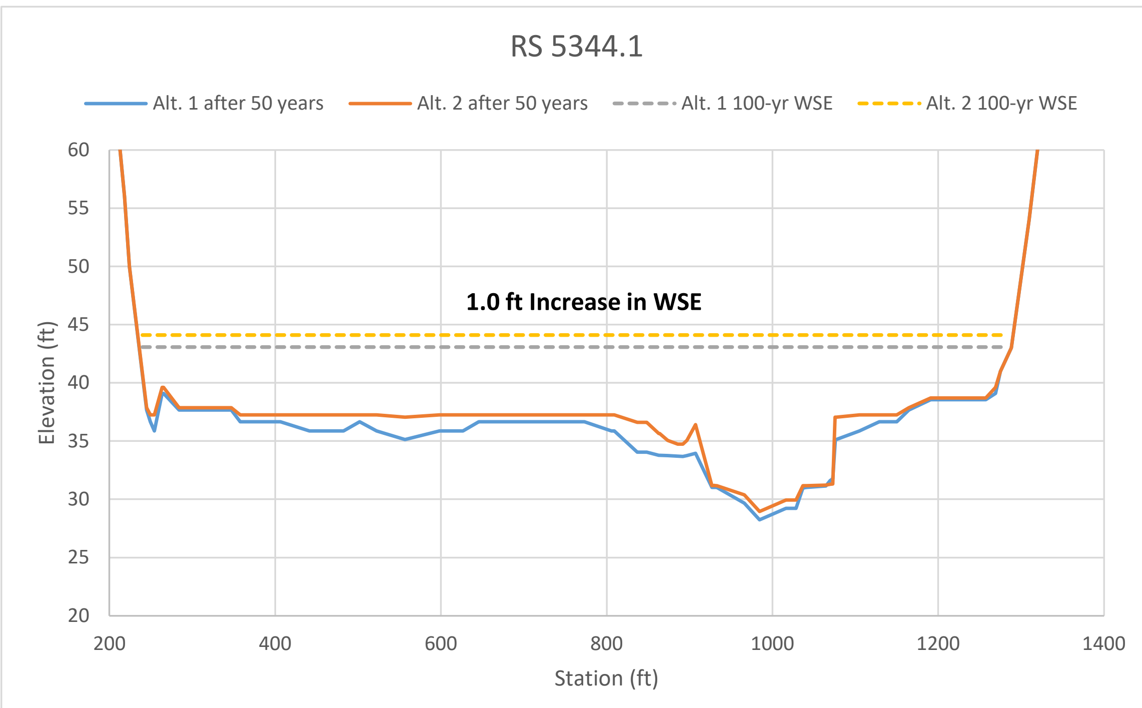
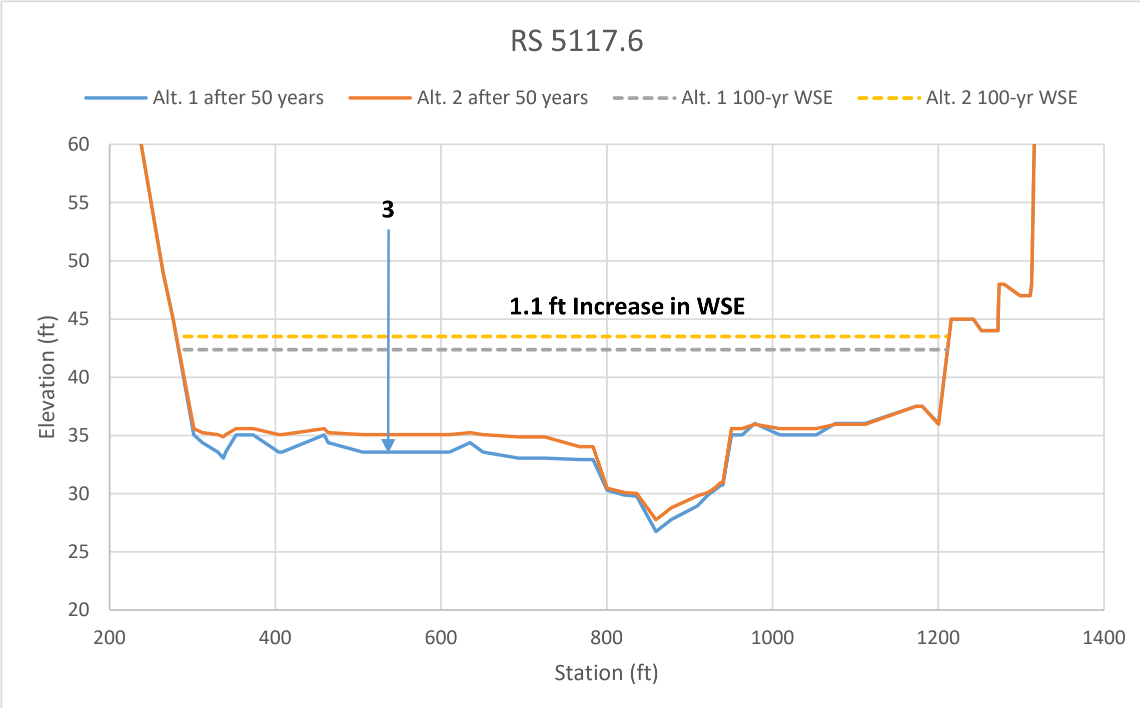


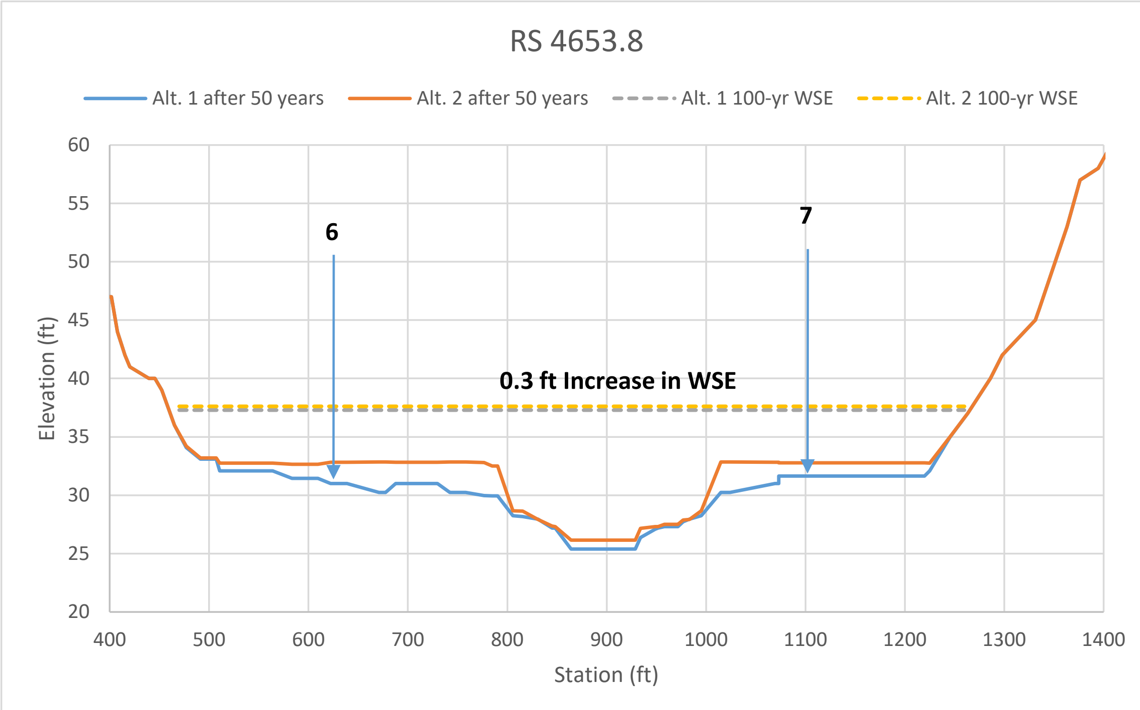
Plate 19-5 Location Map of the Structures near the Cross Sections of Alt. 2 Having Increase in Water Surface Elevation of 0.5 FT or Greater Compared to Alt. 1

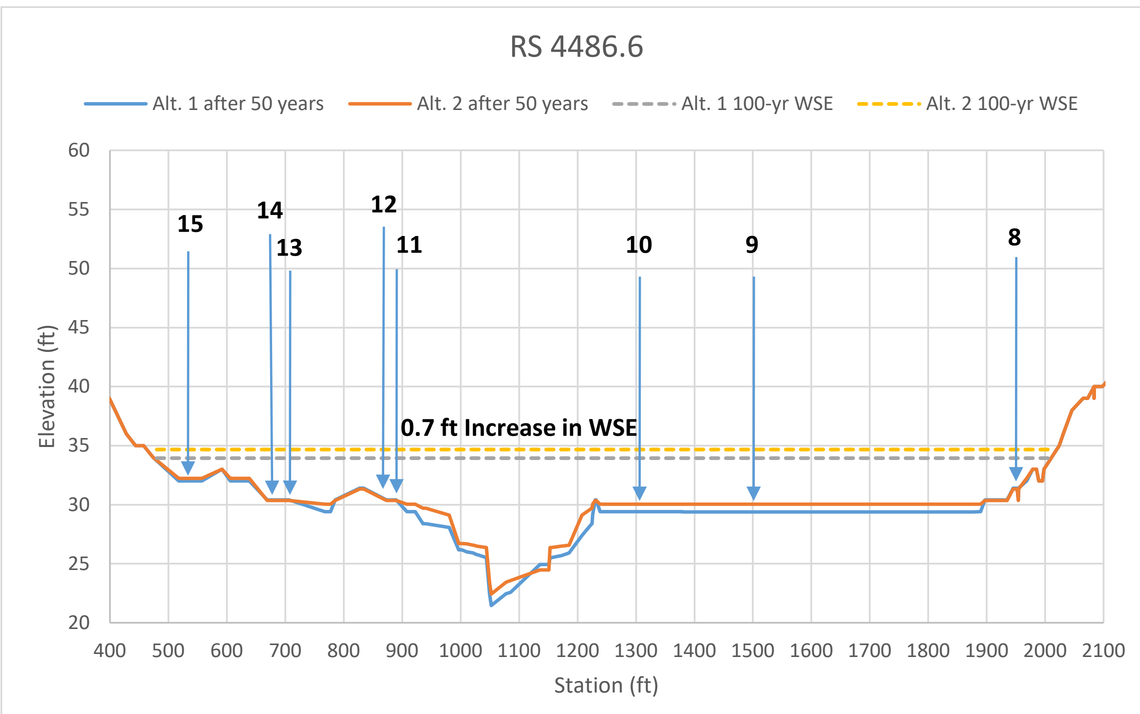

RS 5844
Alt. 1 after 50 years
Alt. 2 after 50 years
Alt. 1 100-yr WSE
Alt. 2 100-yr WSE
Elevation (ft)
70
65
60
55
50
45
40
35
30
2
1
0.9 ft Increase in WSE
200
400
600
800
1000
1200
1400
1600
Station (ft)


RS 5344.1
Alt. 1 after 50 years
Alt. 2 after 50 years
Alt. 1 100-yr WSE
Alt. 2 100-yr WSE
Elevation (ft)
60
55
50
45
40
35
30
25
20
1.0 ft Increase in WSE
200
400
600
800
1000
1200
1400
Station (ft)


RS 5117.6
Alt. 1 after 50 years
Alt. 2 after 50 years
Alt. 1 100-yr WSE
Alt. 2 100-yr WSE
Elevation (ft)
60
55
50
45
40
35
30
25
20
3
1.1 ft Increase in WSE
200
400
600
800
1000
1200
1400
Station (ft)


RS 4900.6
Alt. 1 after 50 years
Alt. 2 after 50 years
Alt. 1 100-yr WSE
Alt. 2 100-yr WSE
Elevation (ft)
60
55
50
45
40
35
30
25
20
4
5
1.2 ft Increase in WSE
400
500
600
700
800
900
1000
1100
1200
1300
Station (ft)


RS 4653.8
Alt. 1 after 50 years
Alt. 2 after 50 years
Alt. 1 100-yr WSE
Alt. 2 100-yr WSE
Elevation (ft)
Station (ft)
0.3 ft Increase in WSE
6
7
60
55
50
45
40
35
30
25
20
400
500
600
700
800
900
1000
1100
1200
1300
1400


RS 4486.6
Alt. 1 after 50 years
Alt. 2 after 50 years
Alt. 1 100-yr WSE
Alt. 2 100-yr WSE
Elevation (ft)
Station (ft)
0.7 ft Increase in WSE
15
14
13
12
11
10
9
8
60
55
50
45
40
35
30
25
20
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100

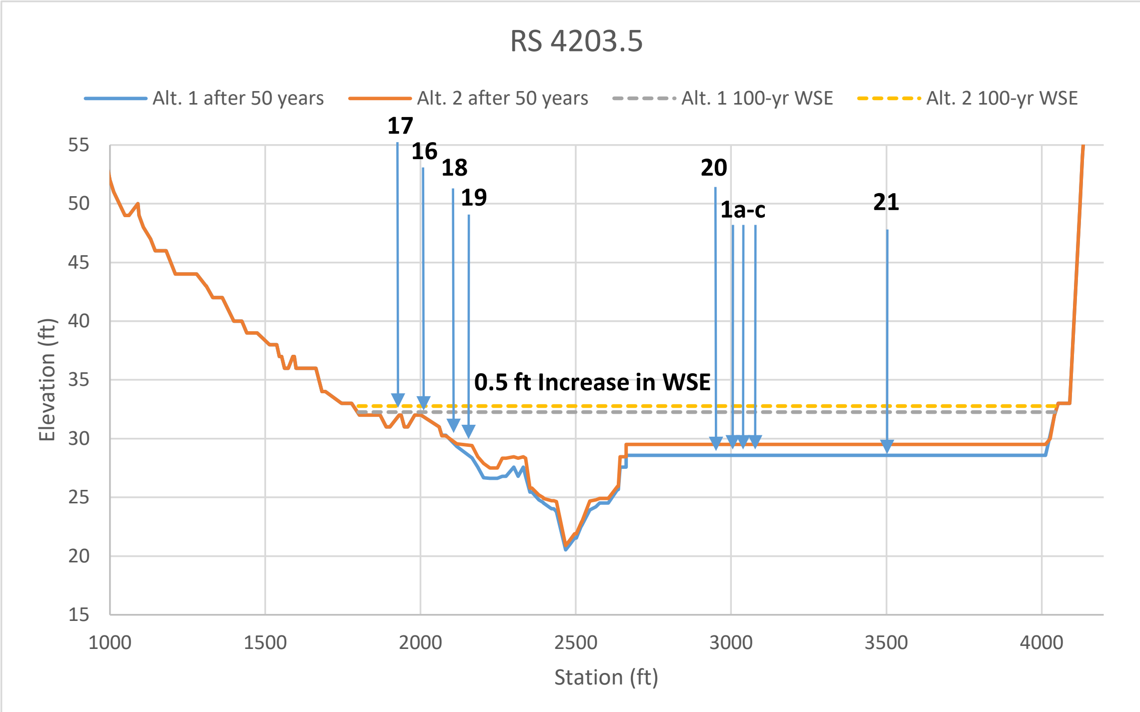


Plate 19-6 Simulated Cross Sections of Alt. 1 and Alt. 2 after 50 years with the Locations of Structures

In addition, the floodplain boundaries after 50 years for the other frequency storm events (2-, 5-, 10-, 25-, 50-, 200-, and 500-yr events) were compared to figure out the flood risk due to the project during these storm events. The comparison did not show any significant increase in floodplain boundary due to the project with the exception of 2-yr event. **Plate 19-7** compares the 2-yr floodplain boundaries of Alt. 1 and Alt. 2 after 50 years. This plate presents the additional flooded area attributed to Alt. 2 (within the dashed red circle), which is approximately 8 acres. Additional sediment and floodplain modeling is required to verify this additional flooding due to the project, however, it is recommended to investigate the measures to abate potential sediment deposition and increased floodplain boundary during the 2-yr event.

19.2 Comparison of the Results after 5 Years.

To evaluate the impact of Alt. 2 on the flood risk during construction period (5 years), streambed and water surface elevations of these two alternatives after 5 years were compared. **Plate 19-8** shows the streambed and 100-yr water surface profiles after 5 years within the reaches downstream of the canyon mouth (i.e., Reaches 1, 2a, 2b, and lower 15,000 ft of Reach 3). In these reaches, the maximum increase in streambed elevation is 4.5 ft, which is greater than that after 50 years (1.0 ft). The maximum increase in 100-yr water surface elevation is 2.4 ft in the same reaches, which is also greater than that after 50 years (1.2 ft). **Plate 19-8** shows expected aggradation of the streambed in the downstream reaches regardless of the alternatives during the initial 5 years. However, the actual amount of sediment deposition may be much less than that predicted in this study, because of the conservative assumption for the downstream boundary condition of using MHHW tide level.

Similar to the 50-year simulations, simulated cross sections after 5 years were compared. **Plate 19-9** shows the simulated cross sections of Alt. 1 and Alt. 2 after 5 years with the 100-year water surface elevations and location markups of the inhabited and uninhabited structures at each cross section. **Plate 19-9** shows that at several cross sections, the increases in 100-yr water depth (due to the sediment deposition) of Alt. 2 after 5 years are significant relative to the 100-year flood depths of Alt. 1.

The sediment transport modeling performed in this study is focused on figuring out the differences in sedimentation along Malibu Creek between the existing and proposed alternatives rather than predicting the actual amount of sedimentation for each alternative. A conservative downstream boundary condition was used in order to capture worst-case scenario conditions to consider when evaluating alternatives. More detailed sediment transport modeling needs to be performed in the next phase of this study. If a similar amount of sediment deposition is predicted in the future sediment transport study, the flood risk during the construction due to sediment deposition should be offset by sediment removal and maintenance plans at key locations along the downstream reaches.

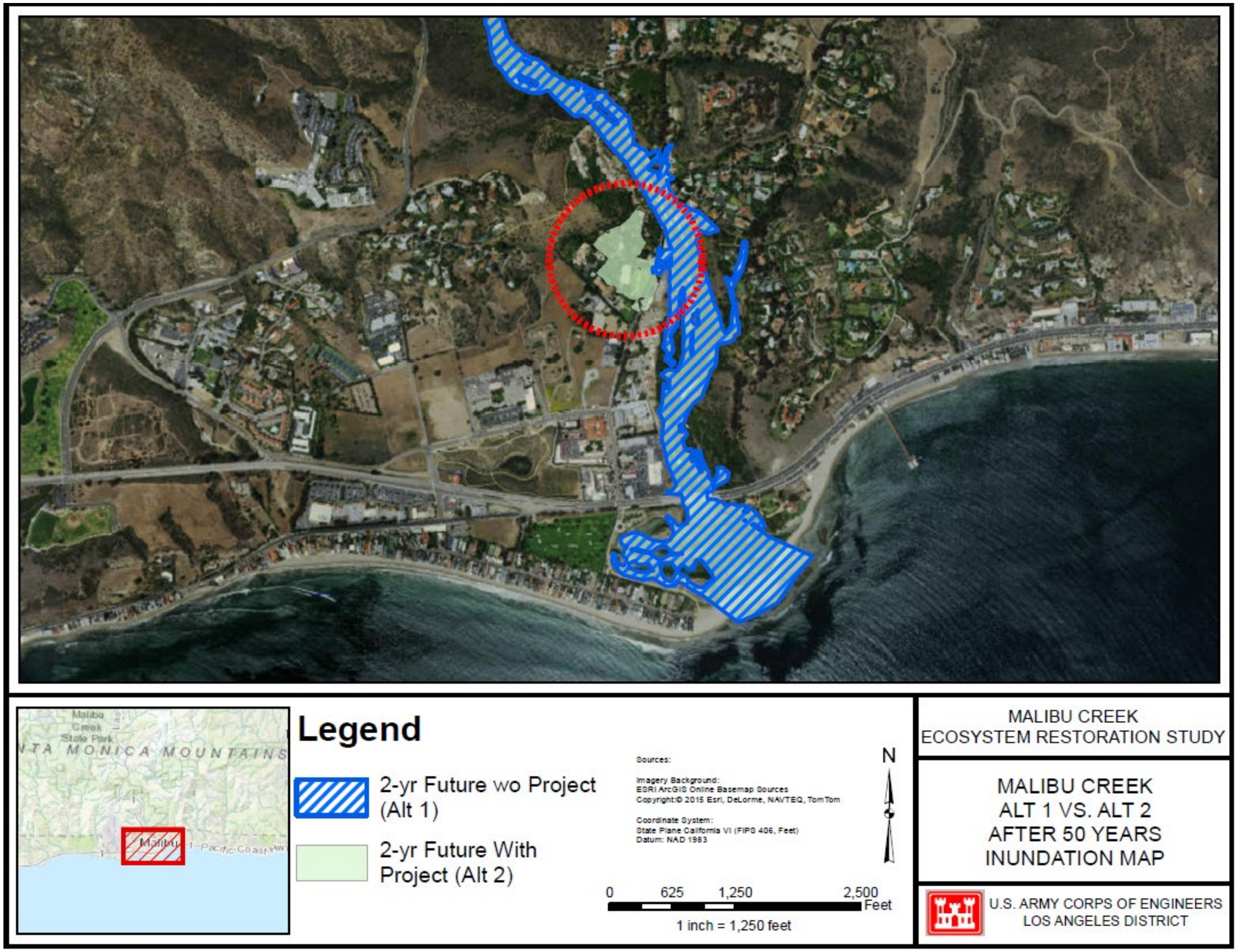
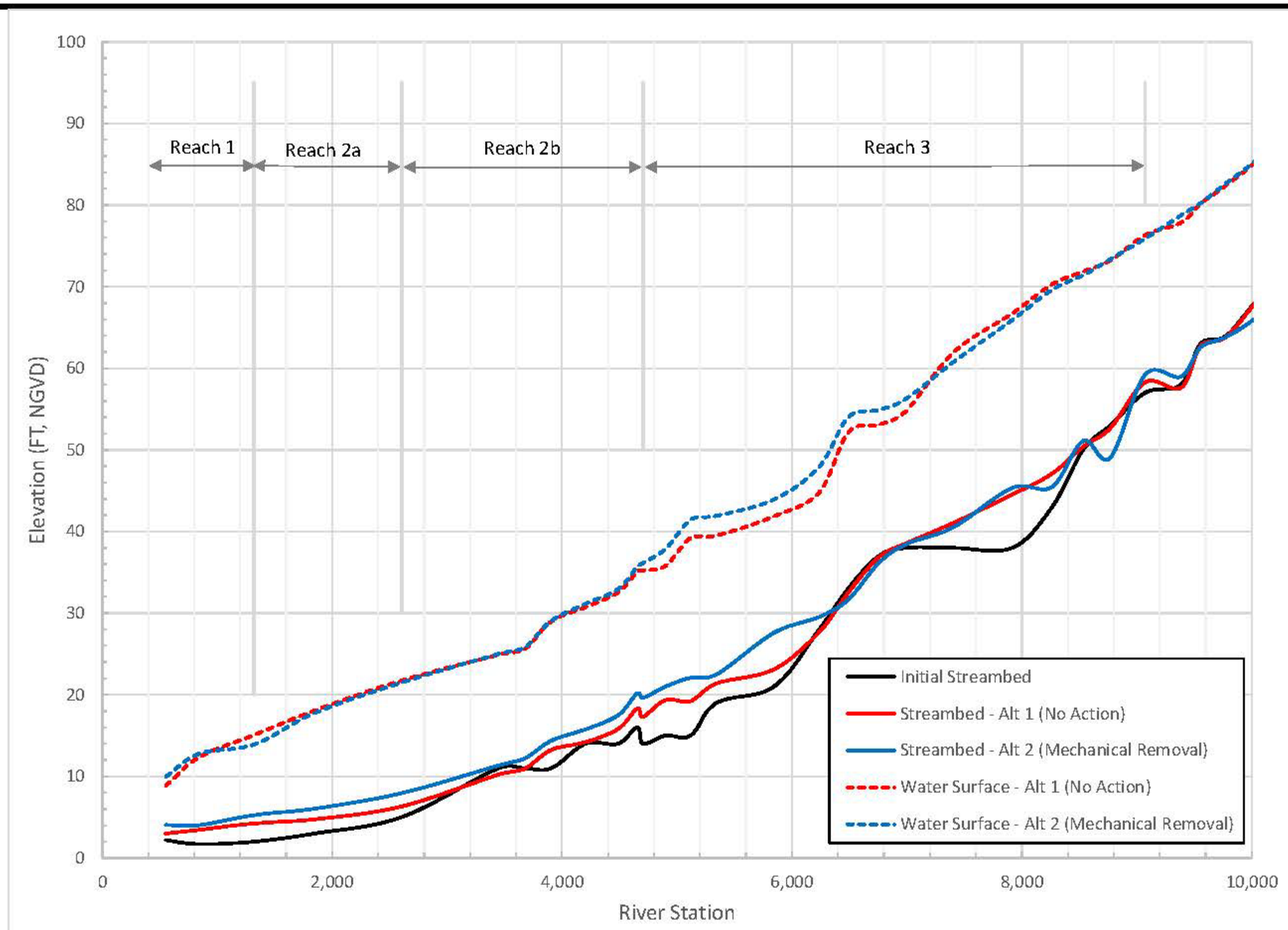


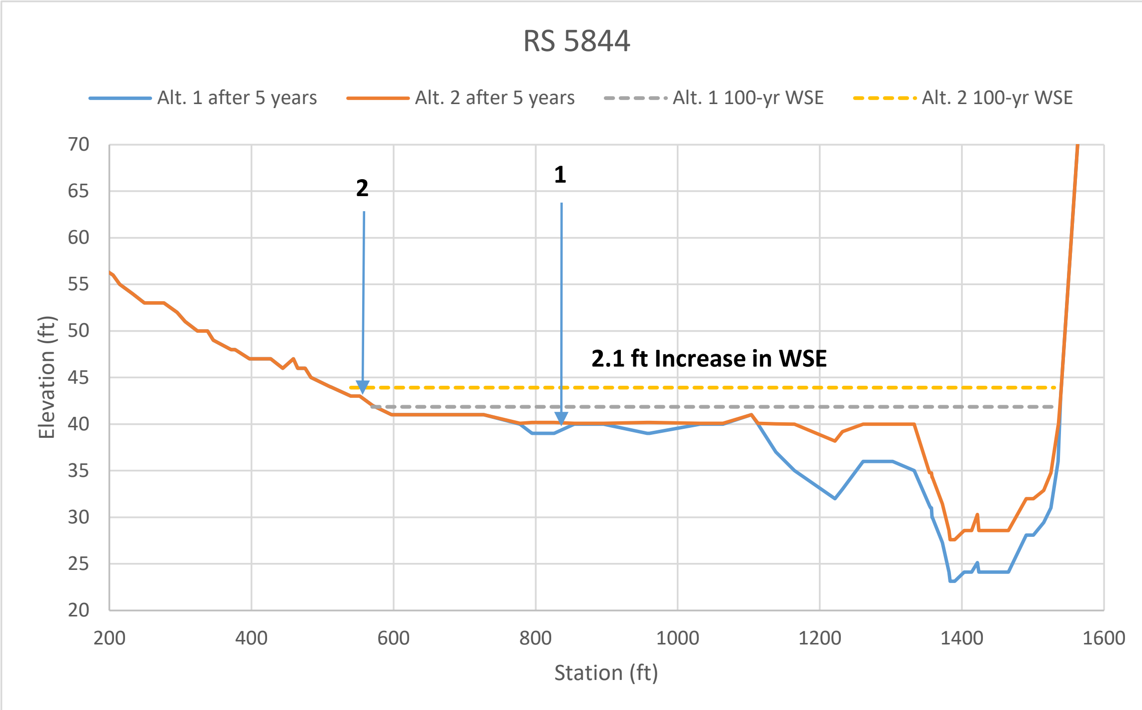
Plate 19-7 Malibu Creek Alt. 1 vs. Alt. 2 after 50 Years Inundation Map (2-year Floodplain)

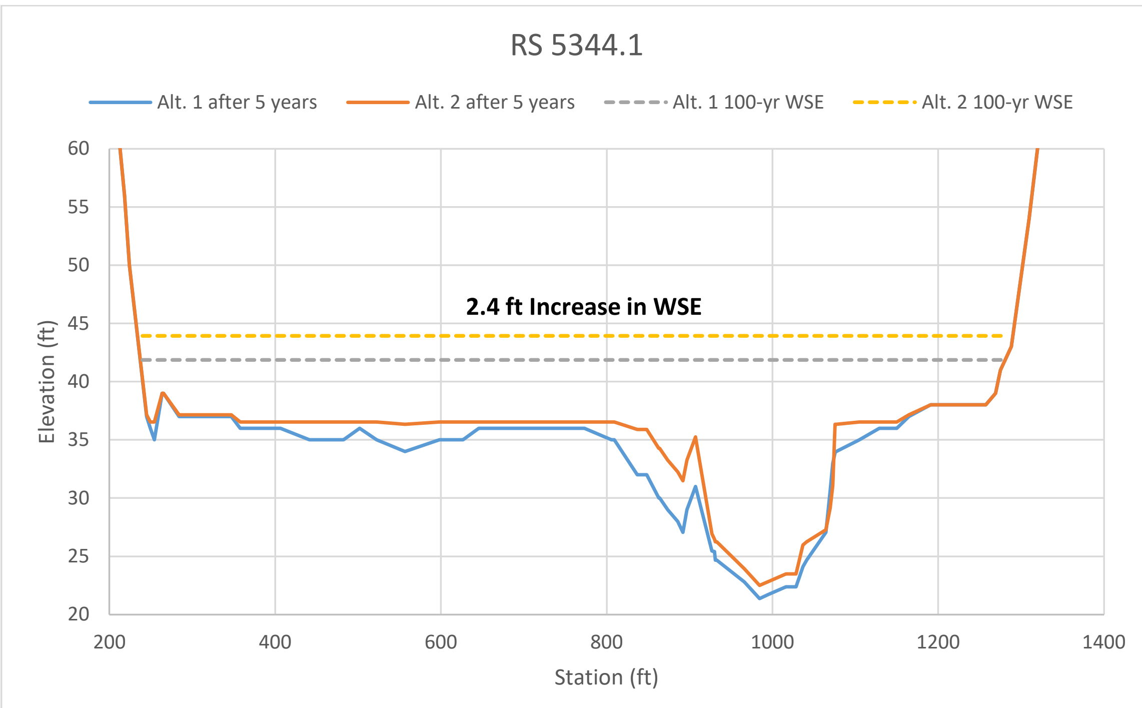


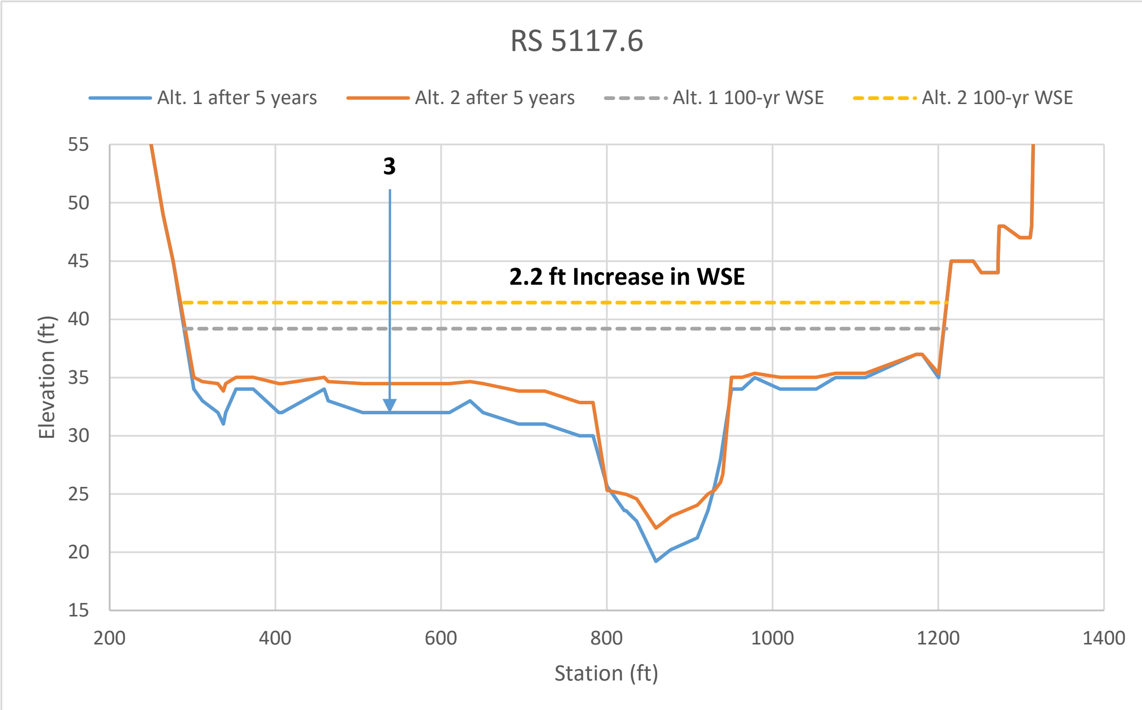
Notes: Not to Scale

Malibu Creek Ecosystem Restoration Study	**Malibu Creek Streambed and 100-yr Water Surface Profiles After 5 Years**		U.S. ARMY CORPS OF ENGINEERS LOS ANGELES DISTRICT

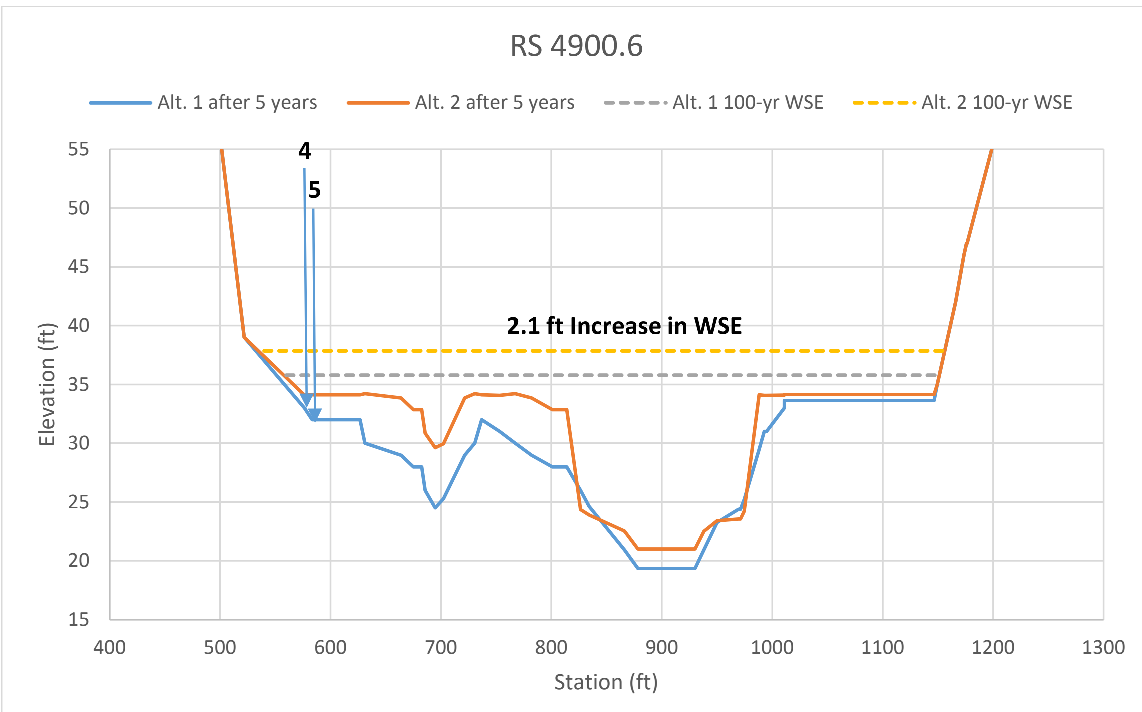
Plate 19-8 Malibu Creek Streambed and 100-yr Water Surface Profiles after 5 Years


RS 5844
Alt. 1 after 5 years
Alt. 2 after 5 years
Alt. 1 100-yr WSE
Alt. 2 100-yr WSE
2
1
2.1 ft Increase in WSE
Elevation (ft)
70
65
60
55
50
45
40
35
30
25
20
200
400
600
800
1000
1200
1400
1600
Station (ft)

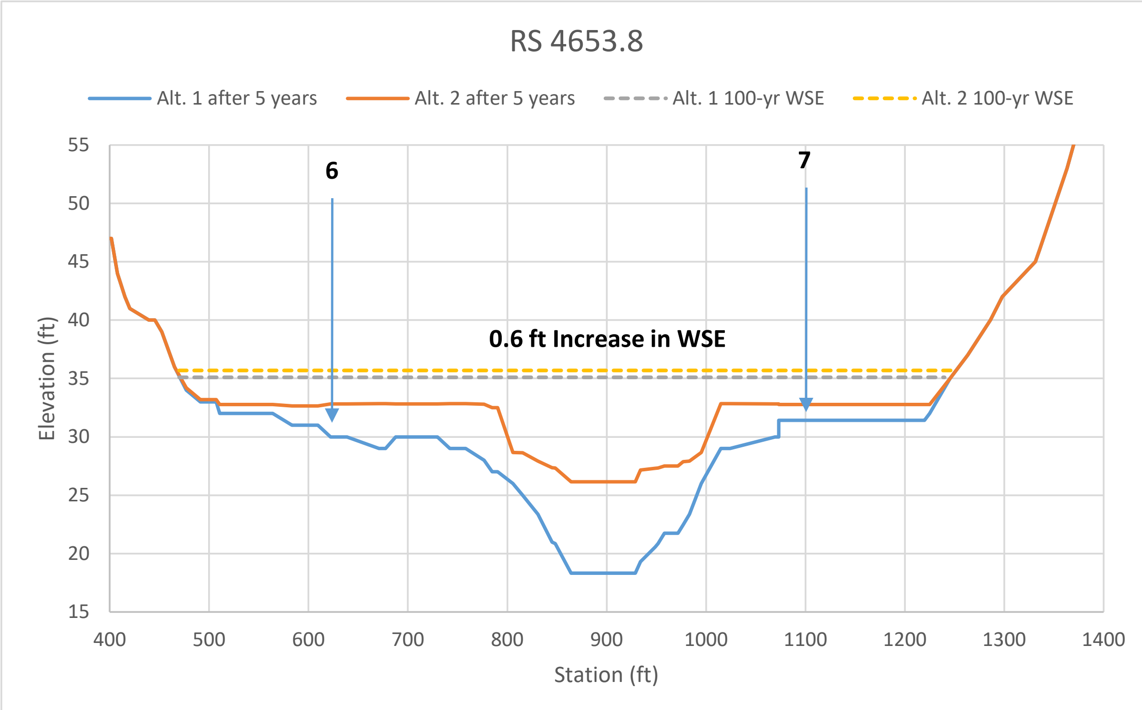

RS 5344.1
Alt. 1 after 5 years
Alt. 2 after 5 years
Alt. 1 100-yr WSE
Alt. 2 100-yr WSE
2.4 ft Increase in WSE
Elevation (ft)
60
55
50
45
40
35
30
25
20
200
400
600
800
1000
1200
1400
Station (ft)

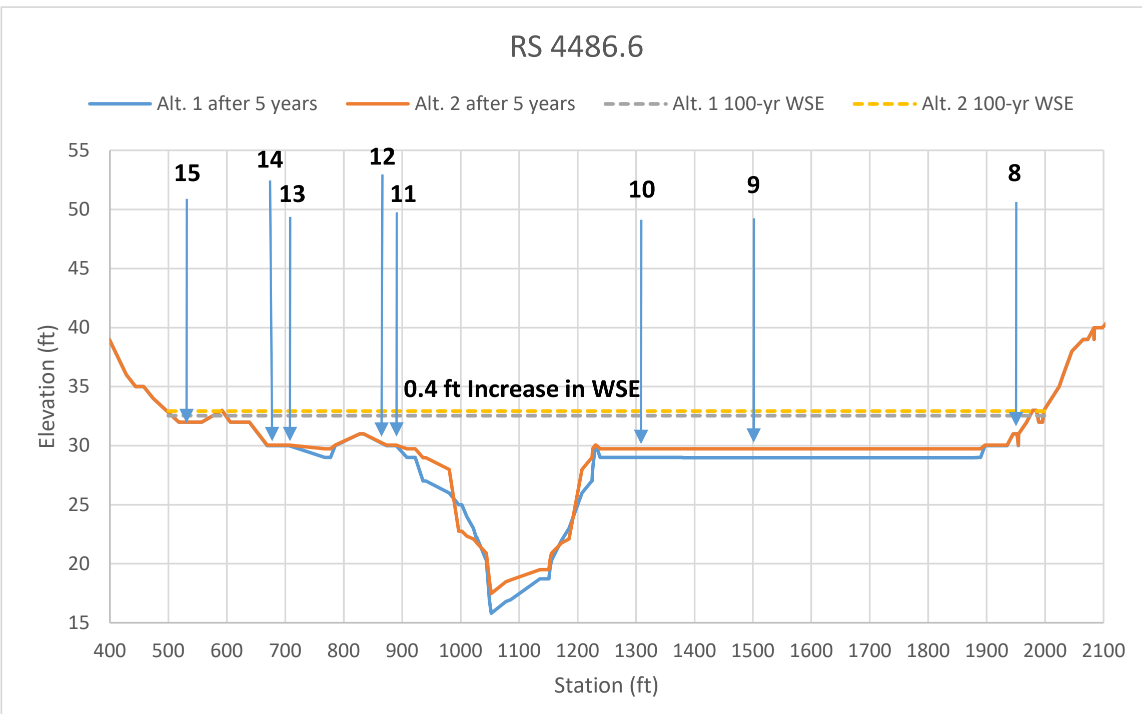


RS 5117.6
Alt. 1 after 5 years
Alt. 2 after 5 years
Alt. 1 100-yr WSE
Alt. 2 100-yr WSE
3
2.2 ft Increase in WSE
Elevation (ft)
Station (ft)
55
50
45
40
35
30
25
20
15
200
400
600
800
1000
1200
1400



RS 4900.6
Alt. 1 after 5 years
Alt. 2 after 5 years
Alt. 1 100-yr WSE
Alt. 2 100-yr WSE
4
5
2.1 ft Increase in WSE
Elevation (ft)
Station (ft)
55
50
45
40
35
30
25
20
15
400
500
600
700
800
900
1000
1100
1200
1300


RS 4653.8
Alt. 1 after 5 years
Alt. 2 after 5 years
Alt. 1 100-yr WSE
Alt. 2 100-yr WSE
Elevation (ft)
Station (ft)
6
7
0.6 ft Increase in WSE


RS 4486.6
Alt. 1 after 5 years
Alt. 2 after 5 years
Alt. 1 100-yr WSE
Alt. 2 100-yr WSE
Elevation (ft)
Station (ft)
15
14
13
12
11
10
9
8
0.4 ft Increase in WSE

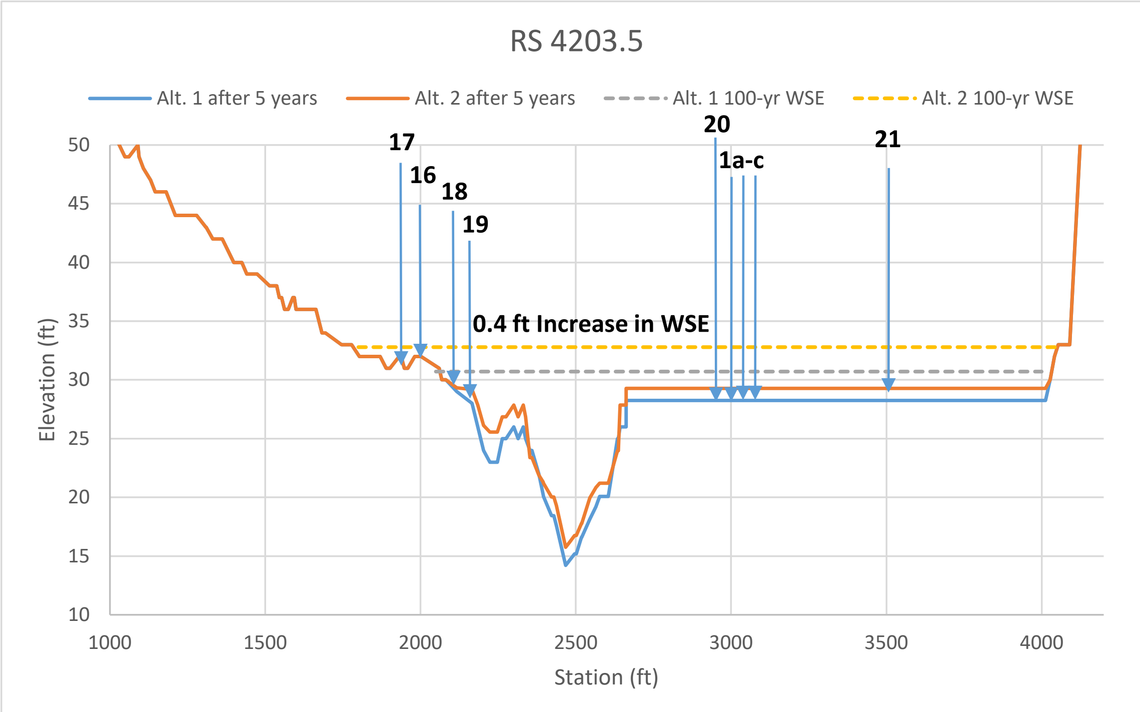


Plate 19-9 Simulated Cross Sections of Alt. 1 and Alt. 2 after 5 years with the Locations of Structures

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