APPENDIX A-1f: Geomorphology

ALISO CREEK MAINSTEM
ECOSYSTEM RESTORATION STUDY
Orange County, California

September 2017

US Army Corps of Engineers

Orange County Public Works
Environmental Resources
Department

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U.S. Army Corps of Engineers
Los Angeles District

Aliso Creek Mainstem Geomorphic Baseline Assessment

County of Orange, California

Final Report

January 2014

Prepared by:

TETRA TECH

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Prepared for:
U.S. Army Corps of Engineers
Los Angeles District
915 Wilshire Boulevard
Los Angeles, California 90017

Prepared by:
Tetra Tech, Inc.
17885 Von Karman Avenue, Suite 500
Irvine, CA 92614
(949) 809-5000

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Executive Summary

This geomorphic assessment of Aliso Creek was conducted to provide a basis for interpreting the hydraulic engineering work associated with the comparison of alternative environmental restoration plans, and specifically to provide a rational basis for prediction of future geomorphic conditions associated with the no-action plan. This assessment builds on numerous earlier hydrologic, hydraulic, geotechnical, and geologic studies and investigations conducted in the Aliso Creek watershed.

The report begins with an evaluation of the potential for flood hydrology to change (Section 2). Due to the near buildout of developable area in the watershed, there is little potential for peak floods and flood volumes to change in response to changes in the land cover in the watershed. Flood flow characteristics derived from available watershed models and from stream gaging data were used as input to hydraulic models and for calculations of sediment transport.

Section 3 includes an evaluation of the geology in the study area. A key finding is that the nature and distribution of bed material in Aliso Creek below the Aliso Creek Wildlife Habitat Enhancement Project (ACWHEP) structure (built in the early 1990s to impound a water supply for irrigating the overbanks to establish a mitigation bank) are a function of historical landslides that led to blockages of the creek and upstream deposition of clay layers. The clay layers are influential in controlling streambank strength and the potential for the channel to widen. Faulting may be responsible for the presence of bedrock, another natural control on channel morphology, at the thalweg elevation near river miles 1.6 and 3.1. Colluvial inputs to the valley bottom, particularly through landslides, have provided an ample supply of gravels and cobbles to the creek, and tributary/gulley confluences continue to be sources of coarse material. These coarse materials are being concentrated into natural grade controls throughout the study area. Section 3 also includes the delineation of geomorphic reaches. These reaches provide a context for classifying existing geomorphic conditions using an incised channel evolution model (ICEM), and for predicting future geomorphic changes.

The calibration of the hydraulic model for Aliso Creek described in Section 4 provides a greater level of confidence in the model results relative to results from earlier models. These results were averaged over the geomorphic reaches to produce inputs for the analyses of bed material mobility.

The sediment supply and bed material transport within the study area are evaluated in Section 5 to characterize the balance between these two processes and their influence on channel morphology. The sediment supply was calculated using multiple approaches, which in general indicate that the range of bed material supplied from the Aliso Creek watershed to Aliso Beach ranges from 1,000 to 200,000 tons per year, with an average annual load of 20,000 to 60,000 tons. This range is somewhat greater than the previously calculated average annual load of 15,300 tons (USACE 2009) due to the more refined methodology applied in this study. The gradations of bed and bank material samples collected since 1980 show that the valley fill into which Aliso Creek has incised contains up to 75 percent silt and clay (i.e., wash load), but that the remaining material includes enough coarse gravel and cobble, that due to sorting and concentration over time, to form relatively immobile natural grade controls. Incipient motion analyses confirmed that existing hydraulic conditions are incapable of mobilizing cobbles, but that gravels may be susceptible to mobilization if tules and cattails in the channel do not persist. The effective discharges calculated in Aliso Creek range from 260 to 1,100 cfs. This range was verified against observed geomorphic features both upstream and downstream of the ACWHEP structure. The reach-averaged bed material transport capacities were compared to effective discharges and selected flood flows, and the annual bed material loads for water years 1992 to 2008 were calculated. The results compared favorably with the annual load calculated from the effective discharge computations and from the upland based methods.

A geomorphic model is presented in Section 6. This model was developed and tested to explain the potential for future changes in channel morphology. The model confirms that future vertical adjustments to the bed profile will be limited because (1) the widened channel and decreased channel slope have decreased unit discharge and bed material transport capacity, and (2) the formation of grade controls such as riffles and plugs (relatively immobile concentrations of coarse sediment in the bed of the channel) that cannot readily be mobilized by flood flows up to the peak of the 500-year event. The non-eroding/ equilibrium bed slopes in the future are therefore likely to be within the range of average bed slopes currently exhibited – approximately 0.30 to 0.45 percent. Where clay exposures are present in the bed, the channel is expected to continue vertically incising into the clay layer. Two locations in particular, one near river mile (RM) 2.75 (downstream of the Wood Canyon Creek confluence) and the other near RM 6.0 (downstream of the where the Joint Regional Water Supply System pipelines cross the creek) were investigated to calculate incision profiles for 25, 35, and 50 years under the no action plan. These calculations show that incision upstream of these sites could be 0.8 to 1.1 feet for a non-eroding slope of 0.45 percent or 3.0 to 4.1 feet for a non-eroding slope of 0.30 percent. The significance of these results is that the ultimate bed profile will closely resemble the existing profile and where localized changes are expected to occur, the magnitude and extent of the incision is expected to be relatively minor compared to degradation that has occurred since 1980. The ICEM indicates that future systematic upper bank erosion is expected where banks are nearly vertical, are composed of alluvium, and contain tension cracks that extend the height of the upper bank thereby exceeding the critical bank height (the maximum geotechnically-stable height of a bank given the bank materials and bank angle) for geotechnical stability. Localized bank erosion is also expected where the active channel is located against the toe of the terrace. The presence of more erosion-resistant clay-rich sediments that form the toes of most of the banks provides stability and limits the potential for systematic widening of the inset floodplain (a hydrologically-connected depositional surface adjacent to the bed of the incised channel). Sand-sized and coarser sediment introduced to the system from on-going bank erosion will deposit on the heavily vegetated inset floodplain, increasing the capacity of the active channel, likely toward the upper range of the calculated effective discharges (i.e., 1,100 cfs). Both localized (colluvial) and more widespread (fluvial) deposition of sediment on the inset floodplain will reduce the effective heights of the banks to the point where they no longer exceed the critical height and this, combined with reduced bank angles, will ultimately lead to bank stabilization. Despite this natural progression towards stable banks, stabilization measures may be required for those locations where infrastructure is at risk from continued bank erosion. As deposition of sediment continues on the inset floodplain, a net reduction in sediment delivery from the watershed is expected. Observations made in October 2009 and February 2010 confirmed the abundance of sand splays (relatively recent, localized deposits of sand on surfaces of bars and floodplains) on the inset floodplain, indicating the aggradation process has already started in most reaches downstream of the ACWHEP structure. As the delivery of bed material decreases, the load of sand supplied to Aliso Beach will decrease, and the beach morphology may return to something similar to the morphology exhibited in the 1920s – further study is needed to confirm future changes to the beach morphology.

Section 7 summarizes the analyses and presents conclusions regarding the existing and future morphology of Aliso Creek.

References are provided in Section 8.

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LIST OF ACRONYMS

ACWHEP	Aliso Creek Wildlife Habitat Enhancement Project
AT	adjustment-transposition
AWMA	Aliso Water Management Agency
CL	low plasticity clay
DYB	Diaz Yourman Boring
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
FISRWG	Federal Interagency Stream Restoration Working Group
H&H	Hydrology and Hydraulics
HEC	Hydrologic Engineering Center
HEC-RAS	Hydrologic Engineering Center Riverine Analysis System
ICEM	Incised Channel Evolution Models
ID	Identification
LAD	Los Angeles District
LB	Left Bank
MUSLE	Modified Universal Soil Loss Equation
NAD	North American Datum
NAVD	North American Vertical Datum
NGVD	National Geodetic Vertical Datum
NRCS	Natural Resources Conservation Service
OCHM	Orange County Hydrology Method
PCH	Pacific Coast Highway
PSIAC	Pacific Southwest Interagency Committee
RB	Right Bank
RM	River Mile
RTK GPS	Real time kinematic global positing system
SC	Clayey sand
SOCWA	South Orange County Wastewater Authority
SR	State Route
TOB	Top of Bank
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WMS	Watershed Management Study
WMP	Watershed Management Plan

1.0 INTRODUCTION

This report presents the results of a geomorphic assessment of Aliso Creek in support of the ongoing Aliso Creek Mainstem Ecosystem Restoration Study. The feasibility-level Restoration Study considers alternative restoration plans to reestablish natural ecological functions to Aliso Creek, its floodplains, and the watershed. The Restoration Study is cost-shared between the U.S. Army Corps of Engineers, Los Angeles District (USACE) and the local sponsor Orange County Public Works.

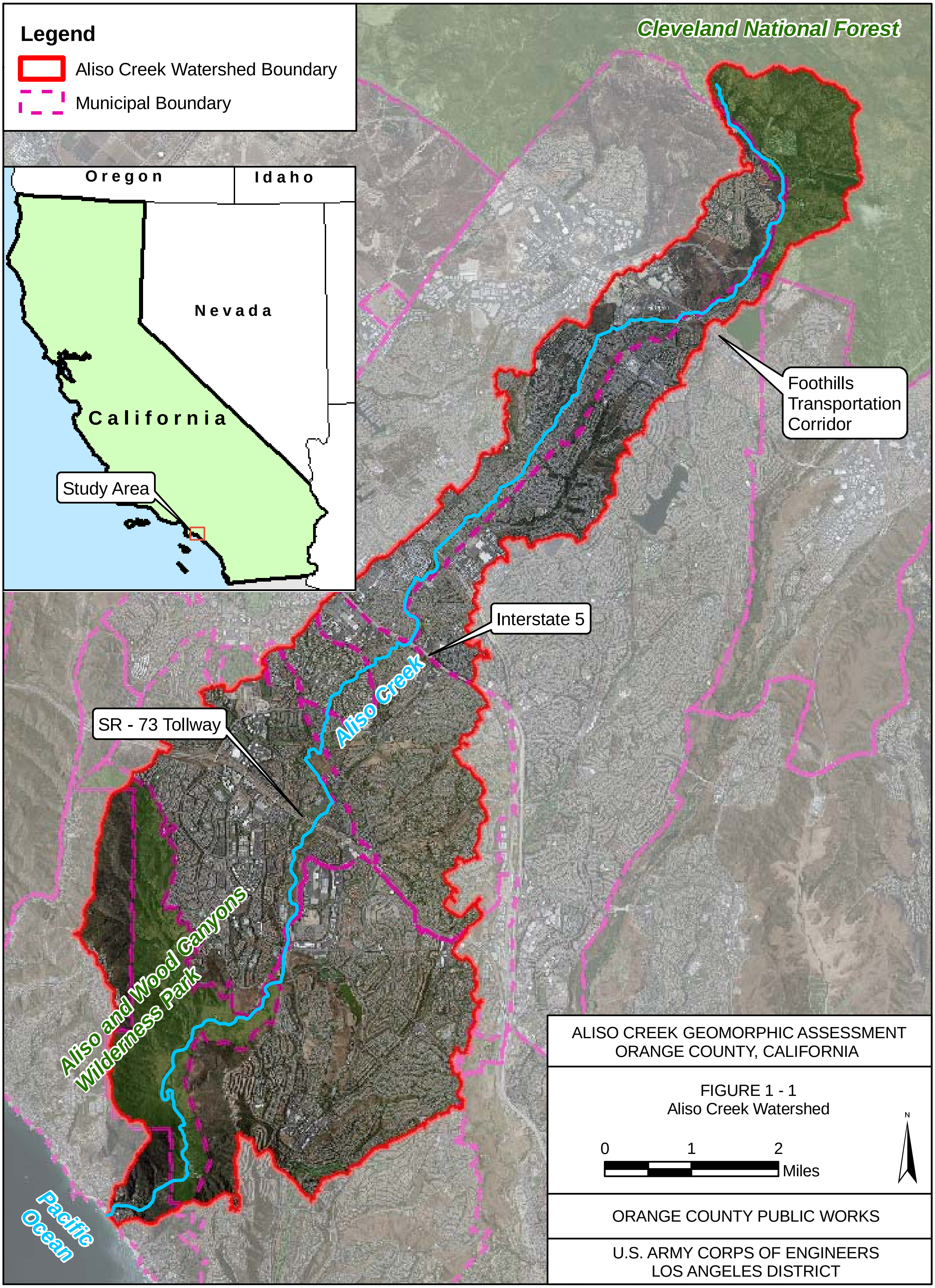
1.1 STUDY AREA

The Aliso Creek watershed is located in southern California, approximately 40 miles southeast of the City of Los Angeles. As shown in Figure 1-1, the creek drains a long, narrow coastal watershed, with its headwaters in the Cleveland National Forest and its mouth at the Pacific Ocean. The drainage area is 34.6 square miles, and the mainstem of the creek is approximately 19.5 miles long.

Except for a small portion of the Cleveland National Forest in the upper watershed, and the Aliso and Wood Canyons Wilderness Park in the lower watershed, the Aliso Creek watershed is nearly fully developed. Portions of the following cities are located in the watershed: Lake Forest, Aliso Viejo, Mission Viejo, Laguna Niguel, Laguna Hills, and Laguna Beach. The drainage systems associated with this development are typically improved, and in places, the creek channel has been realigned and or modified.

The mainstem of Aliso Creek originates in the Santiago Hills and flows south for a distance of 1.5 miles within the Cleveland National Forest. It flows from the National Forest under the Foothills Transportation Corridor and through highly developed areas in Mission Viejo and Lake Forest. Further southwest, the creek flows through a fully urbanized area along the I-5 corridor and the City of Laguna Hills. Upstream of Pacific Park Drive, Aliso Creek enters a floodwater retarding basin; downstream of Pacific Park Drive the creek flows through an engineered channel toward the confluence of Sulphur Creek and the upstream end of the Aliso and Wood Canyons Wilderness Park. Sulphur Creek conveys runoff from an 8.9-square-mile watershed, nearly half of which first flows into Sulphur Creek Reservoir (also called Laguna Niguel Lake) before draining into Aliso Creek. Downstream of the Sulphur Creek confluence (approximately 14.5 miles downstream from the origin and 5 miles upstream from the mouth), the Park opens into a coastal canyon that is nearly undeveloped. Aliso Creek continues approximately 1.5 miles to the diversion structure for the Aliso Creek Wildlife Habitat Enhancement Project (ACWHEP). This diversion structure was built to impound water so that it could be diverted onto the floodplains as irrigation water. While the structure is still in place, no managed diversions are ongoing. Roughly 0.3 miles downstream of ACWHEP is the confluence of Wood Canyon Creek, a right bank tributary draining nearly 4 square miles largely within the park. The combined flows continue to the south through the narrow canyon. Approximately 1 mile upstream from the Pacific Ocean, Aliso Creek flows out of the Wilderness Park and enters the private Aliso Creek Golf Course located in the confined valley. Just upstream of the ocean, the creek passes through a narrow strip of development along the Pacific Coast Highway in the City of Laguna Beach.

The study area (Figure 1-2) focuses on the lower reach of Aliso Creek from the SOCWA bridge to Pacific Park Drive, a distance of approximately 5.2 miles; however, consideration of the impacts included in this report extends downstream to the Pacific Ocean.

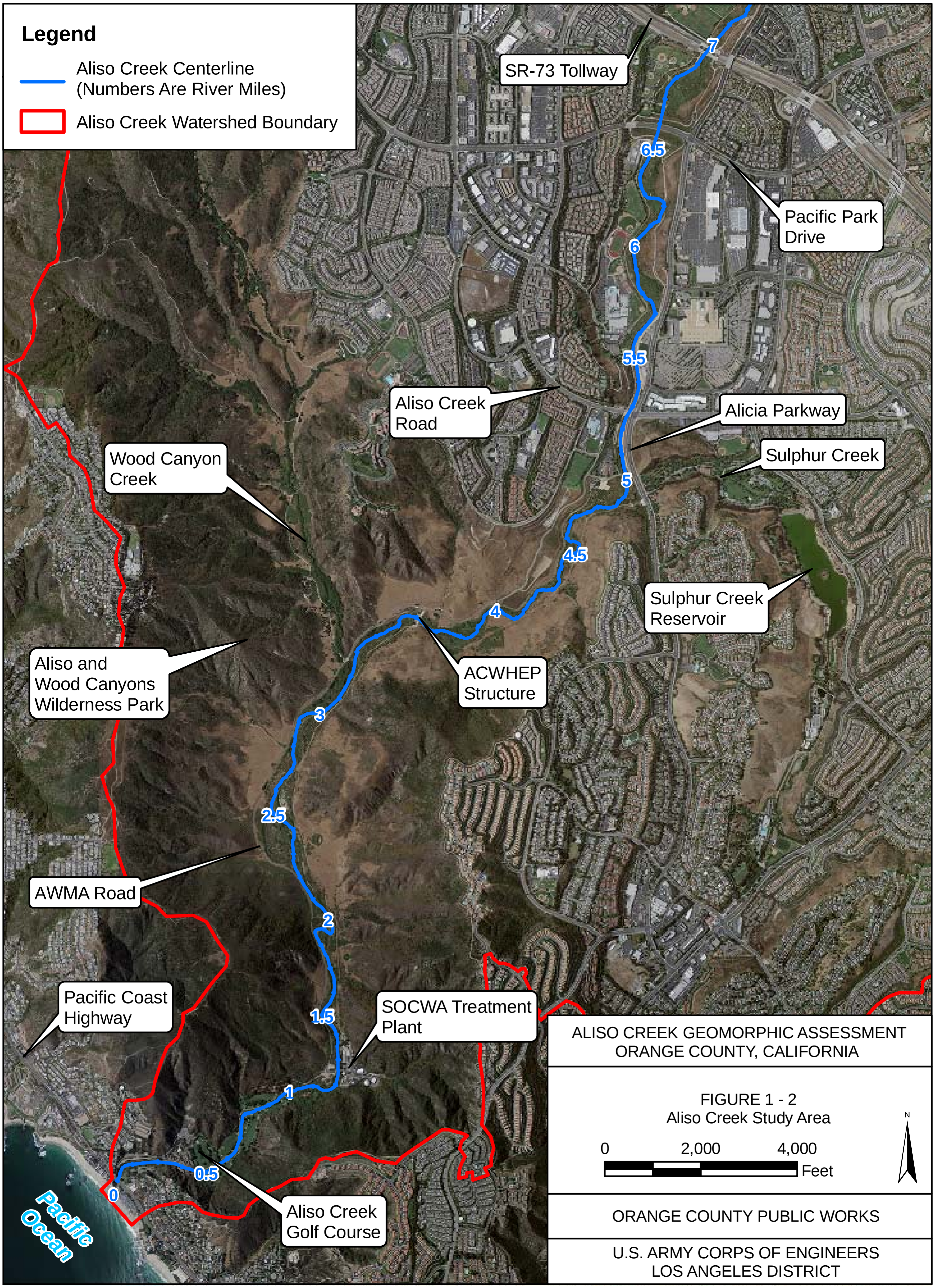


ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 1 - 1
Aliso Creek Watershed

ORANGE COUNTY PUBLIC WORKS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 1 - 2
Aliso Creek Study Area

ORANGE COUNTY PUBLIC WORKS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

1.2 PROJECT BACKGROUND

In October 2002, the USACE completed the Aliso Creek Watershed Management Study (WMS). As a product of the WMS, an array of alternative restoration plans was proposed as a component of the Watershed Management Plan (WMP). Each component has been identified as an effective means for addressing particular watershed problems. The Aliso Creek Mainstem Ecosystem Restoration Study was one of the components of the WMP recommended for further analysis through a "spin-off" feasibility study.

The feasibility phase of the Aliso Creek Mainstem Ecosystem Restoration Study includes documentation of the without-project baseline conditions for the watershed, descriptions of the selected with-project alternatives, and the supporting with-project analyses to characterize their performance. A revised Hydrology and Hydraulics (H&H) Appendix to the Aliso Creek Mainstem Ecosystem Restoration Study was prepared in Fall 2009 to update without-project baseline conditions analyses since the completion of the WMS. Analyses carried out in support of the revised H&H Appendix were based on recent (i.e., 2006 through 2008) topographic mapping that reflected changes in channel morphology produced by the large winter floods in 2004/2005. Continuing feasibility study efforts (not part of this current document) will include detailed analyses of with-project conditions associated with selected restoration alternatives.

The without-project baseline conditions documented in the revised H&H Appendix (USACE 2009) suggest the possibility of further degradation to the bed and banks of Aliso Creek, particularly in the reaches below the ACWHEP diversion structure. As noted in the H&H Appendix, factors such as bedrock outcrops and channel widening may limit future degradation of the bed, and these factors were recommended for further analysis under the No Action Plan Alternative.

The with-project restoration alternatives listed below are preliminary and may change as the feasibility study progresses. These alternatives represent formulated plans that will be further designed to a sufficient level of detail so that a selected plan can be recommended. This Geomorphic Baseline Assessment will provide a foundation on which to base future with- and without-project conditions.

- <u>No Action Plan Alternative.</u> The hydraulic and sedimentation impacts shall be determined for future conditions without implementation of any ecosystem projects (without-project baseline conditions). This alternative is the basis for alternative comparison and selection.

- <u>Raised Channel Stabilization Alternative.</u> This alternative will stabilize the grade through a series of grade control structures that raise the channel invert elevation to maximize the reconnection of the channel and the historical floodplain. Channel sinuosity (a dimensionless ratio of channel length to the length of the valley bottom containing the channel) will be incorporated in this alternative as appropriate.

- <u>Channel Stabilization at Existing Grade Alternative.</u> This alternative will stabilize the channel near the existing grade. An appropriate number of grade control structures (determined in part based on limiting the height of each structure) will be incorporated to limit the future height of the structures. This alternative will not include connection to the historical floodplain, but will allow for the establishment of a new floodplain at a lowered elevation. Channel sinuosity will be incorporated in this alternative as appropriate.

- <u>Modified Channel Stabilization Alternative.</u> A modified channel stabilization plan will be a hybrid of Alternatives 2 and 3 that will minimize the infilling inherent to Alternative 2 while allowing connection to high quality adjacent habitat. This alternative will incorporate the results of the hydraulic, sediment transport, biological, and geomorphic assessments as required to take advantage of areas that may be approaching an equilibrium condition. Channel sinuosity will be incorporated in this alternative as appropriate. The number of grade control structures will determined in part based on limiting the height of each structure.

- Detention Basin Alternative. This alternative will include a detention basin (or a series of basins) at one of the following locations: Pacific Park, the Sulphur Creek confluence, within the Chet Holyfield parcel, or at the ACWHEP structure. The basin (or series of basins) shall be multi-purpose to include flow detention, retention, and habitat creation. Neither online nor offline detention basins were recommended for further analysis during the Watershed Management Study, but because of the potential for additional environmental benefits, they will be considered. Grade control structures will also be considered under this alternative.

1.3 OBJECTIVES

The purpose of conducting this geomorphic assessment of Aliso Creek is to support the Aliso Creek Mainstem Ecosystem Restoration Study. The objectives of the geomorphic assessment are:

- to calibrate the existing uncalibrated hydraulic model,
- to provide a rational basis for prediction of future conditions under the No Action Plan , and
- to provide a basis for interpreting the hydraulic engineering work associated with the comparison of the five alternative restoration plans summarized in the previous section.

An important aspect of this assessment is the determination of an equilibrium/non-eroding bed slope within the studied reaches of Aliso Creek. These slopes are characteristic of a stable/graded channel, one with a balance between sediment transport capacity and the amount of sediment supplied to it (Schumm 1977). The ultimate bed profile of Aliso Creek, a key component of the future No Action Plan, is partly dependent upon the determination of this slope.

2.0 HYDROLOGY

The H&H Appendix to the Aliso Creek WMS (USACE 2000) and the revised H&H Appendix (USACE 2009) summarize available stream gaging data as well as results of HEC-1 models calibrated to watershed conditions. The gaging data were used primarily to describe the historical flood record whereas the model output was used to calculate peak flows and runoff volumes associated with N-year floods. Integrating both sources of data provides a means for understanding patterns and changes in watershed hydrology.

2.1 DEVELOPMENT OF THE ALISO CREEK WATERSHED

It is helpful to consider changes in the land cover (i.e., development) in the watershed since 1930 before evaluating the historical flood record or considering predictions of future flooding. The general trends of development were compiled in the H&H Appendix (USACE 2000) based on reviews of historical aerial photography and from data presented in the Aliso Creek/San Juan Creek Watershed Management Study Reconnaissance Report (USACE 1997). Table 2-1 presents these development trends.

Table 2-1. Historical Development in the Aliso Creek Watershed

Year	Percent of Watershed Developed[1]	Data Source
1938	1	1938 aerial photograph, 1” = 660’, Orange Co. Archive
1959	4	1959 aerial photograph, 1” = 500’, Orange Co. Archive
1968	8	1997 USACE Reconnaissance Study
1972	15	1997 USACE Reconnaissance Study
1981	33	1997 USACE Reconnaissance Study
1986	47	1997 USACE Reconnaissance Study
1990	59	1997 USACE Reconnaissance Study
1998	74	1998 digital aerial photograph
2005	75	2005 digital aerial photograph

[1] *considers the entire Aliso Creek watershed, not only the portion draining to the Jeronimo Road gage*

As shown in Table 2-1, most development in the watershed has occurred since 1970, although a considerable area of the watershed was used for agriculture prior to the onset of major residential and commercial development. The 1938 aerial photographs show several thousand acres of agricultural land, primarily orchards, within the watershed area upstream of the current I-5 crossing. The portion of the watershed downstream of I-5 contained far less agricultural land and remained undeveloped through the 1950s. In the 30 years between 1968 and 1998, development in the entire Aliso Creek watershed increased from 8 to 74 percent. Between 1998 and 2005 development leveled off, and future development will be limited by existing development and the boundaries of the Cleveland National Forest in the headwaters and the Aliso and Wood Canyons Wilderness Park in the lower watershed.

2.2 HISTORICAL FLOOD RECORD

Four streamflow gaging stations have been operated at various times since 1930 in the Aliso Creek watershed. The U.S. Geological Survey (USGS) has operated two gages; Orange County Watersheds Program operates the other two gages (formerly operated by Orange County Environmental Management Agency). Table 2-2 provides general descriptions of each gage.

Table 2-2. Descriptions of Aliso Creek Stream Gages

Gage ID	Gage Name	Drainage Area (square miles)	Period of Record
USGS 11047500	Aliso Creek at El Toro	7.9	1930 – 1980
USGS 11047700	Aliso Creek at South Laguna	34.4	1982 – 1987
OC #4	Aliso Creek at Jeronimo Road	8.1	1980 – present
OC#1146	Lower Aliso Creek at Treatment Plant	30.4	2002 - present

The stream gage at Jeronimo Road is located approximately 300 feet upstream of Jeronimo Road; the USGS gage at El Toro was located adjacent to Second Street, approximately 800 feet upstream of Jeronimo Road. Due to the similar location of these two gages, their records are considered as a single continuous record. The relatively short period of record of the USGS gage at South Laguna limits its usefulness for considering the long-term flood record in the creek. The Orange County gage at the South Orange County Wastewater Authority (SOCWA – a joint powers authority with ten member agencies that manage wastewater in South Orange County) treatment plant also has a relatively short period of record, and due to rehabilitation of the bridge abutments at the gaging station between October 2008 and July 2009, the applicability of the rating curve to subsequent flows is under review. Therefore, the analysis of the historical flood record was based on the flows as measured upstream of Jeronimo Road. It is noted that this record reflects runoff only from the upper one-quarter of the Aliso Creek watershed, and that the gage is located in a concrete lined section of the creek that under some flow conditions can become supercritical (although Orange County describes the rating curve as “good”). The annual peak flow and the annual total runoff volume for each water year since 1932 are provided in Table 2-3. Major flood events, defined for comparison purposes as floods having peak flows of at least 1,500 cfs, are identified in Table 2-3 in **bold text**.

Table 2-3. Aliso Creek Annual Peak Flow and Annual Runoff Volume (Jeronimo Road Gage)

Water Year	Peak Flow (cfs)	Annual Runoff Volume (ac-ft)	Water Year	Peak Flow (cfs)	Annual Runoff Volume (ac-ft)	Water Year	Peak Flow (cfs)	Annual Runoff Volume (ac-ft)
1932	508	558	1958	964	1,380	1984	519	1,310
1933	352	165	1959	2	2	1985	442	1,530
1934	494	155	1960	32	13	1986	508	1,950
1935	1,240	633	1961	0	0	1987	190	372
1936	1,420	353	1962	73	177	1988	321	1,910
1937	**1,950**	**618**	1963	88	62	1989	315	2,780
1938	1,280	1,610	1964	67	24	1990	260	1.060
1939	231	386	1965	81	391	1991	610	1,290
1940	547	301	1966	277	404	**1992**	**3,000**	**2,290**
1941	632	2,550	1967	333	571	**1993**	**2,090**	**7,150**
1942	20	28	1968	35	174	1994	459	1,360
1943	943	1,910	**1969**	**2,500**	**4,320**	**1995**	**2,120**	**5,340**
1944	879	613	1970	95	49	1996	387	1,750
1945	678	365	1971	35	47	1997	1,070	1,760
1946	182	111	1972	81	212	**1998**	**4,500**	**6,920**
1947	90	156	1973	636	508	1999	254	1,490
1948	102	130	1974	223	373	2000	772	2,570
1949	2	1	1975	300	325	2001	572	3,130
1950	85	11	1976	58	54	2002	254	1,160
1951	0	0	1977	57	200	**2003**	**1,690**	**3,280**
1952	950	1,520	1978	324	1,270	2004	330	1,620^{P}
1953	133	45	1979	245	1,870	**2005**	**2,470**	**8,020**
1954	122	79	**1980**	**2,100**	**6,420**	2006	934	1,600
1955	15	6	1981	225	973	2007	402	1,150
1956	505	425	1982	161	1,040	**2008**	**1,580**	**2,180**
1957	2	1	**1983**	**1,670**	**2,980**	2009	909	1,628^{P}

^{P} *denotes partial annual volume*

***Bold text** indicates flood events with peak flows of at least 1,500 cfs*

2.3 MODELED N-YEAR FLOODS

The H&H Appendix (USACE 2000) documents in detail the development and calibration of the HEC-1 rainfall-runoff models for the Aliso Creek watershed. These models were developed to calculate peak rates of runoff and storm event volumes for various recurrence interval storm events (referred to as N-Year floods). A few key notes from the 2000 Appendix regarding the development and calibration of the models follow:

- The HEC-1 models were developed following the Orange County Hydrology Method (OCHM), which is a regionally calibrated rainfall-runoff model developed by the County in cooperation with the USACE Los Angeles District for prediction of flood peaks and runoff volumes on ungaged watersheds.

- The HEC-1 input parameters specified in the OCHM provide a regional best fit to discharge frequency curves from a number of stream gage records in Orange County and Los Angeles County.

- The Orange County Public Facilities and Resources Department (now known as Orange County Public Works) considers the method to represent the best information for regional rainfall-runoff calibration on small ungaged watersheds in the Orange County area of southern California.

- Due to the limited available stream gage data in the study area portion (e.g., downstream portion) of the Aliso Creek watershed, the stream gage data is suitable for comparison to model results, but not as the primary standard for model calibration.

The results of the HEC-1 models provided peak discharges and runoff volumes for existing conditions (representative of 2005/2006) at several concentration points. Due to the limited future development potential, as evidenced in Figure 1-1, particularly in the study area portion of the watershed, the existing conditions results are appropriate for representation of future conditions; however, this may need to be revisited as climate change projections related to precipitation are more fully developed (Section 2.5). The modeled peak discharge results for N-year storm events under existing conditions were plotted against the adjusted streamflow record (e.g., adjusted to account for different levels of imperviousness over time) from the Aliso Creek gage and against peak discharge estimates from the 1993 FEMA Flood Insurance Study (FIS), and a smooth curve with negative skew (i.e., -0.2) similar to regional skew was drawn through the results. This curve resulted in adopted peak flow values greater than the modeled values for the 2-year and 5-year events, but similar adopted and modeled values for the 10-year through 500-year floods. This procedure for calculating peak flows was used to satisfy both Orange County and the USACE, and the results compared favorably with the FEMA FIS (1993) and local agencies. Peak discharges at locations of interest for this geomorphic assessment in addition to the concentration points determined for the revised 2009 H&H Appendix (2009) are provided in Table 2-4. This table also includes peak discharges for the 1.1-year flood, calculated by extrapolation of the flood frequency curves plotted for the locations of interest.

Table 2-4. Adopted Peak Discharges for N-Year Storms, Existing Conditions

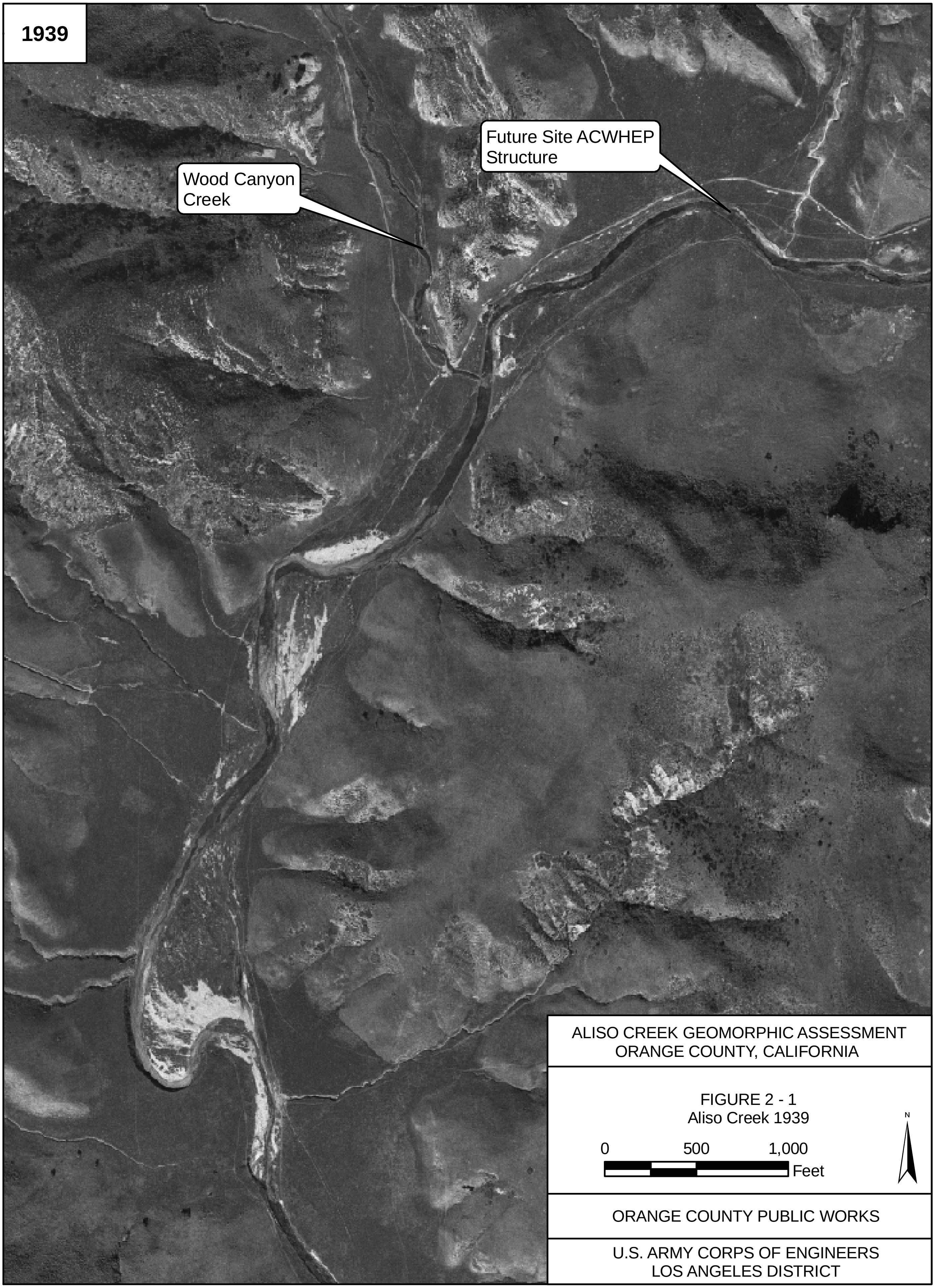
Location	HEC-1 Conc. Point	Drainage Area (sq. mi.)	1.1-YR (cfs)	2-YR (cfs)	5-YR (cfs)	10-YR (cfs)	25-YR (cfs)	50-YR (cfs)	100-YR (cfs)	200-YR (cfs)	500-YR (cfs)
Jeronimo Gage	1	8.6	210	670	1,300	1,760	2,400	2,820	3,320	3,900	4,600
Moulton Parkway	2	10.9	700	1,020	1,700	2,210	2,650	3,040	3,460	3,780	4,270
Confluence with trib. from WS G	n/a	14.9	1,000	1,410	2,120	2,600	3,300	3,920	4,660	5,180	5,900
Pacific Park Ret. Basin Inflow	n/a	17.0	1,190	1,640	2,550	3,110	3,990	4,640	5,450	6,330	7,430
Pacific Park Ret. Basin Outflow	n/a	17.0	1,180	1,560	2,360	2,830	3,460	3,950	4,450	4,900	5,330
U/S Sulphur Ck. Confluence	3	17.9	1,210	1,590	2,400	2,900	3,570	4,060	4,560	4,980	5,480
D/S Sulphur Ck. Confluence	4	28.1	1,210	1,590	2,830	3,810	5,120	6,100	7,240	8,480	10,100
D/S Wood Canyon Ck. Confluence	5	31.9	1,300	1,620	3,040	4,170	5,300	6,890	8,120	9,540	11,400
U/S of Abandoned Oxbow	6A	32.5	1,300	1,620	3,100	4,250	5,900	7,100	8,300	9,470	11,400
U/S of S-Bend	6B	33.4	1,310	1,640	3,150	4,400	6,000	7,200	8,400	9,610	11,500
U/S of SOCWA Treatment Plant	6C	33.8	1,320	1,650	3,200	4,450	6,050	7,300	8,550	9,620	11,500
U/S end of Golf Course	6D	34.3	1,330	1,670	3,260	4,550	6,120	7,360	8,610	9,720	11,500
Pacific Coast Highway	6	34.6	1,320	1,620	3,110	4,270	5,930	7,130	8,480	9,710	11,500
Wood Canyon Outlet	n/a	3.9	120	410	810	1,130	1,550	1,870	2,230	2,580	3,110

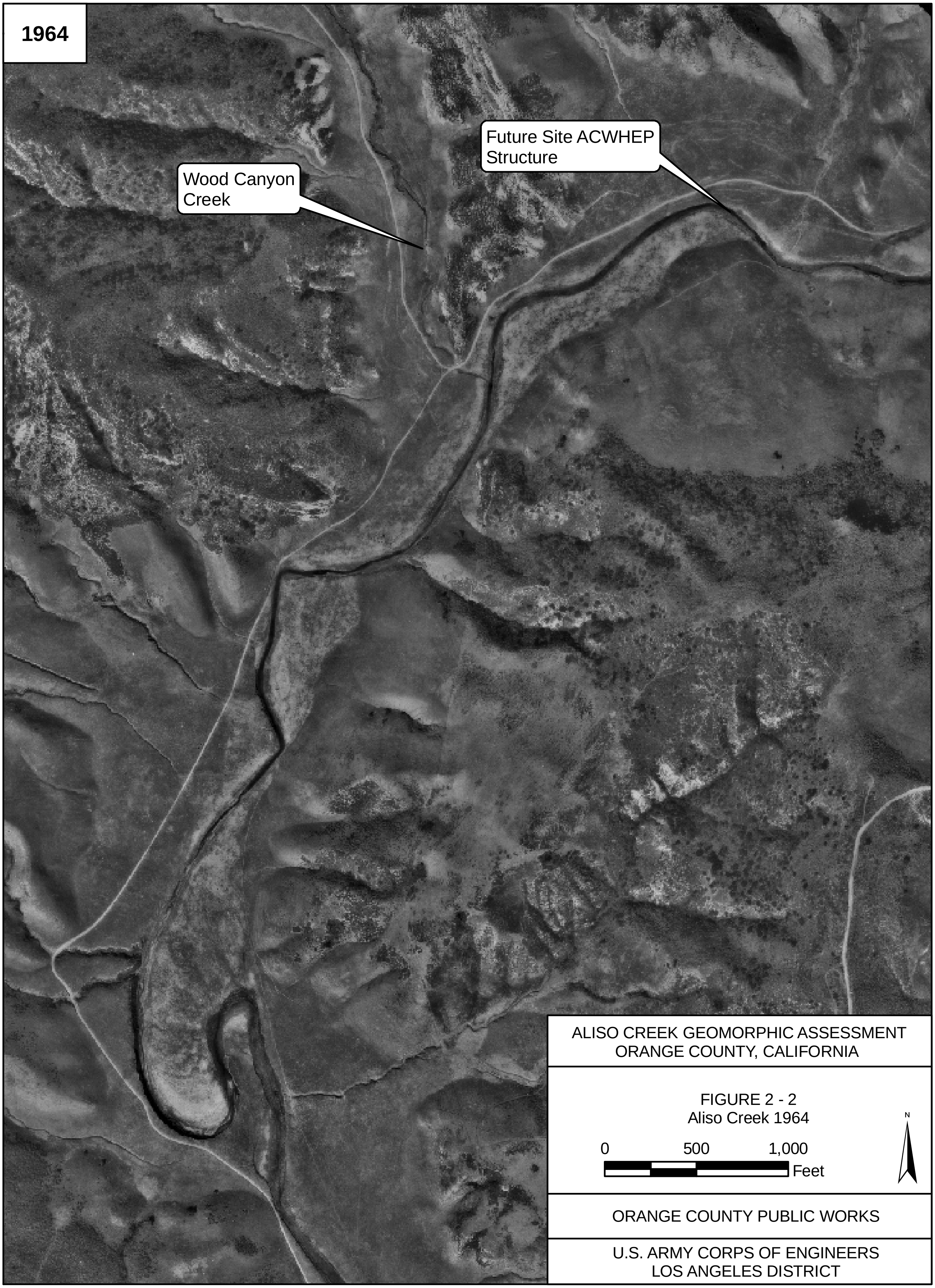
2.4 ANNUAL HYDROLOGIC REGIME

Referring back to Table 2-3, the annual runoff volume exhibits trends consistent with the development of the watershed. Prior to 1978, the annual runoff volume exceeded 650 acre-feet only in six of the 46 years of record (13 percent). Since 1978, the annual runoff volume has exceeded 650 acre-feet in every year, or 30 of the 30 years (100 percent). Further, nine major floods have occurred in the 30 years since 1978 whereas only two occurred in the 46 years between 1932 and 1978. The magnitude of the peak flows has also increased since 1978. Prior to 1978, the magnitude of the annual peak flow exceeded 1,500 cfs only two times (maximum flow of 2,550 cfs in 1941); since 1978, nine years have had peak flows in excess of 1,500 cfs (maximum flow of 4,500 cfs in 1998).

The noted increase in total annual runoff volume, even in years without a major flood, indicates that the baseflow in Aliso Creek during the dry season has increased. The wet season, in which the low flows generally consist of interflow and baseflow drainage following Pacific frontal storm events, extends from September/October to March/April. In the dry season, which extends from March/April to September/October, the low flows are most likely generated by irrigation of residential and commercial landscaping associated with development of the watershed. The H&H Appendix (USACE 2000) documents in further detail the apparent confirmation of the increase in low flows due to development, and verifies that the increases do not appear to be the result of long-term meteorological effects because precipitation records show fairly constant rainfall over the period of record.

Historical documentation (EDAW 2002) indicates that throughout the 1800s, local channels throughout the region were perennial for most of the year. At some point the hydrologic regime was transformed from perennial to ephemeral. The more recent increase in the dry season baseflow of Aliso Creek restores a perennial flow regime that provides a year-around water source for vegetation growing in the riparian areas along the channel. This water source has allowed willows, sycamore, and cottonwood trees to thrive in an environment where they would otherwise not flourish. The influence of the baseflow on the abundance and density of riparian vegetation is apparent when comparing aerial photographs from the late 1930s, mid 1960s, and 2009. Examples from the reach containing the ACWHEP structure are shown in Figures 2-1 through 2-3. Note the absence of established riparian vegetation other than brush until the 2009 photograph.


1939
Future Site ACWHEP
Structure
Wood Canyon
Creek
ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA
FIGURE 2 - 1
Aliso Creek 1939
0
500
1,000
Feet
N
ORANGE COUNTY PUBLIC WORKS
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT


1964
Future Site ACWHEP
Structure
Wood Canyon
Creek
ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA
FIGURE 2 - 2
Aliso Creek 1964
0
500
1,000
Feet
N
ORANGE COUNTY PUBLIC WORKS
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 2 - 3
Aliso Creek 2009

0 500 1,000
Feet

N

ORANGE COUNTY PUBLIC WORKS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

2.5 IMPACTS OF CLIMATE CHANGE

A part of the Integrated Resources Water Management Plan for South Orange County, a climate change analysis was performed. This analysis is documented in *Climate Change and Vulnerability in the South Orange County IRWMP Planning Region* (Tetra Tech 2013). The report shows a small decrease in projected precipitation by the late-21st century. However, the models show a consistent and substantial increase in mean annual temperature, from greater than 2 ^{o}F to greater than 5^{o}F over the mid- to late-21st century. In general, the climate models project more adverse conditions (i.e., warmer and drier) in the latter part of the 21st century.

Besides the changes in average conditions, climate change is considered likely to increase variability, with more extreme heat events, longer droughts, and more intense flooding through atmospheric rivers that transport moisture from the tropics to the Pacific coast. Although these changes are anticipated on a broad scale, they are typically not quantified at the spatial scale of the South Orange County planning region in which the Aliso Creek watershed is located.

3.0 GEOLOGY AND GEOMORPHOLOGY

Since the period of European settlement, the Aliso Creek watershed has undergone extensive human-induced changes. European settlement and associated livestock grazing in the Coastal California watersheds caused significant degradation of the native grasses in the early 1800s and by the mid-late 1800s there were widespread barren lands that increased on-slope erosion and watershed sediment yield (Pulling 1944). Somerfield and Lee (2003) documented significant increases in watershed sediment yields with offshore sedimentation rates being much higher than those during pre-colonial times. Peak rates of sedimentation in estuaries along the California coast occurred in the mid-late 19th century in conjunction with the peak degradation of the rangelands in the coastal watersheds (Warrick 2004). The net effect of these early changes along Aliso Creek was most probably depositional. Post-settlement alluvium deposits of between 3 and 4 feet in thickness can be observed above paleosols (well-developed buried soil) exposed in the current banks of the creek (refer to Figure 3-36). Land-based (Weston 1937) and aerial (1939, 1947) photography indicated that there was sparse riparian vegetation along Aliso Creek, probably the result of livestock grazing. The paucity of riparian vegetation may have lowered the stability threshold for Aliso Creek during subsequent man-made disturbances and made the creek more susceptible to erosion (Haible 1980; Harvey and Schumm 1987).

Commencing in the 1960’s, the Aliso Creek watershed was urbanized, and by 1998 about 74 percent of the watershed was developed; it is noteworthy that most of the remaining undeveloped land in the watershed is dedicated to park land and will not be developed. The fact that a change from natural or agricultural land use to urban land use has dramatic effects on water and sediment yields from a drainage basin has been widely documented since the 1960s (Wohl 2001). Numerous studies throughout the United States (Wolman 1967; Miller et al. 1971; Graf 1975; Morisawa and LaFlure 1979; Harvey et al. 1983; Miller 1987; Von Guerard 1989a, b; Urbonas and Benik 1995; MEI 2008; Stogner 2000; Harvey and Morris 2004) have documented the adverse effects of urbanization on channel stability and flood regimes. In common with channels in other urbanized watersheds, Aliso Creek incised in response to the changes in the water-sediment balance. Unlike most incised channels where degradation starts in the lower reaches and migrates upstream through time (Schumm et al. 1984), comparative thalweg profiles of Aliso Creek (USACE 2009) indicate that, in general, degradation originated in the upstream sections of the channel and progressed downstream through time, which is a characteristic of channels where there has been a major change (as described in Section 2.4) in basin hydrology (Harvey et al. 1987). The available thalweg data indicate that degradation in the reaches upstream of the existing ACWHEP structure commenced in the early 1970’s and continued into 2006 in the reaches immediately downstream of the ACWHEP structure. As the channel was degrading upstream of the existing ACWHEP structure in the 1970’s, the increased sediment loading from channel erosion was causing aggradation downstream of the ACWHEP structure until about 1980. Construction of the ACWHEP diversion structure in the early 1990’s had a significant impact on channel stability downstream, resulting in about 20-30 feet of degradation. Some degradation in the lower reaches of Aliso Creek may have been caused by channelization between 1947 and 1964 in the vicinity of the Aliso Creek Inn, where a bend was cut off which reduced the local channel length by about 63 percent. Degradation of the upper reaches of Aliso Creek was arrested by the placement of grade-control structures at the ACWHEP irrigation diversion, the AWMA road crossing and at six other locations farther upstream. However, with the exception of the grade-control sill at the SOCWA Bridge, there are no man-made grade controls in the reach below the ACWHEP structure, and hence the current and future degradational/aggradational status of the channel in this reach is of paramount interest to this project. In the context of aquatic habitat in Aliso Creek and wildlife habitat on the floodplain and terraces and along the riparian corridor, it is necessary to identify whether the system has attained a new state of equilibrium and stability or whether it will continue to degrade. Watershed sediment delivery to the coast is also dependent on the equilibrium state of the channel.

Numerous studies of incised channels formed in alluvial materials and located in humid and semi-arid regions of the U.S. have shown that following incision, the channel passes through a consistent, predictable sequence of channel forms through time (Ireland et al. 1939; Schumm et al. 1984; Harvey and Watson 1986; Simon and Hupp 1986; Simon 1986; Gellis et al., 1991; Harvey et al. 2007) until a new state of dynamic equilibrium between watershed hydrology and sediment supply and channel morphology is attained. These systematic temporal and spatial adjustments have been collectively referred to as channel evolution. A number of geomorphic models (i.e., Incised Channel Evolution Models – ICEM) that are based on the concept of location for time substitution (Paine 1985; Schumm 1991) have been developed to provide a logical basis for interpreting past and present channel form and process, as well as prediction of future channel form and process (Schumm et al. 1984; Simon and Hupp 1986).

A five-class ICEM was developed by Schumm et al. (1984) and modified to a six-class ICEM that included a channelized class by Harvey and Watson (1986) to explain the evolution of incised channels from a state of disequilibrium characterized by system-wide vertical and lateral instability to a new state of dynamic equilibrium characterized by system-wide vertical and lateral stability. The new channel is bounded by a functional floodplain that is inset below the former floodplain that has become a hydrologically-disconnected terrace. Figure 3-1 illustrates the spatial relation of these morphological features that are represented in the ICEM.

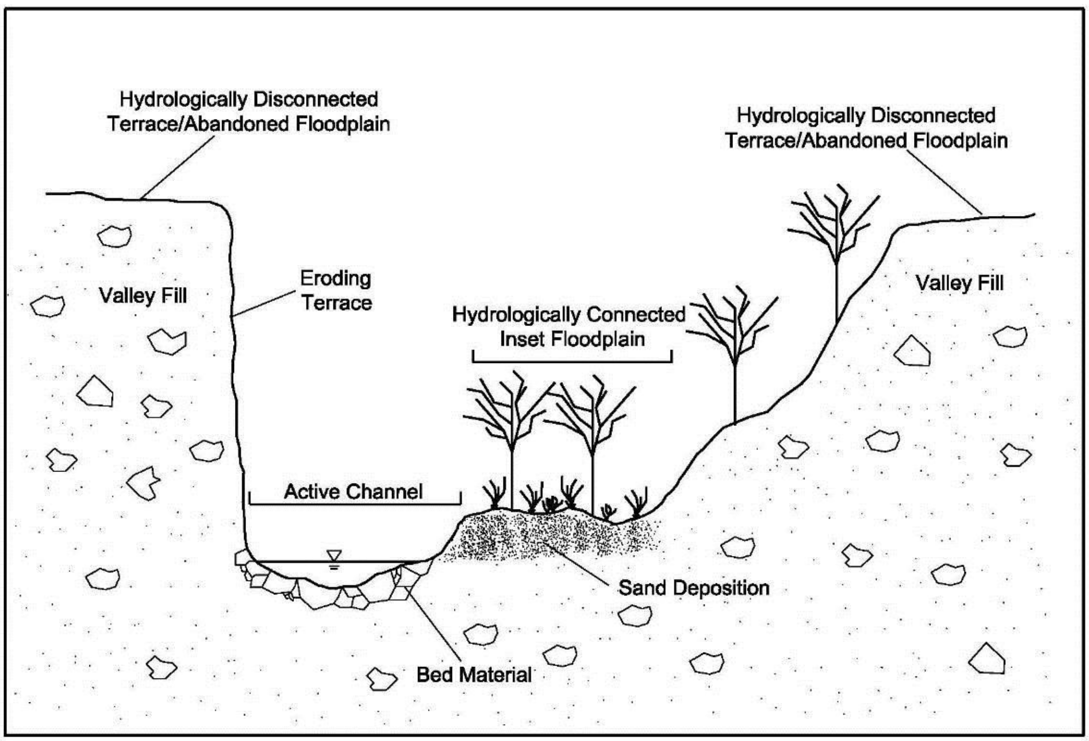


Figure 3-1. Schematic of an incised alluvial channel

The six-class model describes the systematic evolution of a channelized stream from a state of human-induced disequilibrium (Class II) to a new state of dynamic equilibrium (Class VI) (Figure 3-2). The six classes represent a continuum of morphological changes with gradational boundaries between the

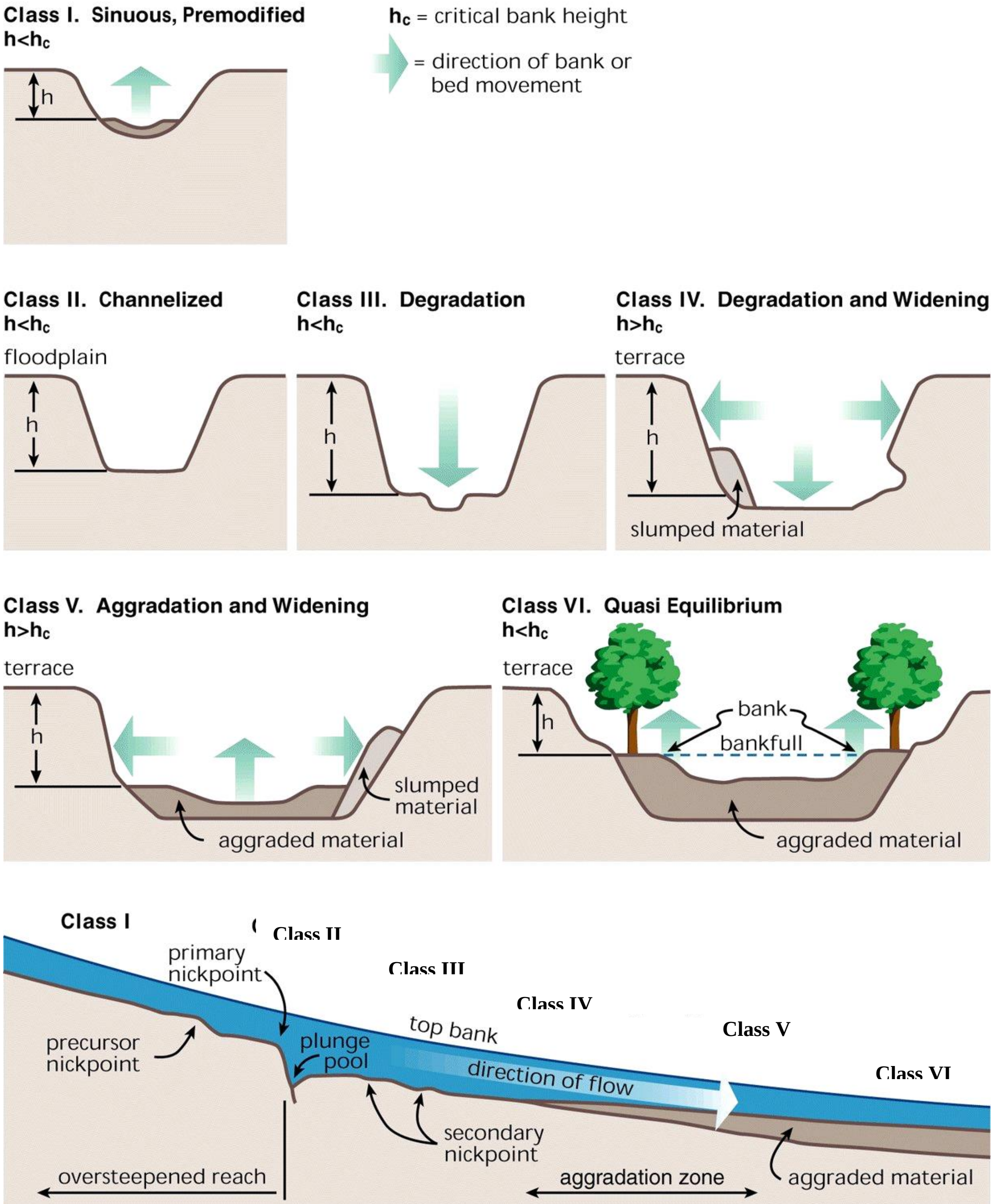


Figure 3-2. Incised Channel Evolution Model (ICEM) (after Schumm et al. 1984)

individual classes. The model identifies, quantifies, and integrates four important components of channel evolution: bank stability, the dominant/effective discharge (see Section 5.3), the hydraulic energy and sediment transport capacity of the dominant/effective discharge, and the morphological adjustments of the channel through time and space (Harvey and Watson 1986; Watson et al. 1988). Following human-induced disequilibrium (Class II), the channel incises (Classes III and IV), widens as a result of failure of the excessive bank heights (Classes IV and V), and ultimately aggrades (Class VI), at which point an equilibrium channel reflecting a dynamic balance between sediment supply and transport capacity has formed within the over-widened channel incised in the valley floor. Mass bank failure occurs when the bank height exceeds the critical bank (the maximum geotechnically-stable height of a bank given the bank materials and bank angle) height (Little et al. 1981; Watson et al. 1988). When the banks are steep, slab or wedge failures predominate (Class IV) and as the bank angle is subsequently reduced, deeper seated slump failures predominate (Class V) (Lohnes and Handy 1968; Harvey and Watson 1986; Thorne 1988; Thorne 1999; Simon and Darby 1999). System-wide, as opposed to local, channel widening as a consequence of bank failure will continue as long as the failed bank materials are removed by flows. Conversely, retention of the failed bank materials will promote bank stability and prevent further channel widening (Carson and Kirkby 1972; Thorne 1982, 1991).

During the course of the evolution of an incised channel, sediment yields from the watershed are dominated by evacuation of material stored within the valley floor. Repeat cross section surveys of an incised channel, Oaklimiter Creek, in Northern Mississippi (Schumm et al. 1984) and a computer simulation of the geomorphic evolution of that channel (Watson et al. 1986), indicated that total sediment loss due to channel erosion (bed and banks) from the 42 square mile watershed was on the order of 6.5M tons over a 15-year period. Initial rates of erosion were on the order of 0.1M tons/year (3.7 tons/ac/yr), but the maximum rate occurred when the channel was most actively widening and approached 0.5M tons/year (19 tons/ac/yr). Eventually, channel erosion rates diminished to about 0.05M tons/year (1.9 tons/ac/yr) as the channel approached a new state of equilibrium. Simon (1989) showed similar trends with erosion rates eventually returning to less than 2 tons/ac/yr. Other studies of incised channels (Simon et al. 1996; Simon and Darby 1999; Harvey et al. 2007) have shown that sediment derived from actively eroding incised channels can represent up to 80 percent of the total sediment yield from the landscape.

The channel evolution sequence can take 40 to 50 years in channelized streams of the humid southeastern U. S. (Schumm et al. 1984; Schumm 1999; Simon 1989), about 75 years in the drier climate of the north Texas Hills (Harvey et al. 2007) and over 100 years in the arroyos in the semi-arid southwest U.S. (Gellis et al. 1991). The semi-arid, Mediterranean-type climate of the Aliso Creek watershed, with its high annual and inter-year flow variability, places the expected timeframe of the channel evolution sequence somewhere between these bounds, likely closer to the 100-year duration of southwest streams. However, the timeframe for channel adjustment in Aliso Creek may have been shortened by two factors working in combination. In contrast to most alluvial rivers in more humid environments, the dynamics of the southern California coastal streams appear to be dominated by extreme hydrologic events that may in fact be the dominant flows (Downs 2007). Review of the time-sequential thalweg profiles of Aliso Creek (USACE 2009) indicates that the major incision downstream of the ACWHEP structure occurred in response to the flood events of the 1990s that included the flood of record in 1998, and there has been very little adjustment since that time in spite of the occurrence of a number of sizable floods in 2003, 2005, 2008 and 2010. Additionally, the increased baseflow as a result of the urbanization of the watershed support extensive riparian vegetation that have become established along the inset floodplain (i.e. a hydrologically-connected depositional surface adjacent to the bed of the incised channel), thereby providing “effective cohesion” to the bed and bank materials (Gellis et al. 1991). An approximately 25-year recurrence interval peak flow in 2010 was unable to dislodge this vegetation, and field observations clearly indicate that the vegetation is inducing overbank sedimentation on the developing inset floodplain that is essential to establishment of a new dynamic equilibrium state. The already established vegetation is likely to persist even under drought or reduced base flow conditions because of the proximity of the current channel bed to shallow groundwater.

The evaluation of the current and historical geomorphic characteristics of Aliso Creek provides a means for identifying where different reaches are in the sequence of channel evolution, and allow for predictions of future geomorphic adjustments and their impacts on the ecological functions of Aliso Creek. An ICEM is well-suited for the geomorphic assessment of existing conditions and expected future conditions within Aliso Creek. For example, categorizing a reach as Class III indicates existing vertical instability with expected bank erosion and channel widening in the future; whereas categorizing a reach as Class V indicates that major adjustments have already occurred and the channel is naturally stabilizing. These categorizations become particularly useful when considering management options. Action such as installation of grade control structures taken in a Class III channel could arrest incision, preventing major changes to channel geometry, instream habitat, and riparian vegetation and reducing sediment loading from the channel boundary. Grade controls and bank stabilization measures implemented in a Class V reach may be less beneficial as the channel is naturally approaching a new state of dynamic equilibrium.

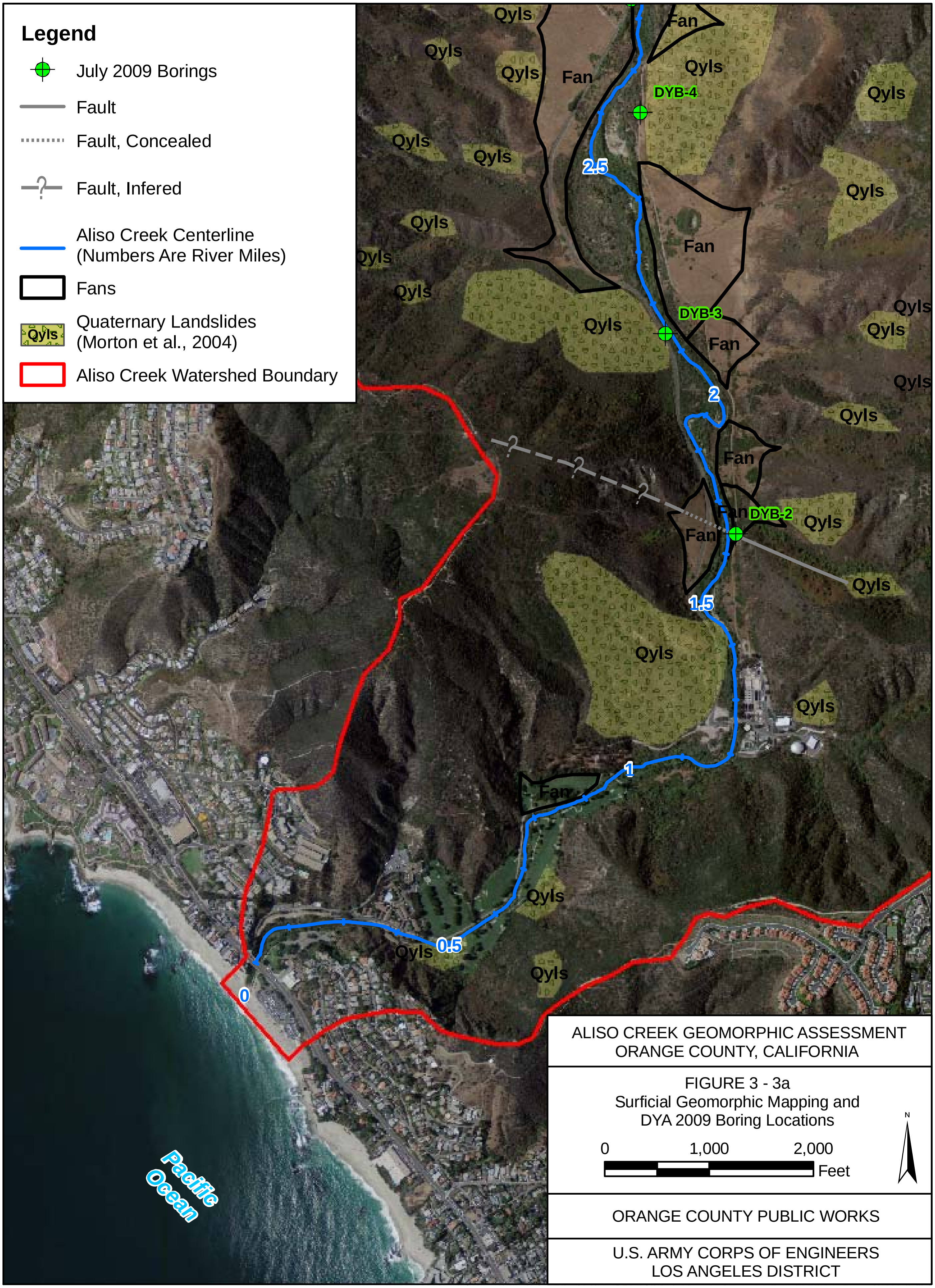
It should be noted that an ICEM is a conceptual model for classifying and understanding the existing geomorphic condition, as well as probable future geomorphic conditions. The concept of an ICEM as developed and applied in this Geomorphic Baseline Assessment was based on work done for the USACE in Yazoo Basin (Mississippi) and is also documented in Chapter 7 of Stream Corridor Restoration: Principles, Processes, and Practices (FISRWG 1998).

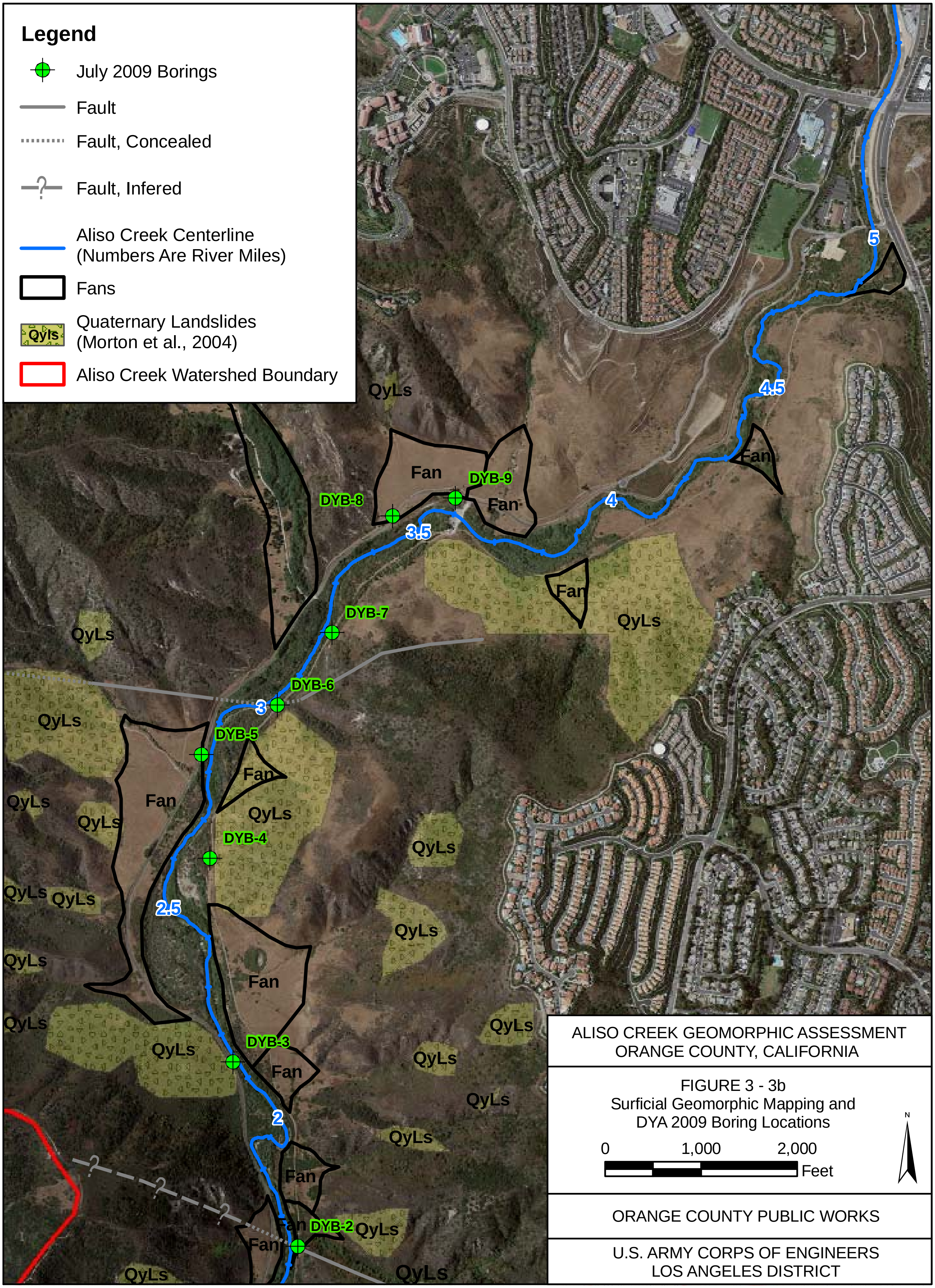
3.1 GEOLOGIC SETTING

The Aliso Creek watershed is located within the San Joaquin Hills, which form the northwestern corner of the Peninsular Ranges Geomorphic Province. The rugged San Joaquin Hills are a northwest-trending anticlinal structure that has been incised by several drainages that outlet southwest to the Pacific Ocean (Grant and others 1999). The bedrock geology of the San Joaquin Hills is composed of Tertiary-age marine and non-marine sedimentary rocks (Morton et al. 1974). Bedrock in the northeastern portion of the watershed consists of slide-prone, siltstones and claystones of the Capistrano and Monterey Formations. In the southwestern portion of the watershed, these formations overlie the interbedded siltstone and sandstone of the Topanga Formation together with lesser amounts of the San Onofre Breccia Formation. The San Onofre Breccia consists of massive to thickly bedded light gray to yellow-brown sandstone, pebbly and cobbly sandstone, and conglomerate. The San Onofre Breccia is generally dense and is locally cemented (Mactec 2007). Bedding attitudes within the northeastern portion of the watershed generally strike north with dip values ranging from 10 to 25 degrees west. Within the southern portion of the watershed, south of the inactive Temple Hill fault, bedding attitudes generally strike east-west with dip values ranging from 8 to 25 degrees south (Diaz Yourman and Associates (DYA) 2009).

Numerous modern and ancient landslides have been mapped in the hills along both sides of Aliso Creek (Morton et al. 1974). In general, south-facing hillslopes underlain by the Topanga Formation have the highest occurrence of landslides. Alluvium derived from the surrounding hills has filled in Aliso Canyon throughout the Quaternary. Subsequent uplift and incision by the modern Aliso Creek has created alluvial terraces on and a number of alluvial fans that have prograded out onto both the historical terraces and the pre-incision floodplain on both sides of the creek. Movement of the large (>15 acres) landslides within the area likely predates the recent Holocene alluvial terraces along the banks of Aliso Creek (Morton et al. 1974).

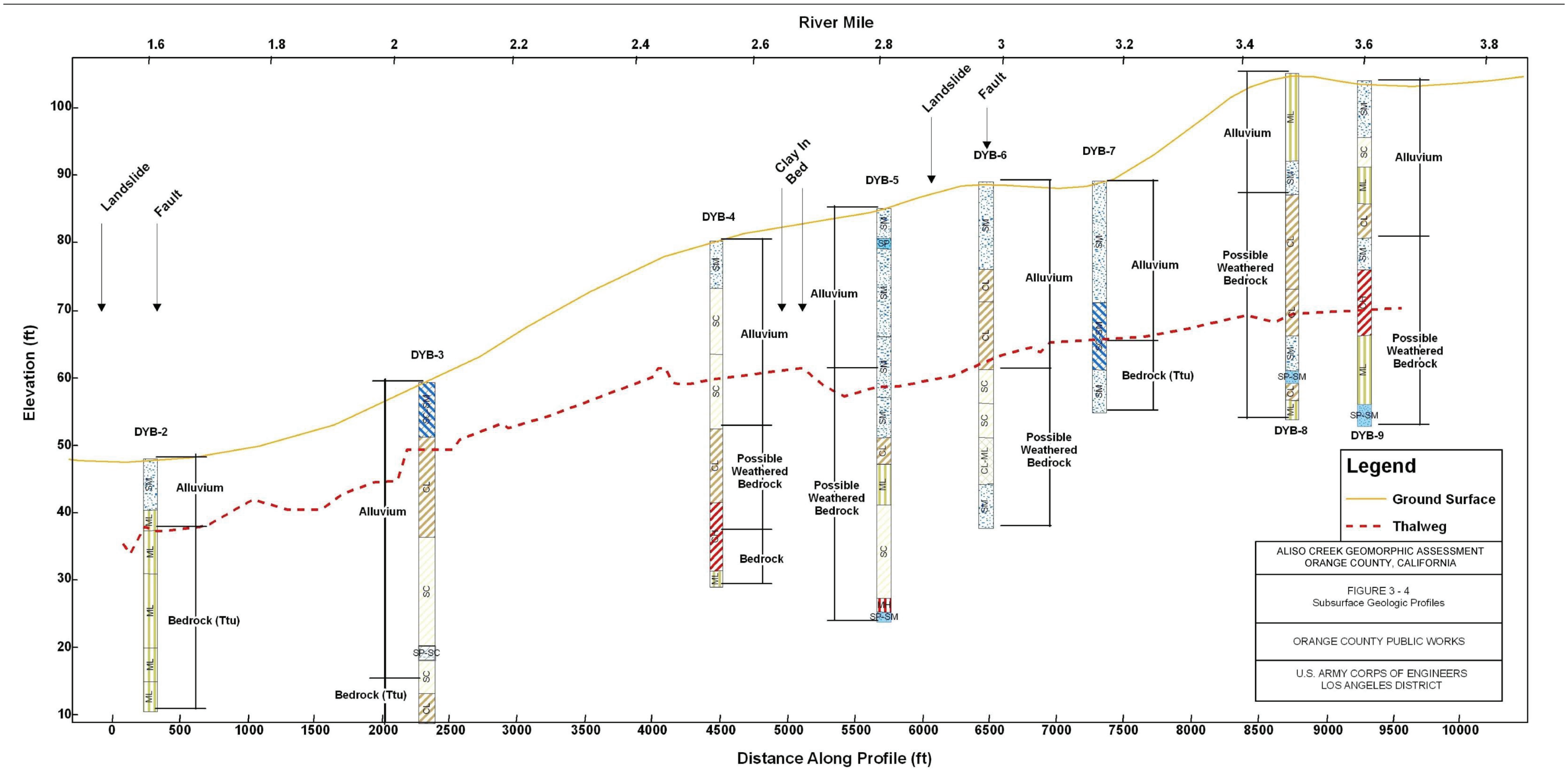
The distribution of Quaternary-age landslides and alluvial fans based on the mapping by Morton et al (2004) within the project reach of Aliso Creek is shown in Figure 3-3. The locations of the landslides, especially in the reach below the ACWHEP structure may explain the presence of clay-rich units (i.e., SC, CL) that dominate the valley fill sediments, and that were described as possibly being weathered bedrock on the basis of borings and seismic refraction profiles (Diaz, Yourman and Associates 2009). The locations of the eight borings performed in 2009 by DYA are shown in Figure 3-3. Field observations along Aliso Creek clearly demonstrate the importance of these clay units to both bed and bank stability. Clay outcrops control the current elevation of the channel bed at RM 2.4, RM 2.6 and RM 2.75, and the planform of the river at RM 2.0 (S-Bend) (refer to Figure 3-35). Additionally, clay units form the toe materials in numerous, near vertical banks along the deeply incised reach between the S-Bend and the toe of the ACWHEP structure. Mass failure of the overlying alluvium occurs at the contact with the underlying clays and fluvial erosion erodes the clays at a lower rate resulting in the convex-shaped lower bank profile (refer to Figure 3-32).


Legend
July 2009 Borings
Fault
Fault, Concealed
Fault, Infered
Aliso Creek Centerline
(Numbers Are River Miles)
Fans
Quaternary Landslides
(Morton et al., 2004)
Aliso Creek Watershed Boundary
Qyls
Fan
DYB-4
DYB-3
DYB-2
2.5
2
1.5
1
0.5
0
Pacific Ocean
ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA
FIGURE 3 - 3a
Surficial Geomorphic Mapping and
DYA 2009 Boring Locations
0
1,000
2,000
Feet
N
ORANGE COUNTY PUBLIC WORKS
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT


Legend
July 2009 Borings
Fault
Fault, Concealed
Fault, Infered
Aliso Creek Centerline
(Numbers Are River Miles)
Fans
Quaternary Landslides
(Morton et al., 2004)
Qyls
Aliso Creek Watershed Boundary
5
4.5
4
3.5
3
2.5
2
DYB-2
DYB-3
DYB-4
DYB-5
DYB-6
DYB-7
DYB-8
DYB-9
Fan
QyLs
ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA
FIGURE 3 - 3b
Surficial Geomorphic Mapping and
DYA 2009 Boring Locations
0
1,000
2,000
Feet
N
ORANGE COUNTY PUBLIC WORKS
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

Re-plotting of the boring logs developed by Diaz, Yourman and Associates (DYA 2009) into a single longitudinal profile of Aliso Creek from just upstream of the SOCWA plant to the ACWHEP structure, and addition of the 2009 surveyed thalweg profile and the locations of major landslides and faults helps to explain the spatial distribution of valley fill units and bedrock exposures that control the vertical stability of Aliso Creek (Figure 3-4). A large landslide located between RM 1 and RM 1.5 (Figure 3-3a) probably blocked the channel of Aliso Creek and very likely formed an upstream lake that historically in-filled with fine-grained sediments. The uppermost elevations of the CL units in Diaz Yourman Boring 3 (DYB-3), DYB-4 and DYB-5 are very similar, suggesting a lacustrine origin. Clay outcrops observed in the bed of the channel at RM 2.4, 2.6, and 2.7 are composed of this depositional unit. A large landslide between RM 2.5 and RM 3 (Figure 3-3b) may have also blocked the channel and formed an impoundment that resulted in deposition of the CL unit in DYB-6, and similarly, this could have occurred as a result of a landslide at RM 3.5 in DYB-8 and DYB-9.

The presence of confirmed bedrock at the thalweg elevation at DYB-2 and DYB-7 is probably related to the presence of the mapped faults (Morton et al. 1974). Weathered sandstone outcrop was also observed in the bed of the channel at RM 2.44 (refer to Figure 3-33). However, it is not known whether this represents in-situ bedrock or translated bedrock as part of the large landslides between RM 2.2 and RM 3.0. It is clear that the landslide at RM 2.2 has affected the planform of the river and upstream valley floor sedimentation. Development of the historically distorted bend at RM 2.4 that eventually cutoff to become the oxbow was clearly controlled by the presence of more erosion resistant materials from the landslide, which also formed a valley floor constriction that resulted in upstream sediment deposition over time.


River Mile
Elevation (ft)
Distance Along Profile (ft)
Landslide
Fault
DYB-2
DYB-3
DYB-4
DYB-5
DYB-6
DYB-7
DYB-8
DYB-9
Clay In Bed
Alluvium
Possible Weathered Bedrock
Bedrock
Bedrock (Ttu)
Legend
Ground Surface
Thalweg
ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA
FIGURE 3 - 4
Subsurface Geologic Profiles
ORANGE COUNTY PUBLIC WORKS
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

3.2 GEOMORPHOLOGY

The H&H Appendix (USACE 2000) contained a geomorphic assessment of the planform, profile, and cross section geometry to evaluate the physical stability of Aliso Creek. The changes in the morphology of the creek were considered along with the historical flood record and the increase in development in the watershed. The assessment was based primarily on field reconnaissance and review of historical topographic surveys, historical aerial photographs, and previous studies. Descriptions, dates, and sources of historical data sources are summarized in Table 3-1.

Table 3-1. Historical Data Sources

Description	Publication Date	Source
Topographic Surveys		
7.5-minute topographic maps (1:24k, 20-ft CI[1])	1967	USGS
Aliso Beach to Moulton Parkway (1" = 50', 1-ft CI)	1967	Orange County Public Works
Sulphur Creek confluence to I-5 (1" = 100', 2-ft CI)	1971	Orange County Public Works
Ocean Outlet to Aliso Creek Road (1" = 80', 5-ft CI)	1977	Orange County Public Works
Sulphur Creek confluence to SR-73 (1" = 40', 1-2-ft CI)	1983	Orange County Public Works
ACWHEP to Leisure World boundary (1" = 50', 2-ft CI)	1994	Orange County Public Works
Aliso Creek Environmental Restoration Study project mapping (1:1,000, 1-m CI)	1998	Orange County Public Works
Aerial Photography		
Aerial Survey (1" = 660')	1939	Orange County Archive
Aerial Survey, Rural & Urban (1" = 500')	1959	Orange County Archive
Aerial Survey, Urban (1" = 500')	1964	Orange County Archive
Aerial Survey, Urban (1" = 600')	1970	Orange County Archive
Digital Color Aerials (600 dpi)	1996	Aerial Foto Bank, Inc.
Digital Aerials (100 dpi)	1996	City of Mission Viejo
Color Aerials (1" = 2,000')	1997	Orange County Public Works

[1] *CI = contour interval*

Additional data sources were available for the revised H&H Appendix (USACE 2009), including newer topographic surveys and aerial photography. Descriptions, dates, and sources of these data are presented in Table 3-2.

Table 3-2. Recent Data Sources

Description	Publication Date	Source
Topographic Surveys[1]		
SOWCA to Sulphur Creek confluence (2-ft CI[2])	2003	SOCWA
SOWCA treatment plant to 300' downstream of ACWHEP, bank to bank channel surveys approx. every 80 feet along the thalweg	2006	Orange County Public Works
Pacific Ocean to SOCWA treatment plant (1-ft CI)	2007	Athens Group
ACWHEP to Skate Park (1:4,300 LiDAR, 1-ft CI)	2008	Orange County Public Works
Aliso Creek Road to Moulton Parkway (2-ft CI)	2008	USACE LAD
Aerial Photography		
Orange County (1m resolution)	2002	AirPhoto USA
Orange County (1m resolution)	2009	USDA NAIP

[1] ***All topographic mapping, if not referenced to the North American Vertical Datum 1988, were converted to this datum***
[2] *CI = contour interval*

The topographic surveys used to develop the current hydraulic and sediment models were based on the most recent data available (2006 through 2008). However, mapping information from 1998 was used to analyze geomorphic trends of Aliso Creek. In addition to being used as a stand-alone 1998 topographic mapping, the mapping information from 1998, which has the largest mapping limits among the various recently collected data, was used to supplement mappings of 2003, 2006, 2007, and 2008 for the areas where no topographic information was available for the mapping of the respective year. This merged dataset is hereafter referred to as the 2006 dataset.

For all data collected since the 1998 survey, original horizontal and vertical controls for these mapping sources were the North American Datum (NAD) 1983, State Plane, California VI FIPS 0406 (Feet) and National Geodetic Vertical Datum (NGVD) 1929 (Feet), respectively. The 1998 survey conducted by USACE has horizontal control in NAD 1983 UTM Zone 11N (Meter) and vertical control in the North American Vertical Datum (NAVD) of 1988. In order to accommodate its horizontal datum, the 1998 mapping was re-projected to NAD 83, State Plane, California VI (Feet) using ESRI ArcMap software. For all datasets prior to 1998, the elevations were converted to reference NAVD88 (Feet).

3.2.1 Field Reconnaissance

A field reconnaissance was performed in October 2009 to observe geomorphic conditions along Aliso Creek. As part of this effort, Aliso Creek was walked from the SOCWA Treatment Plant (RM 1.26) to Pacific Park Drive (RM 6.59). During this three-day walk, locations of significant geomorphic features were mapped and the location and elevation of observed high-water marks were recorded with a survey-grade GPS unit, pictures were taken, and notes of observations were recorded. A Trimble 4600 RTK GPS receiver was used to record locations and elevations of features of interest. The collected data were referenced to the NAD 1983, State Plane, California VI FIPS 0406 coordinate system in units of feet; vertical control was based on the NAVD88 in units of feet.

3.2.2 Historical Channel Characteristics

The morphology of Aliso Creek is the result of the runoff and sediment delivered from the watershed and their movement through the alluvial materials in which the creek is formed. The morphology of the creek is spatially manifested in three dimensions (i.e., elevation, distance along the direction of flow in the creek, and distance perpendicular to the direction of flow in the creek), and it changes over time. The interrelations between the three-dimensional morphology of the channel are complex, so a series of two dimensional perspectives allow for a simpler comparison of historical channel characteristics. These perspectives include: planform, longitudinal profile, and cross section geometry. The planform is the horizontal representation of the channel as seen in an aerial photograph (elevation is not explicitly quantified). The longitudinal profile illustrates changes in elevation of the streambed along the direction of flow. Cross section geometry represents changes in elevation perpendicular to the flow direction. Comparisons of each of these indicators of channel morphology made between 1939 and 2009, where data were available, are provided in the following sections.

3.2.2.1 Changes in Planform

The comparison of historical aerial photographs described in the H&H Appendix (2000) shows the dynamic nature of Aliso Creek. Although channel lengths typically increase over time due to lateral erosion at the bends, several major bend cutoffs were observed historically, resulting in reductions in channel length. Some changes in the planform result from human actions whereas other changes appear to result from natural processes.

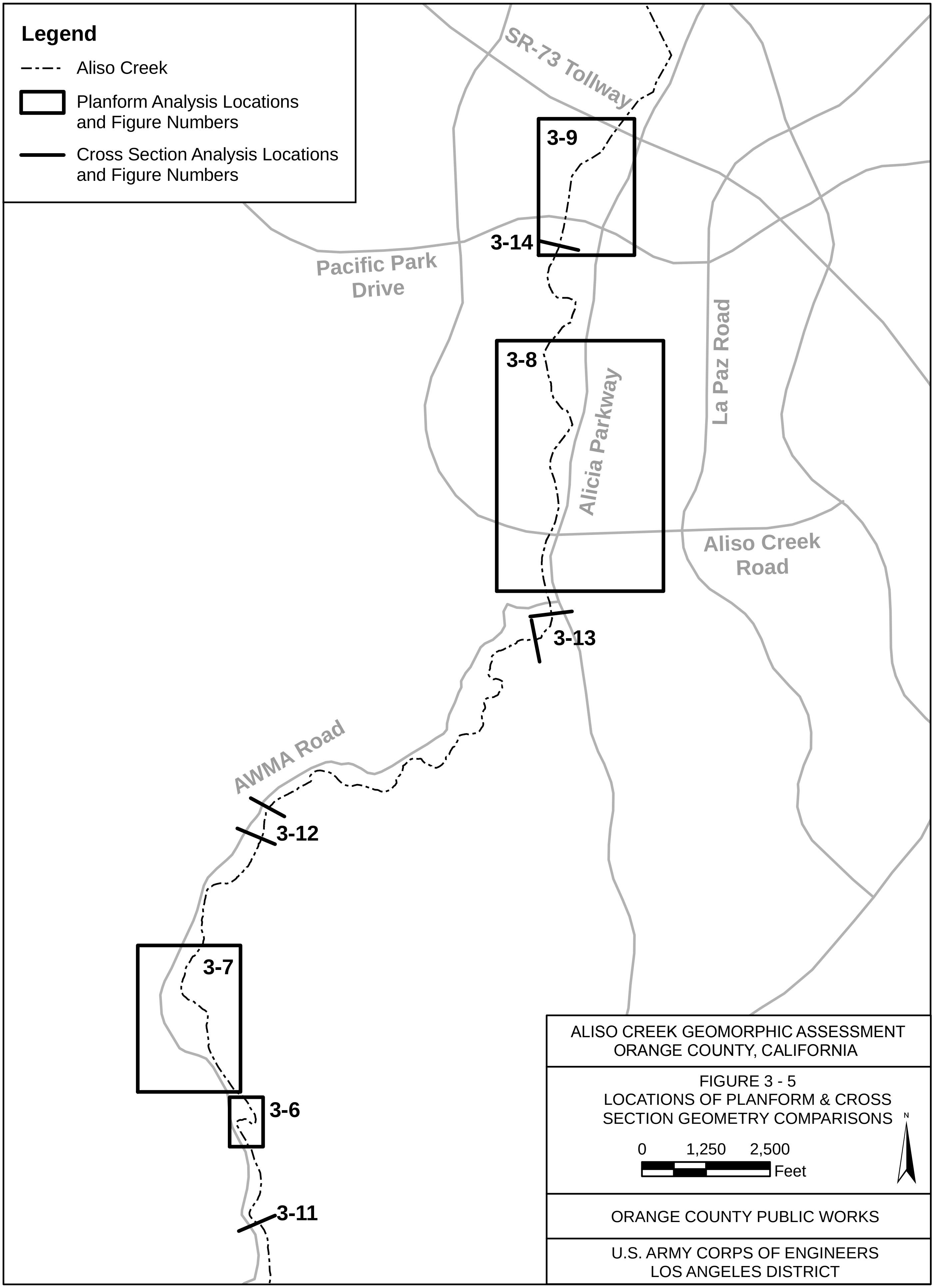
To quantify the changes in planform, the Aliso Creek centerline was digitized from various historical aerial photographs (i.e., 1939, 1959, 1964, 1970, 1996, and 2006) and topographic maps (i.e., 1967, 1983, 1994, and 1998). The centerlines were superimposed at the same scale to allow for comparisons over time. As a result of the process of digitizing historical data, the comparisons of historical data to recent data are most appropriately used for general comparisons over time; apparent differences from one year to the next may result from errors associated with digitization and spatial referencing of the data sources. Initial reviews of the centerlines revealed four areas within the current study area where changes in planform appear most dynamic. The locations of these four areas are shown in Figure 3-5; detailed views of each area are provided in Figures 3-6 through 3-9. A description of the changes shown in these figures follows.

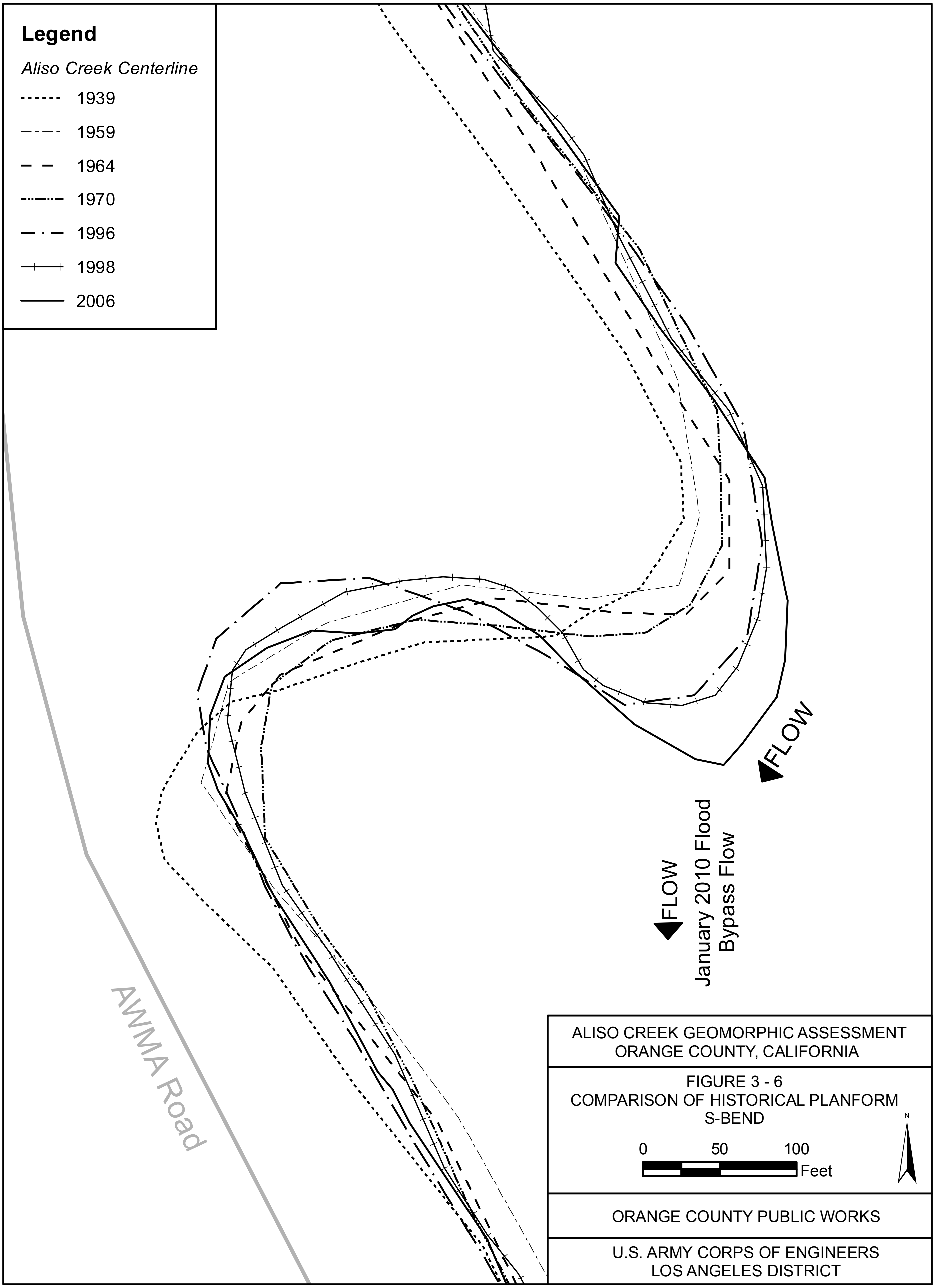
- *Figure 3-6: S-bend.* The S-bend (a double horseshoe bend) exhibits progressive extension in the upper bend on the order of 1.5 feet per year from 1939 to 2006 (i.e., 120 feet over 67 years). The position of the downstream bend has fluctuated over this same period, but has not demonstrated progressive movement in a single direction. The left bank in the upper bend was observed to have considerable clay content throughout the vertical bank profile. If not for this clay, the rate of extension of this bend would be much greater. A sandy point bar is being developed on the opposite bank. During the February 2010 reconnaissance, conducted after a series of floods in late January, evidence was observed of flows in the channel entering the floodplain at the upper bend and bypassing the lower bend (see note on Figure 3-6). At the downstream end of the bypass channel, a headcut approximately 3 feet in height had formed and will progress upstream to eventually cutoff this bend. This cutoff is expected to abandon approximately 850 feet of the creek, and the new channel will thus be approximately 500 feet shorter than the existing channel.

- *Figure 3-7: Abandoned Oxbow.* As shown in the 1939 aerial photography, Aliso Creek followed a prominent double horseshoe bend (referred to as the Abandoned Oxbow). The 1959 and 1964 aerials show extension of both bends, elongating the channel length. Most likely at some time in the mid-1980s, probably as a result of the flood of 1980 or 1983, this bend was cutoff and the channel length decreased by approximately 1,600 feet. From 1996 to 2006 the cutoff channel has migrated approximately 300 feet in the downstream direction.

- Figure 3-8: *Chet Holifield Federal Building*. The Chet Holifield Federal Building was constructed between 1968 and 1971 along the left bank of Aliso Creek, just north of the Aliso Road crossing. A 3,000-foot engineered channel was constructed in 1969 as part of a flood control and erosion mitigation project that cutoff approximately 3,200 feet along a meander bend on the site of the federal building. The new channel reduced the channel length by approximately 1,500 feet. Riprap bank protection and concrete drop structures were installed to limit future channel incision and migration in this shortened and steepened reach. Since 1970, the planform of the channel has remained as constructed in 1969.

- Figure 3-9: *Pacific Park Drive to San Joaquin Hills Transportation Corridor (SR-73 Tollway)*. The 1939 aerial photograph shows a series of tight meander bends in this reach. Between 1939 and 1959, these bends were cutoff and the channel length decreased by approximately 800 feet. Due to the influence of the Pacific Park Drive culvert replacement around 1992, the retarding basin upstream of the culvert influences local hydraulics, particularly during flood flows, and contributes to the dynamic nature of the planform through this basin. As seen in the 1996 and 1998 aerials, the meander bends reformed, but again appear to have cutoff by 2006.


Legend
Aliso Creek
Planform Analysis Locations and Figure Numbers
Cross Section Analysis Locations and Figure Numbers
SR-73 Tollway
3-9
3-14
Pacific Park Drive
3-8
Alicia Parkway
La Paz Road
Aliso Creek Road
3-13
AWMA Road
3-12
3-7
3-6
3-11
ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA
FIGURE 3 - 5
LOCATIONS OF PLANFORM & CROSS SECTION GEOMETRY COMPARISONS
0 1,250 2,500
Feet
N
ORANGE COUNTY PUBLIC WORKS
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

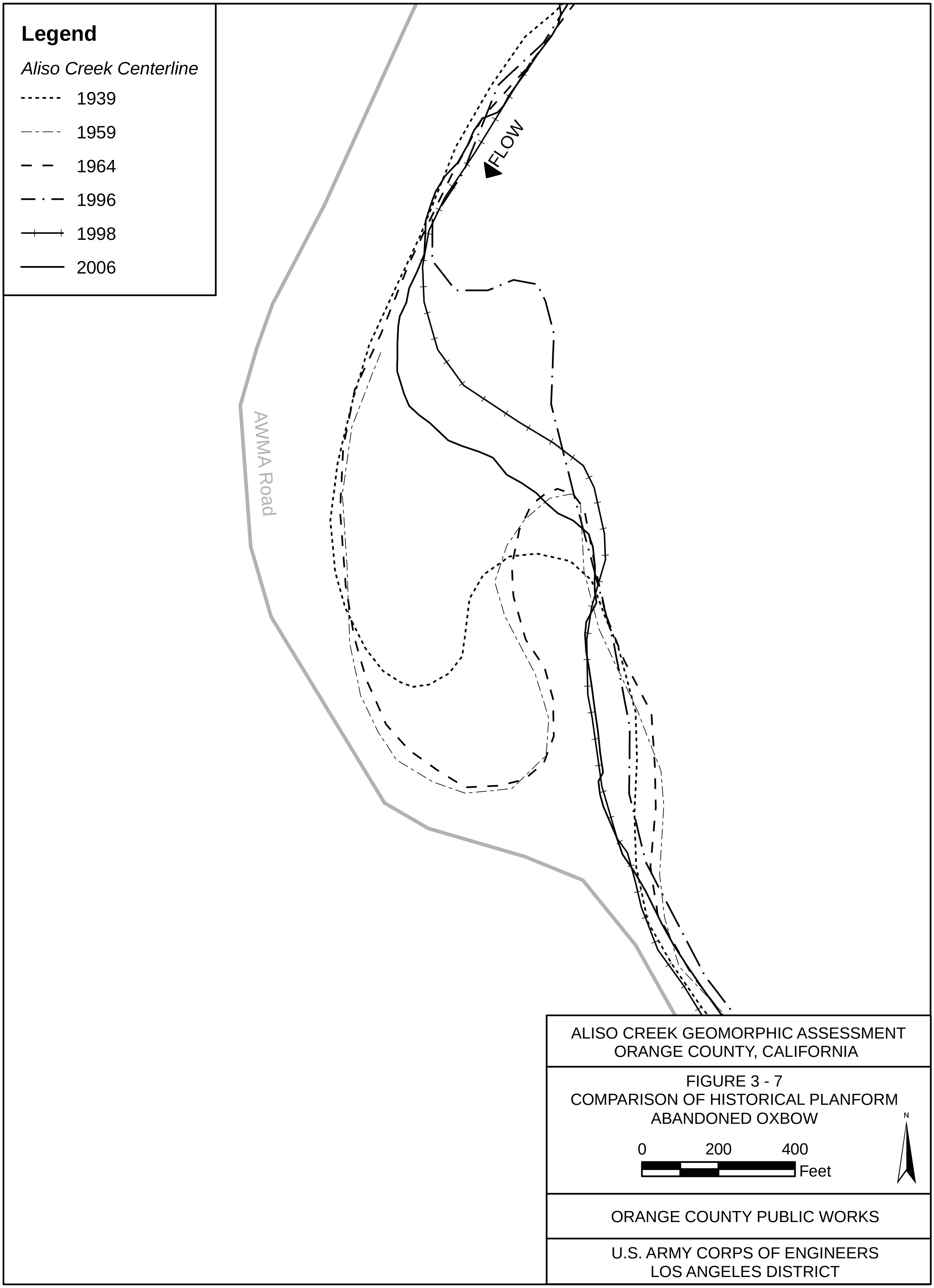


ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 3 - 6
COMPARISON OF HISTORICAL PLANFORM
S-BEND

ORANGE COUNTY PUBLIC WORKS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

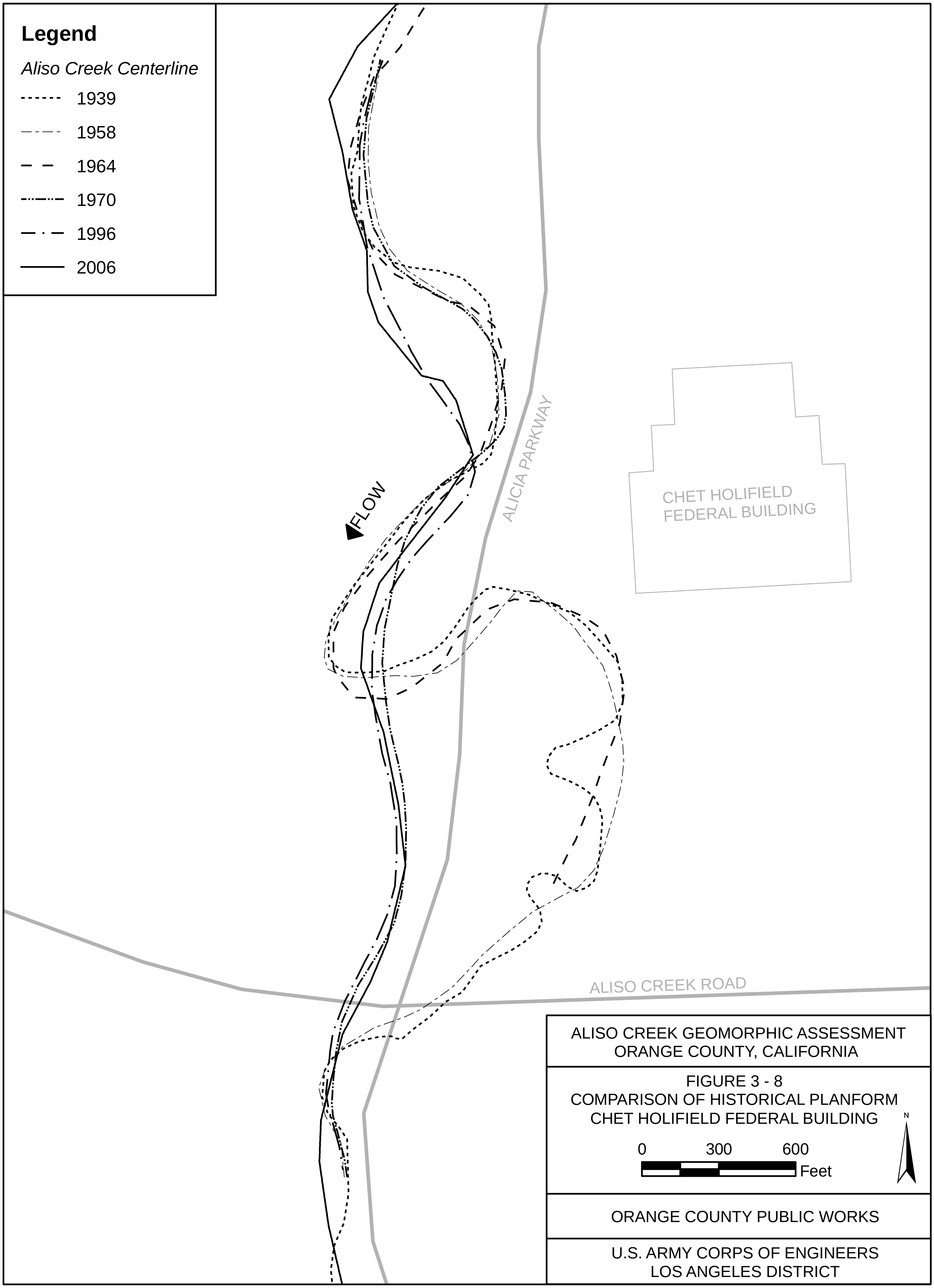


ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 3 - 7
COMPARISON OF HISTORICAL PLANFORM
ABANDONED OXBOW

ORANGE COUNTY PUBLIC WORKS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

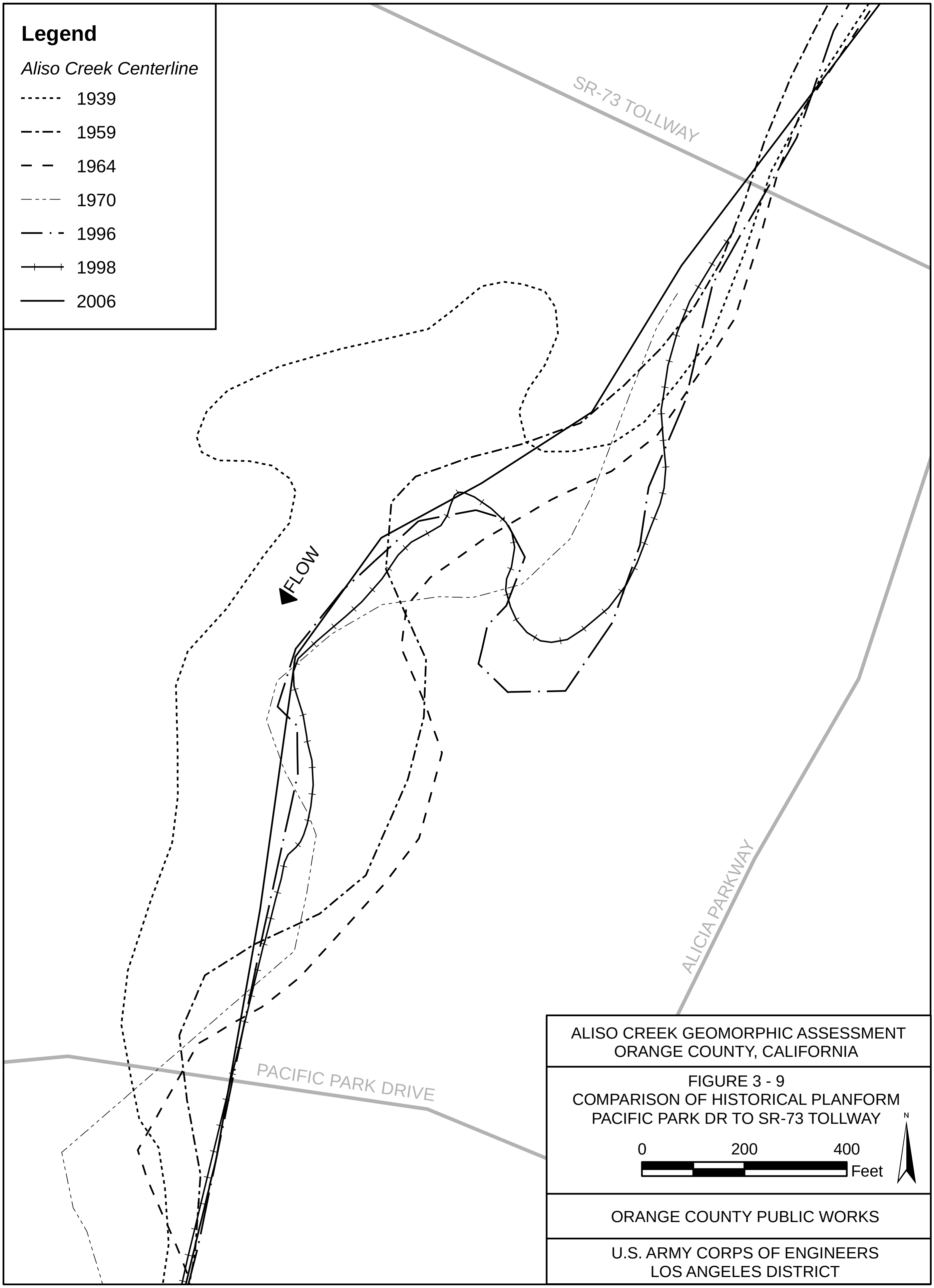


ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 3 - 8
COMPARISON OF HISTORICAL PLANFORM
CHET HOLIFIELD FEDERAL BUILDING

ORANGE COUNTY PUBLIC WORKS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 3 - 9
COMPARISON OF HISTORICAL PLANFORM
PACIFIC PARK DR TO SR-73 TOLLWAY

ORANGE COUNTY PUBLIC WORKS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

3.2.2.2 Changes in Profile

Figure 3-10 compares streambed profiles from 1967, 1971, 1977, 1980, 1983, 1994, 1998, 2006, and 2009. Reaches were established between points (bridges, state plane coordinates etc.) that could be located on each of the historical maps, and profiles were plotted. Common points were identified in the historical profiles (e.g., bridge crossings, grade control structures, and tributary confluences), and the stream lengths were proportionally adjusted to match the stream length from the 2006 dataset (the most recent dataset, as described in Section 3.2). All elevations were converted to reference the NAVD88. The resulting profiles are most accurate at the locations of common points, but the accuracy may be lower at greater distances from these points where the channel lengths were adjusted and in places where the distance between reported elevations is greatest.

The figure provides a visual comparison of the vertical changes in the profiles through time. The most significant changes occur at the drop structures, culverts, and other drainage facilities installed since 1967. A brief description of significant changes in the profile follows, proceeding upstream along the profile.

- *SOCWA Treatment Plant to ACWHEP Structure.* The bridge over Aliso Creek for the access road to the SOCWA Treatment Plant provides grade control. The concrete sill under the bridge has maintained a nearly consistent elevation through the 2006 survey. For approximately 1,500 feet upstream of the bridge, localized degradation of up to 6 feet has occurred between 1977 and 2006. However, farther upstream, locations such as RM 2.1 (upstream of the S-bend) and RM 2.5 (upstream of the Abandoned Oxbow) show essentially no degradation over time, indicating that these are local grade controls such as exposed bedrock, erosion resistant clay layers, or plugs (relatively immobile concentrations of coarse sediment in the bed of the channel).

  The 1977 profile shows a localized increased slope between the S-bend and the Abandoned Oxbow (RM 1.7 to 2.3), but generally follows the slope of the 1967 profile up to the ACWHEP structure. While the S-bend is not exhibiting any significant vertical changes, tight bends can be cut-off during large flow events. At this location a cutoff could cause negative impacts to high quality vegetation.

  The downstream end of the 1980 profile shows a localized steep reach (RM 2.8 to 2.9) that reflects an 8-foot head cut; by April 1982 this head cut had progressed upstream without establishing a well-defined drop of appreciable magnitude (CDM 1982). The ACWHEP structure, originally installed in the early 1990s to divert flow for irrigating vegetation in a mitigation bank, has been reinforced over the past two decades and the current drop of approximately 22 feet across the structure makes it the largest grade control in the study area. The 1980 profile follows closely the profiles from 1967 and 1977 in the reaches upstream and downstream of the ACWHEP structure. By 1994, incision of approximately 18 feet has occurred on the downstream side of ACWHEP. Another five feet of degradation is evident by 1998, however, 1998 profile was based on an aerial photograph taken in April 1998 and likely represents the elevation of the water surface and not the thalweg – meaning the degradation between 1994 and 1998 may be greater than shown. Also, the apparent degradation shown in the 2006 profile may actually only be the difference between the low flow water-surface elevation in 1998 and the surveyed thalweg elevation in 2006.

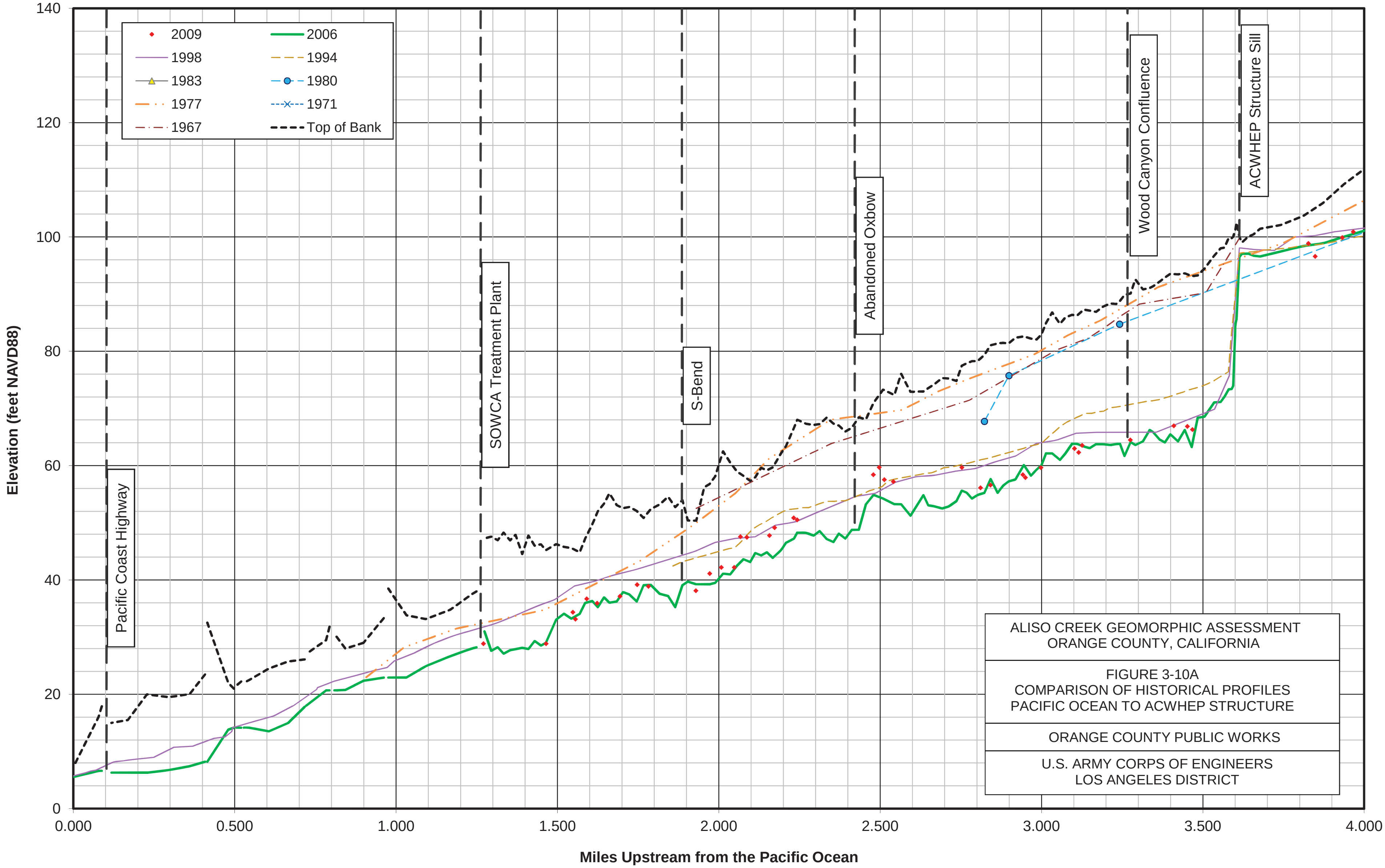
  Based on these indicators, it appears the bed elevation between the SOCWA Treatment Plant and ACWHEP may be stabilizing, likely due to the influence of natural grade controls. Later discussion (Section 6.1) confirms the stabilizing trend.

- *ACWHEP Structure to AWMA Road*. Due to limited points in the 1980 profile, rates of degradation in this reach for the periods 1977 to 1980 and 1980 to 1994 cannot be meaningfully compared; however, it does appear that progressive degradation of the reach occurred between 1967 and 1994. According to CDM (1982), much of the erosion in this reach occurred in the flood of 1980. Since 1994, the channel grade has stabilized, potentially even aggrading slightly. Two drop structures have been constructed in this reach since 1967: a 4-foot concrete sill at the AWMA Road Bridge and a 4-foot riprap drop approximately 500 feet downstream of the Sulphur Creek confluence. The riprap drop structure was likely installed at the natural 6-foot drop captured in the 1980 survey, and observed in February 1982 as a natural drop at about the same location (CDM 1982). During the 2009 reconnaissance, the riprap structure downstream of the Sulphur Creek confluence was not found, and the 2009 spot elevations indicate the structure is now buried by deposition. Since 1998, in the 500 feet leading up to AWMA Road, four to five feet of bed degradation appears to be moving upstream; the concrete sill at the bridge will control and prevent upstream propagation of this degradation.

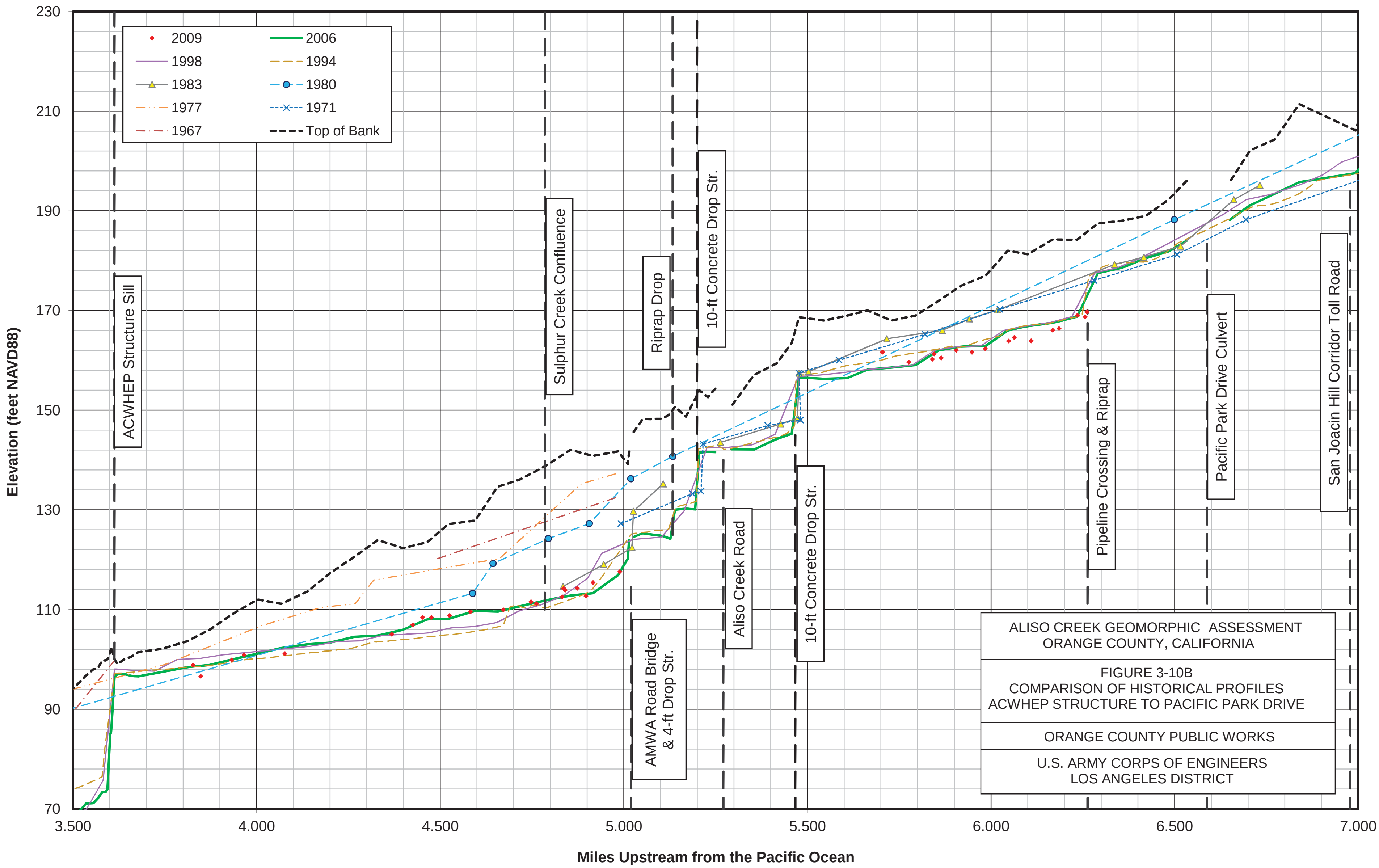
- *AWMA Road to Avila Road (upstream of the Skate Park)*. Two 10-foot concrete drop structures and a five-foot riprap drop were built to maintain the original channel slope when Aliso Creek was channelized through this reach in 1969. Although the drop structures act as control points for the channel profile, they do not prevent sedimentation. A case in point is the downstream drop structure, which was visible in the 1971 survey, covered by sediment in the 1977 and 1983 surveys, and exposed again in the 1994 survey.

- *Avila Road (upstream of the Skate Park) to Pacific Park Drive*. Although the channel bed showed less than a few feet of vertical variation from 1971 to 1983, at some point between 1983 and 1994, erosion necessitated the construction of an 8-foot riprap drop structure at the waterline crossing at RM 6.26. The drop is clearly visible in the profiles since 1994.

- *Pacific Park Drive to Pedestrian Bridge for Aliso Viejo Middle School*. The head cut shown in the 1971 channel profile just above the current SR-73 crossing is probably due to the cut-off of the horseshoe bend described in the planform changes upstream of Pacific Park Drive. Upstream migration the head cut is now prevented by the riprap drop structure at the pedestrian bridge. Aggradation of up to 6 feet has occurred between the SR-73 Tollway and the pedestrian bridge between 1994 and 2006.



140
120
100
80
60
40
20
0
Elevation (feet NAVD88)
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
4.000
Miles Upstream from the Pacific Ocean
2009
2006
1998
1994
1983
1980
1977
1971
1967
Top of Bank
Pacific Coast Highway
SOWCA Treatment Plant
S-Bend
Abandoned Oxbow
Wood Canyon Confluence
ACWHEP Structure Sill
ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA
FIGURE 3-10A
COMPARISON OF HISTORICAL PROFILES
PACIFIC OCEAN TO ACWHEP STRUCTURE
ORANGE COUNTY PUBLIC WORKS
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



Elevation (feet NAVD88)
Miles Upstream from the Pacific Ocean
230
210
190
170
150
130
110
90
70
3.500
4.000
4.500
5.000
5.500
6.000
6.500
7.000
2009
2006
1998
1994
1983
1980
1977
1971
1967
Top of Bank
ACWHEP Structure Sill
Sulphur Creek Confluence
Riprap Drop
10-ft Concrete Drop Str.
AMWA Road Bridge & 4-ft Drop Str.
Aliso Creek Road
10-ft Concrete Drop Str.
Pipeline Crossing & Riprap
Pacific Park Drive Culvert
San Joacin Hill Corridor Toll Road
ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA
FIGURE 3-10B
COMPARISON OF HISTORICAL PROFILES
ACWHEP STRUCTURE TO PACIFIC PARK DRIVE
ORANGE COUNTY PUBLIC WORKS
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

3.2.2.3 Changes in Channel Geometry

Cross sections were obtained from topographic maps (1967, 1971, 1977, 1983, 1994, 1998, and 2006) at six locations within the study area. The locations of these cross sections are shown in Figure 3-5. The cross sections from different years are approximately centered to illustrate changes in the channel width and overall cross-sectional shape. The cross sections are plotted from left to right facing downstream in Figures 3-11 through 3-14.

- *Figure 3-11: 1,000 feet upstream of SOCWA Treatment Plant*. Survey data at this location were available for 1967, 1977, 1998, and 2006. In each of these four years, the section has maintained a fairly constant morphology, with only minor increases in bottom width. Despite the consistent shape, the channel has migrated toward the east, approximately 60 feet between 1977 and 1998, with little movement before or after that period.

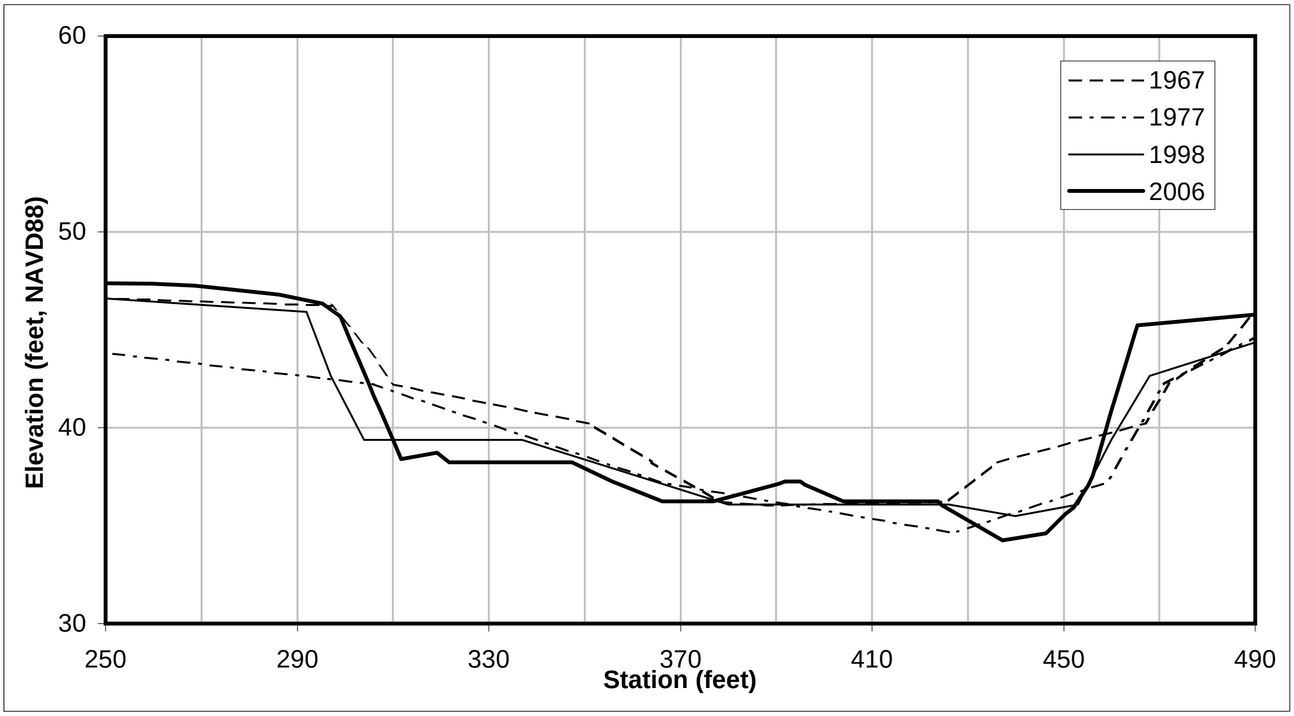
- *Figure 3-12, lower section: 300 feet downstream of Wood Canyon Creek Confluence*. This section shows progressive incision and widening between 1977 and 1998. The apparent aggradation between 1967 and 1977 is more likely the result of differences in the resolution of the topographic survey data rather than actual changes in channel morphology, but it could also be due to increased upstream sediment supply due to upstream channel degradation. The greatest change occurred between 1977 and 1998. Between 1998 and 2006, the cross section has maintained nearly the identical shape and elevation. Over the 31 years between 1967 and 1998, the thalweg elevation dropped approximately 19 feet and the top width increased from approximately 60 feet to 130 feet. As a rough estimate, the cross sectional area increased nearly eight-fold, from approximately 230 square feet in 1971 to 1,780 square feet by 1998. The influence of the ACWHEP structure on sediment continuity through this reach coupled with the extensive development of the watershed explains the severe degradation between the 1977 and 1994 surveys.

- *Figure 3-12, upper section: 300 feet upstream of Wood Canyon Creek Confluence*. This cross section exhibits similar changes in morphology to the cross section 300-feet downstream of the Wood Canyon Creek confluence. The thalweg elevation decreased by 21 feet between 1967 and 2006. The top width increased from roughly 65 feet to 115 feet. As an estimate, the cross sectional area of the channel increased by a factor of nine, from approximately 200 square feet in 1967 to 1,790 square feet in 2006. However, it is important to note that only minor differences are evident in the geometry in 1998 and 2006. The major degradation between the 1977 and 1994 surveys is largely attributed to the location of this section approximately 1,600 feet downstream of the ACWHEP structure.

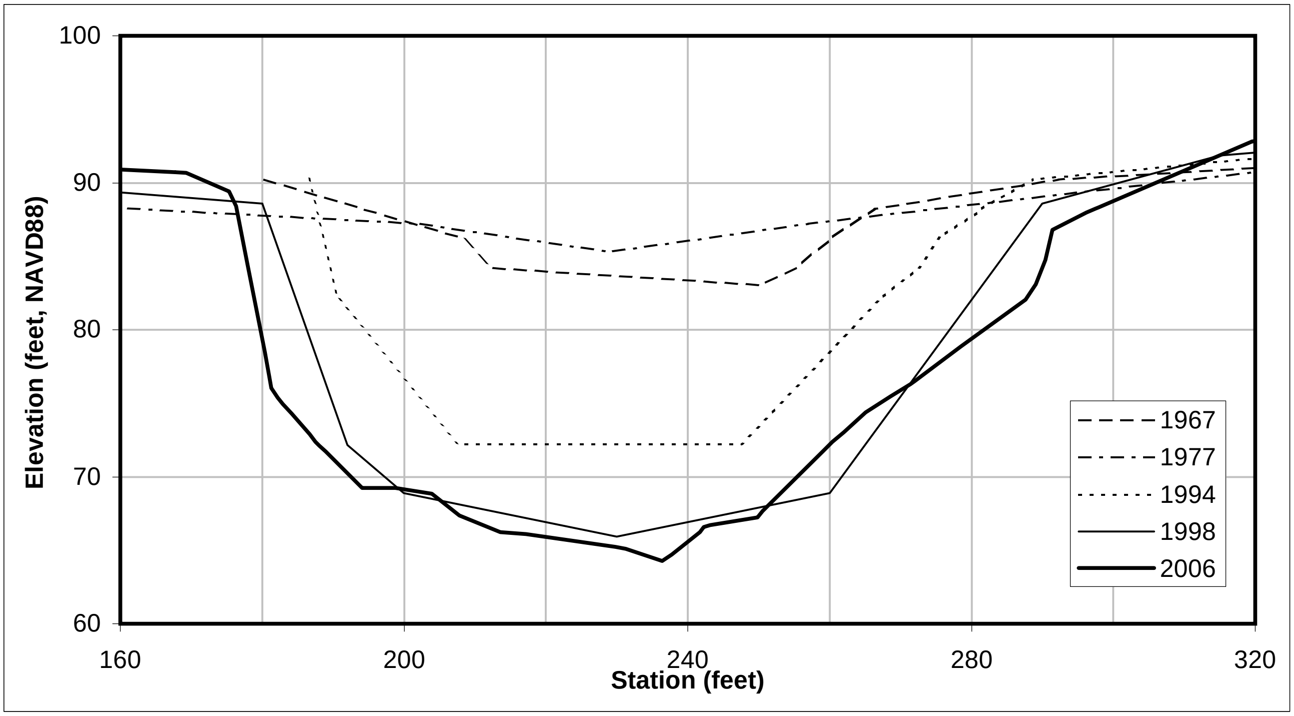
- *Figure 3-13, lower section: 200 feet downstream of Sulphur Creek Confluence*. A consistent pattern of incision and channel widening is apparent up to 1998, but the geometry has not changed much between 1998 and 2006. For the 35 years between 1971 and 2006, the thalweg has incised approximately 9 feet. The top width has increased from 65 feet in 1971 to 135 feet in 2006. The channel appears to have aggraded and narrowed slightly between 1998 and 2006, but future surveys would help confirm whether this reflects a progressive trend or a temporal fluctuation.

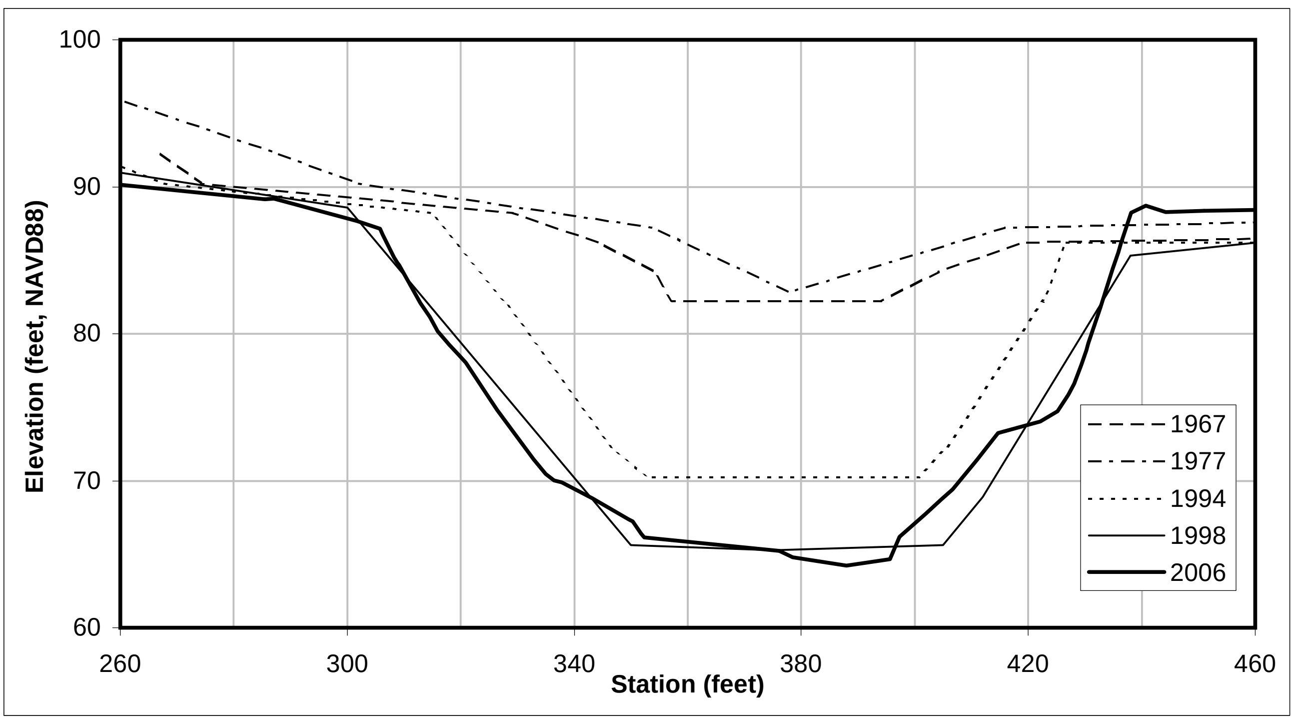
- *Figure 3-13, upper section: 500 feet upstream of Sulphur Creek Confluence*. This section has incised and widened between 1971 and 1994, and aggraded and continued widening between 1994 and 2006. The thalweg elevation decreased by 14 feet between 1971 and 1994, and has increased by 3 feet between 1994 and 2006. The top width has increased from 90 feet to 180 feet over the same period. The aggradation since 1994 is supported by the comparison of historical profiles (Section 3.2.2.2).

- *Figure 3-14: 500 feet downstream of Pacific Park Drive*. The geometry of this cross section has changed little between 1971 and 2006. The bottom width narrowed some from 1971 to 1994, but widened back out to about where it started by 2006. The thalweg elevation has not changed any appreciable amount, likely due to the presence of a water-line crossing and grade-control structure 1,200 feet downstream. The retarding basin on the upstream side of the Pacific Park drive culverts reduces the peak flows during floods through this cross section, also contributing to its relative stability.

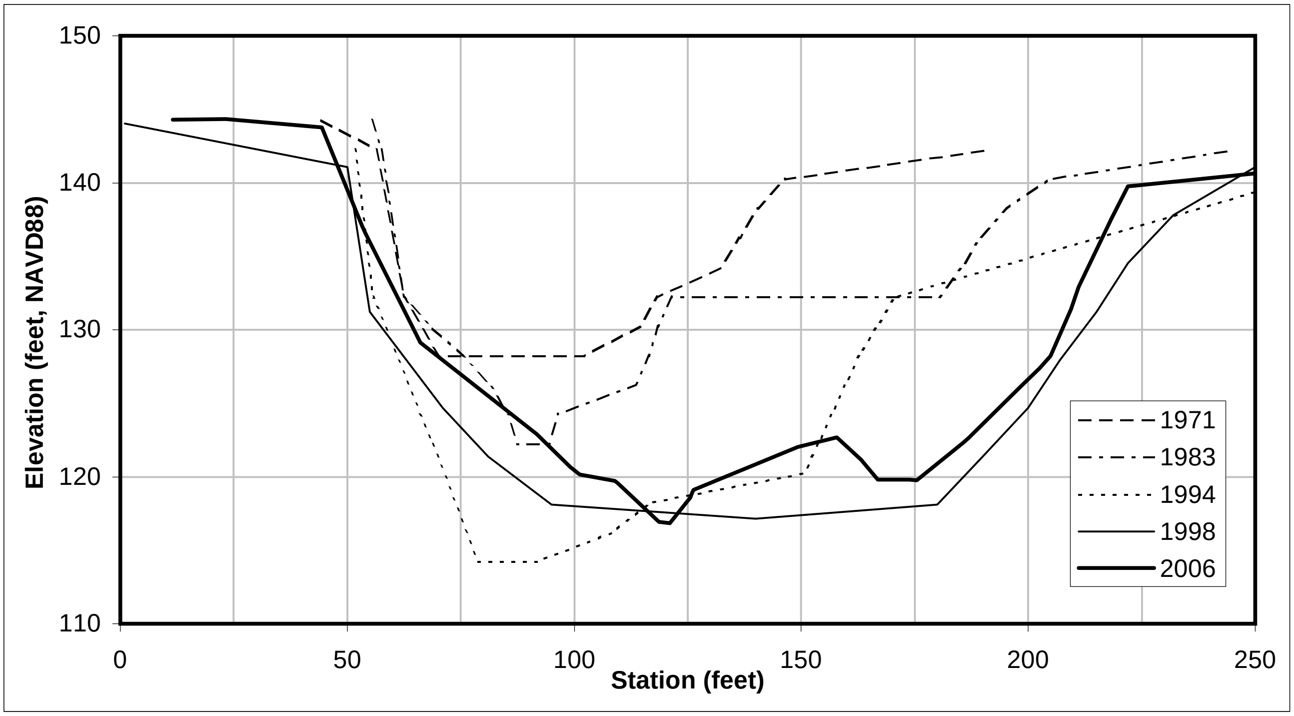


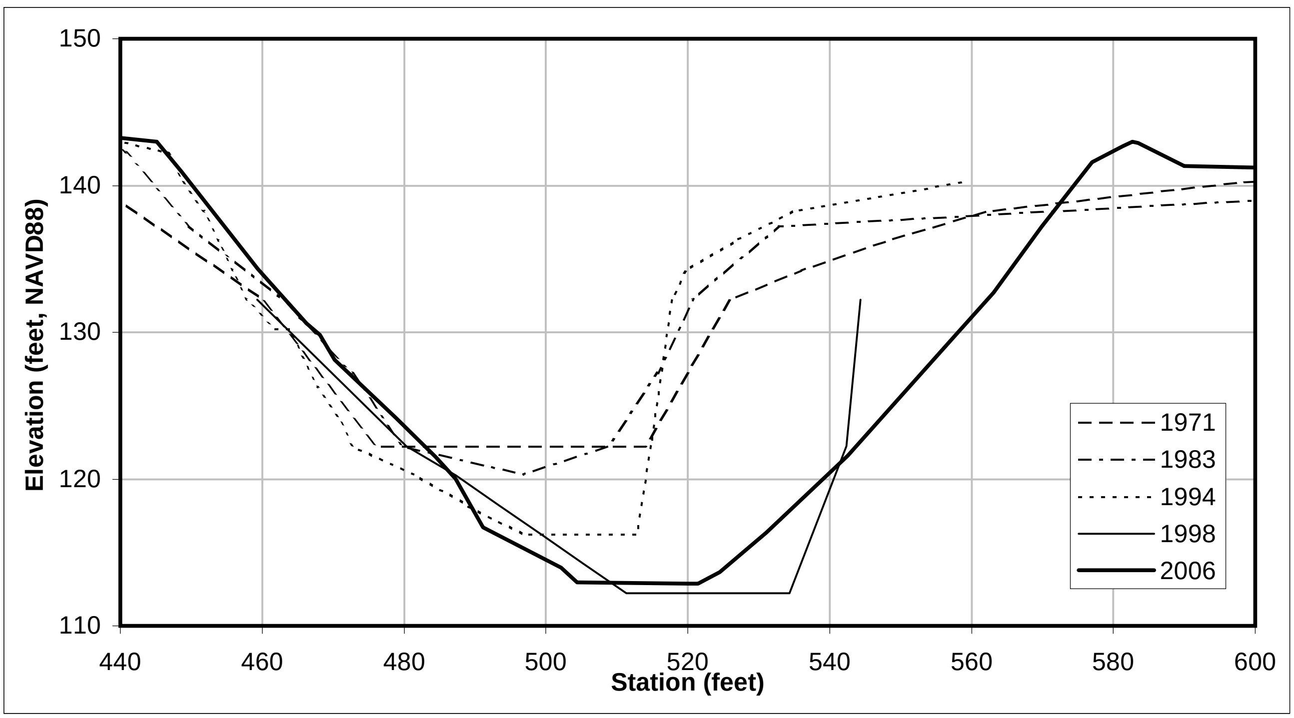
ALISO CREEK GEOMORPHIC ASSESSMENT ORANGE COUNTY, CALIFORNIA
FIGURE 3-11 COMPARISON OF HISTORICAL CROSS SECTION GEOMETRY SOCWA TREATMENT PLANT VICINITY
ORANGE COUNTY PUBLIC WORKS DEPARTMENT
U.S. ARMY CORPS OF ENGINEERS LOS ANGELES DISTRICT





ALISO CREEK GEOMORPHIC ASSESSMENT ORANGE COUNTY, CALIFORNIA
FIGURE 3-12 COMPARISON OF HISTORICAL CROSS SECTION GEOMETRY UPSTREAM (UPPER) & DOWNSTREAM (LOWER) OF WOOD CANYON CREEK CONFLUENCE
ORANGE COUNTY PUBLIC WORKS DEPARTMENT
U.S. ARMY CORPS OF ENGINEERS LOS ANGELES DISTRICT



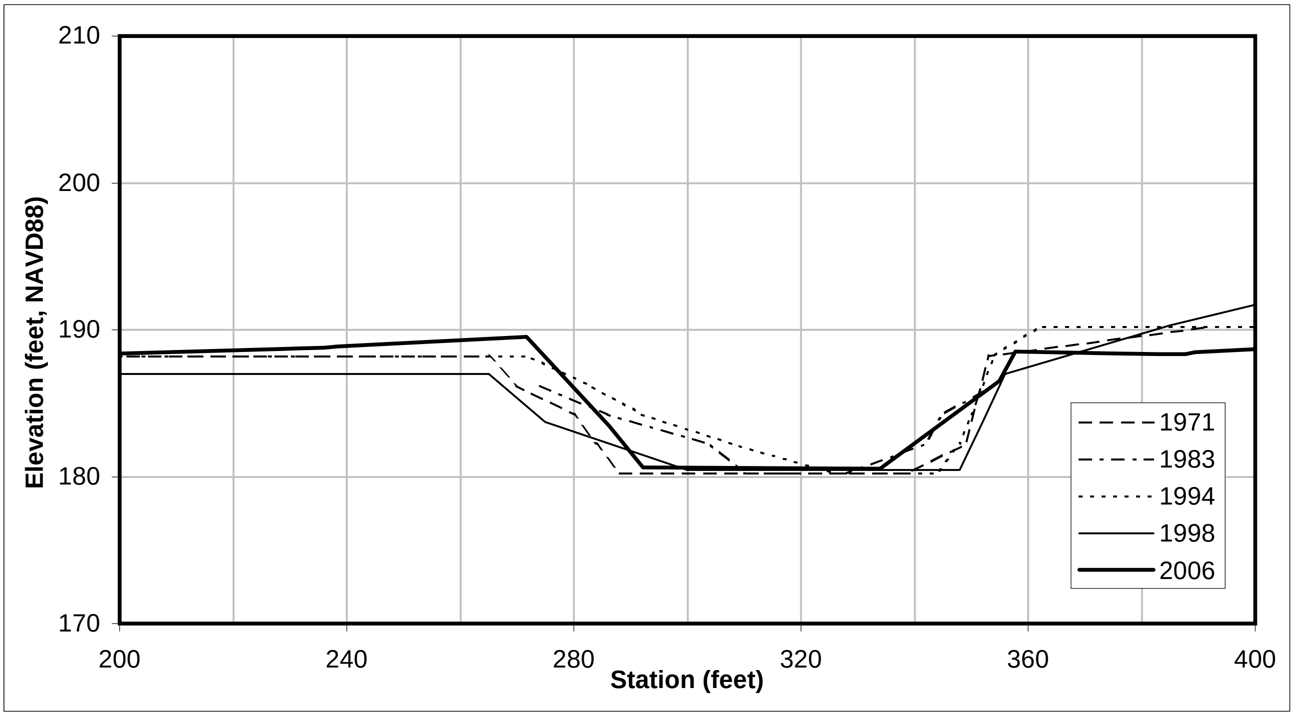


ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 3-13
COMPARISON OF HISTORICAL CROSS SECTION GEOMETRY
UPSTREAM (UPPER) & DOWNSTREAM (LOWER)
OF SULPHUR CREEK CONFLUENCE

ORANGE COUNTY
PUBLIC WORKS DEPARTMENT

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT



ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 3-14
COMPARISON OF HISTORICAL CROSS SECTION GEOMETRY
PACIFIC PARK DRIVE VICINITY

ORANGE COUNTY
PUBLIC WORKS DEPARTMENT

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

3.2.3 Current Channel Characteristics

The comparisons of the historical planform, longitudinal profile, and cross section geometry presented in the previous section provide historical context for understanding the evolution of the channel morphology to its current state. It is obvious that over the past two decades the morphology of much of Aliso Creek, but in particular the reach between the SOWCA treatment plant and the ACWHEP structure, has been changing. The current morphology was characterized to provide a basis for expected future morphological conditions.

3.2.3.1 Planform and Profile Features

The following geomorphic features of interest were noted during the October 2009 reconnaissance:

- Plugs/riffles – deposits of coarse gravel and cobbles, typically spanning the width of the channel, that provide local grade control. Due to the stability of these coarser bed materials, the presence of the plugs is marked by the establishment of tules and cattails across the width of the channel.

- Clay outcrops – erosion resistant clay layers (CL) have been exposed by the degradation of the streambed. These outcrops of the clay layer were observed in the bed of the channel, as well as in the banks. Due to the relative resistance to fluvial erosion compared to non-cohesive materials, the clay outcrops can provide local grade control and can limit the rate of lateral erosion/migration.

- Bedrock outcrops – similar to the clay outcrops, bedrock (e.g., sandstone, breccia) is relatively erosion resistant, and provides local vertical and lateral controls on channel morphology.

- Sand storage reaches – deposition of sand was observed in the bed of the channel, typically on the downstream side of a plug, in the backwatered reach formed by the next downstream plug. The depth of storage was probed and was observed up to approximately five feet. In some cases, the sand wedge extended to the downstream plug; in other cases, the wedge terminated in the pool upstream of the plug.

- Tributary confluences – locations where tributaries join Aliso Creek are important because many of the tributary watersheds drain steeper hillsides, and these areas supply coarse sediment to Aliso Creek.

- Bank protection – angular granitic riprap and sheet piling were observed as bank protection. The materials were installed to protect infrastructure (i.e., access roads, pipelines, trails) by limiting the potential for the channel to naturally adjust.

- Grade-control structures – engineered grade control structures have been installed to limit incision of the bed, and propagation of vertical instabilities. These structures include concrete sills at bridge crossings, riprap blankets, and vertical concrete walls.

The following table lists all of these observed features, referenced to the channel stationing based on the 2006 mapping data. The locations of road crossings are provided for reference. Figures 3-15 through 3-20 show the observed locations of the various features.

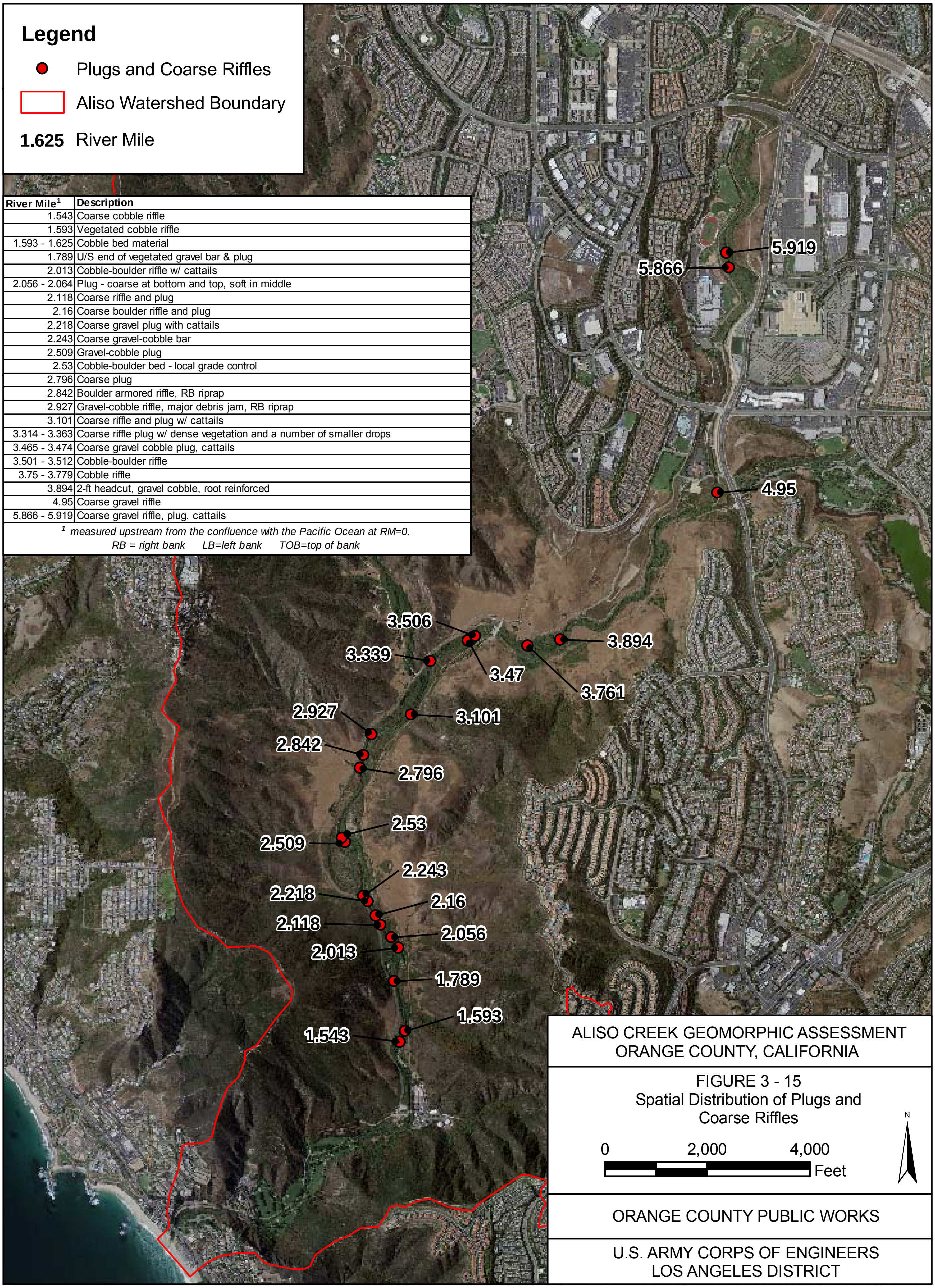
Table 3-3. Spatial Distribution of Planform Features

River Mile[1]	Feature
0.103	PCH Bridge
0.27 – 0.44	Concrete banks through Aliso Creek Inn
0.412	Aliso Creek Inn Bridge #1
0.446	Bedrock (San Onofre Breccia) outcrop
0.501	Aliso Creek Inn Bridge #2
0.524	Golf Course Bridge #1
0.719	Golf Course Bridge #2
0.802	Golf Course Bridge #3
0.969	Golf Course Bridge #4
1.262	SOCWA Bridge
1.27 – 1.35	Deep pool, LB riprap
1.449 – 1.543	Abandoned/high flow channel
1.464 – 1.510	RB riprap
1.543	Coarse cobble riffle
1.593	Vegetated cobble riffle
1.593 – 1.625	Cobble bed material
1.625	Possible outcrop in bed
1.646	Coarse material in alluvial fill being excavated from toe of RB
1.661	Gulley confluence, LB
1.789	U/S end of vegetated gravel bar & plug
1.789	3-ft headcut at end of LB high flow channel
1.85 – 1.96	S-Bend
1.955 – 2.013	LB riprap
2.013	Cobble-boulder riffle w/ cattails
2.025	Possible outcrop in bed
2.035	Gulley confluence, LB
2.056 – 2.064	Plug - coarse at bottom and top, soft in middle
2.064 – 2.118	Deep pool with sand wedge
2.118	Coarse riffle and plug
2.118 – 2.160	Sand storage reach
2.160	Coarse boulder riffle and plug
2.176 – 2.220	RB riprap
2.204	1.5-ft headcut
2.218	Coarse gravel plug with cattails
2.233	Clay induced tight bend, coarse gravel and cobble being eroded out of alluvial fill
2.294 – 2.544	Abandoned Oxbow
2.312	Gulley confluence, LB
2.412	Cohesive clays in bed
2.44	Weathered sandstone outcrop in bed
2.509	Gravel-cobble plug
2.53	Cobble-boulder bed – local grade control
2.479	Gulley confluence, RB
2.484	Coarse bed pool
2.54	Gulley confluence, RB
2.611	Cohesive clays in bed
2.68	Gulley confluence, RB
2.75	Clay outcrop in bed
2.796	Gulley confluence, RB & coarse plug

River Mile[1]	**Feature**
2.796 – 2.842	Pool with 3 – 4-ft sand storage in bed
2.842	Boulder armored riffle, RB riprap
2.842	Noted transition to larger woody vegetation (tree willows and cottonwoods) on valley floor and both banks
2.842- 2.927	Sand storage reach
2.927	Gravel-cobble riffle, major debris jam, RB riprap
2,927 – 2.955	RB erosion along tight bend, coarse material in toe, local supply of coarse gravels and cobbles
2.993	LB riprap
3.101	Coarse riffle and plug w/ cattails
3.101 – 3.314	Sand storage reach, alternate bars forming
3.257	Wood Canyon confluence
3.314 – 3.363	Coarse riffle plug w/ dense vegetation and a number of smaller drops
3.363 – 3.465	Sand storage reach, alternate bars forming
3.465	LB stable, vegetated w/ woody species to TOB
3.465 – 3.474	Coarse gravel cobble plug, cattails
3.501 – 3.512	Cobble-boulder riffle
3.578 – 3.593	Plunge pool at base of ACWHEP, grouted riprap banks
3.593 – 3.613	ACWHEP structure
3.677	Gulley confluence, RB
3.613 – 3.729	Reach backwatered by ACWHEP
3.75 – 3.779	Cobble riffle
3.779 – 3.825	Gravel-cobble pool
3.825 – 3.894	Sand filled pool
3.894	2-ft headcut, gravel cobble, root reinforced
3.966 – 4.076	Sand/gravel storage reach
4.15	Alternate Sand/gravel bars
4.236	Old riprap RB
4.334	Gulley confluence, LB
4.522	Riprap LB
4.625	Old riprap LB
4.834	Riprap in bed, plug
4.834 – 4.864	Sand storage reach, huge sand/gravel bar
4.867	Sulphur Creek confluence
4.867 – 4.931	Clay outcrops in bed
4.95	Coarse gravel riffle
5.012	4-ft concrete sill
5.012	Engineered channel
5.02	AWMA Road Bridge
5.131	5-ft riprap grade control
5.199	10-ft concrete drop structure
5.271	Aliso Creek Road Bridge
5.467	10-ft concrete drop structure
5.794	Riprap RB
5.866 – 5.919	Coarse gravel riffle, plug, cattails
5.919 – 5.975	Sand storage reach
5.975 – 6.022	Sheet pile RB

River Mile[1]	Feature
6.022	Clay outcrop in bed
6.045	Boulder grade control structure
6.119 – 6.152	Clay outcrop in bed
6.168	Clay bench on left bank
6.181	Fat clay in bed
6.234	3-ft riprap grade control structure
6.271	8-ft riprap drop at water line crossing
6.305 – 6.377	Dumped riprap bank protection
6.588	Pacific Park Drive Culverts
6.978	SR-73 Tollway
7.322	Tributary confluence, RB
7.616	Pedestrian bridge & grade control

[1] measured upstream from the confluence with the Pacific Ocean at RM=0.
RB = right bank LB=left bank TOB=top of bank



River Mile[1]	Description
1.543	Coarse cobble riffle
1.593	Vegetated cobble riffle
1.593 - 1.625	Cobble bed material
1.789	U/S end of vegetated gravel bar & plug
2.013	Cobble-boulder riffle w/ cattails
2.056 - 2.064	Plug - coarse at bottom and top, soft in middle
2.118	Coarse riffle and plug
2.16	Coarse boulder riffle and plug
2.218	Coarse gravel plug with cattails
2.243	Coarse gravel-cobble bar
2.509	Gravel-cobble plug
2.53	Cobble-boulder bed - local grade control
2.796	Coarse plug
2.842	Boulder armored riffle, RB riprap
2.927	Gravel-cobble riffle, major debris jam, RB riprap
3.101	Coarse riffle and plug w/ cattails
3.314 - 3.363	Coarse riffle plug w/ dense vegetation and a number of smaller drops
3.465 - 3.474	Coarse gravel cobble plug, cattails
3.501 - 3.512	Cobble-boulder riffle
3.75 - 3.779	Cobble riffle
3.894	2-ft headcut, gravel cobble, root reinforced
4.95	Coarse gravel riffle
5.866 - 5.919	Coarse gravel riffle, plug, cattails

[1] *measured upstream from the confluence with the Pacific Ocean at RM=0.*
RB = right bank LB=left bank TOB=top of bank

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ORANGE COUNTY, CALIFORNIA

FIGURE 3 - 15
Spatial Distribution of Plugs and Coarse Riffles

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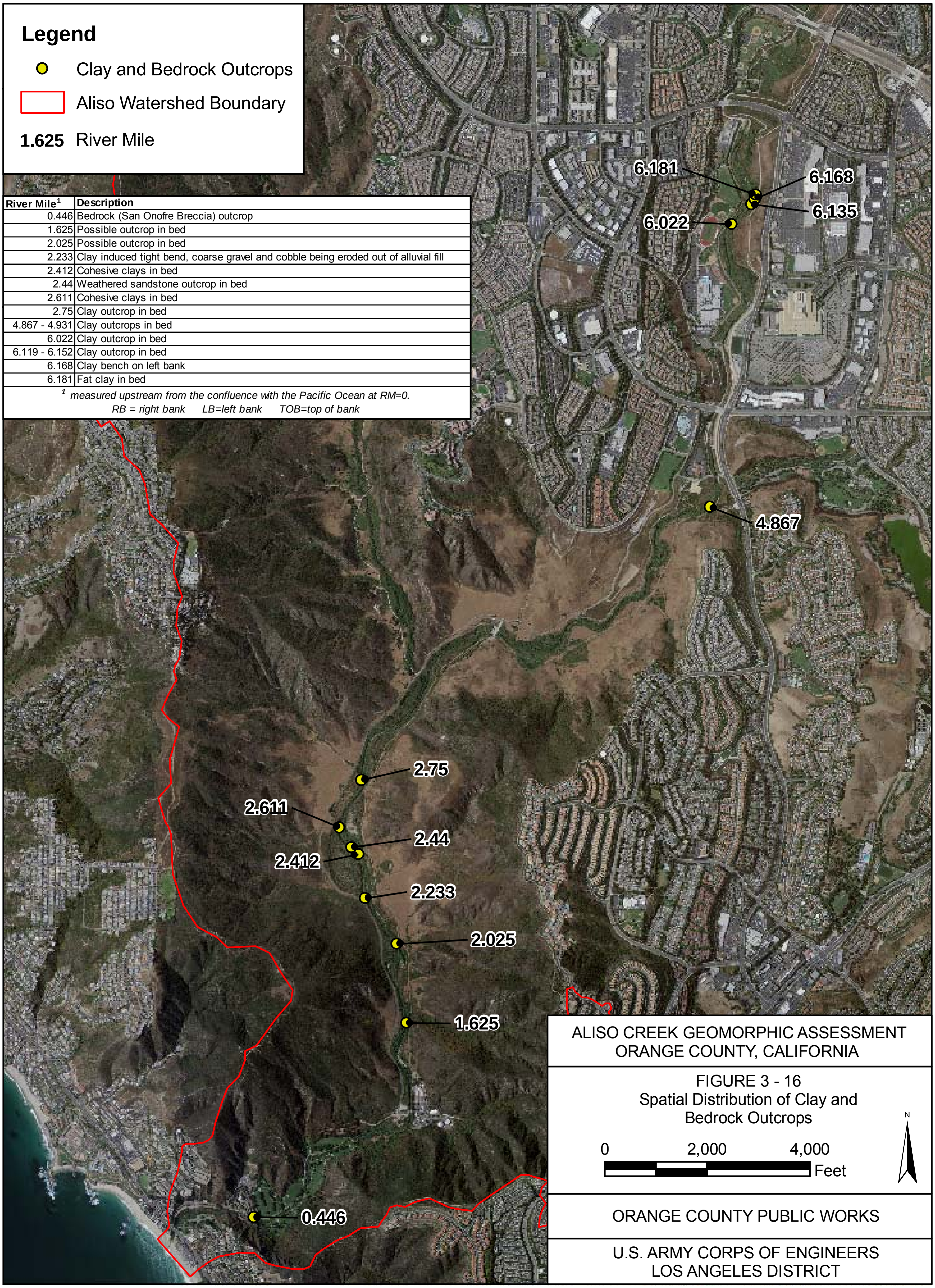

River Mile[1]	Description
0.446	Bedrock (San Onofre Breccia) outcrop
1.625	Possible outcrop in bed
2.025	Possible outcrop in bed
2.233	Clay induced tight bend, coarse gravel and cobble being eroded out of alluvial fill
2.412	Cohesive clays in bed
2.44	Weathered sandstone outcrop in bed
2.611	Cohesive clays in bed
2.75	Clay outcrop in bed
4.867 - 4.931	Clay outcrops in bed
6.022	Clay outcrop in bed
6.119 - 6.152	Clay outcrop in bed
6.168	Clay bench on left bank
6.181	Fat clay in bed

[1] measured upstream from the confluence with the Pacific Ocean at RM=0.
RB = right bank LB=left bank TOB=top of bank

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FIGURE 3 - 16
Spatial Distribution of Clay and Bedrock Outcrops

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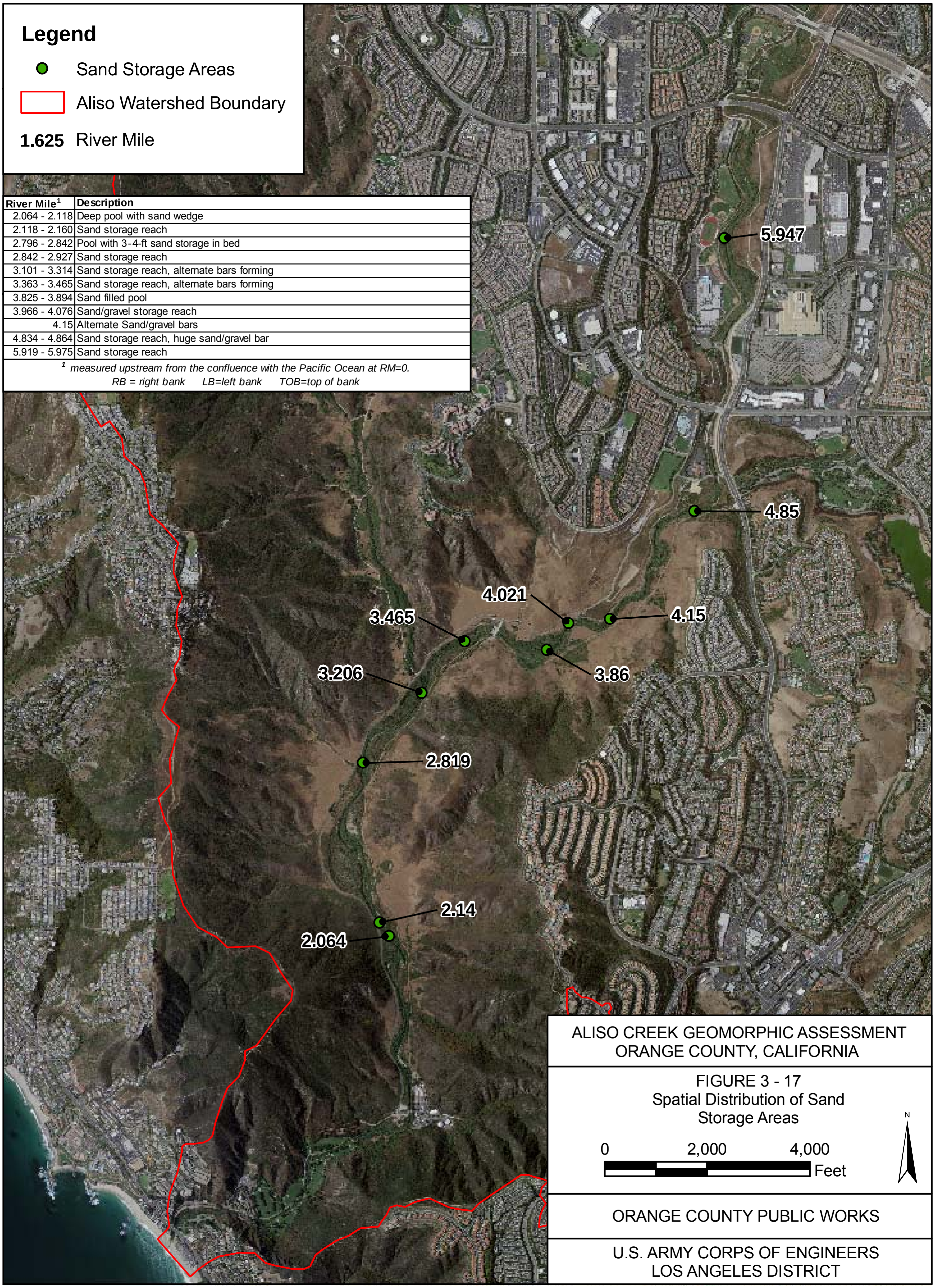

River Mile[1]	Description
2.064 - 2.118	Deep pool with sand wedge
2.118 - 2.160	Sand storage reach
2.796 - 2.842	Pool with 3-4-ft sand storage in bed
2.842 - 2.927	Sand storage reach
3.101 - 3.314	Sand storage reach, alternate bars forming
3.363 - 3.465	Sand storage reach, alternate bars forming
3.825 - 3.894	Sand filled pool
3.966 - 4.076	Sand/gravel storage reach
4.15	Alternate Sand/gravel bars
4.834 - 4.864	Sand storage reach, huge sand/gravel bar
5.919 - 5.975	Sand storage reach

[1] measured upstream from the confluence with the Pacific Ocean at RM=0.
RB = right bank LB=left bank TOB=top of bank

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FIGURE 3 - 17
Spatial Distribution of Sand Storage Areas

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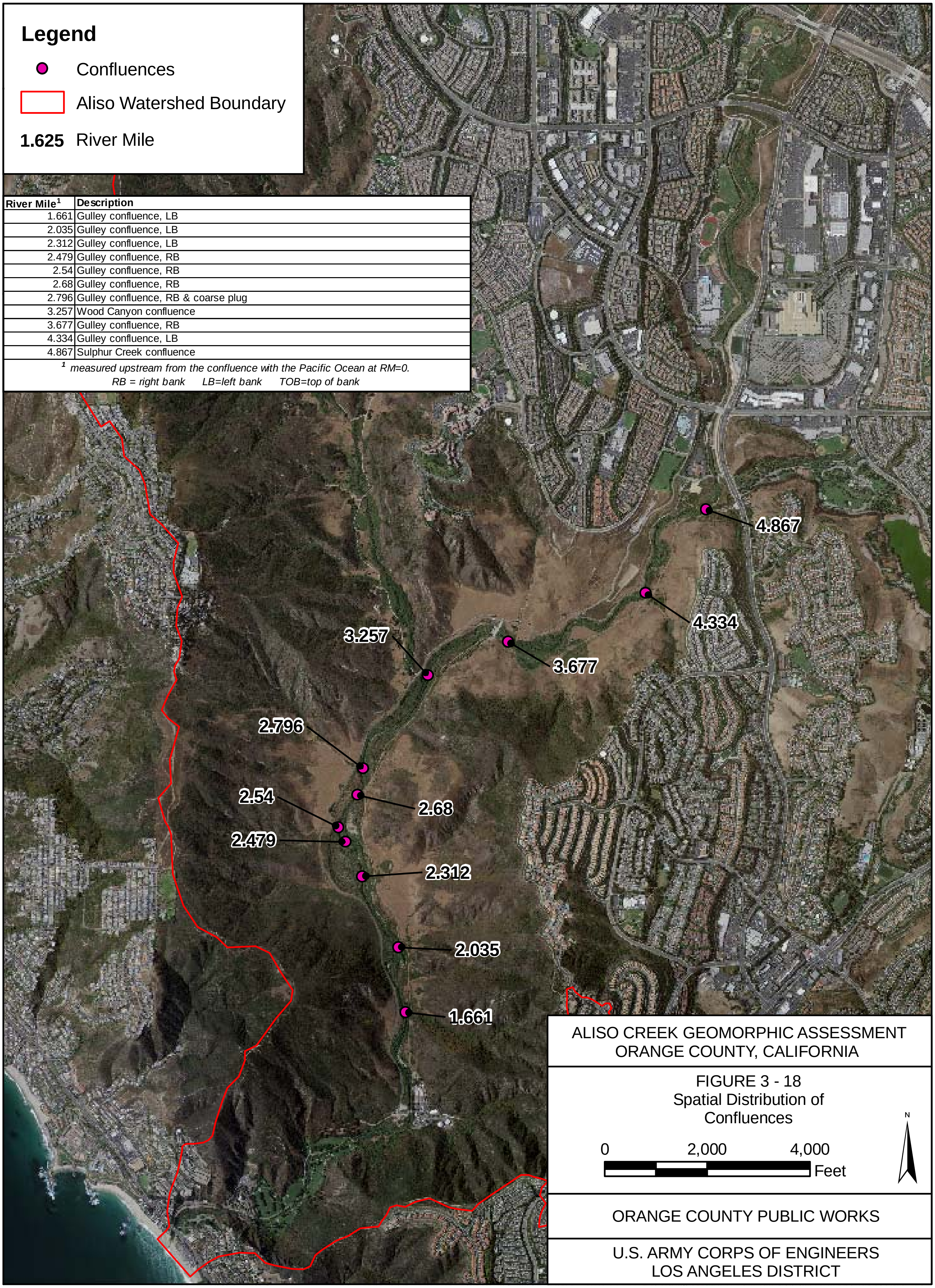

River Mile[1]	Description
1.661	Gulley confluence, LB
2.035	Gulley confluence, LB
2.312	Gulley confluence, LB
2.479	Gulley confluence, RB
2.54	Gulley confluence, RB
2.68	Gulley confluence, RB
2.796	Gulley confluence, RB & coarse plug
3.257	Wood Canyon confluence
3.677	Gulley confluence, RB
4.334	Gulley confluence, LB
4.867	Sulphur Creek confluence

[1] measured upstream from the confluence with the Pacific Ocean at RM=0.

RB = right bank LB=left bank TOB=top of bank

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FIGURE 3 - 18
Spatial Distribution of Confluences

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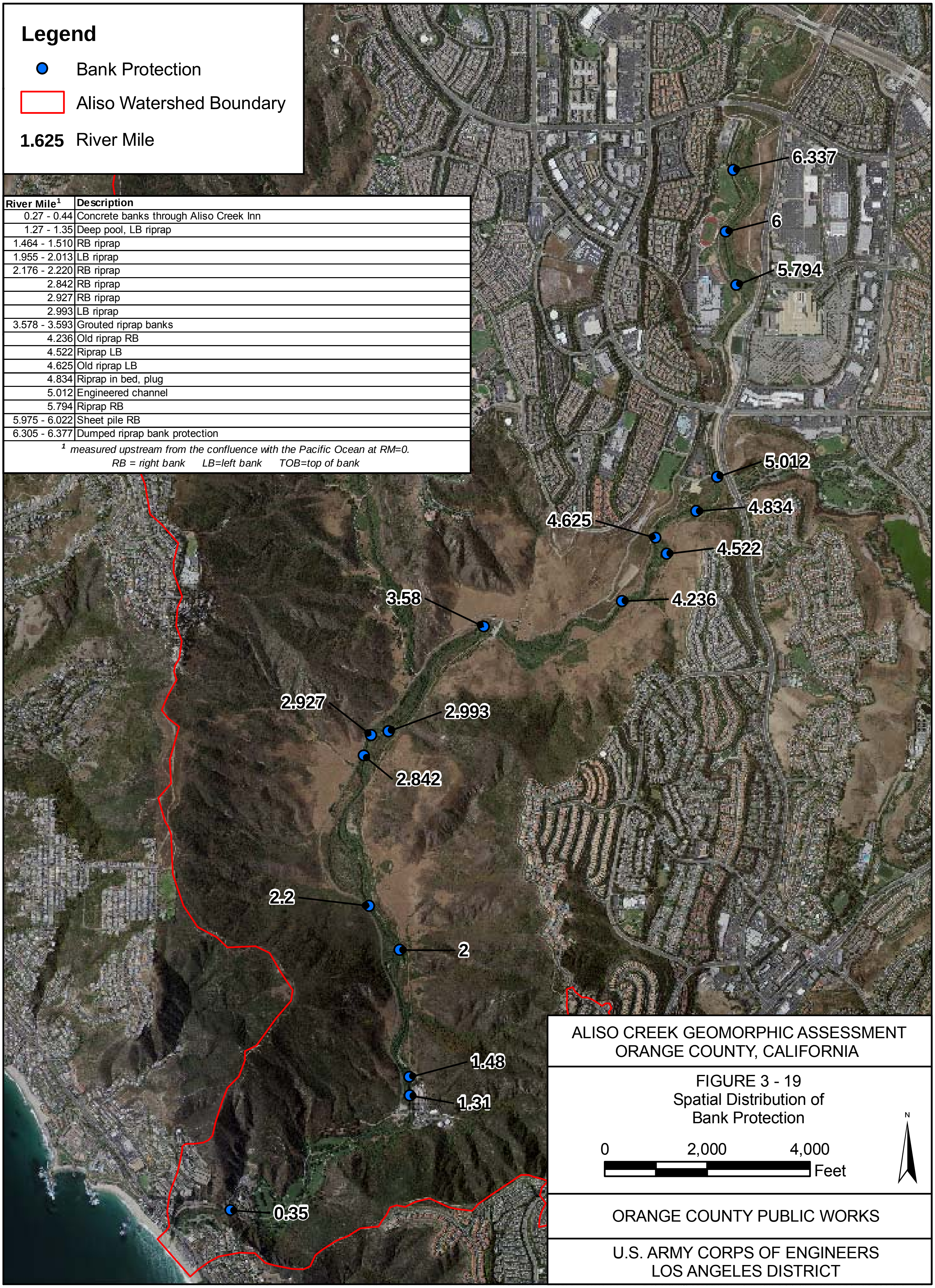

River Mile[1]	Description
0.27 - 0.44	Concrete banks through Aliso Creek Inn
1.27 - 1.35	Deep pool, LB riprap
1.464 - 1.510	RB riprap
1.955 - 2.013	LB riprap
2.176 - 2.220	RB riprap
2.842	RB riprap
2.927	RB riprap
2.993	LB riprap
3.578 - 3.593	Grouted riprap banks
4.236	Old riprap RB
4.522	Riprap LB
4.625	Old riprap LB
4.834	Riprap in bed, plug
5.012	Engineered channel
5.794	Riprap RB
5.975 - 6.022	Sheet pile RB
6.305 - 6.377	Dumped riprap bank protection

[1] *measured upstream from the confluence with the Pacific Ocean at RM=0.*
RB = right bank LB=left bank TOB=top of bank

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FIGURE 3 - 19
Spatial Distribution of
Bank Protection

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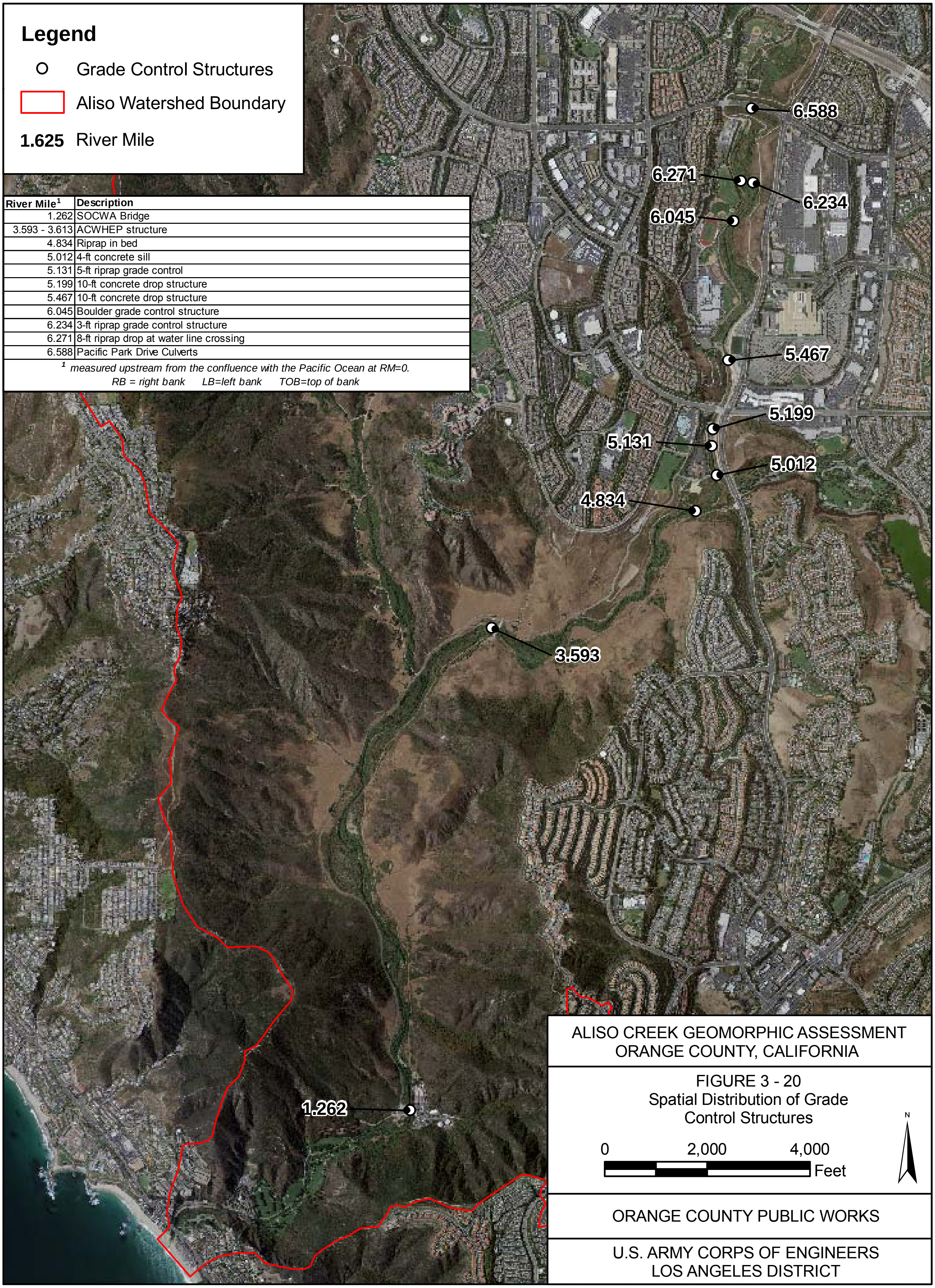

River Mile[1]	Description
1.262	SOCWA Bridge
3.593 - 3.613	ACWHEP structure
4.834	Riprap in bed
5.012	4-ft concrete sill
5.131	5-ft riprap grade control
5.199	10-ft concrete drop structure
5.467	10-ft concrete drop structure
6.045	Boulder grade control structure
6.234	3-ft riprap grade control structure
6.271	8-ft riprap drop at water line crossing
6.588	Pacific Park Drive Culverts

[1] *measured upstream from the confluence with the Pacific Ocean at RM=0.*
RB = right bank LB=left bank TOB=top of bank

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FIGURE 3 - 20
Spatial Distribution of Grade Control Structures

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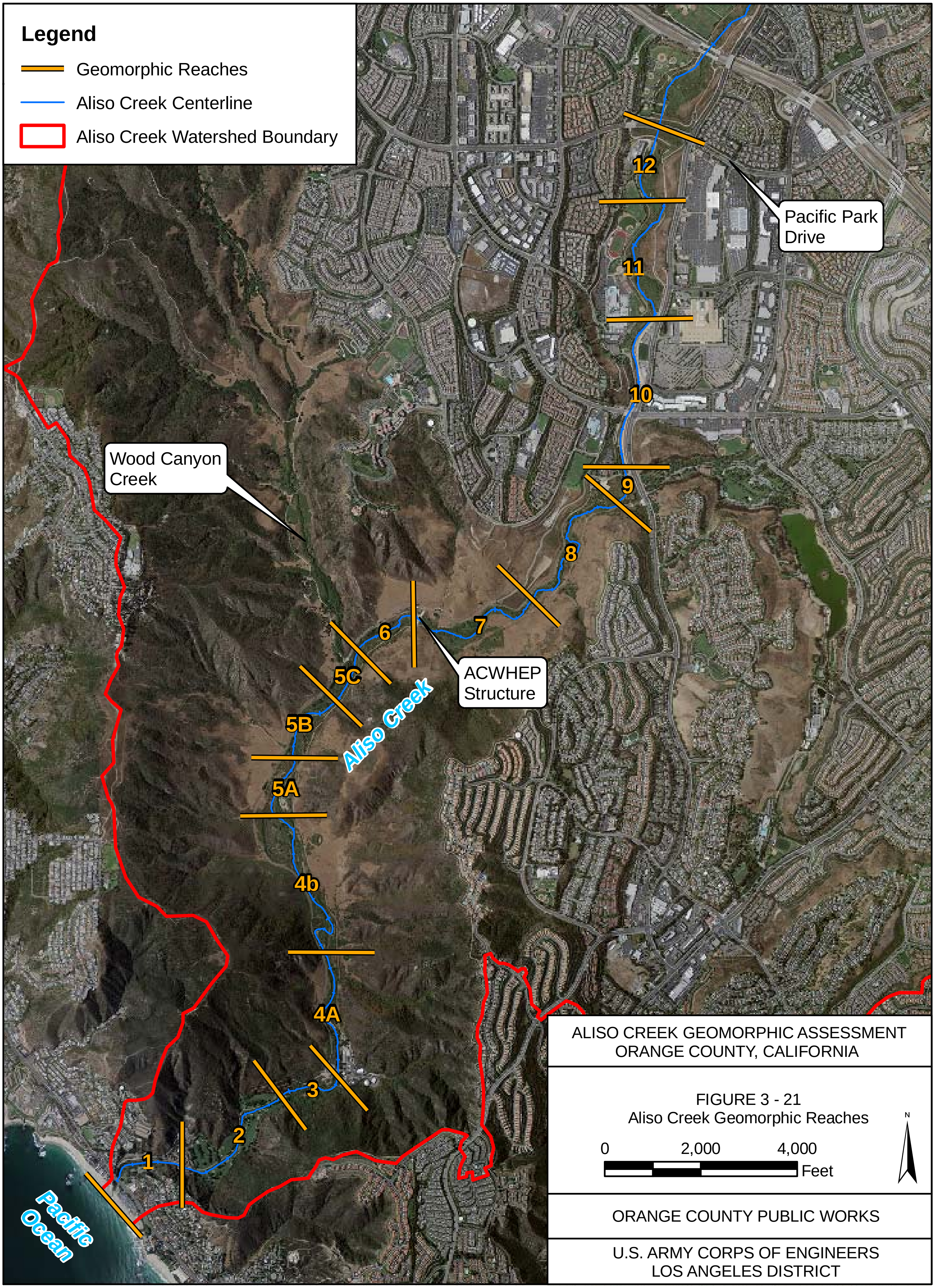
3.2.4 Geomorphic Reaches

As a component of the sedimentation analyses described in the H&H Appendix to the Aliso Creek Mainstem Ecosystem Restoration Study (USACE 2009), Aliso Creek was divided into 13 reaches between the Pacific Ocean and Pacific Park Drive (hereafter referred to as the Revised H&H Appendix Reaches). The objective of these subdivisions was to create reaches, each with similar hydraulic conditions within itself, to adequately represent geomorphic conditions. Hydraulic and bed controls (e.g., bridges, drop structures, culverts) and hydraulic parameters (e.g., top width and depth) were weighed heavily in the reach delineations. During the walk along Aliso Creek in October 2009, observations were made of geomorphic features to evaluate the reasonableness of the Revised H&H Appendix Reach delineations. Subsequent adjustments to the Revised H&H Appendix Reach delineations were made to better represent geomorphic conditions. The updated delineations closely follow Revised H&H Appendix Reaches. The primary difference in the new reaches is the further subdivision downstream of the ACWHEP structure. Figure 3-21 illustrates the updated geomorphic reaches; Table 3-4 provides the downstream and upstream extents of each reach. The following paragraphs summarize conditions within the geomorphic reaches. The class of channel evolution for the November 2009 conditions is assigned based on the six-class Incised Channel Evolution Model (ICEM) developed by Schumm, et al (1984) and subsequently modified by Harvey and Watson (1986).

Table 3-4. Geomorphic Reaches

Reach Number	Downstream Station[1]	Upstream Station[1]
1	0.118	0.415
2	0.480	0.976
3	1.032	1.249
4A	1.274	1.789
4B	1.817	2.434
5A	2.456	2.736
5B	2.753	3.095
5C	3.110	3.314
6	3.335	3.580
7	3.677	4.199
8	4.266	4.854
9	4.916	4.984
10	5.051	5.664
11	5.728	6.234
12	6.291	6.532

[1] *measured in river miles upstream from the confluence with the Pacific Ocean.*


Legend
Geomorphic Reaches
Aliso Creek Centerline
Aliso Creek Watershed Boundary
Pacific Park Drive
Wood Canyon Creek
ACWHEP Structure
Aliso Creek
Pacific Ocean
12
11
10
9
8
7
6
5C
5B
5A
4b
4A
3
2
1
ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA
FIGURE 3 - 21
Aliso Creek Geomorphic Reaches
0 2,000 4,000
Feet
N
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Reach 1 - Downstream of the Pacific Coast Highway, Aliso Creek flows through Aliso Beach. Due to the influence of tides and waves, the channel is frequently blocked by littoral drift (Figure 3-22). The downstream limit of Reach 1 was therefore set to the Pacific Coast Highway (PCH) Bridge (Figure 3-23). The upstream extent was set to the exposed outcrop of San Onofre Breccia between the Aliso Creek Inn and the golf course (Figure 3-24). The total length of Reach 1 is 1,570 feet. Aliso Creek flows in an improved earthen channel upstream of the PCH (Figure 3-25); through the Aliso Creek Inn property the side slopes are lined with concrete (Figure 3-26). There is one bridge crossing associated with the Aliso Creek Inn. Bank heights range from approximately 10 to 15 feet. The bed was obscured by backwater from the blocked channel outlet during recent field investigations. The bottom width of the channel ranges from 25 to 65 feet, with an average of 50 feet. The slope of the channel when the outlet is blocked is 0.12 percent (0.0012 feet / foot), no information is available for conditions when the outlet is free-flowing. Because the man-made and geologic controls in this reach limit the ability of the channel to self-adjust, the ICEM does not apply.

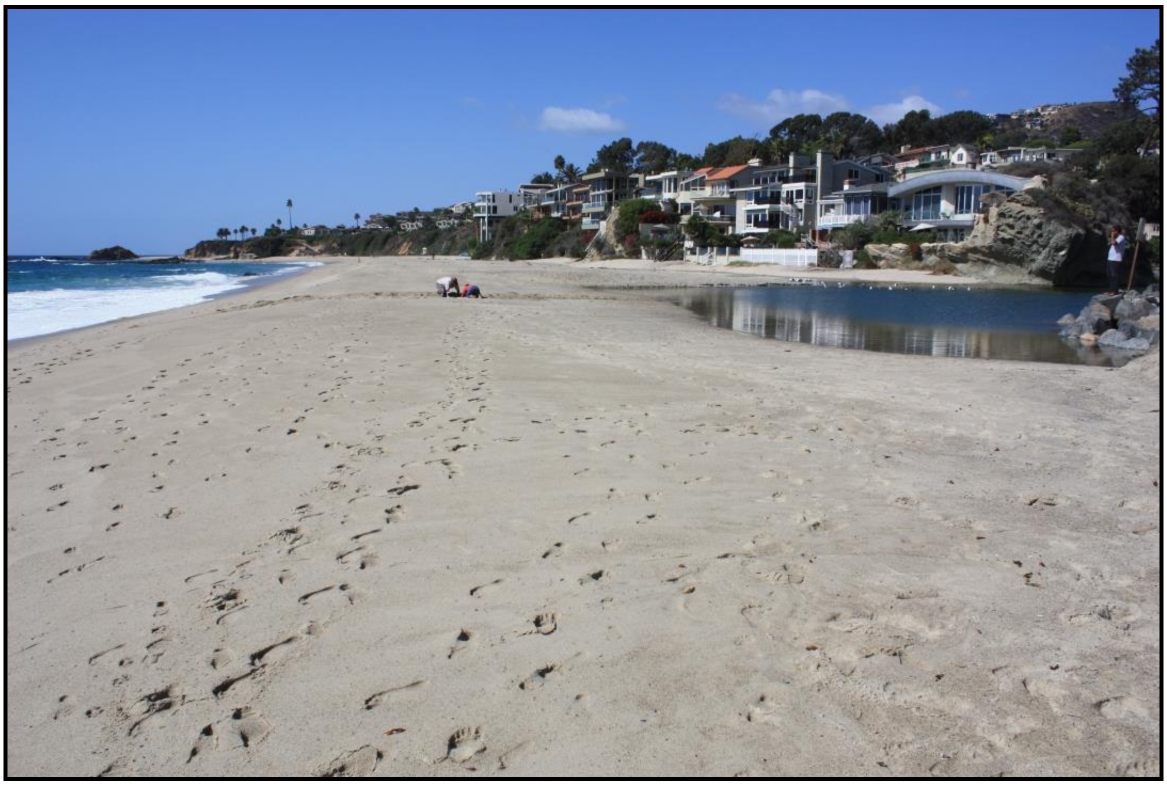


Figure 3-22. Aliso Creek outlet blocked by littoral drift at Aliso Beach

Figure 3-23. Upstream-facing view of PCH crossing of Aliso Creek

Figure 3-24. Exposed San Onofre Breccia outcrop between Aliso Creek Inn and Aliso Creek Golf Course

Figure 3-25. Upstream-facing view of Aliso Creek upstream of the PCH crossing

Figure 3-26. Downstream-facing view of Aliso Creek through the Aliso Creek Inn

Reach 2 - The Aliso Creek Golf Course is contained entirely within Reach 2, from the exposed San Onofre Breccia outcrop at the downstream end to the transition to the natural area at the upstream end. The 2,620 feet of channel through the golf course is maintained: for example, riprap lines some of the banks and the vegetation is trimmed in places (Figure 3-27). The overbank areas contain the managed turf for the golf course. One bridge for the Aliso Creek Inn is located in this reach as are four pedestrian bridges for the golf course. Few signs of instability were noted during the field investigations. As with Reach 1, the bank heights in Reach 2 range from 10 to 15 feet. Gravel bars were observed in the bed through Reach 2. The bed slope is 0.35 percent (0.0035 feet / foot). Bottom widths range from 10 to 50 feet, with an average of 25 feet. This reach is channelized and the banks are lined with riprap, and therefore the channel morphology could be represented as the early stages of Class II in the ICEM; however, the riprap inhibits the ability of the channel to self-adjust, so the ICEM is not applicable.

Figure 3-27. Aliso Creek through the Aliso Creek Golf Course

Reach 3 - The 1,150 feet of channel through the natural area between the Aliso Creek Golf Course and the South Orange County Water Authority (SOCWA) treatment plant bridge makes up Reach 3. This reach is located in a narrow portion of the canyon that separates the Aliso and Wood Canyons Wilderness Park from the Aliso Creek Golf Course. The channel through this reach is not maintained like the channel in Reach 2 (Figure 3-28). The overbanks are well vegetated, and an unpaved road follows the right overbank and connects AWMA Road to the golf course. The SOCWA plant discharges treated effluent through a 36-inch concrete pipe that extends underground through Reaches 1 and 2 to an outfall in the ocean. A concrete sill at the SOCWA Bridge provides stable grade control that defines the upper limit of Reach 3 (Figure 3-29). Bank heights in Reach 3 are fairly consistent, with a typical height of nine feet. This reach was not walked during the field investigations, so information regarding bank instabilities and bed material is not available. The average bed slope is 0.46 percent (0.0046 feet / foot). Bottom widths range from 23 to 60 feet, with an average of 50 feet. This reach is in Class VI of the ICEM.

Figure 3-28. Downstream view of Aliso Creek downstream of SOCWA bridge crossing

Figure 3-29. SOCWA bridge grade control and concrete sill

Reach 4A - This 2,720-foot long reach extends from the SOCWA bridge to the gravel plug at the downstream end of the S-bend. Older riprap bank protection was observed along this reach to protect the AWMA Road along the right overbank and sanitary sewer pipes in the left overbank. A few natural grade controls were observed in this reach (e.g., coarse gravel and cobble plugs/riffles and an outcrop of bedrock). Sandy bed material was noted within this reach, primarily in the pools upstream of the coarse gravel and cobble plugs (Figure 3-30). Bank heights in Reach 4A range from 8 to 20 feet (Figure 3-31). The average bed slope in Reach 4A is 0.30 percent (0.0030 feet / foot). The average bottom width is 22 feet, ranging between 8 and 46 feet. This reach is in Class V of the ICEM where the channel is vertically stable but some additional localized erosion and slumping of geotechnically unstable banks can be expected.

Figure 3-30. Example of pool located upstream of coarse gravel plug in Reach 4A

Figure 3-31. Left bank within Reach 4A

Reach 4B - The 3,260 feet of Aliso Creek between the downstream end of the S-bend (Figure 3-32) and the weathered sandstone and clay outcrop near the upstream end of the abandoned oxbow (Figure 3-33) make up Reach 4B. Two notable geomorphic features include the S-bend and the abandoned oxbow. Due to the influence of historical landslides and associated deposition of clays, the degradation of the channel through this reach has exposed numerous coarse gravel and cobble plugs as well as clay and sandstone outcrops. The presence of these relatively erosion resistant materials has allowed for the persistence of the S-bend and the currently abandoned oxbow. While sandy bed deposits were observed in this reach, coarser gravels and cobbles along with clay outcrops control the bed profile. Bank heights in Reach 4B are around 15 feet up to the downstream end of the abandoned oxbow, where a noticeable increase to approximately 20 feet occurs. Bank materials are composed of valley fill, and ample supplies of gravels and cobble were observed in the fill material (Figure 3-34). The average bed slope in Reach 4B is 0.35 percent (0.0035 feet / foot). The average bottom width is 17 feet, ranging between 5 and 40 feet. This reach is in Class V of the ICEM where the bed is vertically stable but some additional localized erosion and slumping of geotechnically unstable banks can be expected.

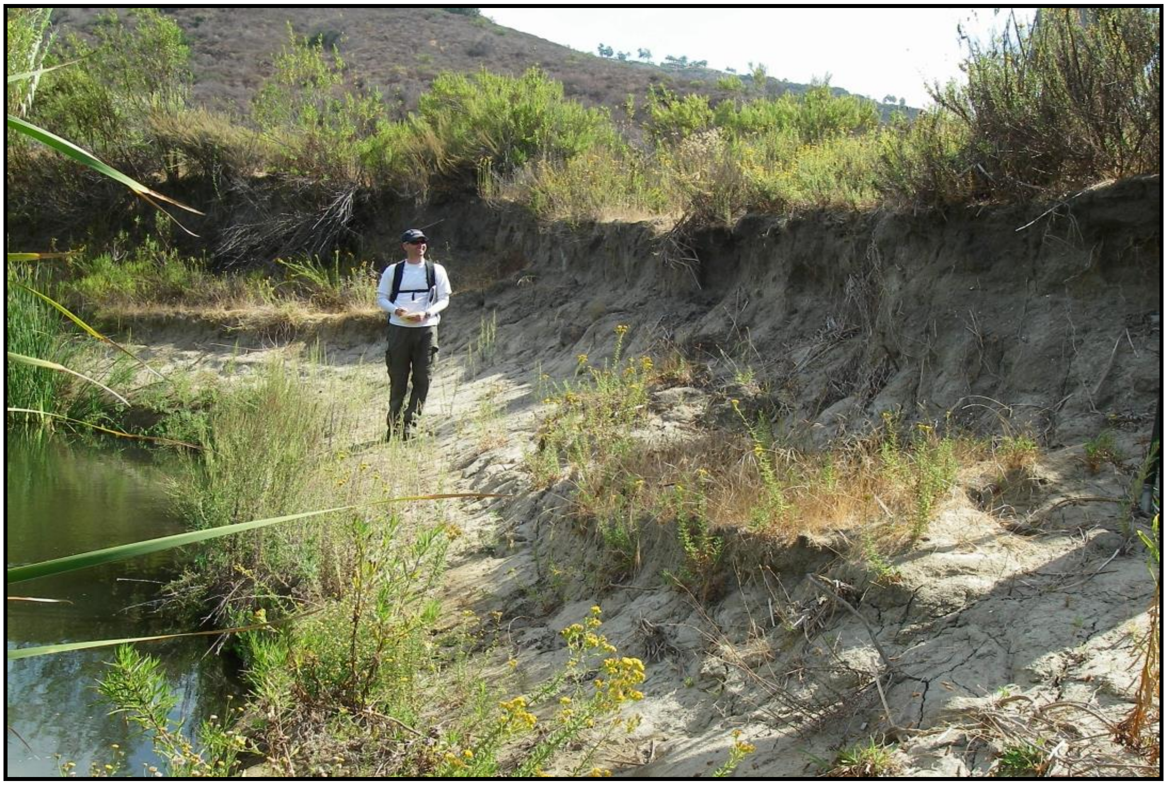


Figure 3-32. Upstream view of clay in left bank of S-bend

Figure 3-33. Exposed sandstone near the upstream end of the abandoned oxbow

Figure 3-34. Cobbles excavated from the valley fill due to bank erosion

Reach 5A - Approximately 1,480 feet upstream of the weathered sandstone at the upper extent of Reach 4B, a major clay outcrop was observed in the bed and lower banks of Aliso Creek (Figure 3-35). This clay outcrop marks the upstream end of the newly-delineated Reach 5A. Since the clay was also observed in the lower few feet of the banks, it indicates that incision into the clay is ongoing. While the clay is more erosion resistant than non-cohesive materials, it is still susceptible to erosive forces. The bank heights in this reach are typically between 20 and 25 feet. A paleosol (well-developed buried soil) overlain by 3 to 4 feet of post-settlement alluvium was observed in the right bank (Figure 3-36). As with Reach 4B, the bank materials were composed of valley fill. The bed material through this reach was dominated by coarse gravels and cobbles, although just downstream from the clay outcrop at the upper end of the reach, a wedge of sand had filled in part of the coarse bedded pool (Figure 3-37). The average bed slope in Reach 4B is 0.30 percent (0.0030 feet / foot). The bottom width ranges from 11 to 45 feet, with an average of 34 feet. This reach is in Class IV approaching Class V of the ICEM where there could be some further degradation into the clay-rich material in the bed and there is likely to be on-going channel widening.

Figure 3-35. Major clay outcrop marking the upstream extent of Reach 5A

Figure 3-36. Typical right bank profile, note the presence of the darker paleosol

Figure 3-37. Sand wedge migrating into a pool at the upper end of Reach 5A

Reach 5B - This reach extends for approximately 1,810 feet upstream from the clay outcrop at the upper end of Reach 5A. This reach is incised, and other than a moderate bend in the middle of the reach, it is fairly straight and densely vegetated (Figure 3-38). Riprap has been placed on the banks in places to protect AWMA Road and the buried infrastructure, specifically along the previously noted bend. A large debris jam was observed in the bend, and the jam was formed primarily of small woody debris, arundo, and trash. A few coarse gravel, cobble, and boulder plugs/riffles were encountered; the most upstream plug marks the upper extent of Reach 5B. This is also approximately the location where the bedrock mapped in boring DYB-7 is at the elevation of the existing thalweg (DYA 2009). The bedrock is a geologic grade control that provides a stable transition from Reach 5B to Reach 5C. The bank heights in this reach are typically 20 to 25 feet. As with Reach 4B, the bank materials were composed of valley fill. Figure 3-39 shows the downstream extent of the reach as seen from the top of the right bank. The bed material in this reach was dominated by sands and fine gravels, with the grade of the reach being maintained by the regularly-spaced plugs/riffles. The average bed slope in Reach 4B is 0.46 percent (0.0046 feet / foot). The bottom width ranges from 8 to 60 feet, with an average of 23 feet. This reach is in Class V to VI of the ICEM where the bed is vertically stable, the channel width has reached a new dynamic equilibrium, but some further localized slumping and failures of geotechnically unstable banks, particularly where the active channel impinges on the toe of the terrace, can be expected.

Figure 3-38. Upstream view of dense vegetation in reach 5B

Figure 3-39. Downstream extent of Reach 5B as seen from the right top of bank

Reach 5C - The most notable feature of reach 5C is the abundance of sand stored in the bed of the channel. Alternate bars were observed throughout the reach (Figure 3-40), and probes were inserted in the sand to a depth of approximately five feet. This reach is approximately 1,080 feet long. The coarse plug at the downstream end overlies bedrock mapped at the elevation of the thalweg. These features control the grade of the reach, causing the observed deposition of sand. It is notable that the confluence with Wood Canyon Creek occurs in this reach. The average bed slope is 0.04 percent (0.0004 feet / foot) – the flattest within the study reach. The bank heights in this reach are typically 25 feet. As with Reach 4B, the bank materials are composed of valley fill. Despite the bank heights, the bank angles were less steep than downstream reaches, and more mature woody vegetation was established across the full floodplain (Figure 3-41). The bed material in this reach was dominated by sands and fine gravels (Figure 3-42). The bottom width ranges from 17 to 37 feet, with an average of 27 feet. This reach is in Class VI of the ICEM where the bed is vertically stable and further systematic channel widening is not expected. However, where the active channel impinges directly on the toe of the terrace, localized bank erosion can be expected to continue.

Figure 3-40. Alternate sand bars observed in Reach 5C

Figure 3-41. Woody vegetation established on left bank of Reach 5C

Figure 3-42. Ripples on the sand stored in the bed of Reach 5C

<u>*Reach 6 -*</u> This reach includes 1,300 feet between the upstream end of the sand storage area in Reach 5C and the toe of the ACWHEP structure. The ACWHEP structure is approximately 25 feet high and made of grouted riprap (Figure 3-43); originally it was constructed as a small diversion structure to divert flow for irrigation of floodplain vegetation. Multiple cobble-boulder riffles were seen in this reach, and riprap, likely displaced from the ACWHEP structure, was observed at various locations in the bed (Figure 3-44). The average bed slope of 0.55 percent (0.0055 feet / foot) is the highest downstream of the ACWHEP structure. The bank heights in this reach are between 25 and 30 feet. Valley fill is the primary component of the bank materials. In places the banks were nearly vertical (Figure 3-45), and some riprap was observed on the left bank to protect the sewer pipelines. The grade of the bed was checked by coarse riffles, so despite the presence of sands and fine gravels in the bed, the slope of the channel is controlled by the cobbles and boulders. The bottom width ranges from 16 to 26 feet, with an average of 23 feet. It is notable that the scoured area downstream of the structure is approximately 175 feet wide. This reach is in Class V of the ICEM where the bed elevation is controlled by coarse materials introduced to the channel at the ACWHEP diversion structure. The banks are generally vegetated and appear to have stabilized except in the immediate vicinity of the drop structure, where flood flows are directed at the geotechnically unstable banks.

Figure 3-43. Upstream view of the ACWHEP structure at the upstream end of Reach 6

Figure 3-44. Boulder riffle in Reach 6

Figure 3-45. Eroded right bank below the ACWHEP structure

Reach 7 - The ACWHEP structure provides substantial influence on the morphology of Aliso Creek, both downstream and upstream of the structure. Reach 7 extends from the sill of the structure to a point 2,750 feet upstream that marks an increase in bank height. Since the sill of the structure was initially constructed a few feet above the bed to divert flow for irrigation, Reach 7 has served as a sediment sink, storing bed material transported from the upstream watershed (Figure 3-46). Figure 3-47 shows the configuration of the sill looking toward the left bank. Consequently, bank heights in Reach 7 are relatively low (around four feet at the downstream end, up to 10 feet at the upstream end, with a transition to 15 feet at the upper extent of the reach) and incision is not as pronounced as in other parts of the project reach. Bank materials are composed of alluvial sands and gravels at the downstream end of the reach, transitioning to valley fill where the channel is more incised at the upstream end. The bed material is primarily depositional sands and fine gravels as seen in Figure 3-48, although coarse gravel and cobble plugs and cobble riffles were observed (Figure 3-49). The average bed slope through Reach 7 is 0.25 percent (0.0025 feet / foot). It is noteworthy that Reach 7 exhibits some sinuosity – the value of 1.2 is relatively high compared to other reaches in the study area. The bottom width ranges from 12 to 37 feet, with an average of 20 feet. This reach is in Class VI of the ICEM where the channel is both vertically and laterally stable.

Figure 3-46. Upstream view of Reach 7 from the ACWHEP structure sill

Figure 3-47. View across ACWHEP sill toward the left bank

Figure 3-48. Low, vegetated banks typical of Reach 7

Figure 3-49. Cobble riffle observed in Reach 7

Reach 8 - The confluence of Sulphur Creek marks the upstream extent of Reach 8. This 3,110-foot long reach is similar to Reach 7, except that the bank heights are noticeably greater. At the downstream end of the reach, the bank height is approximately 15 feet (Figure 3-50), increasing to over 30 feet at the upstream end (Figure 3-51). The bank materials are composed of valley fill, and in the immediate vicinity of Sulphur Creek, the bank materials reflect the incision through the historical alluvial fan at the mouth of the creek. A thick clay layer was noted in the toe of the banks near the Sulphur Creek confluence (Figure 3-52). A large sand and gravel bar exists at, and downstream of, the confluence of the two creeks. The bed morphology of Reach 8 reflects the regular series of coarse gravel and cobble plugs between long sand storage reaches. The bed material switches between gravels and cobbles in the plugs and sands and fine gravels in the intervening pools. The average bed slope through Reach 8 is 0.27 percent (0.0027 feet / foot), nearly matching the average slope of Reach 7. Reach 8 exhibits some sinuosity – the value of 1.3 is the greatest in the studied reaches. The bottom width ranges from 10 to 28 feet, with an average of 19 feet. This reach is in Class V of the ICEM where the channel is vertically stable but further channel widening can be expected as a result of both systematic and local factors.

Figure 3-50. Typical 15-foot bank height at the downstream end of Reach 8

Figure 3-51. Typical 30-foot bank due to incision into the historical Sulphur Creek alluvial fan

Figure 3-52. Clay layer observed in the toe of the bank near the Sulphur Creek confluence

Reach 9 - The 360-foot length of Reach 9 is the shortest of the geomorphic reaches because it represents the transition from the confluence with Sulphur Creek to the downstream end of the engineered channel that terminates at the AWMA Road bridge crossing (Figure 3-53). Due to the location of Sulphur Creek, flows in Reach 9 differ appreciably from flows in Reach 8, and the morphology of the channel is very different from the engineered shape typical of Reach 10. The average bed slope in Reach 9 is 1.0 percent (0.01 feet / foot), and the bottom widths range from 8 to 18 feet, for an average of 12 feet. Despite the similar bank heights (i.e., 25 to 30 feet) and bank material compared to Reach 8, the greater slope and narrower bottom width of Reach 9 produce a coarser bed comprised primarily of gravels and cobbles (Figure 3-54). This reach is in Class V of the ICEM where the bed is vertically stable but further channel widening can be expected.

Figure 3-53. AWMA Road grade control at upstream end of Reach 9

Figure 3-54. Gravel bed material in Reach 9

Reach 10 - Aliso Creek through Reach 10 was realigned in 1969 to accommodate the construction of the Chet Holifield Federal Building. Reach 10 is 3,240 feet long, spanning the engineered channel from the AWMA Road Bridge to the start of the riprap banks across from the Laguna Niguel Skateboard and Soccer Park. This reach includes two 10-foot high concrete drop structures (Figure 3-55) that were installed in 1969 to control incision associated with the straightening of the channel. The bottom width is typically 40 feet, although it ranges between 25 and 60 feet. The side slopes along most of the reach have been laid back at a 2:1 slope and protected with riprap (Figure 3-56). Bank heights range between 10 and 15 feet. The average bed slope in Reach 10 is 1.0 percent (0.01 feet / foot), although this is misleading due to the controlled drops across the two concrete structures. The average slope of the bed between drop structures is 0.31 percent (0.0031 feet / foot). The bed materials are primarily sands and fine gravels. The engineered nature of this reach of the channel precludes meaningful assignment to one of the classes of the ICEM.

Figure 3-55. Concrete drop structure in Reach 10 (drop is 10 feet)

Figure 3-56. Engineered channel and riprap-protected banks typical of Reach 10

Reach 11 - This reach of Aliso Creek covers a distance of 2,670 feet between the upstream end of the engineered channel (Reach 10) and a grouted riprap grade-control structure where the Joint Regional Water Supply System pipelines cross the creek (Figure 3-57). Reach 11 is east of the Aliso Niguel High School, and an access road/bike path runs along the top of the east bank. Riprap was observed at various places along the bank (Figure 3-58), an in a more extreme case, a steel sheet pile wall was supporting the bank near the high school football stadium (Figure 3-59). Bank heights along the reach range from 10 to 20 feet. Outcrops of clay were observed in the bed and in the toe of the banks through this reach (Figure 3-60). A few knickpoints (discontinuities in the bed profile, similar in scale and form to a step) were observed with heights of one to two feet where the channel was incising through the clay layers in the bed of the channel. Coarse gravel plugs were also spaced along the reach, and sandy deposition was observed in the pools between plugs (Figure 3-61). The average bed slope is 0.38 percent (0.0038 feet / foot). Reach 11 exhibits sinuosity of 1.2 (ratio of the length along the flowline to the straight line length from the upstream to the downstream limit of the reach), making it one of the more sinuous reaches in the study area. This reach is in Class IV of the ICEM where further vertical incision and associated channel widening can be expected.

Figure 3-57. Grouted riprap grade control at crossing of water supply pipelines

Figure 3-58. Riprap protecting the access road at the top of the right bank

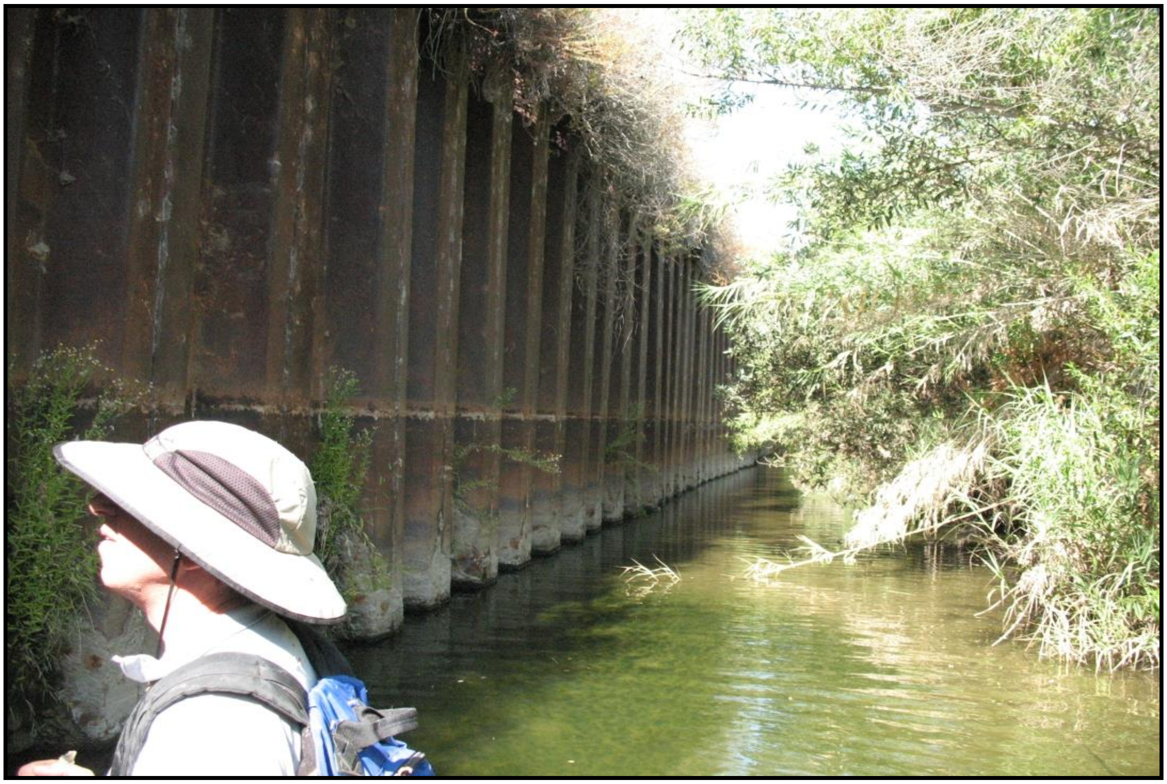


Figure 3-59. Upstream view of sheet pile wall along the right bank

Figure 3-60. Clay outcrop in the bed and bank toe in Reach 11

Figure 3-61. Downstream view of sand-bottom pool and cattail covered gravel plug

Reach 12 - The most upstream reach in the study area extends for a distance of 1,270 feet from the water supply pipeline crossing to the three 8-foot by 8-foot concrete box culverts under Pacific Park Drive (Figure 3-62). As with Reach 11, a bike path runs along the top of the right bank, and riprap has been placed at selected locations along the bank to protect the path; although, in places without riprap, scalloping was observed (Figure 3-63). Approximately 250 feet of the channel immediately below the culvert outlets have been engineered and the banks lined with riprap. Bank heights in this reach are no greater than 10 feet, and the bank materials are composed of valley fill. More coarse gravel plugs were observed in this reach, and a channel spanning gravel bar was observed at the transition from the engineered channel below the culvert outlets to the natural channel (Figure 3-64). Sands and fine gravels were observed in the bed between the coarser controls. The average bed slope in Reach 12 is 0.51 percent. Bottom widths range between 27 and 55 feet. This reach is in Class VI of the ICEM where both the bed and banks are stable.

Figure 3-62. Upstream view of three 8-ft x 8-ft concrete box culverts under Pacific Park Drive

Figure 3-63. Riprap bank protection and bank scalloping between riprap protection

Figure 3-64. Gravel bar below Pacific Park Drive culverts

4.0 HYDRAULICS

The hydraulic model developed for the revised H&H Appendix (USACE 2009) was calibrated to better quantify hydraulic conditions in the study reach for flood flows ranging from the 1.1-year to the 100-year recurrence interval flood. The hydraulic model was developed using the U.S. Army Corps of Engineers one-dimensional HEC-RAS step-backwater software, Version 4.0.0 (USACE 2008).

4.1 HYDRAULIC MODEL REFINEMENT

The development of the hydraulic model is described in the H&H Appendix (USACE 2000), and the revisions that account for the new topographic survey data are described in the 2009 H&H Appendix. A few significant changes were made to the HEC-RAS model revised for the H&H Appendix to improve the representation of hydraulic conditions. The first change was the use of the actual bank-to-bank cross section survey data collected by Orange County in 2006 between the SOCWA Bridge and the ACWHEP structure. The previous version of the model used geometry derived from a digital terrain model (DTM) created from the survey data. To minimize loss of resolution due to data transformation, the actual survey data were used instead. The primary difference this made to the model is an increase in the number of cross section between the SOCWA Bridge and the ACWHEP structure from 34 to 108. The second change was an update of the geometry of the sill and abutments at the SOCWA Bridge. When the USACE rehabilitated the bridge between October 2008 and July 2009, the geometry of the rehabilitated bridge needed to be reflected in the model. The elevation of the concrete sill that runs across the channel under the bridge is higher than the elevation of the previous sill. Since this sill acts as a grade control, it was important to update the geometry. The final changes were the insertion of additional cross sections on the upstream and downstream side of major drop structures (e.g., the 10-foot concrete drops and the ACWHEP structure). These sections were added to improve the representation of hydraulic conditions near the structures and to improve the representation of the structures when plotted in the longitudinal profiles.

4.2 HYDRAULIC MODEL CALIBRATION

The model developed for the Revised H&H Appendix was not calibrated to any specific flows in Aliso Creek because no calibration datasets were available. During the October 2009 reconnaissance, the location and elevation of observed high-water marks were recorded with a survey-grade GPS unit. The elevation of these marks was generally 7 to 12 feet above the bed of the channel, so it was assumed that they were associated with the January 2005 flood (peak flow of 2,470 recorded at the Jeronimo gage, approximately a 25-year flood). The greatest subsequent flood was measured in 2008 with a peak flow of 1,580 cfs (corresponding to a 5- to 10-year flood), so there is enough difference between these floods that the surveyed high-water marks are likely to correlate to the January 2005 flood. The peak flows throughout the study area corresponding to the January 2005 peak of 2,470 cfs at the Jeronimo gage were calculated by interpolating the HEC-1 results provided in Table 2-4. The objective of the calibration was to match the modeled water-surface elevations from the HEC-RAS model to within 1-foot of the surveyed elevations. While a smaller criterion is preferred, the uncertainty associated with the magnitude of the peak flow during the January 2005 flood through the study area suggests that the higher range of ± 1-foot is appropriate. The HEC-RAS software represents energy losses that result from resistance along the channel bed and banks with a roughness coefficient – Manning's n-value. The n-values were adjusted, along with the horizontal distribution of n-values, to increase or decrease the modeled water-surface elevations to approximate the surveyed elevations. Since the majority of Aliso Creek in the study area is incised, the channel n-values were far more influential than any overbank values. Calibrated channel n-values ranged from 0.033 to 0.054. Table 4-1 illustrates the range of n-values used in the previous version of the hydraulic model (USACE 2009) and the calibrated values applied in the hydraulic model for this geomorphic assessment. As shown in this table, channel n-values were decreased to lower the calculated water surface elevations to better match the elevations of the surveyed high water marks. Based on conditions observed during the October 2009 reconnaissance, n-values at specific cross sections where high water marks were surveyed were not adjusted differently than values at adjacent sections for the sole purpose of improving calibration if field observations didn't warrant this adjustment. Details regarding other boundary conditions and model parameters are available in the H&H Appendix (USACE 2009).

Table 4-1. Initial (USACE 2009) and Calibrated Ranges of Manning's n-values

	Initial Model (USACE 2009)				Calibrated Model			
Reach	**# Sections**	**LOB**	**Chan.**	**ROB**	**# Sections**	**LOB**	**Chan.**	**ROB**
1	7	0.013 – 0.100	0.013 – 0.033	0.013 – 0.122	7	0.030 – 0.072	0.030 – 0.033	0.040 – 0.072
2	17	0.035	0.051	0.035 – 0.072	17	0.040 – 0.072	0.035	0.040 – 0.072
3	5	0.072	0.054	0.072	5	0.072	0.035	0.072
4A	10	0.072	0.054	0.072	26	0.072	0.035	0.072
4B	8	0.072	0.054	0.072	31	0.072	0.035	0.072
5A	4	0.072	0.054	0.072	12	0.072	0.035	0.072
5B	6	0.072	0.054	0.072	19	0.072	0.035	0.072
5C	3	0.072	0.054	0.072	12	0.072	0.035	0.072
6	5	0.072	0.054	0.072	14	0.072	0.035	0.072
7	8	0.072	0.054	0.072	12	0.072	0.035	0.072
8	10	0.072	0.054	0.072	10	0.072	0.035	0.072
9	3	0.072	0.054	0.072	2	0.072	0.035	0.072
10	13	0.013 – 0.070	0.013 – 0.051	0.013 – 0.072	17	0.015	0.033	0.015 – 0.072
11	9	0.040 – 0.072	0.033 – 0.051	0.040 – 0.072	9	0.040 – 0.072	0.033 – 0.051	0.040 – 0.072
12	5	0.040 – 0.072	0.033 – 0.051	0.040 – 0.072	5	0.040 – 0.072	0.033 – 0.051	0.040 – 0.072

Note:
LOB = left overbank; Chan. = channel; ROB = right overbank

During the calibration process, it became clear that the elevation of some of the high-water marks was too low to be associated with the January 2005 flood. The elevation of these marks was calculated to be well below critical depth for the estimated January 2005 peak flow, and there was no basis for believing flow at these locations was supercritical during the flood. Therefore, these high-water marks were not considered further in the calibration process. A few additional water-surface elevations were measured during the floods of late January 2010, and these points provided a second dataset for calibration. Using the channel roughness values described above with the estimates of the peak flows, the modeled water-surface elevations for both calibration events agree within one foot of the surveyed elevations of the high-water marks. Review of the modeled water-surface elevations indicates that they were not consistently biased high or low relative to the surveyed high-water mark elevations. Comparisons of the surveyed high- water mark elevations with the modeled water-surface profiles are provided in Figures 4-1 and 4-2.

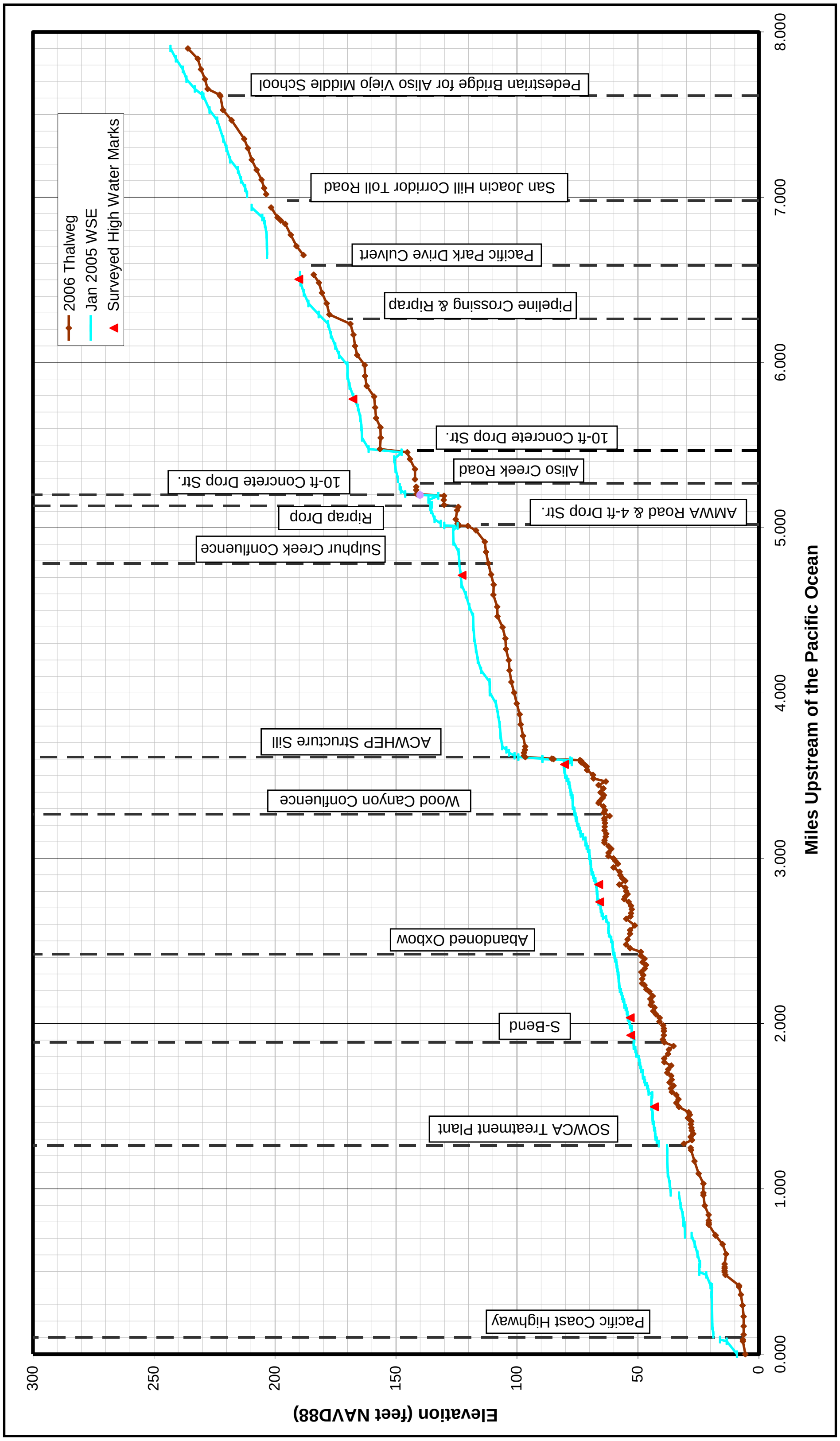


Figure 4-1. Comparison of surveyed high water marks to modeled Jan. 2005 water surface profile

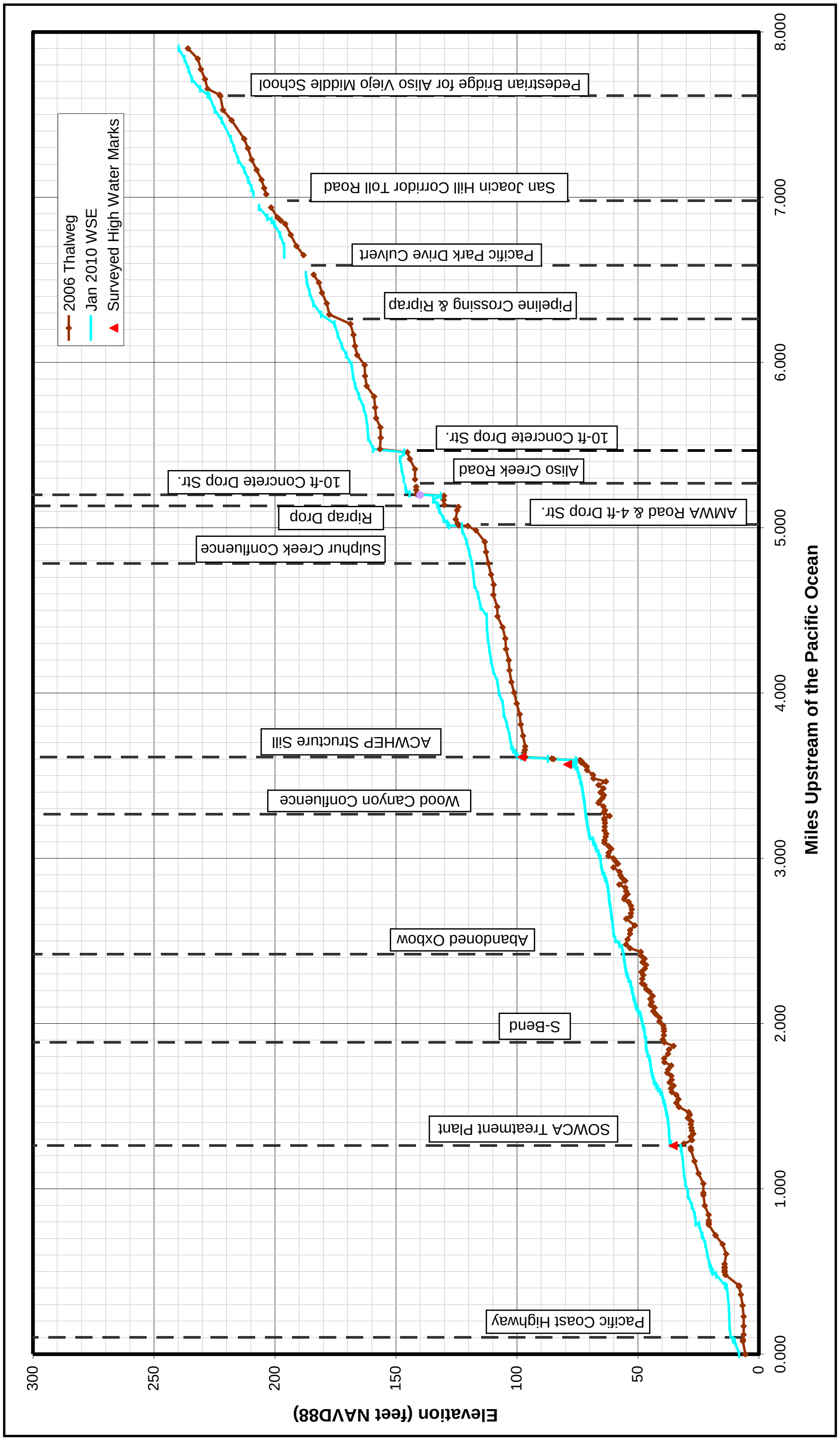


Figure 4-2. Comparison of surveyed high water marks to modeled Jan. 2010 water surface profile

4.3 REACH-AVERAGED HYDRAULICS

The average hydraulic parameters for each of the 15 geomorphic reaches in Aliso Creek were computed using the results of the calibrated HEC-RAS model and are listed in Table 4-2. The average of a given parameter is computed as a length-weighted average of the values at each cross section within a reach. The bed slope (B. Slope) is the average slope across the reach calculated using the thalweg elevations at the upstream and downstream limits of the reach and the reach length. The energy slope (E. Slope) is the slope of the energy-grade line calculated across the reach using the reach length and the energy-grade line elevations at the extents of the reach. The channel velocity, top width, and hydraulic depth were calculated for the channel portion of the cross sections, defined by the bank stations set in the HEC-RAS model, and averaged by weighting the representative length of each section to the total reach length.

Table 4-2. Reach-averaged Hydraulic Parameters

Reach	Downstream Feature Upstream Feature	River Mile	Parameter [1]	2-year	5-year	10-year	50-year	100-year
1			B. Slope (ft/ft)	0.0012				
	PCH Bridge	0.118	E. Slope (ft/ft)	0.0018	0.0018	0.0018	0.0031	0.0032
	Breccia outcrop	0.415	Chnl.Vel. (ft/s)	5.24	6.41	6.93	7.30	7.58
			Top Width (ft)	71.30	79.22	84.53	92.89	93.38
			Hyd. Depth (ft)	4.80	6.77	8.05	11.29	12.52
2			B. Slope (ft/ft)	0.0035				
	Breccia outcrop	0.480	E. Slope (ft/ft)	0.0042	0.0042	0.0042	0.0044	0.0038
	Upstream end of	0.976	Chnl.Vel. (ft/s)	7.07	8.24	8.77	8.12	8.00
	golf course		Top Width (ft)	62.19	72.21	75.91	78.88	79.62
			Hyd. Depth (ft)	4.04	5.59	6.54	8.75	9.65
3			B. Slope (ft/ft)	0.0046				
	Upstream end of	1.032	E. Slope (ft/ft)	0.0020	0.0019	0.0020	0.0015	0.0018
	golf course		Chnl.Vel. (ft/s)	4.70	5.70	6.39	6.54	7.41
	SOCWA bridge	1.249	Top Width (ft)	87.42	96.62	100.42	103.26	103.30
			Hyd. Depth (ft)	4.27	6.14	7.29	10.40	10.63
4A			B. Slope (ft/ft)	0.0030				
	SOCWA Bridge	1.274	E. Slope (ft/ft)	0.0033	0.0032	0.0031	0.0023	0.0024
	Gravel Plug downstream	1.789	Chnl.Vel. (ft/s)	5.18	6.34	6.98	7.15	7.67
	of S-bend		Top Width (ft)	89.07	100.97	106.72	120.06	121.69
			Hyd. Depth (ft)	3.94	5.41	6.43	9.16	9.75
4B			B. Slope (ft/ft)	0.0035				
	Gravel plug downstream	1.817	E. Slope (ft/ft)	0.0030	0.0029	0.0028	0.0027	0.0027
	of S-bend		Chnl.Vel. (ft/s)	4.88	5.97	6.57	7.50	7.81
	Sandstone outcrop	2.434	Top Width (ft)	101.72	115.46	120.95	134.08	138.10
			Hyd. Depth (ft)	3.72	5.05	6.02	7.80	8.48
5A			B. Slope (ft/ft)	0.0004				
	Sandstone outcrop	2.456	E. Slope (ft/ft)	0.0035	0.0039	0.0041	0.0044	0.0045
	Clay outcrop	2.736	Chnl.Vel. (ft/s)	4.25	5.39	6.18	7.50	7.88
			Top Width (ft)	164.53	218.09	227.76	241.31	244.07
			Hyd. Depth (ft)	3.20	3.86	4.41	5.77	6.37
5B			B. Slope (ft/ft)	0.0046				
	Clay outcrop	2.753	E. Slope (ft/ft)	0.0037	0.0035	0.0035	0.0033	0.0033
	Plug/bedrock control	3.095	Chnl.Vel. (ft/s)	5.48	6.49	7.10	8.04	8.34
	downstream Wood		Top Width (ft)	86.29	101.45	109.94	126.24	131.53
	Canyon confluence		Hyd. Depth (ft)	3.63	4.84	5.57	7.16	7.83

Reach	Downstream Feature Upstream Feature	River Mile	Parameter [1]	2-year	5-year	10-year	50-year	100-year
5C	Plug/bedrock control Upstream end sand storage reach above Wood Canyon	3.110 3.314	B. Slope (ft/ft)			0.00041		
			E. Slope (ft/ft)	0.0024	0.0030	0.0033	0.0038	0.0040
			Chnl.Vel. (ft/s)	5.16	6.67	7.56	9.11	9.68
			Top Width (ft)	71.98	80.41	85.19	93.24	96.07
			Hyd. Depth (ft)	4.51	5.75	6.53	8.09	8.72
6	Upstream end sand storage ACWHEP structure toe	3.335 3.580	B. Slope (ft/ft)			0.0055		
			E. Slope (ft/ft)	0.0046	0.0051	0.0057	0.0070	0.0075
			Chnl.Vel. (ft/s)	6.30	6.93	7.30	7.97	8.31
			Top Width (ft)	69.76	90.43	98.14	109.54	113.40
			Hyd. Depth (ft)	4.10	5.25	6.05	7.84	8.59
7	ACWHEP structure sill Transition to 15-ft banks	3.677 4.199	B. Slope (ft/ft)			0.0025		
			E. Slope (ft/ft)	0.0031	0.0034	0.0035	0.0038	0.0037
			Chnl.Vel. (ft/s)	5.80	6.87	7.46	8.13	8.14
			Top Width (ft)	67.70	78.44	82.60	88.91	90.56
			Hyd. Depth (ft)	4.28	5.43	6.13	7.44	8.04
8	Transition to 15-ft banks Sulphur Creek confluence	4.266 4.854	B. Slope (ft/ft)			0.0027		
			E. Slope (ft/ft)	0.0028	0.0028	0.0028	0.0027	0.0028
			Chnl.Vel. (ft/s)	5.53	6.16	6.53	7.29	7.76
			Top Width (ft)	73.60	86.38	93.22	104.24	107.93
			Hyd. Depth (ft)	4.34	5.79	6.75	8.51	9.11
9	Sulphur Creek confluence AWMA Road bridge	4.916 4.984	B. Slope (ft/ft)			0.010		
			E. Slope (ft/ft)	0.0073	0.0036	0.0019	0.0010	0.00083
			Chnl.Vel. (ft/s)	6.34	7.03	5.75	4.89	4.69
			Top Width (ft)	80.67	90.68	99.67	114.30	119.81
			Hyd. Depth (ft)	3.65	4.63	5.69	7.69	8.53
10	AWMA Road bridge Upstream end engineered reach	5.051 5.664	B. Slope (ft/ft)			0.010		
			E. Slope (ft/ft)	0.0098	0.0096	0.0095	0.0093	0.0093
			Chnl.Vel. (ft/s)	7.67	8.46	8.85	9.58	9.83
			Top Width (ft)	71.83	74.95	76.50	79.46	80.66
			Hyd. Depth (ft)	3.64	4.55	5.05	6.08	6.48
11	Upstream end engineered reach Water pipeline crossing	5.728 6.234	B. Slope (ft/ft)			0.0038		
			E. Slope (ft/ft)	0.0044	0.0044	0.0044	0.0045	0.0045
			Chnl.Vel. (ft/s)	4.95	5.68	6.05	6.82	7.07
			Top Width (ft)	94.72	103.59	105.91	108.61	109.65
			Hyd. Depth (ft)	3.81	4.73	5.24	6.34	6.79
12	Water pipeline crossing Pacific Park Drive	6.291 6.532	B. Slope (ft/ft)			0.0051		
			E. Slope (ft/ft)	0.0055	0.0060	0.0062	0.0067	0.0069
			Chnl.Vel. (ft/s)	6.04	6.79	7.21	8.08	8.42
			Top Width (ft)	90.32	97.76	100.29	104.68	106.19
			Hyd. Depth (ft)	3.33	4.03	4.41	5.19	5.49

[1] B. Slope = bed slope (Elevation $_{\text{BED u/s}}$ – Elevation $_{\text{BED d/s}}$) / (reach length)
E. Slope = slope of energy grade line (Elevation $_{\text{EGL u/s}}$ – Elevation $_{\text{EGL d/s}}$) / (reach length)
Chnl. Vel. = length-weighted average channel velocity (defined by bank stations in HEC-RAS model)
Top Width = length-weighted average top width of the active channel
Hyd. Depth = length-weighted average hydraulic depth within the active channel

As indicated in Table 4-2, calculated hydraulic parameters at a few cross sections were excluded from the length-weighted averaging in some reaches. These cross sections were excluded due to localized hydraulic effects that would inappropriately skew the average values. For example, the cross sections immediately upstream the ACWHEP structure were removed from the averaging because of the localized decrease in water surface over the sill and the associated increases in velocity.

To provide further detail regarding the calculated hydraulics, selected indicators for different flows were plotted along the longitudinal profile of Aliso Creek. The selected parameters include the water surface profile (Figures 4-3 and 4-4), top width of the active channel (Figures 4-5 and 4-6), hydraulic depth (Figures 4-7 and 4-8), channel velocity (Figures 4-9 and 4-10), and total channel shear stress (Figures 4-11 and 4-12). These indicators were plotted for the 2-, 5-, 10-, 25-, 50-, and 100-year recurrence interval floods.

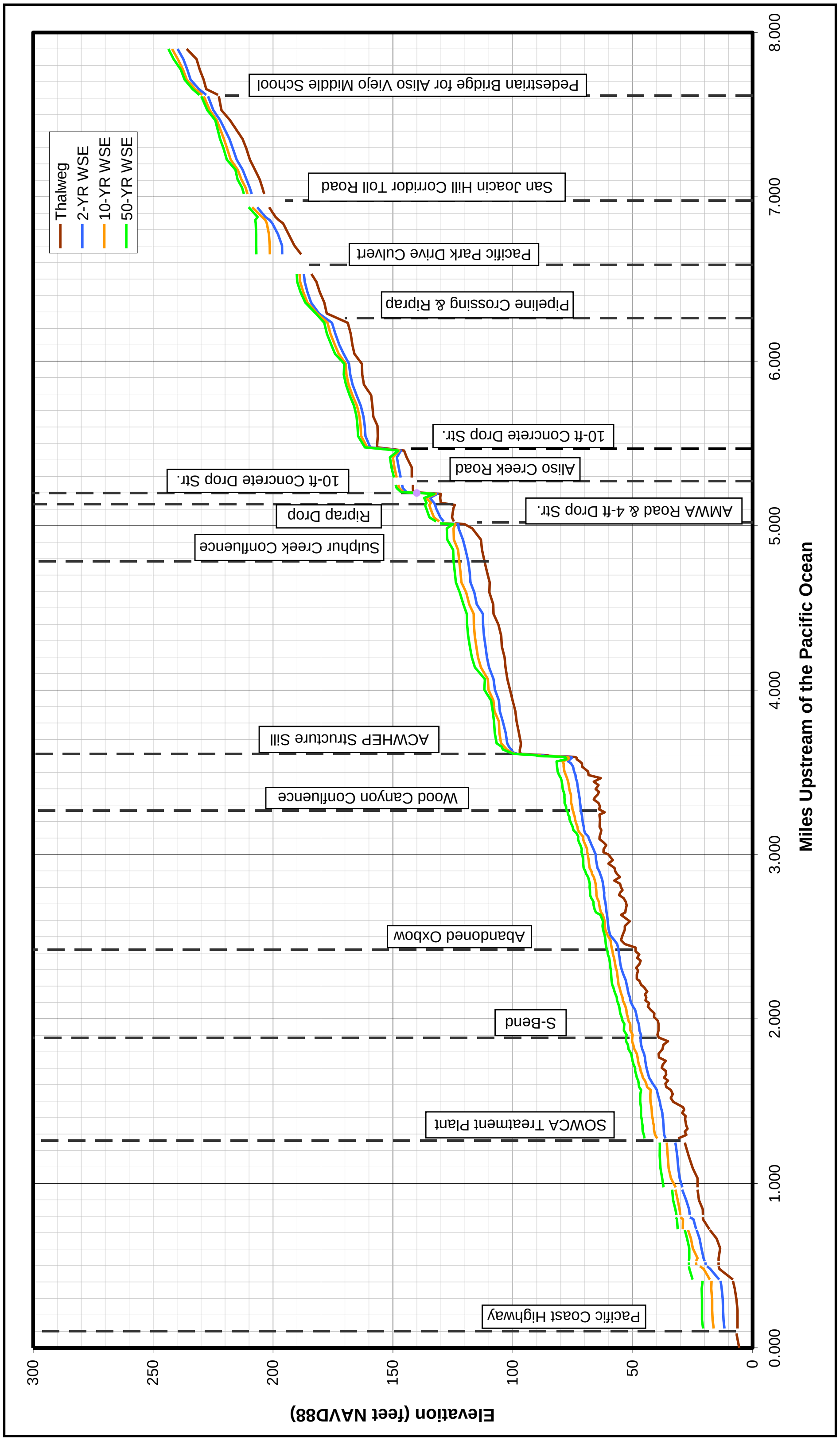


Figure 4-3. Calculated water surface profiles for the 2-yr, 10-yr, and 50-yr flood

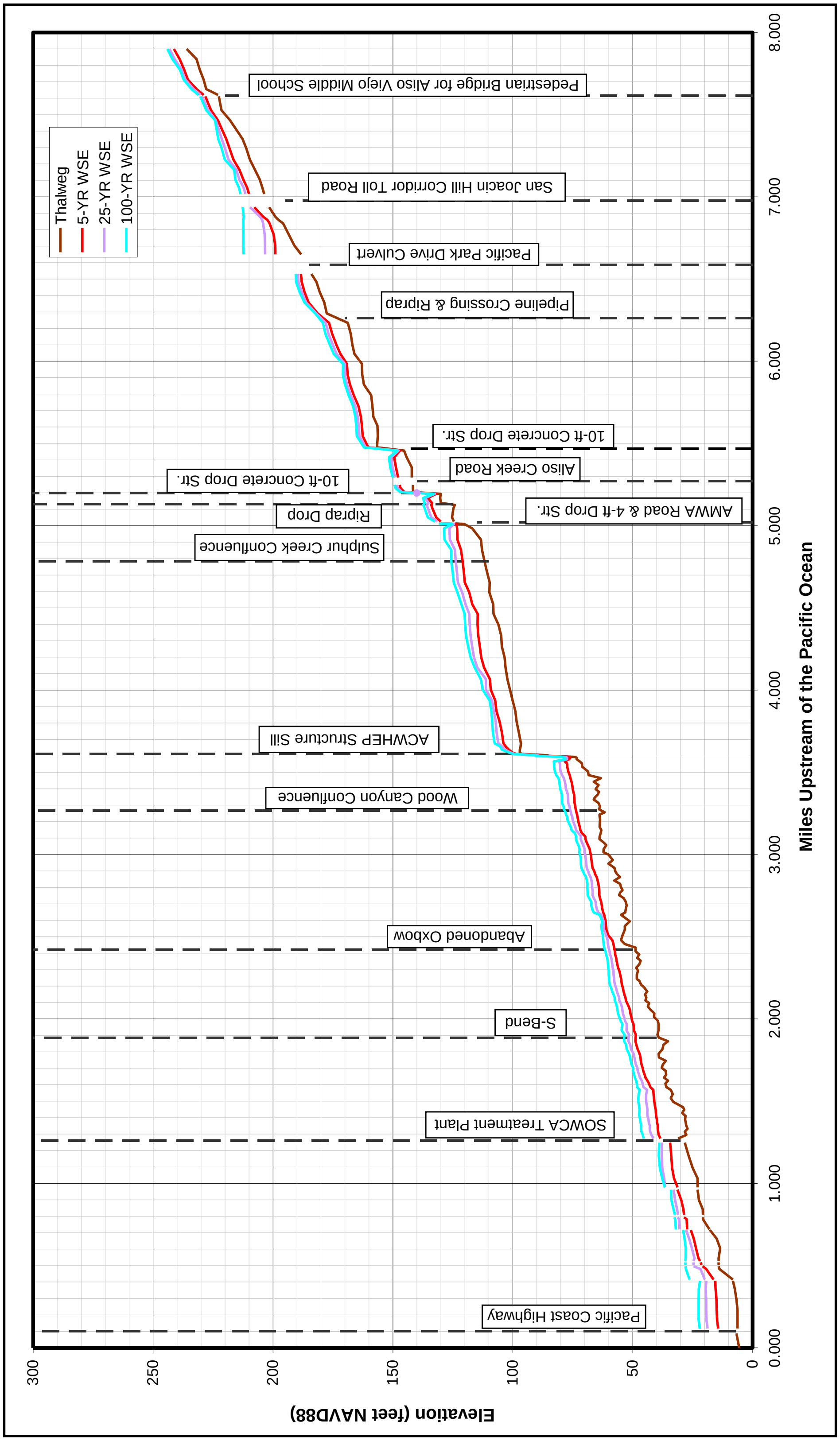


Figure 4-4. Calculated water surface profiles for the 5-yr, 25-yr, and 100-yr floods

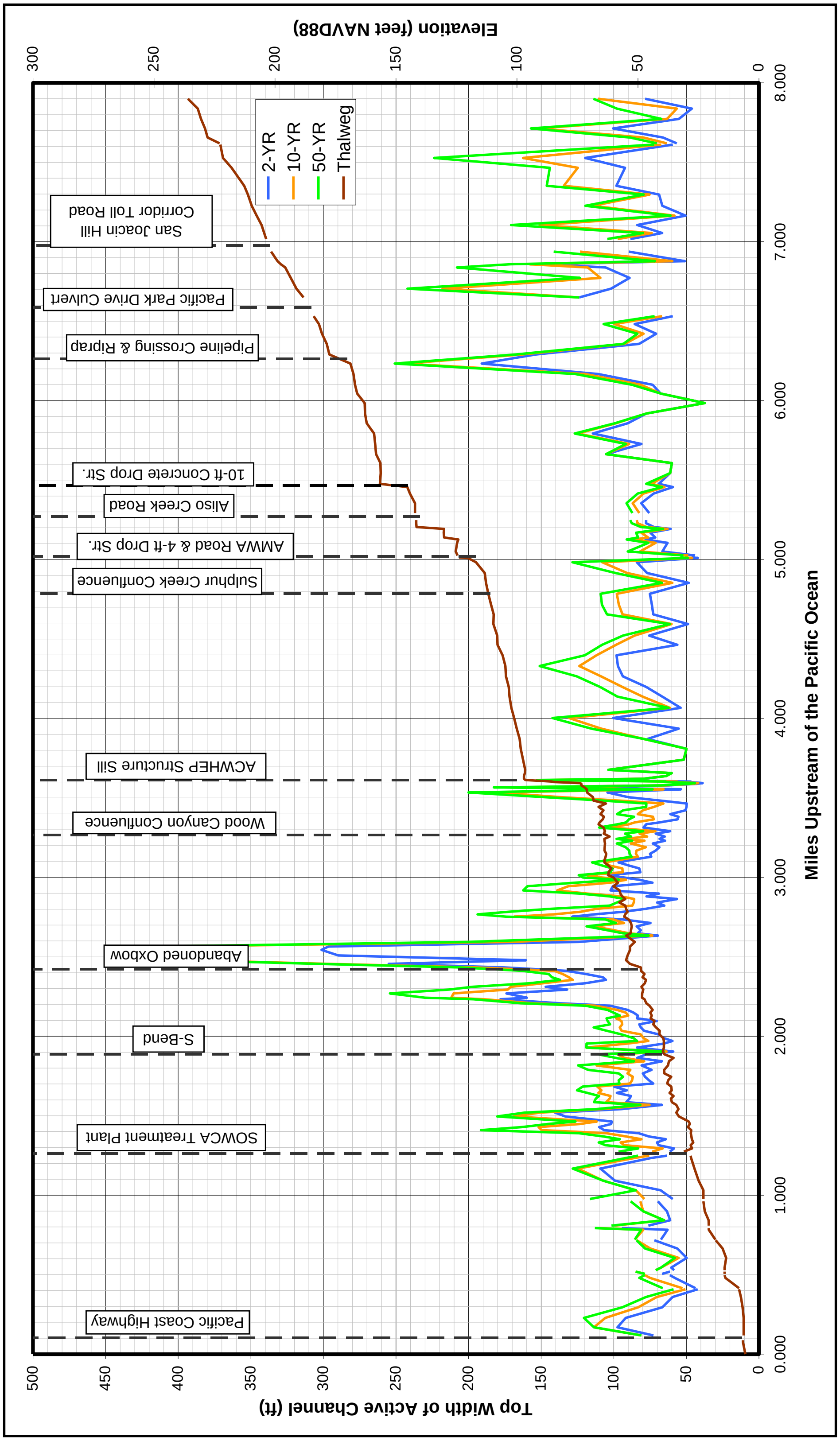


Figure 4-5. Calculated top width for the 2-yr, 10-yr, and 50-yr floods

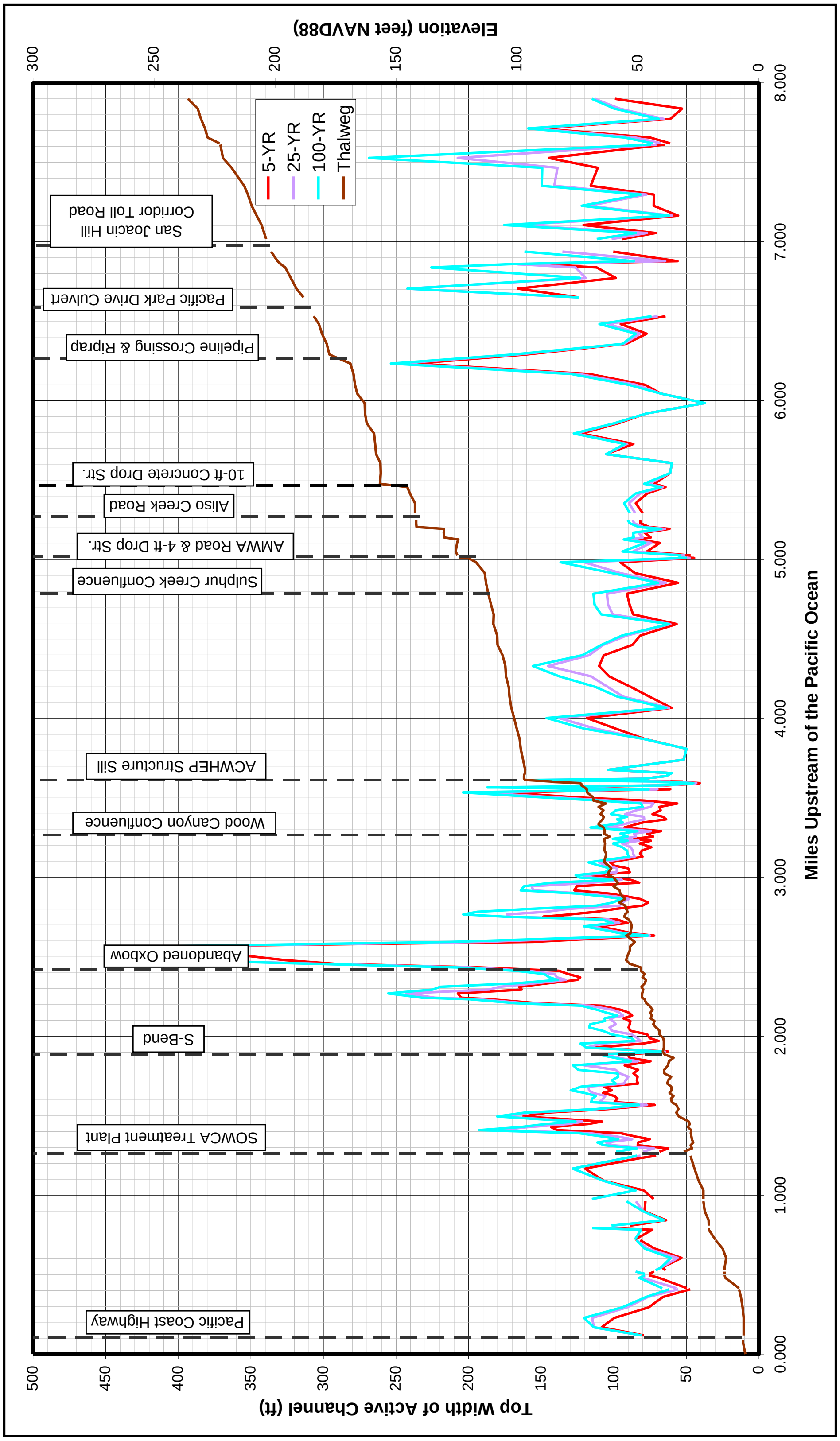


Figure 4-6. Calculated top width for the 5-yr, 25-yr, and 100-yr floods

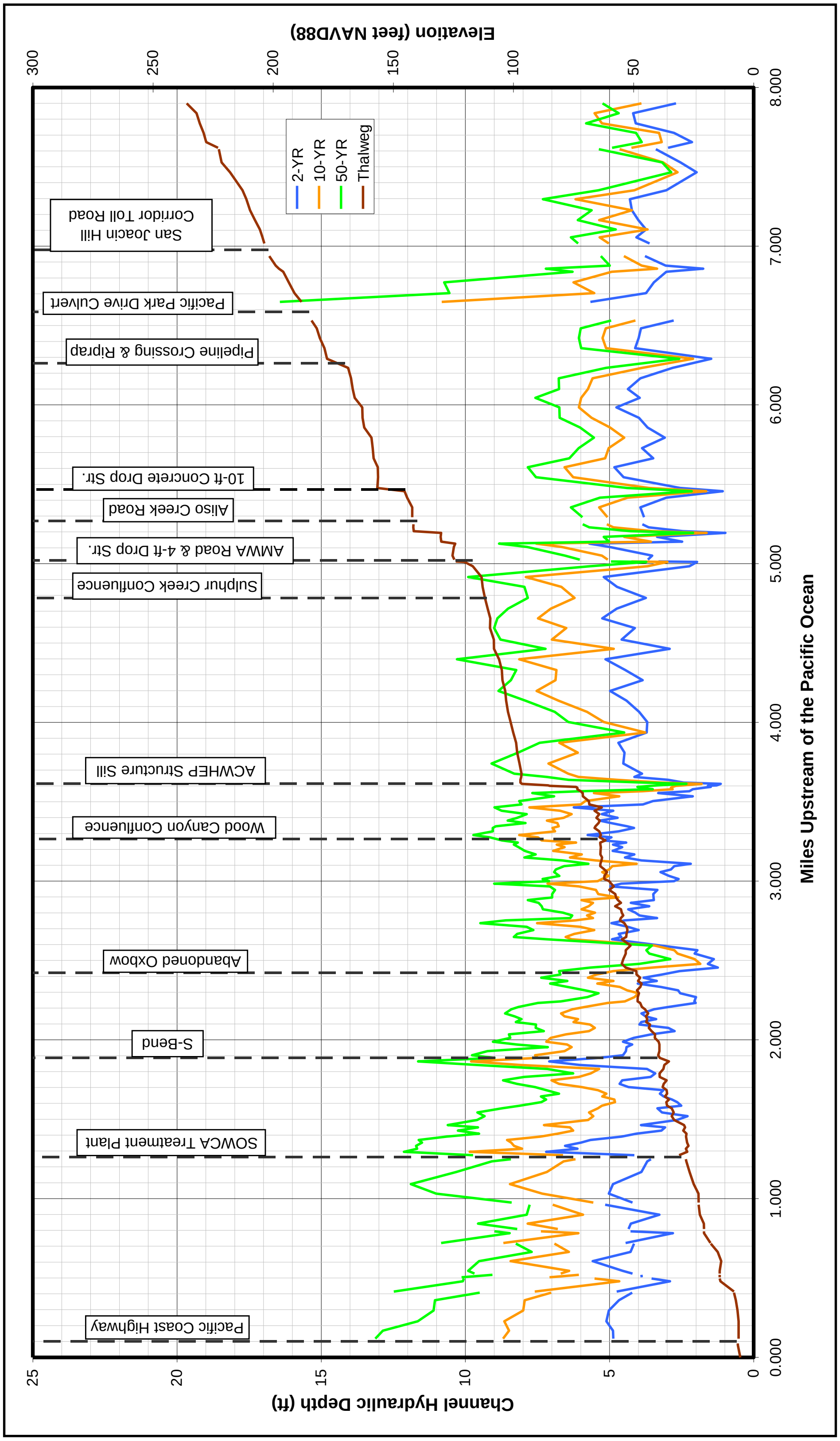


Figure 4-7. Calculated hydraulic depth for the 2-yr, 10-yr, and 50-yr floods

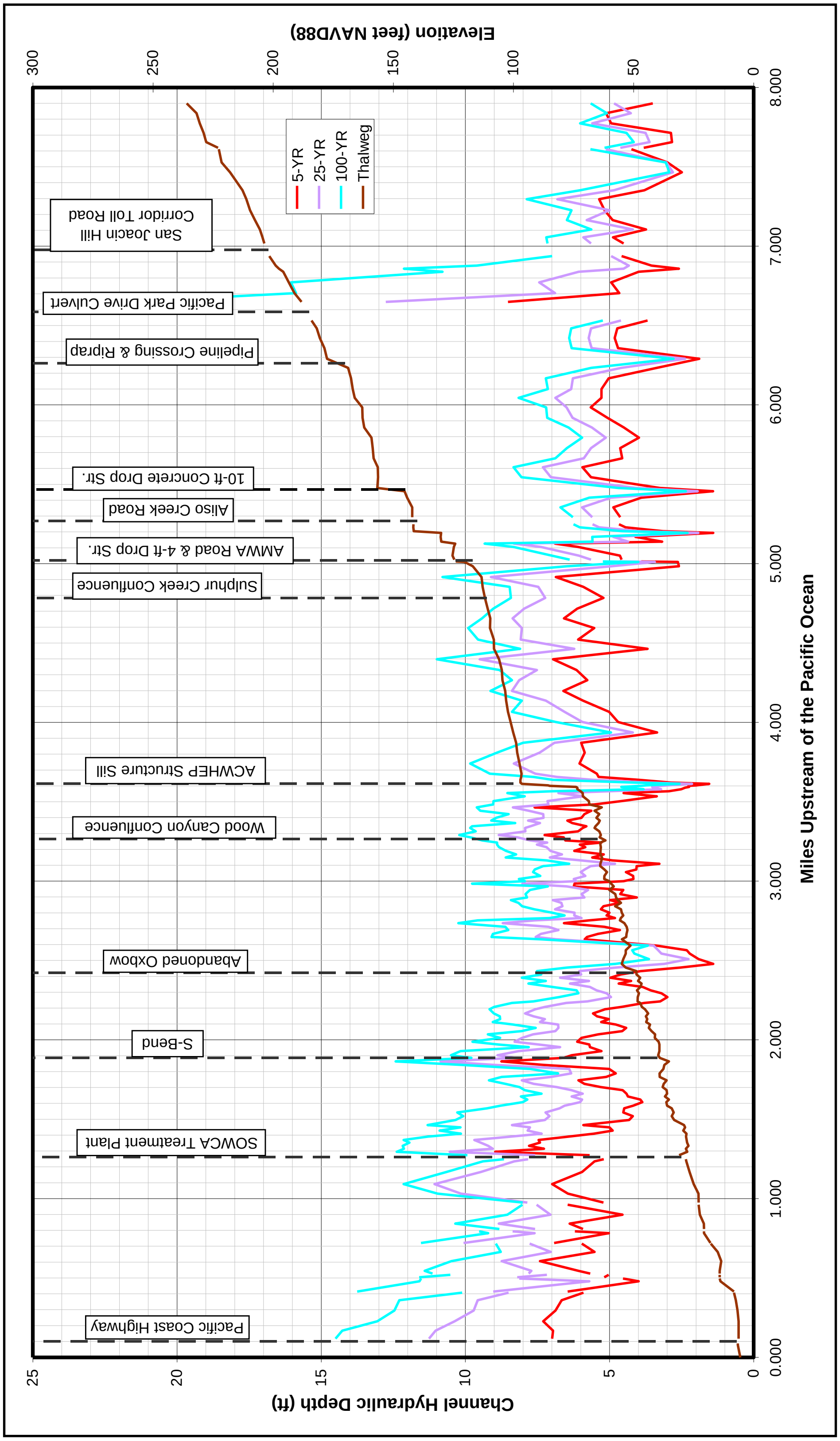


Figure 4-8. Calculated hydraulic depth for the 5-yr, 25-yr, and 100-yr floods

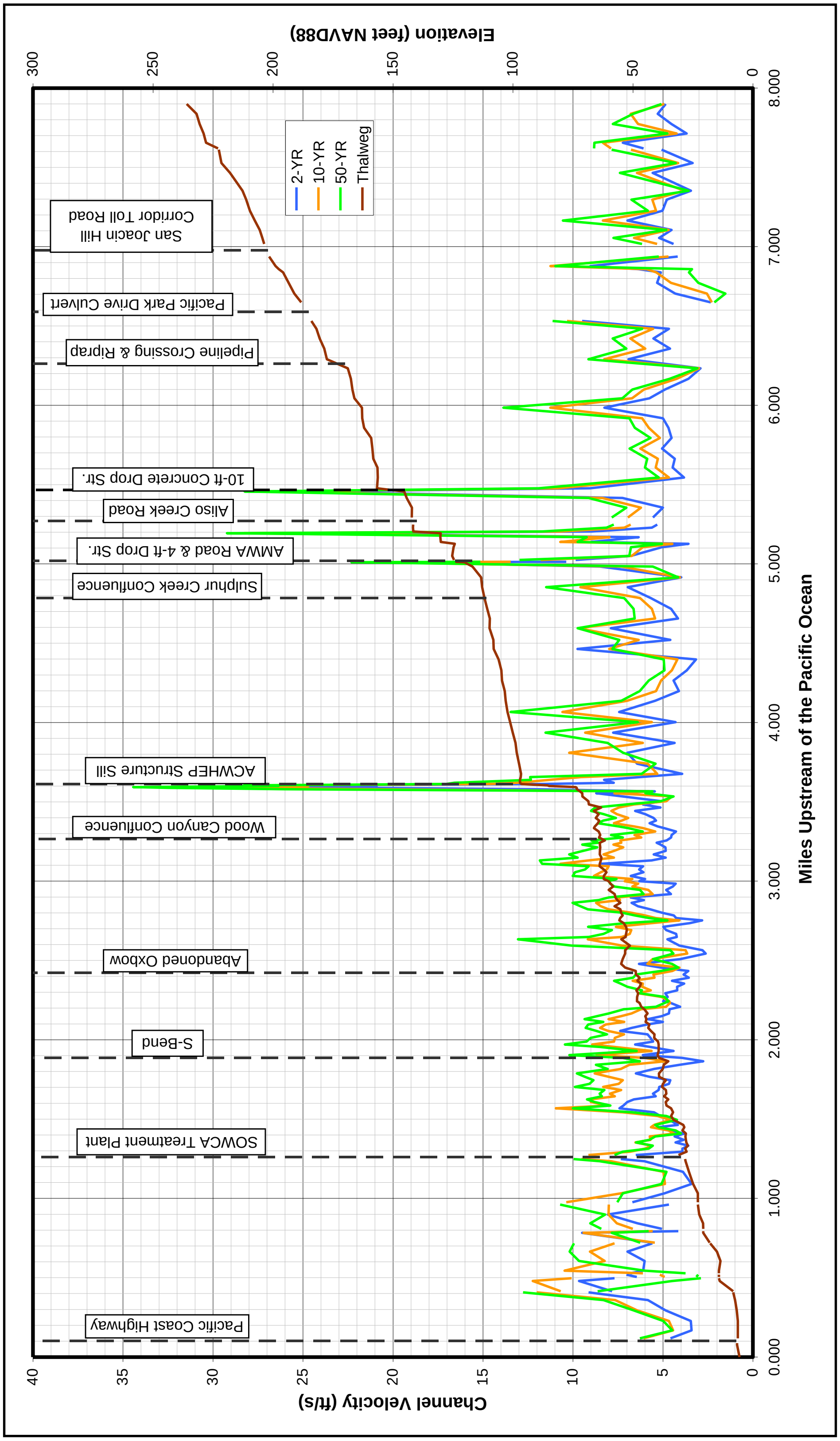


Figure 4-9. Calculated channel velocity for the 2-yr, 10-yr, and 50-yr floods

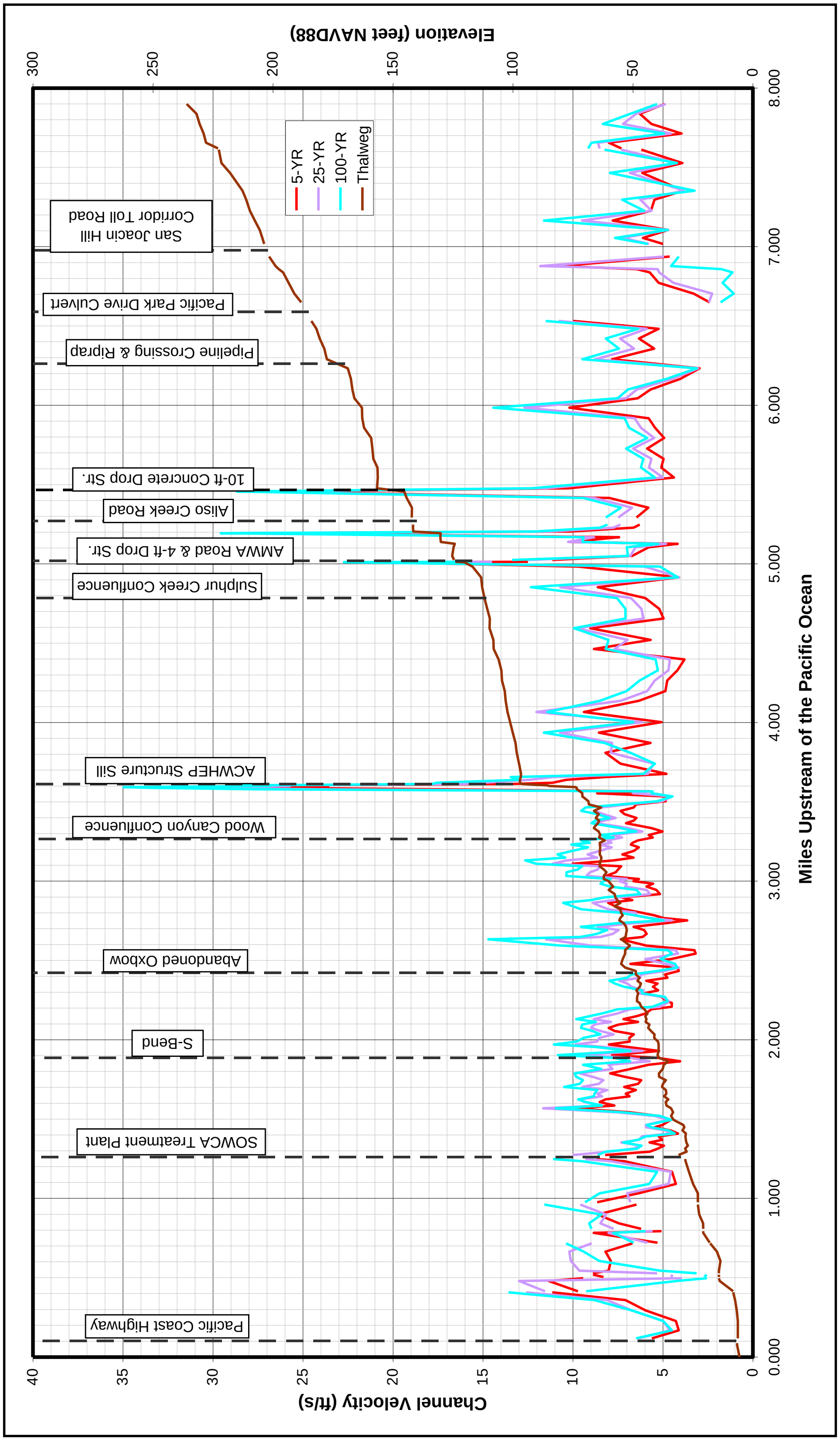


Figure 4-10. Calculated channel velocity for the 5-yr, 25-yr, and 100-yr floods

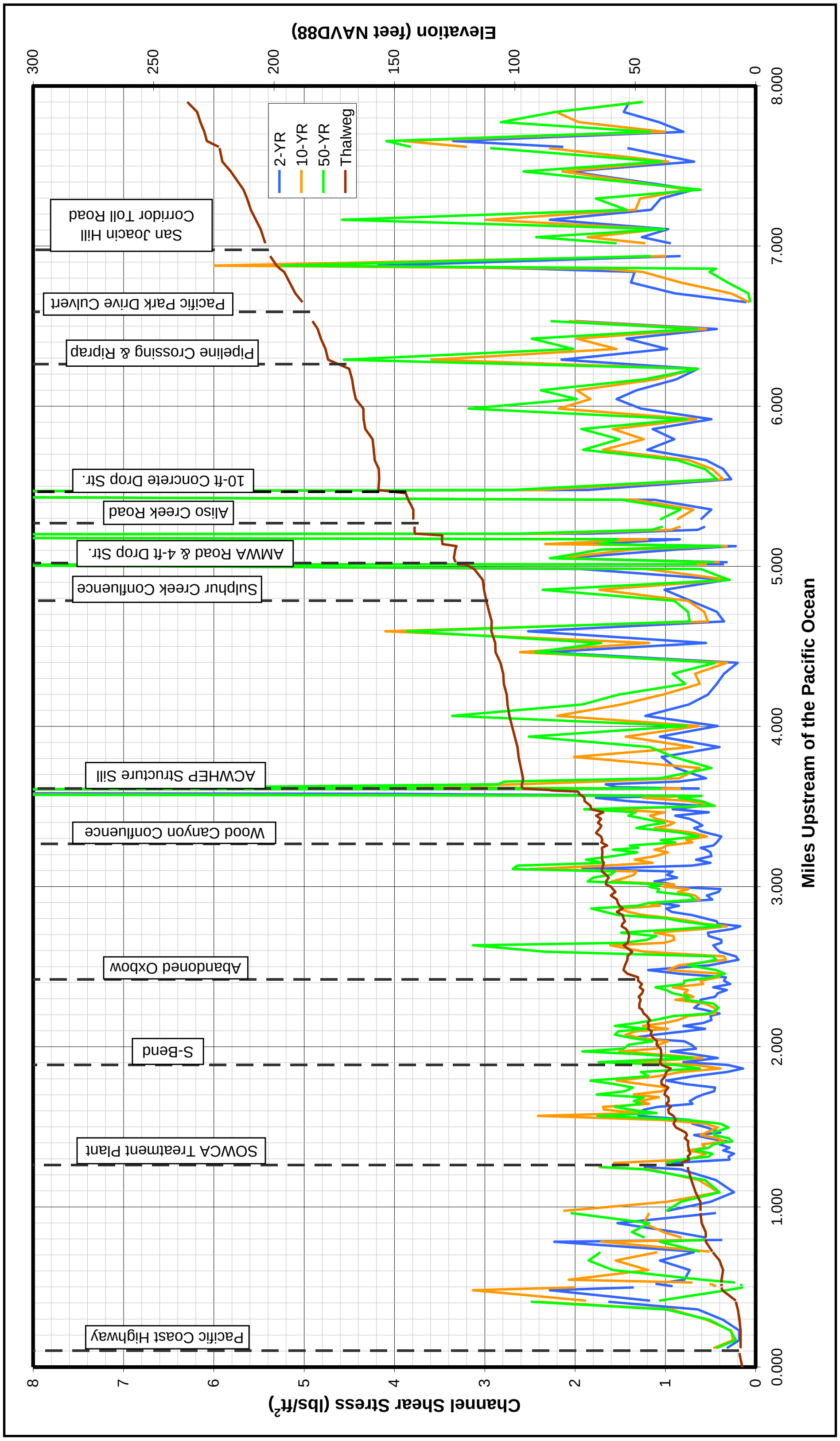


Figure 4-11. Calculated total channel shear stress for the 2-yr, 10-yr, and 50-yr floods

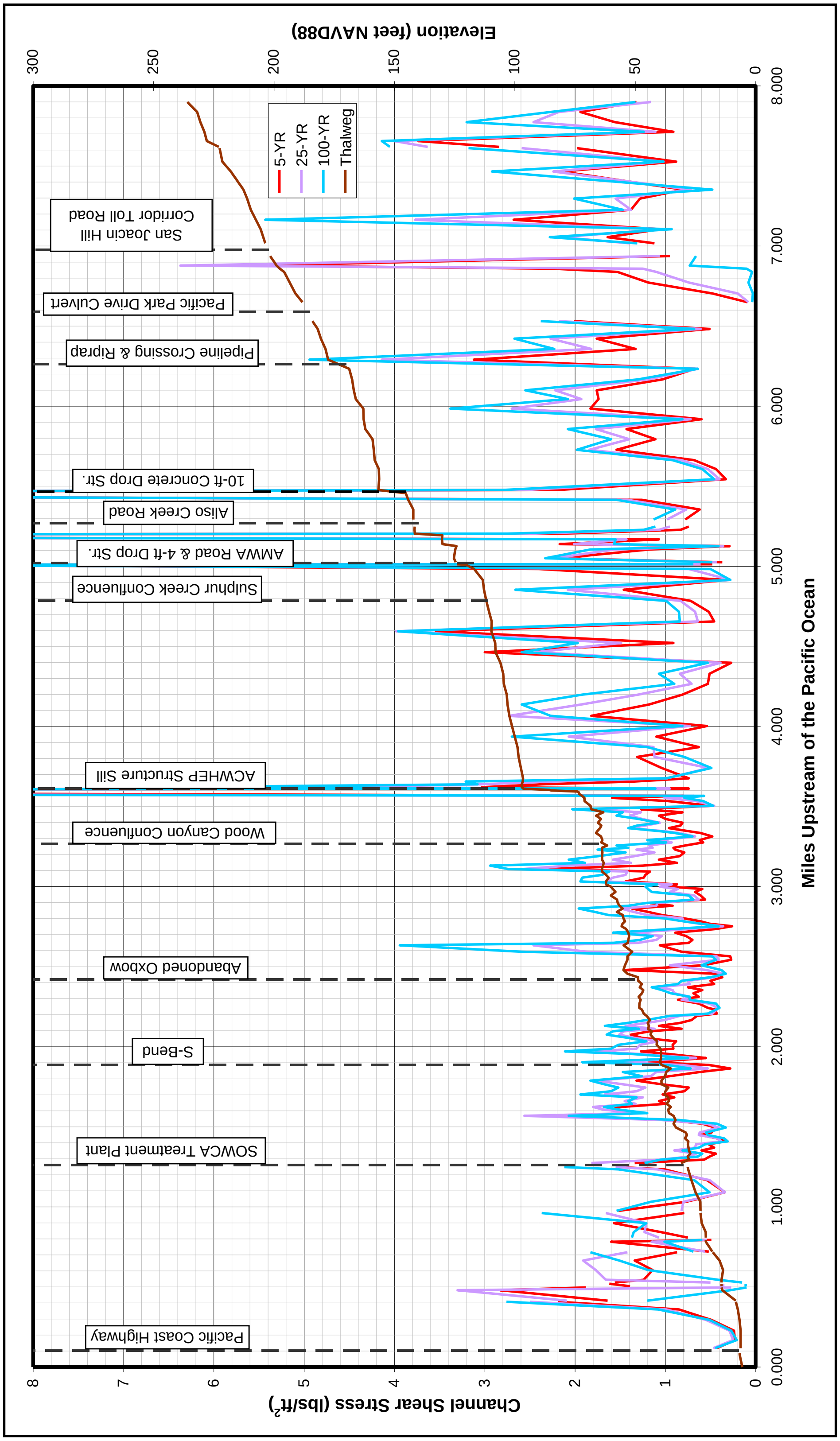


Figure 4-12. Calculated total channel shear stress for the 5-yr, 25-yr, and 100-yr floods

5.0 SEDIMENT SUPPLY AND TRANSPORT

One of the key characteristics of geomorphically-stable channels is a dynamic balance between the sediment supplied to the reach and the sediment transport capacity of the reach. In the Aliso Creek watershed, multiple approaches were pursued to estimate the annual supply of sediment, particularly bed material, from the watershed. Bed material and bank material samples that have been historically and recently collected were compared, conditions of incipient motion were calculated, the effective discharge was determined, and the transport of bed material through the geomorphic reaches was analyzed. Each of these processes was investigated to provide a basis for understanding historical instabilities in the channel morphology, existing morphologic conditions, and the probable future channel morphology.

5.1 SEDIMENT SUPPLY

The supply of sediment delivered from the Aliso Creek watershed to Aliso Beach can be categorized into two sources: 1) the upland supply generated by erosion of surface soils, and 2) the channel supply generated by incision and widening of the channel. Sediment generated from both sources is transported through Aliso Creek as either wash load or bed material load. Wash load represents size fractions that are not found in appreciable quantities in the surface of the bed (i.e., silts and clays). Wash load is primarily transported in suspension, is limited by the available supply, and is of little interest in channel morphology because it is essentially washed through the channel. On the other hand, bed material load is made up of sands, gravels, and cobbles that constitute the size fractions in the bed surface. These size fractions are transported as bed load and suspended load through erosion from and deposition on the bed surface. The transport capacity of the creek as opposed to the available supply in the bed limits the transport of bed material size fractions. The supply and transport of bed material is of greater interest in this study for two reasons (1) the interaction with the channel boundary affects channel morphology, and (2) the transport of sand size fractions represents the supply of sand to Aliso Beach. The following sections describe the methods used to calculate and compare sediment supplies and bed material transport within and from the study area.

5.1.1 Upland Sediment Supply

The revised H&H Appendix (USACE 2009) includes calculations of upland sediment supplies from the Aliso Creek watershed using two methodologies (1) the Modified Universal Soil Loss Equation (MUSLE) (Williams and Berndt 1972), and (2) the Los Angeles District Method for Prediction of Debris Yield (LAD Debris Method) (USACE 2000b). Both of these approaches provide a means for calculating sediment yield from individual storm events. In response to comments received on the revised H&H Appendix related to the calculation of upland sediment yield, the results were updated for this geomorphic assessment. The updated results were compared to other previously reported values (CDM 1982; USACE 1996; USACE 1997b) and to calculations made with other methods (PSIAC 1968). Each method produces an estimate of total sediment yield, including both the wash load and bed material load. To partition the total yield to reflect only the bed material size fractions, the total yield was multiplied by the fraction of sizes coarser than 0.075 mm (i.e., retained on a No. 200 sieve) in the surface soil layers of the contributing drainage areas. This fraction was calculated as an area-weighted average for the soil types as classified by the NRCS in the soil survey of Orange and Western Part of Riverside Counties (2008). For the entire Aliso Creek watershed, the area-weighted average fraction of the surface soils coarser than 0.075 mm is 0.483. The results are summarized in Table 5-1, and details regarding the results of each method follow the table.

Table 5-1. Annual Bed Material Yield from Upland Sources

Source	Annual Total Yield (tons)	Annual Bed Material Yield (tons)[1]	Annual Bed Material Yield Low Value (tons)	Annual Bed Material Yield High Value (tons)	Comments
CDM (1982)	47,000	22,700	7,600	68,100	Based on ultimate buildout and unit weight of 93 lb/ft^3
USACE (1996)		18,600			Basis for separating coarse fraction not specified
USACE (1997b)		17,100	2,070	55,800	Uses unit weight of 0.7 CY/ton, range reflects 200 % error instead of 100 % range published
MUSLE	88,400	42,700	980	153,000	Only appropriate for sizes from 0.075 to 1 mm
LAD Debris Method	112,000	53,900	2,600	185,000	AT Factor = 0.52
PSIAC			16,900	33,900	Score of 58 = Classification 3

[1] Estimated using the area-weighted fraction of sediment sizes greater than 0.075 mm in the surface soils of the contributing watershed (0.483 for the entire Aliso Creek watershed)

5.1.1.1 Previously Published Calculations of Sediment Yield

Numerous reports include estimates of the sediment yield from the Aliso Creek watershed; however, in nearly all cases the estimates are not independent calculations but rather reference values calculated in one of three reports. CDM prepared the earliest report titled *Sediment discharge and mechanics of Aliso Creek* in 1982 and this report includes estimates of annual total sediment yield for difference development scenarios (i.e., prior to development, existing conditions, during construction, and ultimate development). The yield was calculated by multiplying areal rates and acreages of different land cover classes, with the amount of land in each class changing under the different development scenarios. The areal rates were based on data collected from coastal watersheds in southern California. The areal rates were converted from the source data using a unit weight of sediment of 165 pounds per cubic foot – the submerged unit weight of sediment. While this is appropriate for the data based on reservoir sedimentation rates, it is inappropriate for converting between bulk volumes and weights. A more appropriate value for sand is 93 pound per cubic foot. The total yield in Table 5-1 was calculated using areal rates based on 93 pounds per cubic foot and using the land cover distribution associated with the ultimate buildout conditions. The bed material yield was calculated for this geomorphic assessment by multiplying the total yield by 0.483 – the fraction of sizes coarser than 0.075 mm in the surface soils. Since the CDM report notes that the values are estimates and may be in error by as much as 200 percent, the low and high estimates in Table 5-1 reflect this stated level of uncertainty.

In 1996, the USACE Los Angeles District conducted a fluvial sediment investigation of the Orange County Coast and estimated the annual coarse fraction sediment yield from the Aliso Creek watershed.

The total yield estimate for ultimate buildout conditions presented in the 1982 CDM report of 62,000 tons per year was multiplied by an assumed coarse fraction of 0.3 to produce an annual yield of coarse sediment of 18,600 tons. It is not clear what grain size corresponds with the 0.3 fraction of the representative gradation.

The 1997 Everts Coastal report indicates that the annual coarse sediment yield presented in the 1996 USACE report is based on data prepared by CDM in 1982 that are cursory and may be in error by as much as 200 percent. Everts Coastal used the yield estimated by CDM for ultimate buildout conditions (i.e., 62,000 tons per year) and calculated high and low estimates using errors of 100 percent – not 200 percent. Based on the assumption that the coarse material in the discharged sediment varies between 0.1 and 0.3, the annual coarse material yield was calculated to range between 3,100 and 37,200 tons. Based on further assumptions and comparisons, Everts Coastal recommended a coarse sediment yield of 17,100 tons per year. Assuming the authors would have come to the same recommended value using the wider range associated with 200 percent error instead of 100 percent, the high and low estimates in Table 5-1 reflect the wider range.

Due to the lack of clarity in the definition of the size of the material used to define the coarse fraction in the previously published estimates of coarse material yield from the Aliso Creek watershed, it is more appropriate to consider a range of values than a single value. Further, since both the 1996 USACE study and the 1997 Everts Coastal study were based on the 1982 CDM report, the CDM values are the only independent values. The range of values presented in Table 5-1 for the CDM report are based on the revised unit weight, the ultimate land cover distribution, and the area-averaged fraction of grain sizes coarser than 0.075 mm of 0.483. These values are less ambiguous that the USACE (1996) and Everts Coastal (1997) values, so they are given more weight for comparison to calculations made for this study.

5.1.1.2 Updated Estimates using the MUSLE and LAD Debris Method

As described in the revised H&H Appendix (USACE 2009), the average annual sediment yield was calculated by integrating the sediment yield frequency curves developed using both the MUSLE and the LAD Debris Method. These curves plot the sediment yield calculated for individual flood events as a function of the annual exceedance probability. This calculation approach is based on the expectation of an individual flood event each year as is typical of arid environments in the southwest. However, in the coastal watersheds of southern California, multiple flood events occur each year. For example, stream gaging data from Aliso Creek show that between water years 1991 and 2008 an average of nine floods occurred per year with peaks flows in excess of the 1.1-year recurrence interval peak flow. Using calculations of peak flow and storm volume at the outlet of the Aliso Creek watershed (described in more detail in Section 5.3.1), the MUSLE and LAD Debris Methods were used to calculate the total sediment yield for all flood events greater than the 1.1-year flood in water years 1991 through 2008. The results were summed by year to produce annual yields. Since this period contains exceptionally dry and wet years, the range of calculated annual yields reflect the broad range of conditions experienced in the watershed. For comparison purposes, an average annual total yield was calculated for each approach, and the low and high estimates were based on the minimum and maximum values, respectively. Another difference in the calculations compared to the methods documented in the revised H&H Appendix is the increase in the adjustment-transposition (AT) factor in the LAD Debris Method from 0.35 to 0.52.

The resulting annual average yield calculated using the MUSLE is approximately 25 percent less than the yield calculated using the LAD Debris Method. The LAD Debris Method reflects total sediment yield whereas the MUSLE is really developed only for size fractions finer than 1 mm in diameter. Whether this is the primary difference between the results from the two methods is unknown, but it is a reasonable basis for the lower values produced by the MUSLE. Even considering the difference between these two methods, the average annual yield for both methods falls within, but near the upper end, of the range calculated using the approach documented in the 1982 CDM report. However, the annual yields calculated for wet years exceed the upper end of the range associated with the approach from the 1982 CDM report by a factor of approximately 2.2 to 2.7.

5.1.1.3 New Estimate using PSIAC Method

Due to the general increase in the calculated bed material yields compared to previously reported values, the PSIAC method (1968) was used to provide another point of comparison. After scoring the factors that affect sediment yield, the total score of 58 placed the watershed in Classification 3 – corresponding to an average annual total yield of 0.5 to 1.0 acre-feet per square mile. Using a unit weight of 93 pounds per cubic foot and multiplying by the total watershed area results in 35,000 to 70,100 tons per year. Partitioning the total yield into the bed material yield produces a range of 16,900 to 33,900 tons per year.

These results are lower than calculations from the other methods. This is likely due to the extrapolation of the methodology and yields from watershed in the arid southwest to a coastal watersheds in southern California. Despite the lower values from the PSIAC method, they are useful as an estimate of a lower bound for yields from the Aliso Creek watershed.

5.1.1.4 Recommended Range of Annual Bed Material Yield

Commonly referenced values of the annual bed material yield from the Aliso Creek watershed are based on partitioning of total upland yield to produce values on the order of 15,000 tons. It appears many citations may actually refer to potentially erroneous values described in the Sediment Discharge Mechanics of Aliso Creek (CDM 1982). After making revisions to the results of the CDM study, and comparing to calculations made using the MUSLE, LAD Debris Method, and PSIAC method, the range of variability on an annual basis is greater than has been previously documented. Considering the uncertainty in all of these methods, but the relative similarity in the order of magnitude of the average annual yields, the recommended range of annual bed material yield is 20,000 to 60,000 tons. The probable range in annual bed material yields during dry and wet years is 1,000 to 200,000 tons. The recommended annual bed material yield is compared to actual calculations of bed material transport capacity in Section 5.3.4.

5.1.2 Sediment Supply from Channel Degradation

Substantial bank erosion and channel bed erosion is evident in many reaches of Aliso Creek, particularly between the SOCWA treatment plant and the ACWHEP structure and between the ACWHEP structure and the confluence of Sulphur Creek. The Aliso Creek Concept Plan Report (County of Orange 2006) provides a rough estimate based on cross section geometry that indicates on the order of 5,000 to 15,000 cubic yards of sand may have been eroded per year, on average, from 1971 to 1998. This estimate was based on an assumed sand fraction in the eroded material of 0.7. Using a unit weight of 93 pounds per cubic foot, this range equates to 6,300 to 18,800 tons of sand per year. The 28 year period between 1971 and 1998 represents the most active channel degradation; future loadings from channel degradation are not expected to continue at these rates.

The revised H&H Appendix (USACE 2009) documents average annual sand loads generated from channel degradation downstream of the ACWHEP structure between 1998 and 2006 as 21,000 tons. This estimate is similar to the average annual sand load from channel degradation calculated for the Concept Plan (County of Orange 2006). However, the H&H Appendix notes that as the channel morphology adjusts and approaches equilibrium conditions, the amount of channel degradation will decrease and the delivery of the sand material will also decrease.

5.1.3 Bed Material and Streambank Material Characteristics

The bed and streambank materials in Aliso Creek have been sampled at multiple times and locations since the spring of 1998. Prior to 1998, the only known streambed sampling occurred in August 1980 (Southern California Soil and Testing, Inc. 1980). To facilitate comparisons, the locations of all samples were referenced to the 2006 stationing and typical indicators of gradation were calculated (e.g., d_{84}, d_{50}, and percent sand).

5.1.3.1 1980 Sampling

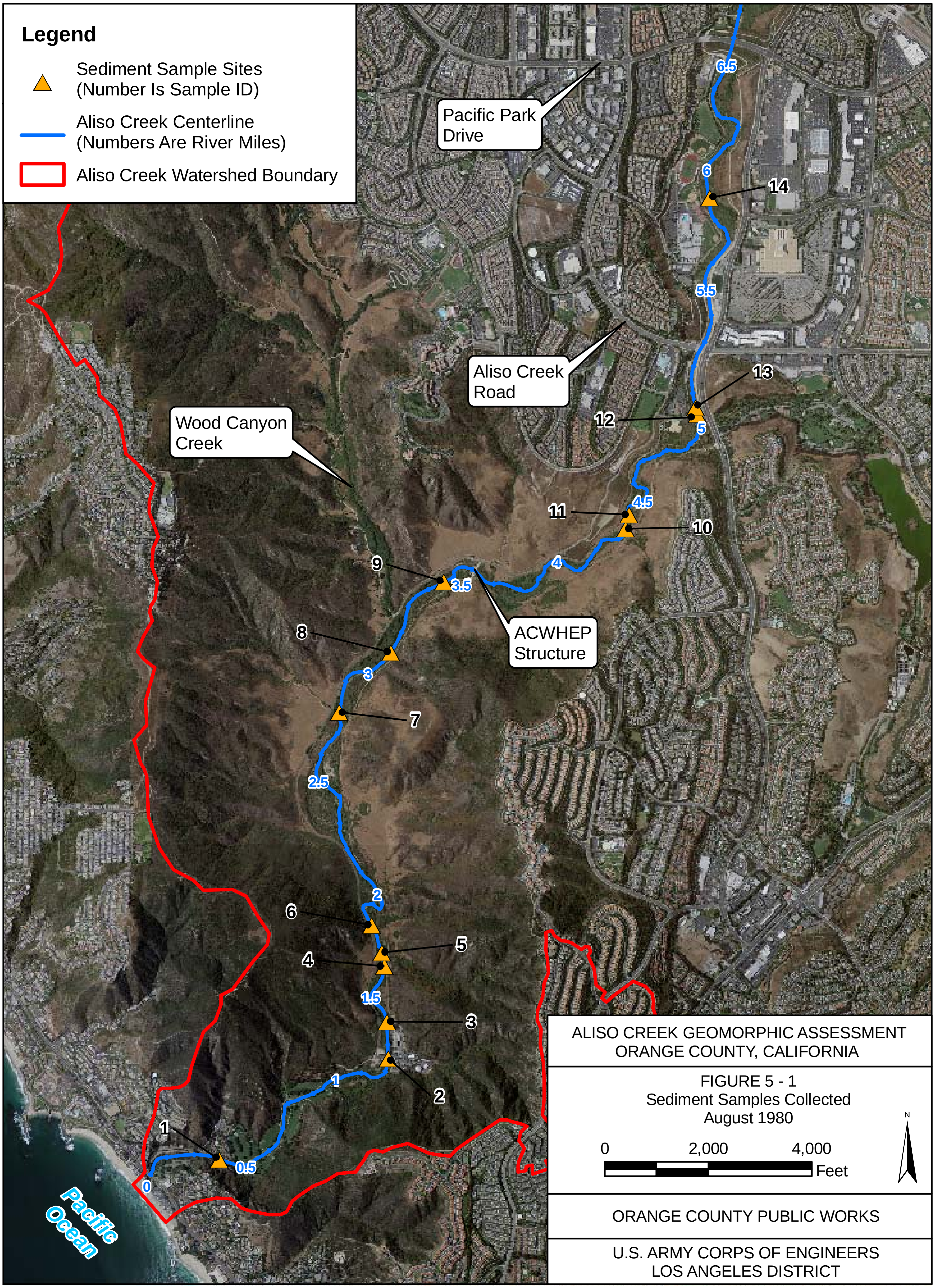
Bed samples were analyzed in 1980 to support the sediment transport analysis performed by CDM in 1982 (Southern California Soil and Testing 1980). Initial sampling was conducted with a shovel of the upper 1.5 feet of the active streambed material. The second phase consisted of logging and sampling backhoe pits excavated into or below the active streambed material. The general character of the moveable bed was described as fine to medium sand at the surface that grades downward to a gravelly, slightly silty medium sand with the base of the active streambed material recognized by the presence of a layer of well-rounded pebbles and cobbles between one-half and six inches in diameter. Surface armoring was observed during the investigations, primarily at the edges of the streambed and on some bars, generally near zones of colluvium. The armor stones were generally flattened with long dimensions of two to four inches. Twenty-three samples were collected, eighteen from Aliso Creek, and fourteen within the current study area. Of these fourteen, nine samples were collected from the surface materials only and five samples represented the combined materials throughout the active streambed.

Due to the coarseness of the stationing for each sample, the conversion of the samples to the 2006 stationing represents a best estimate. The sample locations are illustrated in Figure 5-1; descriptive characteristics of these samples are presented in Table 5-2.

Table 5-2. August 1980 Bed Samples and Characteristics

ID	Location[1]	Analysis[2]	Soil Classification	d_{100} (mm)[3]	d_{84} (mm)	d_{50} (mm)	d_{16} (mm)	Gravel (%)	Sand (%)	Fines (%)
1	0.39	S, Sieve	Poorly graded sand (SP)	8	1.22	0.58	0.24	1.9	94.3	3.8
2	1.25	S, Sieve	Poorly graded sand (SP)	16	1.24	0.59	0.27	3.0	94.8	2.2
3	1.38	C, Sieve	Gravelly sand (SW)	152	10.35	1.35	0.33	29.6	67.7	2.7
4	1.63	S, Sieve	Gravelly sand (SW)	152	2.56	1.08	0.29	13.2	84.7	2.1
5	1.68	S, Sieve	Poorly graded sand (SP)	16	1.26	0.62	0.29	3.4	93.6	3
6	1.78	C, Sieve	Gravelly sand (SW)	152	3.26	1.10	0.28	16.3	83.0	0.7
7	2.78	C, Sieve	Silty sand over gravelly sand (SM-SP)	64	11.72	2.13	0.42	40.2	59.0	0.8
8	3.12	S, Sieve	Poorly graded sand (SP)	64	1.75	0.62	0.21	8.9	89.0	2.1
9	3.46	C, Sieve	Gravelly sand (SP)	64	2.25	1.10	0.33	8.7	91.0	0.3
10	4.35	C, Sieve	Gravelly sand (SP)	64	2.59	1.27	0.46	10.9	87.3	1.8
11	4.41	S, Sieve	Gravelly sand (SP)	64	2.15	1.04	0.45	8.2	90.5	1.3
12	5.03	S, Sieve	Poorly graded sand (SP)	16	1.22	0.60	0.27	1.5	97.5	1
13	5.05	C, Sieve	Poorly graded sand with silt (SP-SM)	16	1.18	0.56	0.22	0.7	88.6	10.7
14	5.89	S, Sieve	Poorly graded sand (SP)	64	2.20	0.84	0.39	11.0	88.3	0.7

[1] 2006 stationing in miles, estimated from 1980 stationing
[2] S = surface; C = combined active layer materials
[3] d_{100} estimated from sieve data, or set to 152 mm (6 in) when less than 100 percent of the sample passed the 64 mm sieve



ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 5 - 1
Sediment Samples Collected
August 1980

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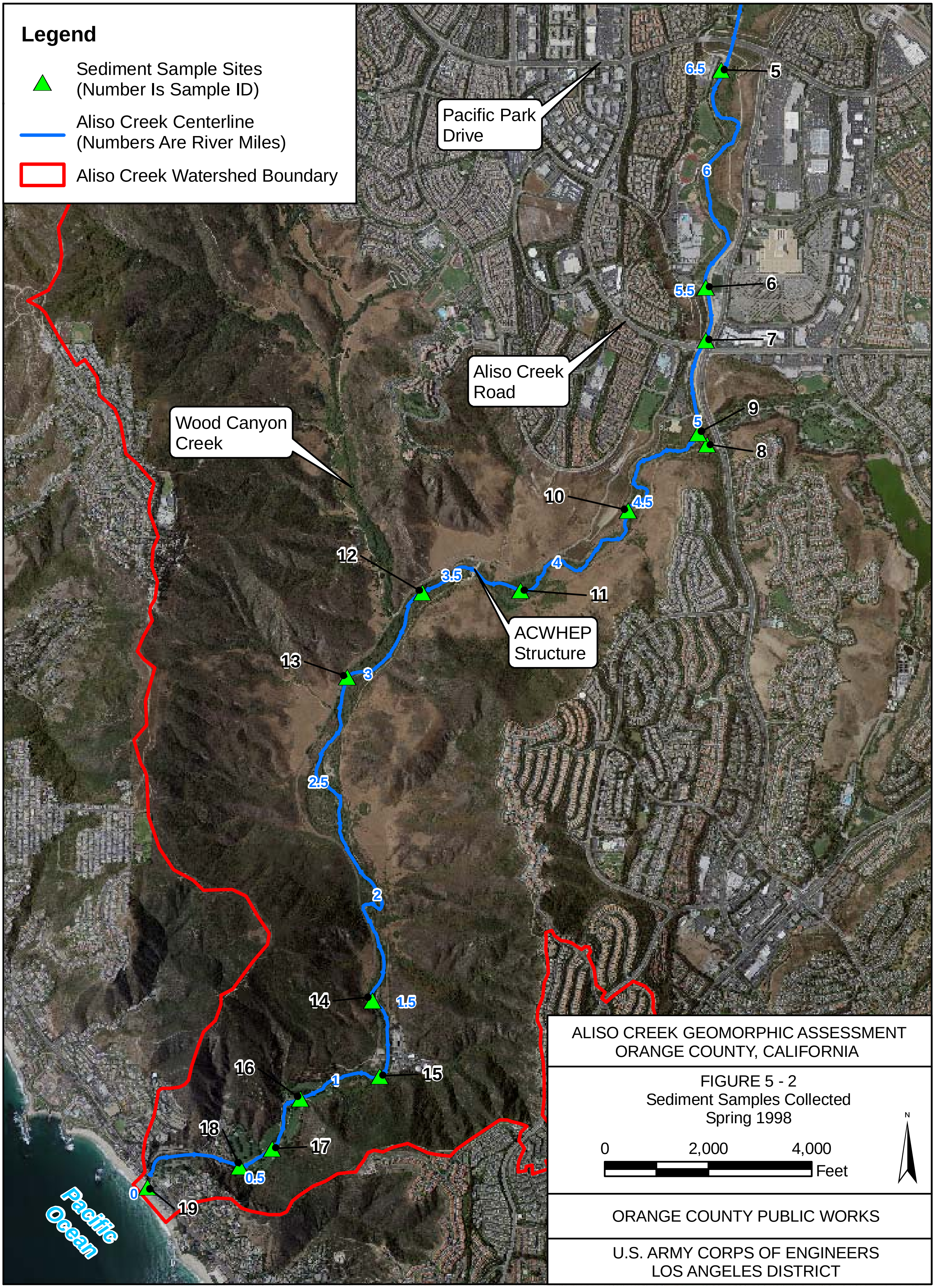
5.1.3.2 1998 Sampling

As reported in the 2000 H&H Appendix (USACE 2000), during the spring of 1998 sediment samples were collected at 19 locations between the Pacific Ocean and Laguna Hills Drive (Figure 5-2). Three of the samples were collected from the bank (i.e., samples numbered 13, 15, and 19); the remainder of the samples was collected from the bed or from depositional features in the channel. Two of the samples (i.e., samples 1 and 18) included gravel and cobble, so the coarser and finer materials were sampled separately. Volumetric samples were collected only from the material filling the voids between the larger size fractions. Where noted, pebble counts were made from a one-meter square area on the bed surface for the coarser size fractions. Descriptive characteristics of the samples are presented in Table 5-3.

Table 5-3. Spring 1998 Sediment Samples and Characteristics

ID[1]	Location[2]	Analysis	Soil Classification	d_{100} (mm)	d_{84} (mm)	d_{50} (mm)	d_{16} (mm)	Gravel (%)	Sand (%)	Fines (%)
5	West bank, RM 6.476	Sieve	Poorly graded sand with silt (SP-SM)	4.75	0.71	0.31	0.12	0.3	92.9	6.8
6	Bed, RM 5.507	Sieve	Poorly graded sand (SP)	9.5	1.0	0.46	0.26	3.3	96.2	0.5
7	Bed, RM 5.309	Sieve	Poorly graded sand (SP)	9.5	0.69	0.40	0.25	0.3	98.4	1.3
8	Bed, Sulphur Ck.	Sieve	Clayey sand with gravel (SC)	19	1.3	0.23	0.01	11.7	50.1	38.2
9	Bed, RM 4.953	Sieve	Poorly graded sand with silt (SM)	2.0	0.48	0.27	0.11	0	92.8	7.2
10	Bed, RM 4.426	Sieve	Silty sand (SM)	9.5	0.23	0.09	0.03	1.2	53.6	45.2
11	Bed, RM 3.806	Sieve	Silty sand (SM)	0.85	0.17	0.09	0.05	0	60.4	39.6
12	Bed, RM 3.376	Sieve	Silty sand (SM)	2.0	0.19	0.08	0.04	0	55.0	45.0
13	West bank, RM 2.919	Sieve	Poorly graded sand (SP)	19	0.76	0.49	0.28	0.9	98.0	1.1
14	Bed, RM 1.485	Sieve	Silty sand (SM)	2.0	0.21	0.11	0.07	0	76.5	23.5
15	West bank, RM 1.038	Sieve	Poorly graded sand with silt (SP-SM)	9.5	0.46	0.23	0.11	0.8	93	6.2
16	Bed, RM 0.849	Sieve	Poorly graded sand (SP)	9.5	1.7	0.66	0.31	10.7	88.0	1.3
17	Bed, RM 0.616	Sieve	Well graded sand with gravel (SW)	50	9.1	2.8	0.60	60.6	34.9	4.5
18	Bed, RM 0.476	Sieve	Silty sand (SM)	4.75	0.38	0.19	0.08	0.2	87.4	12.4
18	Bed, RM 0.476	Pebble Count	n/a	50	39	24	12	100	0	0
19	East bank, RM 0.058	Sieve	Poorly graded sand (SP)	19	1.7	0.69	0.36	11.4	88.5	0.1

[1] samples 1 through 4 collected outside the extents of the geomorphic assessment study area
[2] 2006 stationing in miles
n/a – not applicable



ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 5 - 2
Sediment Samples Collected
Spring 1998

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5.1.3.3 2006 Sampling

In March 2006 an addition 10 sediment samples were collected between the SOWCA treatment plant and the confluence with Sulphur Creek in support of the SUPER Project (County of Orange 2006). These locations are shown in Figure 5-3. Five of these samples were collected from the bed of Aliso Creek; five samples were taken from the streambanks. Descriptive characteristics of the samples are shown in Table 5-4.

Table 5-4. March 2006 Sediment Samples and Characteristics

ID[1]	Location[2]	Analysis	Soil Classification	d_{100} (mm)	d_{84} (mm)	d_{50} (mm)	d_{16} (mm)	Gravel (%)	Sand (%)	Fines (%)
1	Bar deposit ~1.5-ft above REW, RM 1.383	Sieve	Poorly graded sand (SP)	4.75	0.67	0.37	0.18	0.1	95.0	4.9
2	East bank, RM 1.469	Sieve	Silty sand (SM)	4.75	0.28	0.14	0.07	0.2	79.9	19.9
3	East bank, upper 4-5-ft[3], RM 1.569	Sieve & Hydrometer	Sandy clay (CL)	9.5	0.18	0.07	0.01	0.5	46.0	53.5
4	Bed, RM 3.247	Sieve	Poorly graded sand (SP)	12.7	1.8	0.74	0.33	12.2	87.1	0.7
5	Bed, RM 3.276[4]	Sieve	Poorly graded sand (SP)	9.5	1.2	0.62	0.35	2.8	96.9	0.3
7	Bank, stiff layer up to 12/15-ft above WSE, RM 3.525	Sieve & Hydrometer	Clay with sand (CH)	4.75	0.12	0.02	0.01	0.5	24.5	75.0
8	Bank, upper silty layer, 12/15 – 25 ft above WSE, RM 3.525	Sieve & Hydrometer	Sandy clay (CH)	9.5	0.17	0.04	0.01	0.9	36.3	62.8
9	Bed, RM 3.826	Sieve	Poorly graded sand (SP)	9.5	1.5	0.73	0.45	1.9	98.0	0.1
10	Bed, RM 4.158	Sieve	Poorly graded sand (SP)	9.5	1.7	0.78	0.37	8.3	91.5	0.2

[1] sample 6 collected on Wood Canyon Creek
[2] 2006 stationing in miles
[3] Sample taken from upper layer of silty loam; lower 2-feet has more clay
[4] Upper 4-feet of bed is sand represented by sample, gravel underlies the sand
n/a – not applicable

ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 5 - 3
Sediment Samples Collected
March 2006

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5.1.3.4 2008/2009 Sampling

In support of the revised H&H Appendix (USACE 2009) new bed and bank samples were collected during 2008 and 2009 in Aliso Creek (Figure 5-4). The locations matched as closely as possible the locations in the study area originally sampled in the spring of 1998. Within the extent of the current study area, 14 samples were collected from the bed of Aliso Creek (Table 5-5), 14 from the streambanks (Table 5-6).

Table 5-5. 2008/2009 Bed Material Samples and Characteristics

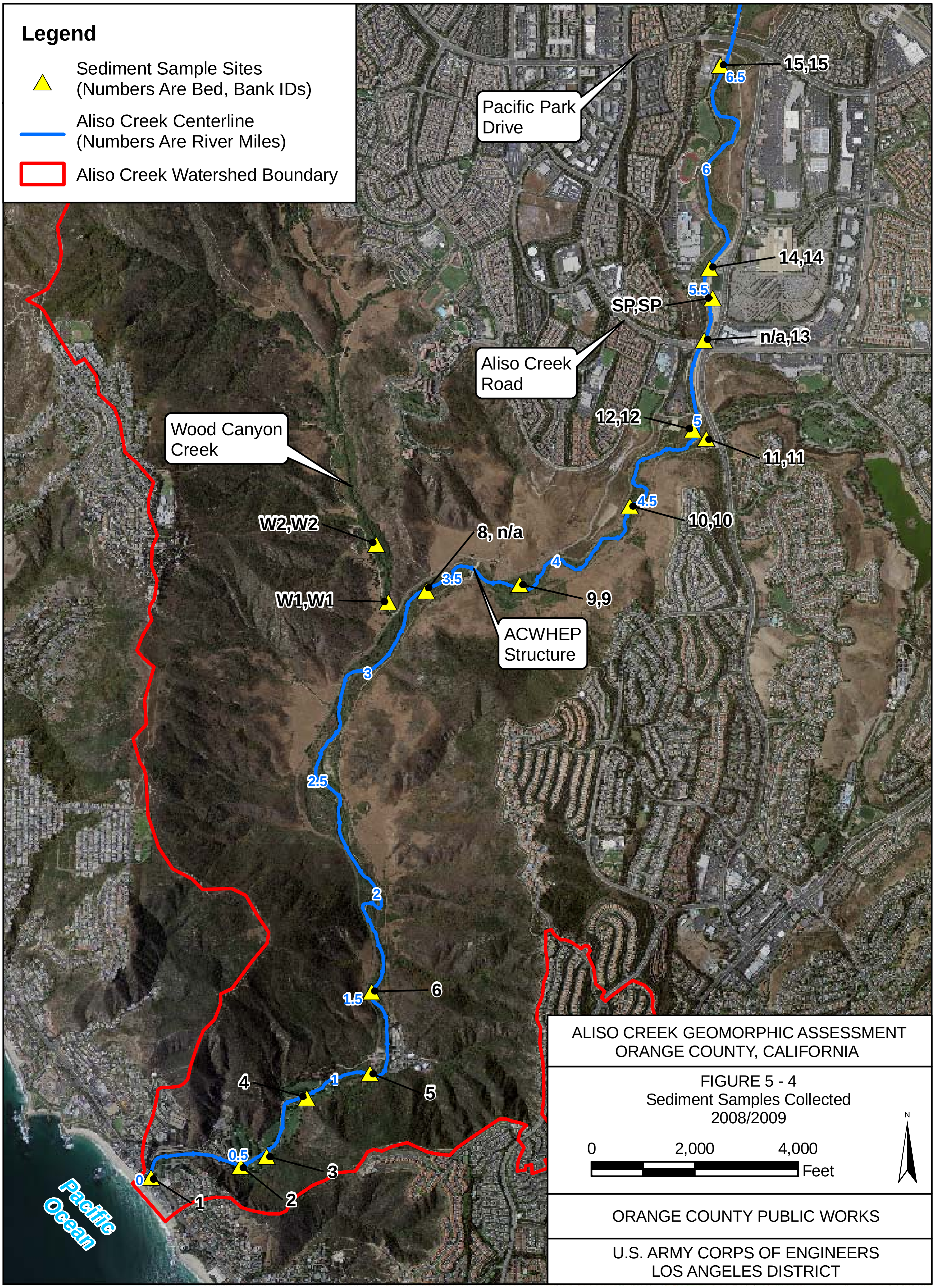
ID[1]	Location[2]	Analysis	Soil Classification	d_{100} (mm)	d_{84} (mm)	d_{50} (mm)	d_{16} (mm)	Gravel (%)	Sand (%)	Fines (%)
1	0.088	Sieve	Poorly graded sand with gravel (SP)	38	30	4.3	0.64	61.1	36.1	2.9
2	0.482	Sieve	Poorly graded gravel with sand (GP)	75	55	13	0.94	76.4	22.6	1.0
3	0.583	Sieve	Poorly graded sand with silt (SP-SM)	1.0	0.87	0.41	0.15	1.8	91.2	6.9
4	0.875	Sieve	Poorly graded sand with gravel (SP)	38	11	1.5	0.48	43.2	56.1	0.7
5	0.993	Sieve	Poorly graded sand with gravel (SP)	1.9	5.4	1.2	0.51	29.7	69.5	0.8
6	1.516	Sieve	Poorly graded sand (SP)	38	3.8	1.3	0.53	26.8	71.9	1.4
9	3.801	Sieve	Silty sand (SM)	9.5	0.97	0.49	0.01	2.7	64.6	32.7
10	4.443	Sieve	Poorly graded sand (SP)	12.5	1.6	0.75	0.38	5.7	93.7	0.7
11	4.963	Sieve	Well graded sand with silt and g ravel (SW-SM)	38	13	2.5	0.28	56.2	35.3	8.5
12	Sulphur Creek	Sieve	Silty sand with gravel (SM)	25	7.1	1.4	0.15	39.7	46.0	14.4
13	5.304	Sieve	Poorly graded sand (SP)	19	2.2	0.97	0.51	17.0	82.3	0.6
SP	5.461	Sieve	Poorly graded sand (SP)	19	1.5	0.69	0.41	5.2	92.0	2.8
14	5.579	Sieve	Poorly graded sand (SP)	12.5	1.4	0.71	0.46	3.6	94.9	1.5
15	6.484	Sieve	Clayey sand (SC)	9.5	1.2	0.56	0.01	2.1	70.9	27.0

[1] ***samples at locations between ID 6 and ID 9 were not sampled due to access issues***
[2] ***2006 stationing in miles***

Table 5-6. 2008/2009 Streambank Samples and Characteristics

ID[1]	Location	Analysis	Soil Classification	d_{100} (mm)	d_{84} (mm)	d_{50} (mm)	d_{16} (mm)	Gravel (%)	Sand (%)	Fines (%)
1	0.088	Sieve	Silty sand (SM)	19	0.48	0.22	0.08	5.0	80.4	14.6
2	0.482	Sieve	Poorly graded sand with gravel (SP)	75	57	1.1	0.32	47.5	49.4	3.1
3	0.583	Sieve	Poorly graded sand with gravel (SP)	25	4.6	1.2	0.50	30.4	68.7	0.9
4	0.875	Sieve	Poorly graded sand (SP)	1.0	0.72	0.43	0.24	0.2	96.6	3.2
5	0.993	Sieve	Silty sand (SM)	9.5	0.30	0.14	0.04	0.3	68.4	31.3
6	1.516	Sieve	Silty sand (SM)	9.5	0.73	0.30	0.06	1.3	80.3	18.4
8	3.801	Sieve	Silty sand (SM)	19	0.24	0.13	0.04	2.2	65.1	32.8
9	4.443	Sieve	Sandy clay (CL)	1.0	0.23	0.05	0.01	0.3	42.3	57.5
10	4.963	Sieve	Silty sand (SM)	9.5	0.42	0.22	0.07	1.4	81.3	17.3
11	Sulphur Creek	Sieve	Sandy silt (ML)	1.0	0.19	0.06	0.02	0.1	43.5	56.4
12	5.304	Sieve	Clay with sand (CL)	1.0	0.14	0.03	0.01	0	29.1	70.9
SP	5.461	Sieve	Clayey gravel with sand (GC)	75	60	1.7	0.04	49.7	26.5	23.8
14	5.579	Sieve	Sand with silt (SP-SM)	19	0.70	0.29	0.11	3.0	87.2	9.8
15	6.484	Sieve	Sandy clay (CL)	9.5	0.13	0.06	0.03	0.5	39.6	59.9

[1] samples at locations between ID 6 and ID 9 were not sampled due to access issues
[2] 2006 stationing in miles



ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 5 - 4
Sediment Samples Collected
2008/2009

ORANGE COUNTY PUBLIC WORKS

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LOS ANGELES DISTRICT

5.1.3.5 2009 Sampling

During a reconnaissance survey of the creek in October 2009 from the SOWCA treatment plant up to Pacific Park Drive, the frequency of coarse gravel and cobble deposits in the bed of the channel was noted. Observations of this coarse material were inconsistent with the majority of the sediment samples that had been previously collected. The inconsistency is due to the collection of the previous samples to represent bed material load whereas the coarse clasts appear to function as local grade controls due to their relative immobility. Pebble counts were performed following the Wolman procedure (Wolman 1954) in November 2009 specifically targeted at these deposits of coarser materials. Additional samples were also collected from sand and gravel bars to characterize mobile gravel size fractions that were not well represented in earlier samples. The pebble count and sample locations are illustrated in Figure 5-5 and general characteristics of the samples are provided in Table5-7.

Table 5-7. 2009 Pebble Count and Bed Material Sample Characteristics

ID[1]	Location[2]	Analysis	Soil Classification	d_{100} (mm)	d_{84} (mm)	d_{50} (mm)	d_{16} (mm)	Gravel (%)	Sand (%)	Fines (%)
3	Side Channel, RM 1.463	Pebble Count	Well graded gravel (GW)	256	64	23	7.6	100	0	0
5	Plug, RM 1.554	Pebble Count	Poorly graded gravel (GP)	128	39	24	13	100	0	0
12	Riffle, RM 2.008	Pebble Count	Poorly graded gravel (GP)	180	52	24	12	95	5	0
18	Plug, RM 2.158	Pebble Count	Poorly graded gravel (GP)	256	43	25	13	99	1	0
23	Plug, RM 2.241	Pebble Count	Poorly graded gravel (GP)	256	108	43	20	97	3	0
28	Plug, RM 2.479	Pebble Count	Poorly graded gravel (GP)	256	124	63	26	95	5	0
38	Riffle, RM 2.932	Pebble Count	Poorly graded gravel (GP)	256	101	56	30	100	0	0
52	Riffle, RM 3.505	Pebble Count	Poorly graded gravel (GP)	375	135	80	32	95	5	0
58	Riffle, RM 3.742	Pebble Count	Poorly graded gravel (GP)	350	149	90	36	99	1	0
66	Bar, RM 4.138	Sieve	Poorly graded sand with gravel (SP)	180	58	27	2.7	86	14	0
77	Bar, RM 4.884	Sieve	Poorly graded sand with gravel (SP)	38	15	1.8	0.4	44	53	3
80	Riffle, RM 4.963	Pebble Count	Poorly graded gravel(GP)	128	74	40	21	100	0	0
84	Plug, RM 5.848	Pebble Count	Poorly graded gravel (GP)	256	49	30	17	100	0	0
93	Bar, RM 6.110	Sieve	Poorly graded sand with gravel (SP)	90	33	20	5.8	92	8	0
100	Bar, RM 6.483	Sieve	Poorly graded sand with gravel (SP)	180	60	31	16	93	7	0

[1] ***corresponds with GPS waypoints recorded during October 2009 field investigations***
[2] ***2006 stationing in miles***

ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA

FIGURE 5 - 5
Sediment Samples Collected
November 2009

ORANGE COUNTY PUBLIC WORKS

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

5.1.3.6 Comparison of Bed and Bank Sample Data

When comparing the sediment samples collected within the Aliso Creek watershed, the following observations are noteworthy:

- The silt and clay (i.e., fines) comprising up to approximately 75 percent of some of the streambank samples are not represented in appreciable quantities in the bed samples. These finer size fractions contribute locally to the wash load delivered from the watershed. Due to the high percentage of silt and clay materials in many of the streambank samples, future erosion of the streambanks will provide some material (e.g., sand, gravel, and cobbles) that will be stored locally in the channel and overbank areas; however, appreciable volumes of the eroded material will be washed directly into the Pacific Ocean during flood events.

- The bed material gradations collected in 1980 are coarser than the bank sample gradations collected in 1998 and later. If the gradations were similar, the source of bed materials could be linked to the supply in the banks. Since the gradations differ, it supports the likelihood that the finer sand and silt in the banks are washed through Aliso Creek to the Pacific Ocean without appreciable exchange with the streambed (e.g., deposition into and mobilization from the bed).

- For comparable locations, the bed material samples collected in 2008/2009 are generally coarser than the samples collected in 1998. This apparent coarsening of the bed may be due to hydraulic sorting, minor differences in locations where samples were collected, the influence of major floods prior to sample collection (i.e., December 1997 flood only months before the 1998 samples were collected and January 2005 flood with only relatively minor annual floods thereafter until the 2008/2009 samples were collected), or a combination of multiple factors.

- Up to six-inch cobbles were noted at the base of the active streambed materials in the 1980 sampling, and two to four inch pebbles were observed in armored areas. Gravel and cobbles were again observed in the bed during the 1998 sampling, and while some samples include gravel, the samples were collected only from the material filling the voids between larger size fractions. The 2009 samples specifically targeted the coarsest size fractions in the bed. Cobbles have been present in the bed of Aliso Creek across the different sampling efforts, but were only well represented in the 2009 pebble count data.

- Due to the confinement of Aliso Creek in a narrow valley/canyon where there is extensive evidence of landsliding, there is no shortage of the supply of gravel and cobbles to the creek. Gravel and cobbles were observed during the October 2009 reconnaissance in regularly spaced “plugs” that were densely vegetated with cattails. Since the cattails were not observed in the sand bed reaches, it is likely that the cobbles are relatively immobile (providing secure substrate for cattails to establish) and thus serve as grade controls. Even through the percentage of the total streambed area covered by cobbles is small compared to the area covered by sand and gravel; the influence of the cobbles plays a key role in the current profile of Aliso Creek.

5.1.3.7 Representation of Bed Material Load

The bed material load transported by Aliso Creek is comprised primarily of sand and fine gravel, with minor contributions of silt and coarser gravel. Due to the stabilizing influence of the ACWHEP structure on sediment transport upstream, the reach upstream of the structure appears to be somewhat aggradational. Bed material samples collected in this reach are, therefore, good candidates for representing the bed material load. The ideal candidate is a subsurface bar sample – sample ID 66 collected in 2009 is the only subsurface bar sample within this reach. The sample was collected from one of a series of alternating bars that exist in a depositional reach upstream of a gravel plug above the ACWHEP structure. Figure 5-6 compares the gradations of the various samples collected upstream of the ACWHEP structure to the gradation of sample ID 66 collected in 2009.

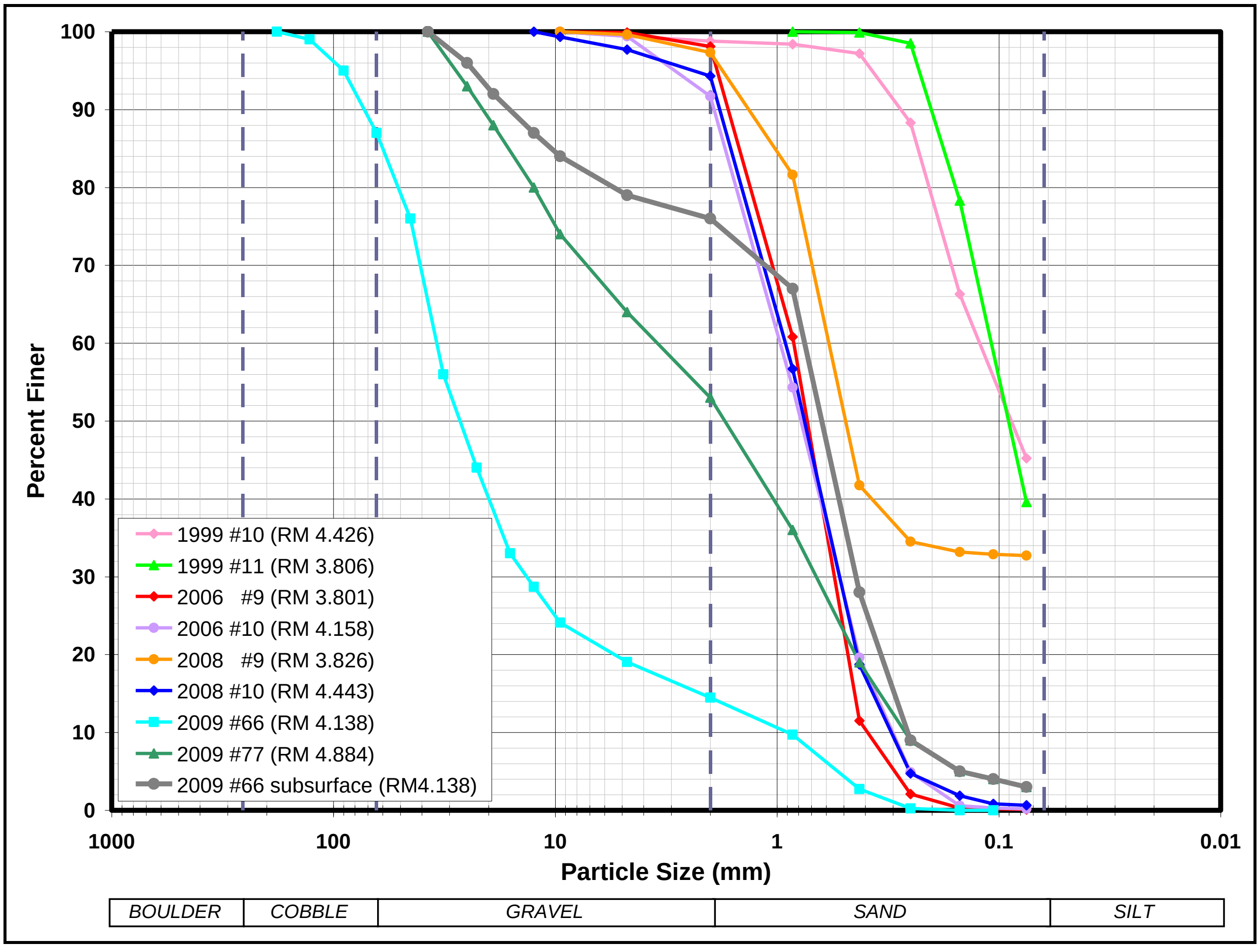


Figure 5-6. Bed material samples collected upstream of the ACWHEP structure

In Figure 5-6, the gradation curve for the subsurface material in sample ID 66 follows the gradations through approximately 1-mm sand for the surface samples collected in 2006 and 2008, but it better represents gravel. The upper end of the ID 66 subsurface curve is similar to the upper end of the ID 77 bar sample collected at the confluence of Sulphur Creek, indicating similarity in the upper size of gravel transported through this reach. The gradation represented by the ID 66 subsurface sample was, therefore, selected as the best representation of the bed material load transported in Aliso Creek.

5.2 INCIPIENT MOTION

The concept of incipient motion was applied to the coarser bed material from the coarse riffles and plugs sampled in November 2009. Figure 3-15 shows the location of the coarse riffles and plugs observed in October 2009; Figure 5-5 illustrates the locations where samples were collected. Incipient motion is taken to be the threshold of mobilization – the condition when the erosive force of the flow in the channel is balanced by the resistive force of the weight of the pebble. The portion of the total channel shear stress acting only on grains on the bed, the grain shear stress, was calculated to quantify the erosive force. The dimensionless Shields parameter (Shields 1936) was applied to the submerged weight of a particular size fraction in the bed to quantify the resistive force. Comparing grain shear stress calculated for different flows to the resistive force provides a method for identifying the flow corresponding to conditions of incipient motion. Since grain shear stress is typically directly proportional to flow rate, all flows greater than the flow at incipient motion can be assumed to be erosive (this assumption should be verified by hydraulic data since backwater conditions at higher flows can reduce shear stress). Determining the flow associated with incipient motion for the coarse materials in the plugs and riffles of Aliso Creek provides a basis for assessing the relative mobility of the materials and the stability of the bed.

The grain shear stress can be calculated numerous ways, and in all cases, the objective is to exclude the shear stress acting on anything other than the surface grains on the streambed (e.g., vegetation, banks, and bedforms). The approach used in this geomorphic assessment is based on the assumed logarithmic velocity profile and the relationship between mean channel velocity and the grain shear velocity. The roughness height was set to 3.5 d_{84} (Hey 1979). The resistive force can also be calculated a multitude of ways, so for this assessment, two values of the Shields parameter (i.e., 0.03 and 0.047) were combined with two representative grain sizes from the samples (i.e., d_{50} and d_{84}).

To generalize the results presented in Table 5-8, when the particle size of interest was approximately 100 mm or greater, the particles were immobile up through the 100-year recurrence interval flood. This is true for either value of the Shields parameter. When the particle size of interest was in the gravel range (25 mm to 64 mm), for either value of the Shields parameter, the particle was mobile at relatively frequent flood events (i.e., 5-year recurrence interval and more frequent). As shown in Table 5-7, none of the samples collected in November 2009 have a d_{50} greater than 100 mm; but quite a few samples have d_{84} exceeding 100 mm. However, comparison of grain sizes in November 2009 and February 2010 (before and after the late January 2010 floods on the order of a 25-year recurrence interval), indicated that the gravel plugs and riffles appeared unchanged. This was attributed to the dense growth of tules and cattails that were established in the gravels. In many cases, the high flows laid over the vegetation, which further sheltered the grains from the erosive force of the flows. In other cases, the vegetation was sheared off a few inches from the bed, but the vegetation was not uprooted and the remaining stubs likely provided enough resistance to create a sublayer of flow that buffered the bed from the most turbulent flows. Thus, it is likely that under any feasible flow conditions, the cobbles will remain immobile and the gravel, so long as they support a stand of tules or cattails, will be buffered sufficiently from the flow by the vegetation to remain immobile.

Table 5-8. Summary of Incipient Motion Results for Existing Conditions

River Mile	Sample	d_{84} (mm)	Shields parameter = 0.03		Shields parameter = 0.047	
			Critical Shear (lbs/ft^2)	Critical Flow (R.I.)[1]	Critical Shear (lbs/ft^2)	Critical Flow (R.I.)[1]
1.463	3	64	0.65	>100	1.02	>100
1.554	5	39	0.40	<1.1	0.62	2
2.008	12	52	0.53	1.1	0.83	5
2.158	18	43	0.43	2	0.68	10
2.241	23	108	1.10	>100	1.72	>100
2.479	28	124	1.25	2	1.96	>100
2.932	38	101	1.02	>100	1.60	>100
3.505	52	135	1.37	>100	2.15	>100
3.742	58	149	1.51	>100	2.36	>100
4.963	80	74	0.75	<1.1	1.17	<1.1
5.848	84	49	0.50	5	0.78	100

[1] recurrence interval (R.I.) of flood required to equal or exceed the critical shear

One concern with the incipient motion analysis is the influence on incipient motion of resistance from riparian vegetation that has established on the floodplains inset in the incised channels. This vegetation has become fairly dense, likely due to the year-round access to water due to the perennial baseflow in Aliso Creek. If this baseflow was to disappear, and the vegetation was to completely die off, would the conditions governing incipient motion of the bed materials change enough to affect channel morphology? The HEC-RAS model was run for a scenario where the Manning's n-values were reduced to reflect conditions without the riparian vegetation. The grain shear was calculated from the results of this scenario, and the results presented in Table 5-9 are similar when compared to the run for existing conditions (see Table 5-8). Slight differences in the results are due to changes in flow depths and energy grade line slope as a result of the reduced n-values. This comparison shows that it is the new channel morphology that has developed in response to channel degradation and subsequent widening (e.g., increased channel width and flatter channel slope) rather than the riparian vegetation that is responsible for the stability of the cobbles in the coarse plugs and riffles. However, the gravels that are currently stable due to the protection provided by the tules and cattails could become mobile; but since this vegetation grows in the bed of the channel, not only would the baseflow need go to zero, the groundwater would also need to drop enough to kill the vegetation. Considering available information, the probability of these conditions occurring seems remote.

Table 5-9. Summary of Incipient Motion Results without Existing Vegetation

			Shields parameter = 0.03		Shields parameter = 0.047	
River Mile	Sample	d_{84} (mm)	Critical Shear (lbs/ft^2)	Critical Flow (R.I.)[1]	Critical Shear (lbs/ft^2)	Critical Flow (R.I.)[1]
1.463	3	64	0.65	10	1.02	>100
1.554	5	39	0.40	<1.1	0.62	5
2.008	12	52	0.53	2	0.83	10
2.158	18	43	0.43	<1.1	0.68	2
2.241	23	108	1.10	>100	1.72	>100
2.479	28	124	1.25	>100	1.96	>100
2.932	38	101	1.02	>100	1.60	>100
3.505	52	135	1.37	>100	2.15	>100
3.742	58	149	1.51	>100	2.36	>100
4.963	80	74	0.75	<1.1	1.17	<1.1
5.848	84	49	0.50	2	0.78	25

[1] *recurrence interval (R.I.) of flood required to equal or exceed the critical shear*

5.3 EFFECTIVE DISCHARGE

The effective discharge is the quantification of the concept of the dominant discharge – the increment of discharge that transports the greatest amount of sediment over the long term (Wolman and Miller 1960; Andrews 1980; Biedenharn et al. 2000). In perennial, self-adjusted streams the effective discharge is typically calculating by integrating the bed material transport capacity rating curve and the flood frequency curve. This approach generally produces an effective discharge on the order of the bankfull discharge (e.g., the one to two-year recurrence interval flood). In arroyos, the effective discharge is calculated by integrating the bed material yield frequency curve to produce the mean annual bed material load. The effective discharge can then be estimated as the peak flow of the flood hydrograph that transports a bed material yield equal to the mean annual bed material yield. This approach applied to minimally developed watersheds typically results in an effective discharge on the order of five-year to ten-year recurrence interval flood peak discharge. In heavily developed watersheds the effective discharge is on the order of the three-year to five-year recurrence interval flood peak discharge (MEI 2008). In a coastal, southern California watershed such as Aliso Creek, neither one of these standard approaches is ideal (Downs 2007). The approach for perennial streams underestimates the effective discharge because there is such a large percent of the annual flow regime that is weighted to the low flows that occur during dry weather. The approach for arroyos is inappropriate for estimating effective discharge because unlike arroyos, Aliso Creek experiences many flood events per year (an annual average of 9 flood events with peak discharges greater than the 1.1-yer recurrence interval flood). A new approach was therefore developed for application to the Aliso Creek watershed.

The basis of the new effective discharge calculation is that minimal bed material is transported except during flood flows. The flow duration curve for Aliso Creek was developed considering only the flows associated with flood events. This approach excludes the dry weather flows that occur most of the year. In a flashy system such as Aliso Creek, the annual flow duration curve is dominated by the dry weather flows and provides poor resolution of flood flows. Due to the high percentage of the year during the base flows, the effective discharge is spuriously calculated as the base flow. Based on field observations of essentially no bed material transport during base flows, and consistent with professional experience in similar systems to Aliso Creek, the base flow is known to not be the increment of annual flows that transports the greatest amount of sediment over the long term. Developing the flow duration curve using only the flood flows provides a more realistic representation of the distribution of flows that are capable of mobilizing and transporting bed material. The development of this flow duration curve, development of the bed material load rating curve, and the calculation and verification of the effective discharge are presented in the following sections.

5.3.1 Effective Discharge Flow Duration Curve

As described in Section 2.2, the only long-term stream gage in the watershed is located near the crossing of Jeronimo Road – there is limited gaging data within the study area. Since the bed material supply appears to somewhat exceed the transport capacity in Reaches 7 and 8, calculations of transport capacity are likely representative of actual transport (as opposed to an armored reach where the transport capacity would exceed the available supply and actual transport would be less than calculated capacity). The issue is that there are no gaging data in reaches 7 and 8 to develop a flow duration curve. The gaging data collected at Jeronimo Road was used to produce the required flows.

Assuming watershed characteristics that affect runoff are similar within the watershed flows are generally related at different locations in the watershed based on a ratio of the drainage area. In the South Coast Region of California, this relationship is exhibited in the regression equations published by the USGS for estimating peak flows (Waananen and Crippen 1977). The peak flows for the South Coast Region are a function of drainage area and mean annual precipitation. The drainage area is raised to a power of 0.72 to 0.87 depending on the recurrence interval of a flood (increases for less frequent floods). Using these relationships, the peak flows at the Jeronimo gage (drainage area of 8.6 square miles) were scaled to the downstream end of Reach 7 (the ACWHEP structure, drainage area of 28.1 square miles).

The data recorded at the Jeronimo gage illustrate the flashy (i.e., rapid rise, peak, and recession of the storm hydrograph) nature of floods. Average daily flow rates are too coarse to adequately represent the flood hydrographs, so average hourly data was considered. Digital archives of sub-daily flow data are maintained by Orange County only for the period after June 1991, excepting July 1995 to June 1996 and October 1998 to September 1999. The hourly flow data were compared to the calculated peak of 130 cfs for the 1.1-year recurrence interval flood at the Jeronimo gage to identify the floods capable of mobilizing and transporting appreciable amounts of bed material. The 1.1-year flood was selected as an indicator of an average annual flood. These peak flows were then scaled to the ACWHEP structure using the ratio of drainage areas and appropriate exponents. As a check, the calculated peak flows compared favorably to the flood frequency curve produced by the HEC-1 model for the concentration point at the ACWHEP structure. The runoff volume associated with each flood was calculated using a ratio of flood volumes as measured at the Jeronimo gage and the SOCWA gage. The period of record for the SOCWA gage begins in water year 2002, and there is concern that the rating curve isn't applicable for flows after the SOCWA bridge replacement in October 2008. However, for the available period of record, the flood volumes measured at the two gages were scaled per square mile of drainage area and compared. Typically the unit runoff volumes decrease as watershed area increases, but in the Aliso Creek watershed, the greater levels of imperviousness below the Jeronimo gage cause the unit runoff volume to increase. This increase is also evident when comparing the unit runoff volumes calculated by the HEC-1 models of the watershed. The range of unit runoff volume ratios is 0.3 to 13.1, with an average value of 2.5. Given the skew in these values, the median value of 1.9 was used instead of the average. The flood volumes in Reach 7 were calculated by converting the volume measured at the Jeronimo gage to a unit runoff volume, multiplying by the drainage area to Reach 7, and multiplying by the median ratio of 1.9. The results of these calculations are provided in Table 5-10.

Table 5-10. Scaled Flow Data for Reach 7

Water Year	Number of Floods[4]	Annual Flood Volume (ac-ft)	Annual Peak Flow Rate (cfs)
1992	6	8,420	6,990
1993	11	33,260	4,110
1994	8	3,360	980
1995[1]	15	23,290	4,840
1996[2]	0[2]	0[2]	n/a
1997	6	3,140	1,230
1998	20	32,140	8,610
1999[3]	n/a	n/a	n/a
2000	6	3,570	1,710
2001	6	6,150	1,200
2002	1	190	370
2003	10	11,900	1,760
2004	6	1,540	770
2005	17	37,110	5,250
2006	6	3,560	1,670
2007	6	1,700	770
2008	10	6,640	2,330

[1] *missing data from July 1 through December 31*
[2] *missing data from January 1 through June 30*
[3] *entire water year missing from electronic archives*
[4] *floods having peak flows greater than or equal to the 1.1-year recurrence interval flood*
n/a = not applicable

To translate the calculated peak flows and runoff volumes into hydrographs at the ACWHEP structure, a duration component is required. For simplification, each flood was assumed to be represented by a triangular shaped hydrograph, with a total duration equal to two times the volume divided by the peak flow. Applying this simplification allowed for the calculation of 15-minute flows within each flood for development of the flow duration curve using only stormflows. The 15-minute flows within each flood recorded between water years 1992 and 2008 were sorted and ranked to produce the flow duration curve shown in Figure 5-7.

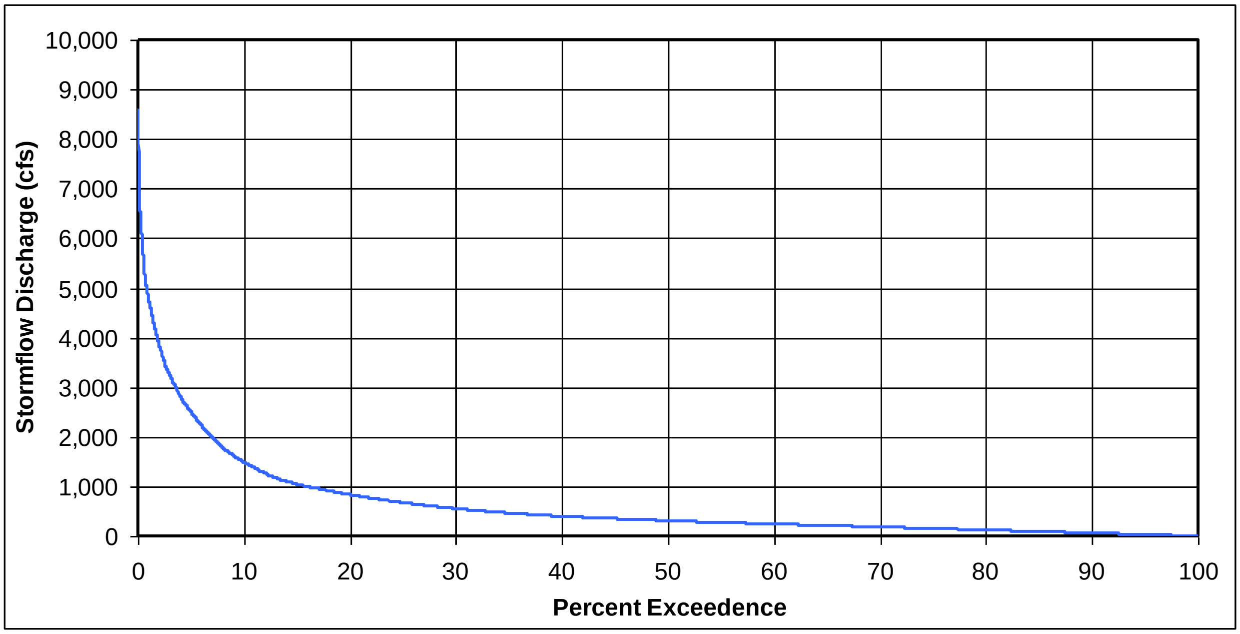


Figure 5-7. Flow duration curve (stormflows only) at the ACWHEP structure

5.3.2 Bed Material Load Rating Curve

The bed material load rating curve quantifies the bed material load transported for various flow rates. No known measurements of bed material load are available for Aliso Creek, so the bed material load rating curve was developed by application of a bed material load transport function. As documented in the revised H&H Appendix (USACE 2009), Yang's transport function (1973, 1984) was identified as the most appropriate function for Aliso Creek. These functions were developed for sand and gravel with median sizes between 2 and 8 mm in diameter, respectively; however, careful review of the transport calculations shows mobilization and transport of all gravel in the representative bed material gradation. The sand transport function (Yang 1973) was applied to bed material less than 2 mm in diameter and the gravel transport function (Yang 1984) was applied to bed material greater than or equal to 2 mm in diameter.

The bed material gradation selected to represent the bed material load is documented in Section 5.1.3.7 and is shown in Figure 5-6. The sample is approximately 24 percent gravel, 73 percent sand, and 3 percent fines. The maximum size gravel is 37.5 mm, the d_{84} is 9.5 mm, and the d_{50} is 0.67 mm.

The peak flows shown in Table 2-4 for concentration point 4 were supplemented with lower flows and input to the HEC-RAS model to produce indicators of channel hydraulics that were length-weighted over Reaches 7 and 8 for input to the Yang transport functions. The resulting bed material load rating curve is presented in Figure 5-8.

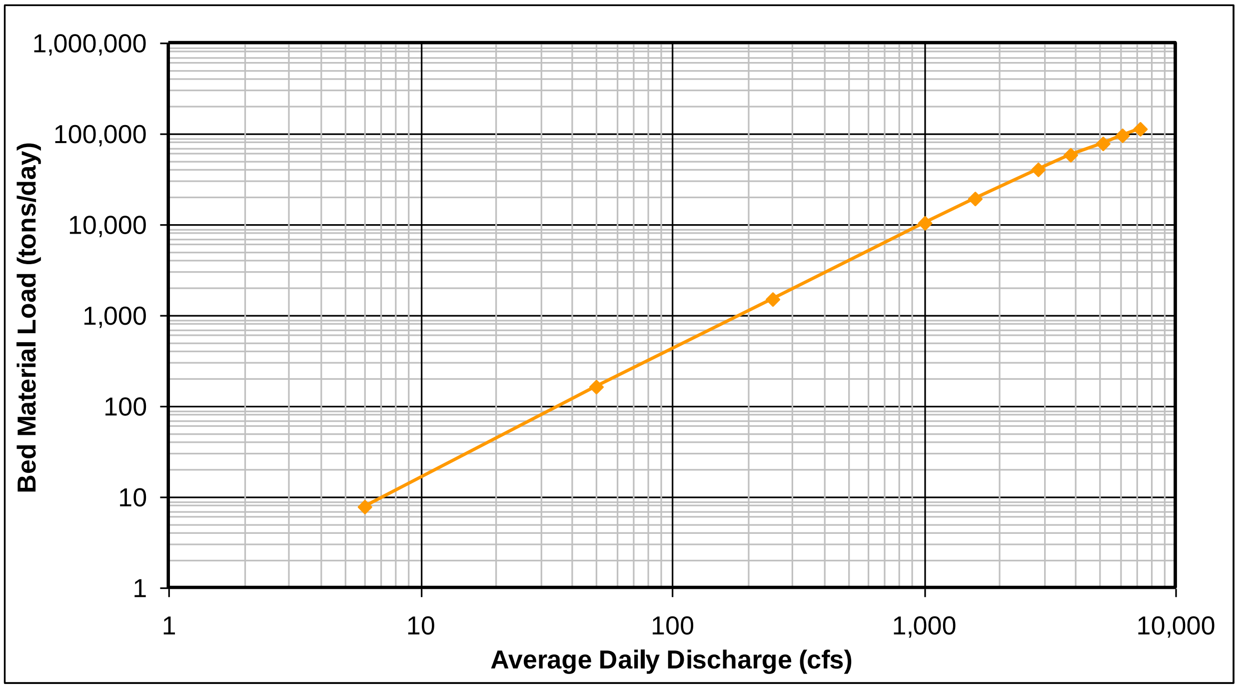


Figure 5-8. Bed material load rating curve for Reaches 7 and 8

5.3.3 Calculation of Effective Discharge

The approach for the calculation of effective discharge requires a flow duration curve and a bed material load rating curve as input for the following general steps:

- Divide the range of flows over the period of interest into a number of arithmetic classes
- Calculate the frequency of occurrence of each flow class over the period of record
- Calculate the bed material load transported by the average flow in each class
- Multiply the calculated load by the frequency of occurrence

The number of arithmetic classes selected for dividing the range of flows can influence the calculated effective discharge. The selected interval should be small enough to accurately represent the frequency distribution of flows, but large enough to produce a continuous distribution (Biedenharn et al. 2000). Typically 25 to 30 classes are used, although a range from 10 to 250 may be required. For Aliso Creek, a range from 20 to 100 classes was tested, and 50 classes were selected. The frequency of occurrence of flows in each class was determined, the bed material load was calculated for the average flow in each class, and Figure 5-8 illustrates the resulting bed material load histogram. Figure 5-8does not show all of the classes to make it easier to interpret the results. As shown in this figure, the increment of flow that transports the greatest amount of bed material is between 260 and 1,100 cfs.

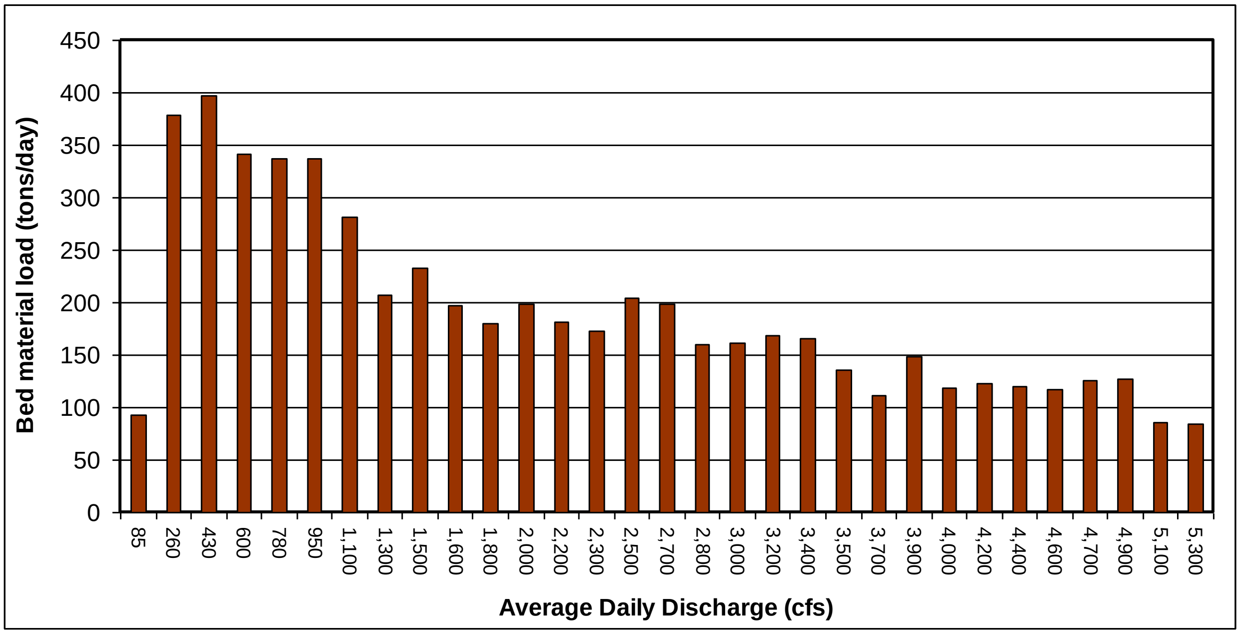


Figure 5-9. Effective discharge calculation for Reaches 7 and 8

5.3.4 Verification of Effective Discharge

To check the reasonableness of the range of calculated effective discharges, the HEC-RAS model was used to simulate flows of 250 cfs, 500 cfs, and 1,200 cfs (the 1.1-year recurrence interval flood peak flow, a close approximation of the upper end of the effective discharge range of 1,100 cfs). The water-surface elevation was compared to the elevation of the banks of the active channel. Upstream of the ACWHEP structure, the banks of the active channel were coincident with the floodplain elevation. Once the active channel was noticeably incised, both toward the Sulphur Creek confluence and downstream of the ACWHEP structure, the bank elevations were set at the elevation of the new inset floodplain forming in the base of the incised channel. Through the non-incised sections upstream of ACWHEP, the capacity of the active channel was typically between 500 and 1,200 cfs. In the incised sections, the capacity of the active channel was typically between 250 and 500 cfs. These trends verify the reasonableness of the calculated range of effective discharges.

A separate check on the verification of the effective discharge calculation is comparison of the annual bed material load transported to the calculations of annual load determined from upland sources presented in Section 5.1.1. Considering all flows throughout the year, not just stormflows, the annual flow duration curve shows that three percent of year flows exceed 30 cfs (the selected threshold between storm and base flows described in Section 5.3.1). This corresponds with approximately 11 days per year. Applying the concept of the effective discharge, if the effective discharge was maintained continuously over these 11 days, the bed material yield should approximate the average annual load. Using 250 cfs, the annual bed material load is 15,300 tons and using 1,100 cfs the annual load is 115,000 tons. These estimated loads are in reasonable agreement with the range of values calculated from the upland-based approaches. The range of 40,000 to 60,000 tons of bed material per year corresponds with effective discharges of approximately 500 to 700 cfs, respectively. These calculations provide another means to verify the reasonableness of the effective discharge calculation.

5.4 BED MATERIAL TRANSPORT CAPACITY

The relationships between channel hydraulics and bed material transport capacity were investigated two ways. The first way was to compare the calculated transport capacities through the geomorphic reaches to consider the continuity of transport through the study area. The second approach was to calculate the bed material load for each flood event hydrograph (see section 5.3.1) in Reach 7 to calculate annual bed material load for comparison to the annual loads calculated from the upland based approaches.

5.4.1 Reach-based Bed Material Transport Capacity Comparison

The bed material transport capacity was calculated for each of the geomorphic reaches as a means for comparing the transport capacity through the study area. A similar process was followed as was used for the generation of the bed material rating curve for the calculation of effective discharge. Hydraulic parameters were length-weighted within each reach as indicators of reach-averaged hydraulics. These average values were input to the Yang transport function (1973, 1984) with the representative bed material load gradation to calculate the bed material transport capacity of a reach. This was done for a range of flows and flood events. The results covering the range of effective discharges are shown in Figure 5-10; Figure 5-11 illustrates the results for a selected range of peak flood flows (i.e., the 2-year, 5-year, 25-year, and 100-year recurrence interval peak floods).

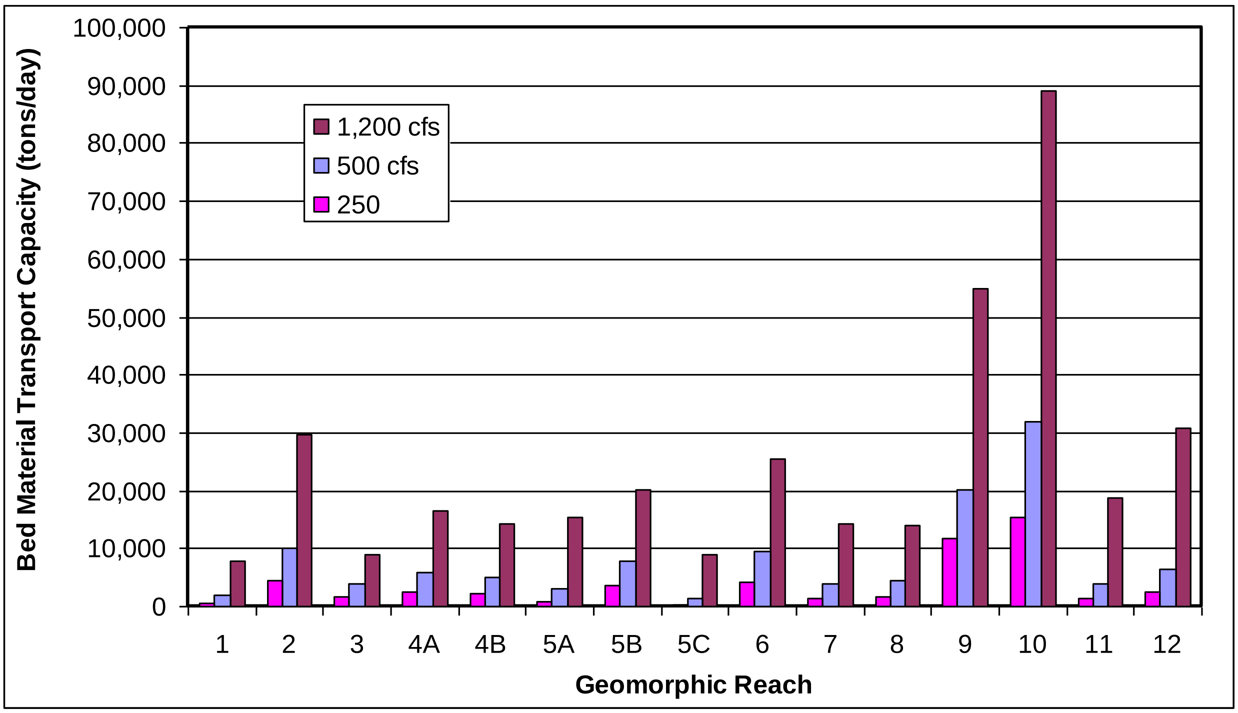


Figure 5-10. Bed material transport capacity for effective discharges

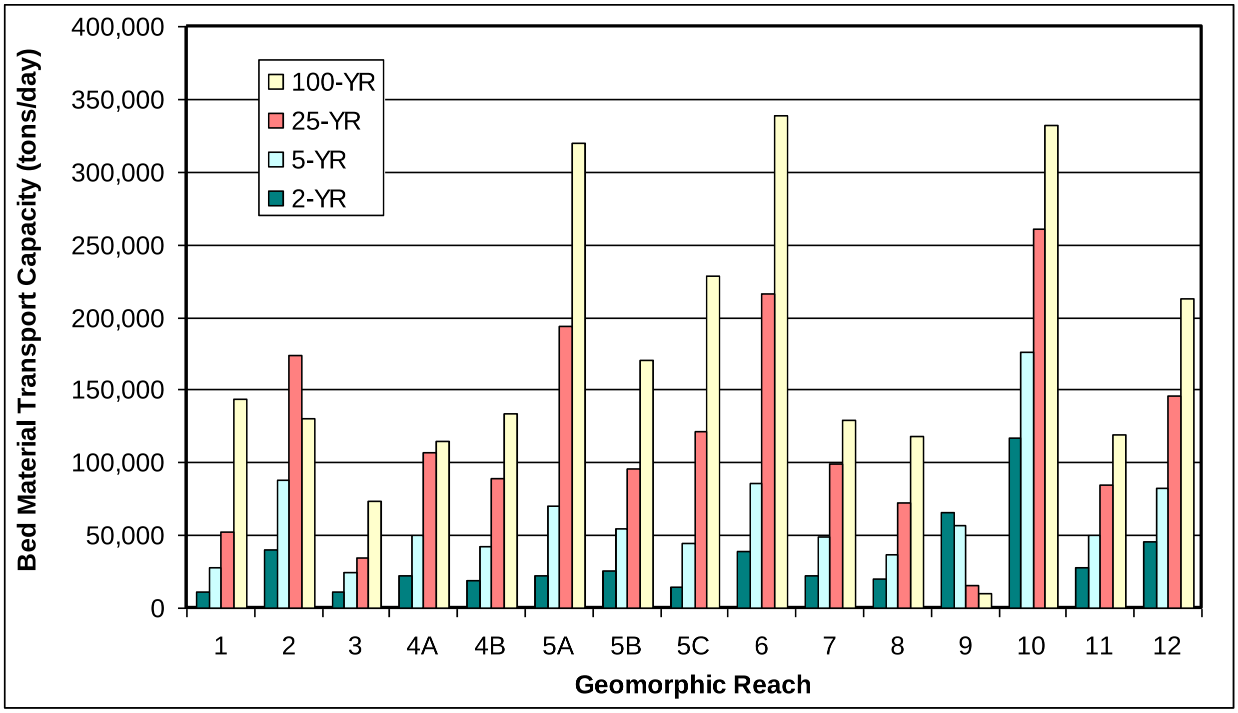


Figure 5-11. Bed material transport capacity for selected peak flood flows

Similar patterns emerge in both Figures 5-10 and 5-11. Assuming that Reach 7 represents the reach that is most self-adjusted between sediment supply and transport capacity, the load transported through Reach 7 can provide an indication of the equilibrium load. Reaches with transport capacities greater than Reach 7 have a greater probability of degradation whereas reaches with lower transport capacity have a greater probability of aggradation. Notable observations from Figure 5-10 include:

- Reach 10 is a "pass-through" reach. Due to the riprap banks and concrete grade-control structures, all bed material entering this reach will be passed through to downstream reaches with limited potential for aggradation or degradation of the bed.

- The transport capacity of Reach 9 indicates the potential for degradation; however, the coarser gravel bed material provides some grade control.

- The similarity between Reach 8 and Reach 7 indicates that Reach 8 may also be near an equilibrium condition.

- The transport capacity of Reach 6 exceeding Reach 7 is expected given the coarser cobble and boulder riffles in this reach, the higher bed slope, and the observed incision downstream of the ACWHEP structure.

- Reach 5C exhibits the lowest transport capacity in the study area, consistent with the depth of sand and fine gravel (up to 5 feet) observed in the bed of this reach.

- The transport capacity in Reaches 4A, 4B, and 5A is comparable to Reaches 7 and 8, indicating these reaches may be close to approaching a balance between bed material delivered from upstream reaches and transport capacity.

Notable observations from Figure 5-11 include:

- For the selected flood flows, the transport capacities in Reach 8 are slightly less than the transport capacities in Reach 7.

- The transport capacities in Reach 2 are relatively high, likely due to the lack of woody riparian vegetation through the Aliso Creek golf course. Once flows access the overbank areas, the managed turf and landscaping provide considerably less resistance compared to the dense vegetation through the Aliso and Wood Canyons Wilderness Park.

- For floods with peak flows exceeding the peak flow for the 2-year recurrence interval, Reaches 2, 5A, 5B, 5C, and 6 exhibit bed material transport characteristics most different from Reach 7. If not for the controlling influence of clay outcrops, bedrock outcrops, coarse plugs, and coarse riffles, these reaches would be the most susceptible to future incision.

5.4.2 Annual Bed Material Loads

As described in Section 5.3.1, the flow duration curve for the effective discharge calculation was developed by fitting triangular-shaped hydrographs to the scaled up peak flows and runoff volumes in Reach 7. Average 15-minute flow rates were calculated for the duration of each hydrograph, so these flows were used with a sediment rating curve scaled to 15 minutes to calculate the bed material transported by each flood. Summing up the load from each storm provides another method to estimate the annual bed material load delivered from the Aliso Creek watershed. Some assumptions for this analysis are (1) the hydraulics of Reach 7 have remained fairly constant since water year 1992, (2) the bed material gradation has not changed appreciably over this period, and (3) the bed material load transported through Reach 7 is a reasonable approximation of the load delivered to the Pacific Ocean. The first assumption is reasonable due the stabilizing influence of the ACWHEP diversion structure installed in the early 1990s. The second assumption is supported by the similarity in the gradation of bed material samples collected between 1980 and 2009. The third assumption is not valid given the massive degradation of the channel below ACWHEP over this period, but the channel contribution is not included in the loads calculated using the methods based on upland yield Thus, for the purpose of comparing to the upland based loads, the third assumption is reasonable. The annual bed material loads are summarized in Table 5-11.

Table 5-11. Annual Bed Material Load Transport through Reach 7

Water Year	Number of Floods[4]	Annual Flood Volume (ac-ft)	Annual Peak Flow Rate (cfs)	Annual Bed Material Load (tons)
1992	6	8,420	6,990	56,200
1993	11	33,260	4,110	188,000
1994	8	3,360	980	13,400
1995[1]	15	23,290	4,840	138,000
1996[2]	0[2]	0[2]	n/a	n/a
1997	6	3,140	1,230	12,800
1998	20	32,140	8,610	188,000
1999[3]	n/a	n/a	n/a	n/a
2000	6	3,570	1,710	15,800
2001	6	6,150	1,200	26,700
2002	1	190	370	610
2003	10	11,900	1,760	58,300
2004	6	1,540	770	5,500
2005	17	37,110	5,250	234,000
2006	6	3,560	1,670	15,100
2007	6	1,700	770	6,300
2008	10	6,640	2,330	34,200
AVERAGE	**9**	**11,730**	**n/a**	**66,200**

[1] missing data from July 1 through December 31
[2] missing data from January 1 through June 30
[3] entire water year missing from electronic archives
[4] floods having peak flows greater than or equal to the 1.1-year recurrence interval flood
n/a = not applicable

As presented in Table 5-11, the annual bed material load transported through Reach 7 has varied from 610 to 234,000 tons, with an average annual value of 66,200 tons. This range and the average value are consistent with the range and recommended values derived from the upland based approaches (i.e., range of 1,000 to 200,000 tons per year and recommended average of 20,000 to 60,000 tons). The average value of 66,200 tons correlates to an effective discharge of approximately 750 cfs, which falls within the calculated range of effective discharges. Thus, the results of this approach provide further support to the validity of the other estimates of the range and average annual bed material loads transported from the Aliso Creek watershed.

Plotting the values from Table 5-11 of annual bed material transport capacity as a function of the annual flood volume produces the relationship illustrated in Figure 5-12. As is expected, bed material transport capacity is exponentially related to the annual flood volume.

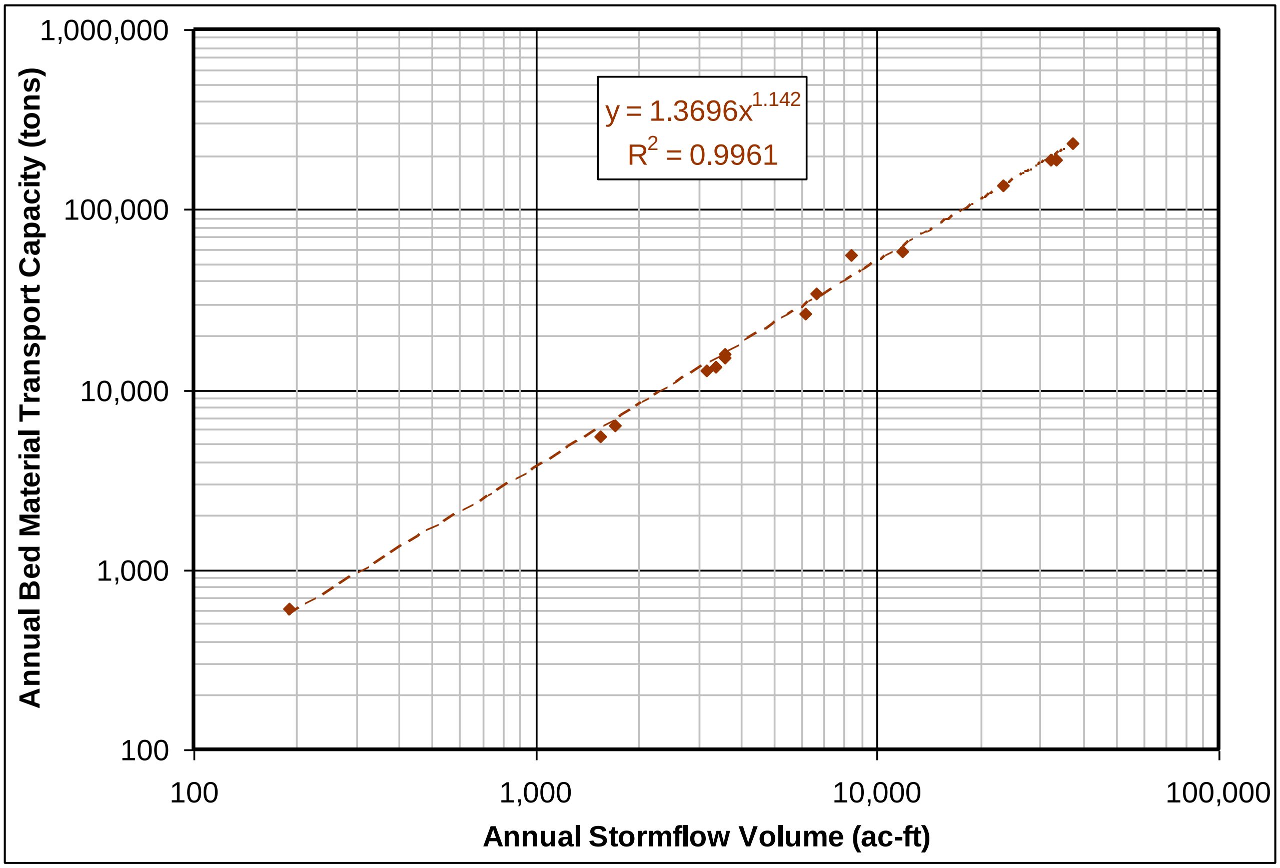


Figure 5-12. Aliso Creek Reach 7 relationship between annual stormflow bed material transport capacity and annual stormflow volume

6.0 FUTURE CHANNEL MORPHOLOGY

The baseline conditions documented in the revised H&H Appendix (USACE 2009) suggest the possibility of further degradation of the bed and erosion of the banks of Aliso Creek, particularly in the reaches below the ACWHEP diversion structure. As noted in that appendix, factors such as bedrock outcrops and channel widening may limit the future degradation of the bed, and these factors were recommended for further analysis during the No Action alternative. Consequently, one of the primary objectives of this geomorphic assessment is to provide a rational basis for the prediction of future conditions under the no-action plan. A geomorphic model was developed to support this objective.

6.1 ALISO CREEK GEOMORPHIC MODEL

The vertical degradation and widening of Aliso Creek, particularly the reach between the SOCWA Treatment Plant and the AWMA Road Bridge, is documented through historical analyses of aerial photographs and surveys. This degradation can be coupled with a conceptual Incised Channel Evolution Model (ICEM) to understand what, if any, future changes in channel morphology are expected. The development of the watershed has increased the frequency, magnitude, and volume of stormflow runoff, while concurrently decreasing the yield of upland sediment. These changes initiated stages of downstream-progressing bed degradation and subsequent channel widening in Aliso Creek. In conjunction with the discontinuity in sediment transport associated with the early 1990s construction of the ACWHEP diversion structure, the incision and widening downstream of the structure are especially pronounced. As the channel incises and decreases the bed slope and initiates bank instabilities that result in channel widening, the net result is a lower discharge per unit width of the channel (i.e., unit discharge). The sediment transport capacity of the channel is directly proportional to unit discharge, so as the unit discharge decreases, vegetation can establish and persist where transport capacity is no longer sufficient to mobilize the bed materials. The newly-established vegetation provides hydraulic resistance, creating backwater during floods that forces flow and suspended sediment into overbank areas where riparian vegetation enhances retention of suspended materials. Building of the overbank areas through this deposition leads to the development of a new, stable channel and inset floodplain within the historical floodplain/current terrace.

In Aliso Creek, one of the key questions is whether further vertical degradation is expected or whether the channel is beginning to establish a new, stable morphology. Observations made during October 2009 and February 2010 (after the January 2010 flood with an estimated recurrence interval of 25-years) indicate that Aliso Creek downstream of the ACWHEP structure is beginning to stabilize. Key field observations include the stability of coarse gravel and cobble plugs/riffles after the major January flood event, the establishment and persistence of tules and cattails within these plugs/riffles, the lack of woody debris jams (indicating woody vegetation was not uprooted), and the presence of sand splays (relatively recent, localized deposits of sand on surfaces of bars and floodplains) and deposition in overbank areas. A basic geomorphic model of future system behavior was developed on the basis of these field observations and knowledge of incised channel dynamics as reviewed in Chapter 3.

The model is based on the concept of incipient motion – the condition that occurs when hydraulic forces that can mobilize bed materials are just balanced by the forces resisting motion (Section 5.2). This concept can be quantified through a ratio of the grain shear stress (i.e., the portion of the total shear stress acting only on grains in the bed of the channel – the mobilizing force) divided by the critical shear stress for a particular size bed material (i.e., the submerged weight or the resisting force, calculated using the Shields equation (1936) with a Shields parameter of 0.03). When this ratio is greater than one, the bed materials can be mobilized and bed degradation can occur; ratio values less than one indicate stable bed materials.

Historical information from the past few decades is available to represent channel geometry and bed slope required to calculate grain shear stress, and historical sediment gradation data allow for calculation of critical shear stress. For example, approximately 300 feet upstream of the Wood Canyon Creek confluence, five historical geometric surveys are available between 1967 and 2006 (Figure 6-1). Bed profiles are available for these same five periods. Historical bed material gradation data are far more limited, but some simplifying assumptions are appropriate for testing the geomorphic model. While the grain shear is proportional to grain size, the critical shear, which is also directly related to grain size, is more sensitive to changes in grain size. Thus, while increasing the size fraction of interest may increase the grain shear stress, it will definitively increase the critical shear stress, with the result being a reduction in the ratio of grain shear to critical shear stress. Bed material samples collected in 1980 noted the presence of well-rounded pebbles and cobbles up to 152 mm (6 in) in diameter (Southern California Soil and Testing, Inc. 1980). If the critical shear stress is calculated using the d_{100} of 152 mm, and the ratio of grain shear to critical shear exceeds a value of one (i.e., these cobbles are mobile), then it is reasonable to expect that all smaller size materials are also mobile, allowing for bed degradation. Conversely, if the ratio is less than one for a smaller size fraction (e.g., d_{50}), it is reasonable that all larger sizes are also stable.

Figure 6-1 illustrates the progressive changes in channel geometry of Aliso Creek near the confluence with Wood Canyon Creek between 1967 and 2006. As shown in this figure, it is clear that the channel underwent substantial degradation from 1967 to 1998, but relatively minor changes from 1998 to 2006. Considering these observations, the critical shear stress was calculated for the estimated d_{100} of 152-mm cobbles for the first three periods, and for an estimated d_{50} of 56-mm gravel for the latter two (based on pebble count data collected in 2009). The grain shear was calculated for each period using a normal-depth assumption with bed slopes calculated from historical profile data.

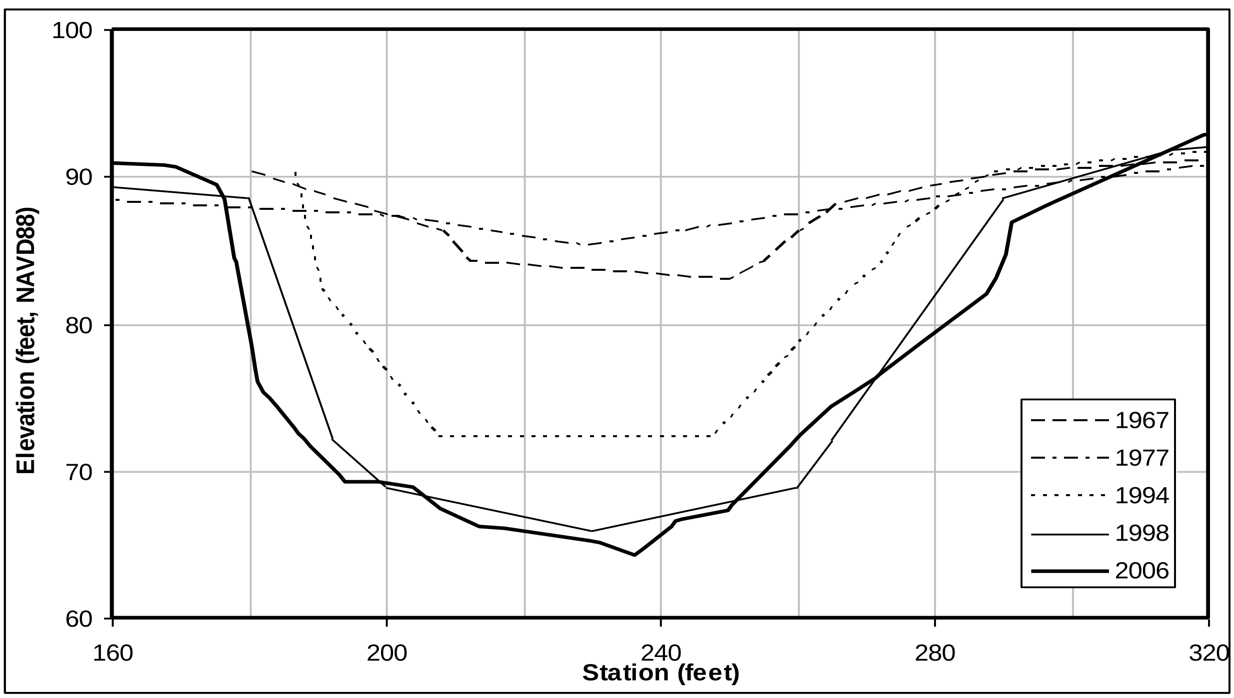


Figure 6-1. Aliso Creek channel geometry 300 feet upstream of the Wood Canyon Creek confluence

The calculated ratios of grain shear (τ_g) to critical shear (τ_c) are presented in Figure 6-2. Values of grain shear were calculated for the largest flood event immediately prior to the individual surveys, which in all cases was approximately equal to or exceeded the active channel capacity at that time.

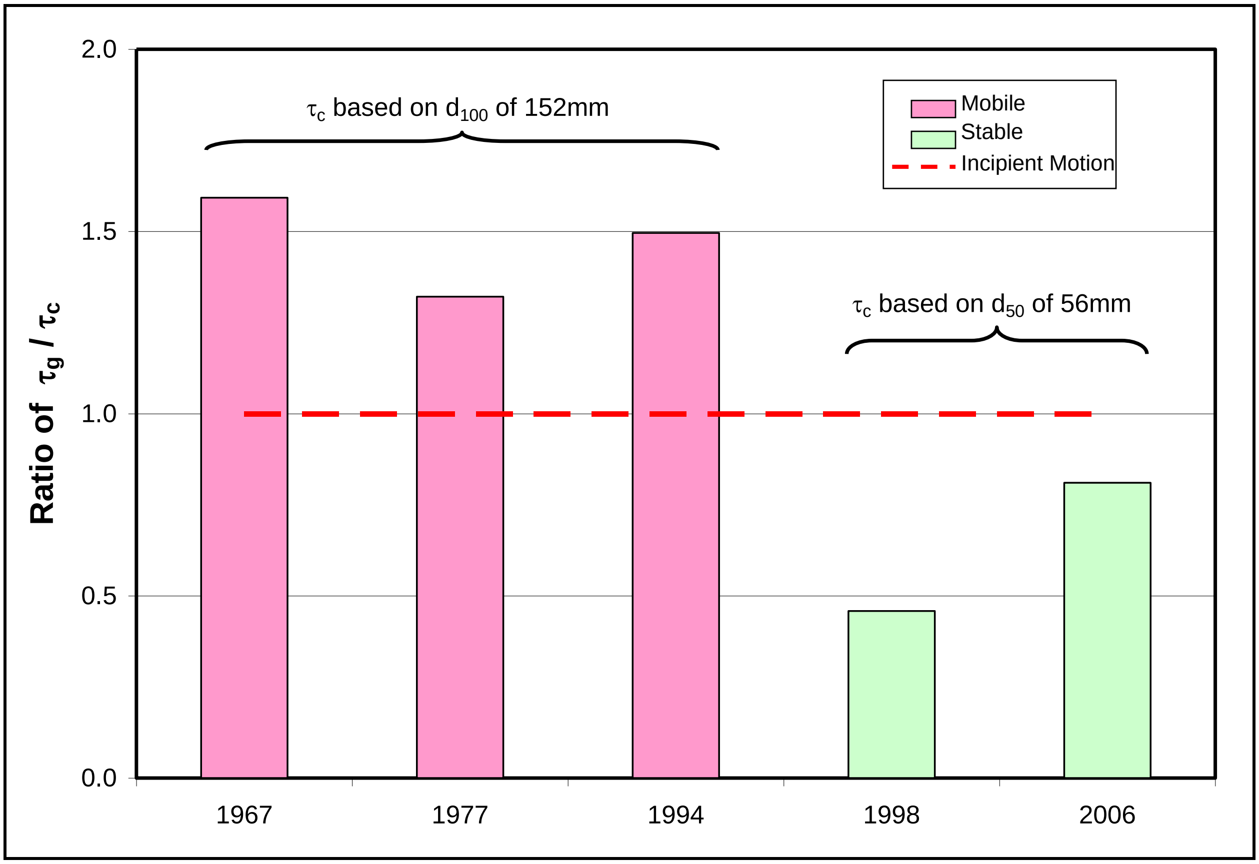


Figure 6-2. Geomorphic model for Aliso Creek

As is expected based on measured changes in channel geometry, the coarsest size fractions in the bed (i.e., 152-mm cobbles) were mobile in 1967, 1977, and 1994. In response to the reduced upstream sediment supply, the channel incised and widened, decreasing the unit discharge, and decreasing sediment transport capacity. By 1998, not even the d_{50} (i.e., 56-mm gravel) was mobile – applying the concept of equal mobility, this indicates the entire gradation of the coarse riffles and plugs was stable. The increase in the ratio from 1998 to 2006 is due to a localized increase in bed slope, but the 2006 ratio still indicates continued stability of bed materials. The conservative bias of this comparison (i.e., mobilization of the coarsest size fractions in 1967 to 1994, and stability of the d_{50} in 1998 and 2006) indicates that the historical vertical degradation of Aliso Creek in the vicinity of Wood Canyon Creek will not continue. This conclusion is in agreement with recent field observations, and is supported by conceptual ICEMs. The results at this location are representative of other locations within the study area based on the consistency in surveyed channel geometry between 1998 and 2006 (Figures 3-11 through 3-14), and progressive flattening of bed slopes due to incision (Figure 3-10). Further, since the grain shear stress values for 1998 and 2006 were calculated for a flow rate approximating an annual exceedance probability of 0.02 percent (i.e., the 500-year recurrence interval flood), and given that current levels of watershed development are near built-out conditions, it is unlikely that future hydraulic conditions could lead to substantial increases in grain shear stress.

The results of the application of this basic model of bed material mobilization capacity in Aliso Creek support the hypothesis that vertical degradation of the channel is not expected to continue; rather, the channel will begin to form a new, stable morphology and inset floodplain. The future potential for vertical degradation will remain in check because of the influence of the bedrock exposures and the plugs and riffles formed of gravels and cobbles that are essentially immobile. Sand and fine gravel that are episodically transported down Aliso Creek will scour and deposit between these stable grade controls causing fluctuations in bed elevation, but the combined influence of the man-made and natural grade controls are expected to prevent systematic, progressive degradation in the future. However, the clay outcrops that are currently providing vertical control are eroding, albeit at a slower rate than would non-cohesive sand and gravel, and future channel morphology upstream of these controls is susceptible to limited future incision.

6.2 APPLICATION OF INCISED CHANNEL EVOLUTION MODEL (ICEM) TO ALISO CREEK

Within the framework on which ICEMs are based, given sufficient time, incised channels are expected to progress through stages of bed degradation and channel widening to establish a new, stable form inset in the incised channel. Reaches that are in Class III through IV will undergo changes until reaching Class VI – unless external factors affect the ability of the channel to self-adjust. In Aliso Creek, the class of the ICEM developed by Schumm et al. (1984) and Harvey and Watson (1986) was assigned to each of the geomorphic reaches based on existing conditions. These assignments were used to understand expected changes in future morphology. Table 6-1 summarizes the existing ICEM classes.

Table 6-1. ICEM Class for Existing Conditions

Reach Number	ICEM Class
1	n/a
2	n/a
3	VI
4A	V
4B	V
5A	IV
5B	V – VI
5C	VI
6	V
7	VI
8	V
9	V
10	n/a
11	IV
12	VI

n/a = not applicable

Reaches in Class III are expected to continue to incise until the bank heights become so steep that the banks become geotechnically unstable. Bank failure occurs when the bank height exceeds the critical bank height (Little et al. 1981; Watson et al. 1988). When the banks are steep, slab or wedge failures predominate (Class IV) and as the bank angle is subsequently reduced, deeper seated slump failures predominate (Class V) (Lohnes and Handy 1968; Harvey and Watson 1986; Thorne 1988; Thorne 1999; Simon and Darby 1999). The channel widens as a result of failure of the excessive bank heights (Classes

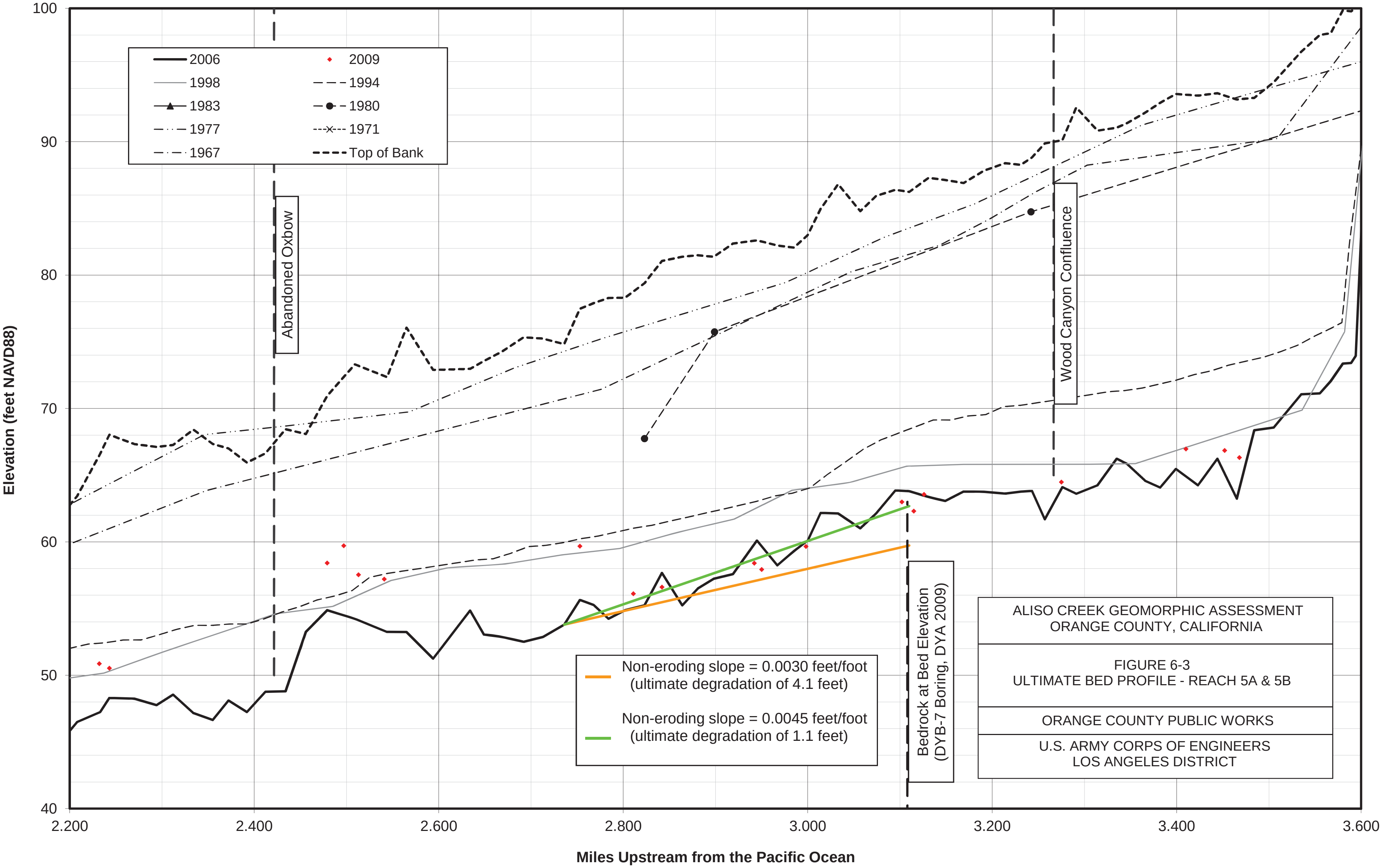
IV and V), and ultimately aggrades (Class V), at which point an equilibrium channel reflecting a dynamic balance between sediment supply and transport capacity has formed within the over-widened channel incised in the valley floor (Class VI). The transition between Reaches 5A and 5B and Reach 11 are the only geomorphic reaches in Class IV. This classification was assigned primarily because of the ongoing incision through the clay exposures in the bed. While currently controlling the grade of the reach, these clays are susceptible to continued incision.

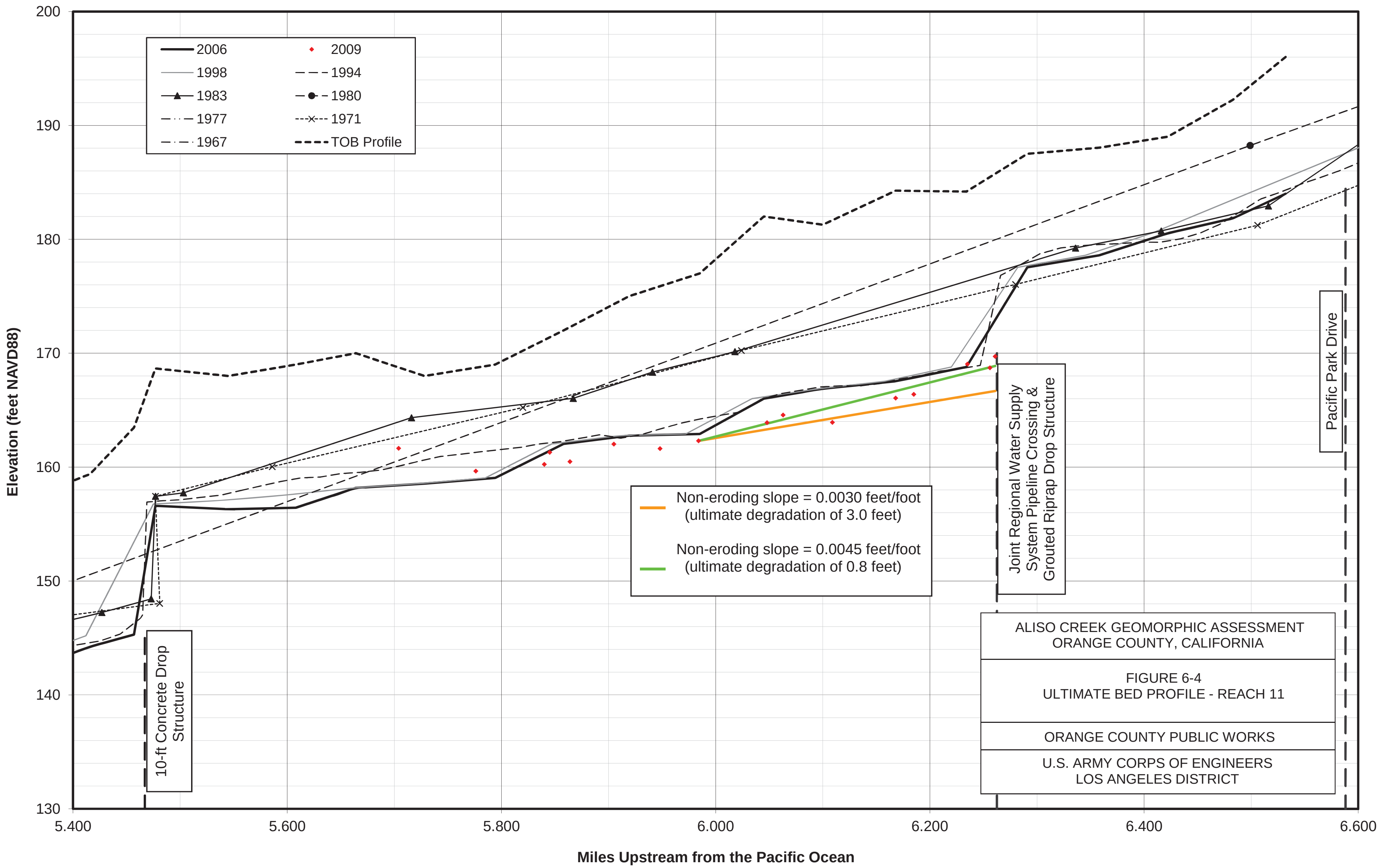
6.2.1 Ultimate Degradation Bed Profiles

Other than reaches categorized as Class IV, the expectation is that future bed profiles will exhibit average slopes similar to the existing slopes. To estimate an ultimate profile of the thalweg through the Class IV reaches, the rates of incision into the clay were applied to equilibrium/non-eroding slopes. Historical thalweg profiles were compared to the elevations of clay units mapped in borings DYB-3, DYB-6, and DYB-8 (Figure 3-4) to estimate the historical rate of incision into the clay units. The range of incision rates is 0.4 to 1.3 feet per year. The existing bed slopes were compared throughout the study reach, and due to the approaching stabilization of the longitudinal profile, average slopes of the geomorphic reaches range from 0.25 to 0.55 percent. The low end of this range is from the somewhat aggradational reach upstream of the ACWHEP structure whereas the upper end is from the coarse riffle and coarse plug dominated reach immediately downstream of the ACWHEP structure. Removing these values from consideration, the majority of the geomorphic reaches exhibit average bed slopes between 0.30 and 0.45 percent. Thus, the expected range of non-eroding average bed slopes is 0.30 to 0.45 percent.

From the low spot in the channel just downstream of the downstream end of Reach 5A (approximately RM 2.75), future incision through the clay exposures in the bed is expected to progress at an average annual rate of 0.4 to 1.3 feet per year until the average bed slope reduces to 0.45 to 0.30 percent. This incision will likely be checked at the upstream end of Reach 5B where boring DYB-7 shows bedrock at the existing channel bed elevation. It is assumed that the bedrock will prevent incision from propagating upstream, and then a drop over the bedrock exposure will form. The magnitude of incision immediately downstream of the bedrock was calculated to be 1.1 feet for a 0.45 percent non-eroding slope and 4.1 feet for a 0.30 percent non-eroding slope. Given the calculated rates of incision through the clay units, and assuming future hydraulic conditions are similar to recent past conditions, the expected degradation may occur in approximately 1 to 10 years. Once the non-eroding slope is reached, no further degradation is expected. The ultimate degradation profiles through the transition between Reach 5A and Reach 5B are shown in Figure 6-3.

Knickpoints in clay outcrop exposure in the bed were observed in Reach 11 upstream of approximately RM 6.1. As with the transition between Reach 5A and Reach 5B, future incision through the clay is expected to progress at an average annual rate of 0.4 to 1.3 feet per year until the average bed slope reduces to 0.45 to 0.30 percent. This incision will be checked at the upstream end of the reach by the grouted riprap grade control structure protecting the Joint Regional Water Supply System pipeline crossing of the creek. It is assumed that the grade control will be maintained and will prevent incision from propagating farther upstream. The magnitude of incision at the toe of the structure was calculated to be 0.8 feet for a 0.45 percent non-eroding slope and 3.0 feet for a 0.30 percent non-eroding slope. Given the calculated rates of incision into the clay units, and assuming future hydraulic conditions are similar to recent past conditions, the expected degradation may occur in approximately 1 to 8 years. Once the non-eroding slope is reached, no further degradation is expected, therefore the profiles are the same at 25, 35, and 50 years in the future. The ultimate degradation profiles in Reach 11 are shown in Figure 6-4.


2006
2009
1998
1994
1983
1980
1977
1971
1967
Top of Bank
Abandoned Oxbow
Wood Canyon Confluence
Bedrock at Bed Elevation
(DYB-7 Boring, DYA 2009)
Non-eroding slope = 0.0030 feet/foot
(ultimate degradation of 4.1 feet)
Non-eroding slope = 0.0045 feet/foot
(ultimate degradation of 1.1 feet)
Elevation (feet NAVD88)
Miles Upstream from the Pacific Ocean
100
90
80
70
60
50
40
2.200
2.400
2.600
2.800
3.000
3.200
3.400
3.600
ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA
FIGURE 6-3
ULTIMATE BED PROFILE - REACH 5A & 5B
ORANGE COUNTY PUBLIC WORKS
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT


Elevation (feet NAVD88)
Miles Upstream from the Pacific Ocean
200
190
180
170
160
150
140
130
5.400
5.600
5.800
6.000
6.200
6.400
6.600
2006
2009
1998
1994
1983
1980
1977
1971
1967
TOB Profile
Non-eroding slope = 0.0030 feet/foot
(ultimate degradation of 3.0 feet)
Non-eroding slope = 0.0045 feet/foot
(ultimate degradation of 0.8 feet)
10-ft Concrete Drop Structure
Joint Regional Water Supply System Pipeline Crossing & Grouted Riprap Drop Structure
Pacific Park Drive
ALISO CREEK GEOMORPHIC ASSESSMENT
ORANGE COUNTY, CALIFORNIA
FIGURE 6-4
ULTIMATE BED PROFILE - REACH 11
ORANGE COUNTY PUBLIC WORKS
U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

6.2.2 Expected Lateral Adjustments

Reaches in Classes IV and V are widening, and as demonstrated in the geomorphic model presented in Section 6.1, will continue to widen until the unit discharge decreases to the point that mobilization of the gravel and cobbles in the bed is limited. During the widening, bank material will continue to be input to Aliso Creek until the bank angles become geotechnically stable. In many reaches, the channel appears to be sufficiently wide to accommodate flows up to the peak of the 100-year recurrence interval flood; however, the banks still remain overly steep and geotechnically unstable. In some locations, the slab failures and mass-wasted materials observed in November 2009 at the toe of the terraces were mobilized and transported through the system during the January 2010 flood. Unless this material can remain in place long enough to vegetate and accumulate sufficiently, the effective height of the bank does not decrease, failures will continue, and the channel will widen (at least at the top of the banks, if not at the bank toes). It is important to note that the failure mechanism of the banks along most of Aliso Creek is not hydraulic; rather, saturation and associated geotechnical instability is driving the bank failures. However, the removal of the slumped material is due to hydraulic action. Many reaches in the study area exhibited classical conditions associated with Class V of the ICEM. The bank slumping associated with these reaches presents a threat to the vegetation and habitat on the abandoned floodplain/terrace, but more importantly, could compromise the AWMA Road or the sanitary sewer pipelines flowing to the SOCWA treatment plant. Since the bottom width of the incised channels appears to be great enough that unit discharges are no longer high enough to mobilize coarse bed materials, stabilization of the banks is possible without negatively affecting the natural evolution of the channel morphology to Class VI.

Figure 6-5 illustrates trends in channel width based on the cross section survey data plotted in Figures 3-11 through 3-14. The distances between the top banks of the terraces were measured from the historical data to demonstrate the changes in channel width at these selected locations over the past few decades. In general, this figure shows that channel width remained fairly constant until the mid-1980s, increased through the late-1990s, and the rate of widening has since decreased. This generalization fits with the categorization of much of the study reach into Class V and VI of the ICEM. The decrease in the rate of widening since 1998 reflects the change from hydraulically driven widening processes to geotechnically driven processes. This does not mean that further widening will not occur; rather, that the widening is expected to occur episodically as saturation and geotechnical instabilities result in bank slumping and an associated increase in width.

Reaches in Class V and VI are aggrading reaches where the sediment transport capacity has decreased to the point that material eroded from the banks remains at the toe of the bank and deposition of suspended sediments occurs on the inset floodplain. The deposition at the toe of the banks effectively decreases the height of the bank, decreasing the amount of erosion required for the bank to reach a geotechnically stable angle. The deposition on the floodplain allows for the development of a new active channel in the base of the incised channel. A key distinction of Class V and VI reaches from other classes in the ICEM is that they are sediment sinks instead of sediment sources. Until the channel reaches a dynamic equilibrium between sediment supplied to the reach and sediment transport capacity within the reach, sediment will deposit on the inset floodplain such that the net export of sediment from the reach will be less than the supply delivered to the reach. This pattern of elevated sediment production during incision and widening followed by reduced production due to the end of incision and widening coupled with sediment storage in the widened channels has been documented through experimental studies and field observations (Schumm et al. 1987; Gellis et al. 1991; Simon 1989; Harvey et al. 1987). Once Class VI channels aggrade to the point of dynamic equilibrium, the sediment transported from the reach will balance the sediment supplied to the reach. Reaches 5C and 7 most clearly typify conditions associated with Class VI reaches, including well vegetated banks, low bank angles, and the development of alternate bars in the newly formed active channel.

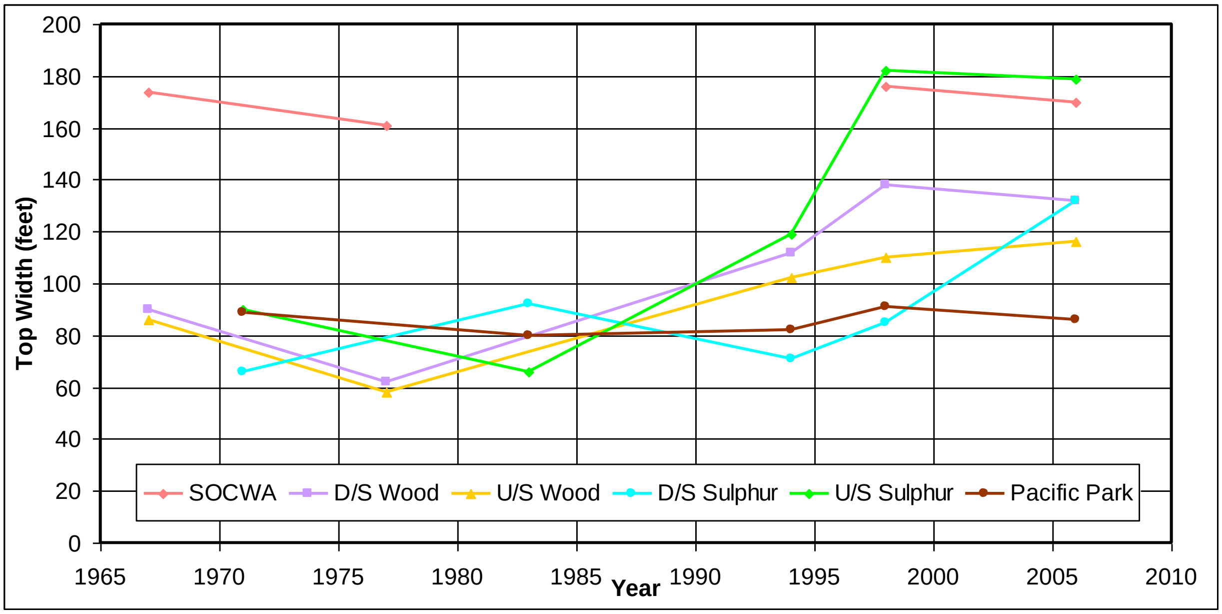


Figure 6-5. Changes in Aliso Creek channel width at selected locations

7.0 SUMMARY AND CONCLUSIONS

This geomorphic assessment of Aliso Creek between the Pacific Ocean and Pacific Park Drive was conducted to provide a rational basis for predicting future channel conditions under the no action plan. A secondary benefit of this objective is that establishing these conditions provides a basis for interpreting upcoming hydraulic engineering work associated with the comparison of alternative restoration plans for the study area.

7.1 SUMMARY

The assessment of hydrologic conditions showed that developable area in the watershed is nearly built out and future hydrologic conditions will likely be similar to existing conditions; however, this may need to be revisited as climate change projections related to precipitation are more fully developed. One hydrologic component that may change is the magnitude of summer base flows. The existing baseflow supports a dense corridor of riparian vegetation along the inset floodplains of Aliso Creek. If efforts are pursued to eliminate all dry weather discharges to the creek, baseflow will likely decrease. This decrease could affect the existing vegetation, and may warrant further studies of the depths to shallow groundwater and its ability to sustain the existing vegetation under drought or future reduced baseflow conditions.

The evaluation of the geology in the study area revealed that the nature and distribution of bed materials in Aliso Creek below the ACWHEP structure is heavily influenced by historical landslides that lead to blockages of the creek, formations of upstream lakes, and deposition of clay layers. The clay layers are evident in the convex toe of the streambanks through many reaches of the study area. The presence of the clay in the banks governs the bank strength and the potential for failure and widening. Faulting may be responsible for the presence of bedrock at the thalweg elevation near RM 1.6 and RM 3.1; these bedrock exposures serve as natural grade controls. Colluvial inputs to the valley bottom have provided an ample supply of gravels and cobbles to the creek, and tributary/gulley confluences continue to be sources of coarse material.

The geomorphic classification of reaches within the study area provided a framework for understanding the historical factors that shape existing morphology, and the potential for future changes in morphology. Historical changes to channel profile and cross section geometry document a relatively progressive reduction in slope and increase in width – with the combined result being a reduction in unit discharge and sediment transport capacity. Refinement of the geomorphic reaches also allowed for more appropriate calculation of reach-averaged hydraulic conditions.

The calibration of the hydraulic model for Aliso Creek provided a greater level of confidence in the model output. These outputs were weighted by the distances between cross sections to calculated reach-averaged hydraulic parameters within the geomorphic reaches. These hydraulics parameters served as inputs for the analyses of bed material mobility. The average bed slopes were used to establish the range of expected future equilibrium/non-eroding slopes.

The sediment supply and bed material transport within the study area were evaluated to characterize the balance between these two processes and their influence on channel morphology. The sediment supply was calculated using multiple approaches, which in general indicate that the range of bed material supplied from the Aliso Creek watershed to Aliso Beach ranges from 1,000 to 200,000 tons per year, with an average annual load of 20,000 to 60,000 tons. This range is somewhat greater than the previously calculated average annual load of 15,300 tons (USACE 2009) due to the more refined methodology applied in this study. The gradations of bed and bank material samples collected since 1980 show that the valley fill into which Aliso Creek has incised contains up to 75 percent silt and clay (i.e., wash load), but that the remaining material includes enough coarse gravel and cobbles, that due to sorting and concentration over time, have now formed relatively immobile natural grade controls. Analyses of incipient motion confirmed that existing hydraulic conditions are incapable of mobilizing cobbles, but that gravel may be susceptible to mobilization if tules and cattails do not persist. Since future hydraulic conditions are expected to be similar to existing conditions, these coarse materials are expected to remain immobile. The effective discharges in the Aliso Creek were calculated as 260 to 1,100 cfs. This range was verified against observed geomorphic features both upstream and downstream of the ACWHEP structure. The reach-averaged bed material transport capacities were compared to effective discharges and selected flood flows, and the annual bed material loads for water years 1992 to 2008 were calculated. The results compared favorably with the load calculated from the effective discharges and from the upland based methods.

A geomorphic model was developed and tested to explain the potential for future changes in channel morphology. The model confirms that future vertical adjustments to the bed profile are expected to be limited because the widened channel and decreased channel slope have decreased unit discharge and bed material transport capacity and the concentration of coarse pebbles in riffles and plugs has increased the critical flows needed to mobilize these materials. Two location of probable future bed degradation were identified were the channel bed is incising through clay exposures. At both locations, the maximum incision was calculated to be on the order of three to four feet, with the degradation occurring within approximately 10 years (assuming hydraulic conditions are similar to the historical conditions). Through application of an Incised Channel Evolution Model, future bank erosion and associated increases in channel width can be expected in Class IV and V reaches. As this erosion occurs, sediment introduced to the system will deposit on the inset floodplain, increasing the capacity of the active channel, likely toward the upper range of the calculated effective discharges. Unless the banks are stabilized, the widening will continue until a stable bank angle is reached. As the inset floodplain aggrades a net reduction in sediment delivered from the watershed can be expected. Observations made in October 2009 and February 2010 confirmed the abundance of sand splays on the inset floodplain, indicating the aggradation process has already started in some reaches.

The application of the ICEM to Aliso Creek, coupled with the geomorphic model described in the previous paragraph, provided a rational basis for predicting future channel morphology under the no action plan and for broadly identifying potential measures that could help mitigate future instabilities under restoration alternatives (Table 7-1).

Table 7-1. Predicted Future Channel Morphology and Potential Stabilization Measures

Reach Number	Existing ICEM Class	Predicted Future Channel Morphology	Potential Stabilization Measures
1	n/a	Similar to existing	Monitor and maintain
2	n/a	Similar to existing	Monitor and maintain
3	VI	Vertical incision, then widening	Grade control structures
4A	V	Upper bank slumping	Bank stabilization
4B	V	Upper bank slumping	Bank stabilization
5A	IV	Limited widening, upper bank slumping	Bank stabilization
5B	V – VI	Upper bank slumping, incision if clay outcrop at downstream limit is cut through	Bank stabilization and grade control structure at clay outcrop (RM 2.75)
5C	VI	Similar to existing	Monitor and maintain
6	V	Upper bank slumping	Bank stabilization
7	VI	Similar to existing, assuming ACWHEP structure maintained	Maintain ACWHEP structure, bank stabilization
8	V	Upper bank slumping	Bank stabilization
9	V	Upper bank slumping	Bank stabilization
10	n/a	Similar to existing	Monitor and maintain
11	IV	Vertical incision, then widening	Grade control structure at clay outcrop (RM 6.1)
12	VI	Similar to existing	Monitor and maintain

n/a = not applicable

7.2 CONCLUSIONS

The following conclusions are based on the results of this geomorphic assessment:

- Compared to conditions during 1970 when the watershed was approximately 10 percent developed, future upland sediment supplies will remain reduced due to erosion resistant land covers associated with development approaching fully built-out conditions.

- Due to nearly built-out development conditions, there is low potential for future land cover-induced changes to the flood regime; although, the summer base flows could be reduced as a result of elimination of dry weather discharges

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- The floodplain in the valley bottom between SOCWA and ACWHEP as recently as the 1980 is now an abandoned and hydrologically-disconnected terrace.

- Under the No Action Plan, continued loss of the historical riparian corridor will continue due to bank erosion and channel widening. This loss will not occur in a gradually progressive manner; rather, episodic changes will occur in response to major flood events. The morphology of Aliso Creek will lurch from catastrophic flood to catastrophic flood until the channel width and reduced sediment transport capacity enables geotechnically stable bank angles to form.

- System-wide continued upper bank failure is to be expected through much of the study reach; however, field observations suggest that mass-failed bank materials are not consistently being removed from the base of the bank by fluvial entrainment. Retention of the failed blocks is enhanced by the high density of the riparian vegetation. In contrast, where the channel locally impinges against the base of the terrace, continuing erosion and retreat of that bank can be expected.

- The supply of bed material to Aliso Beach has been artificially elevated over the past two to three decades as thousands of years' worth of alluvial and colluvial sediment has been excavated from the valley fill. Likely this increase in loading has masked the reduction of sand supplied from upland sources due to development of the Aliso Creek watershed.

- In light of the relatively consistent, but slightly progradational beach at the mouth of Aliso Creek, it is likely that the steep shoreface indicates the beach is and has been maintained at/near its holding capacity since the 1920s (Everts Coastal 1997). The absence of a delta off the mouth of Aliso Creek suggests this deficiency following high flow events is probably due to the steep shoreface (USACE 1996). The apparently narrower beaches of the nineteenth century imply that watershed contributions before the advent of intensive ranching and development were less than the supply between 1927 and 1984. Aliso Beach is one example where less sand was present in the 1920s than 1981. Since the watershed supply of sand is the greatest source to the beach, reductions in the sand supply due to development, stabilization of eroding channels, and aggradation of inset floodplains may result in a beach similar in morphology to the 1920s. Further studies would need to be conducted to confirm this hypothesis.

- The potential for future vertical degradation of Aliso Creek is limited, except in a few locations where incision into clay outcrops is ongoing (i.e., approximately RM 2.9 and RM 6.1). The creek is currently hung up on these outcrops, but future incision is expected to be no more than three to four feet, an amount that should occur in no more than approximately 10 years, assuming future hydraulic conditions are similar to past conditions.

- The expected vertical stability of Aliso Creek within the study area is highly dependent on the preservation of the existing grade control function of the ACWHEP structure. It is imperative that the grade control function be maintained to avoid widespread degradation of Aliso Creek. Other man-made grade controls also need to be maintained to prevent future degradation.

- Due to the approaching stabilization of the longitudinal profile within the study area, the existing average slopes of the geomorphic reaches of 0.25 to 0.55 percent (13.2 to 29.0 feet per mile) represent the expected range of equilibrium/non-eroding slopes. The low end of the range is taken from the reach above the ACWHEP structure, which is somewhat aggradational; the upper end of the reach is taken from the coarse riffle and coarse plug dominated reach immediately downstream of the ACWHEP structure. Within this overall range, the majority of the geomorphic reaches exhibit bed slopes between 0.30 and 0.45 percent (15.8 to 23.8 feet per mile) – a range better representative of non-eroding slopes within the study area.

- Aggradation of the inset floodplain will continue as the active channel increases its conveyance capacity to better match the upper end of the calculated effective discharges (approximately 1,100 cfs). This flow rate may be an ideal design parameter should any instream restoration measures be considered in the restoration alternatives.

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