U.S. Environmental Protection Agency Region 9

Malibu Creek & Lagoon TMDL for Sedimentation and Nutrients to address Benthic Community Impairments

Draft December 2012

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1. Introduction

The United States Environmental Protection Agency (USEPA) Region IX is establishing Total Maximum Daily Loads (TMDLs) for Malibu Creek and Lagoon in the Los Angeles Region (Figure 1-1). USEPA was assisted in this effort by the Los Angeles Water Quality Control Board (Regional Board). A variety of water quality impairments have been identified in the watershed. This report specifically addresses the impaired benthic biota in the Malibu Creek main stem and Malibu Lagoon, while discussing conditions throughout the watershed that may impact these impairments. The remainder of this section presents the regulatory background, a description of the elements of a TMDL, and a brief discussion of the physical setting.

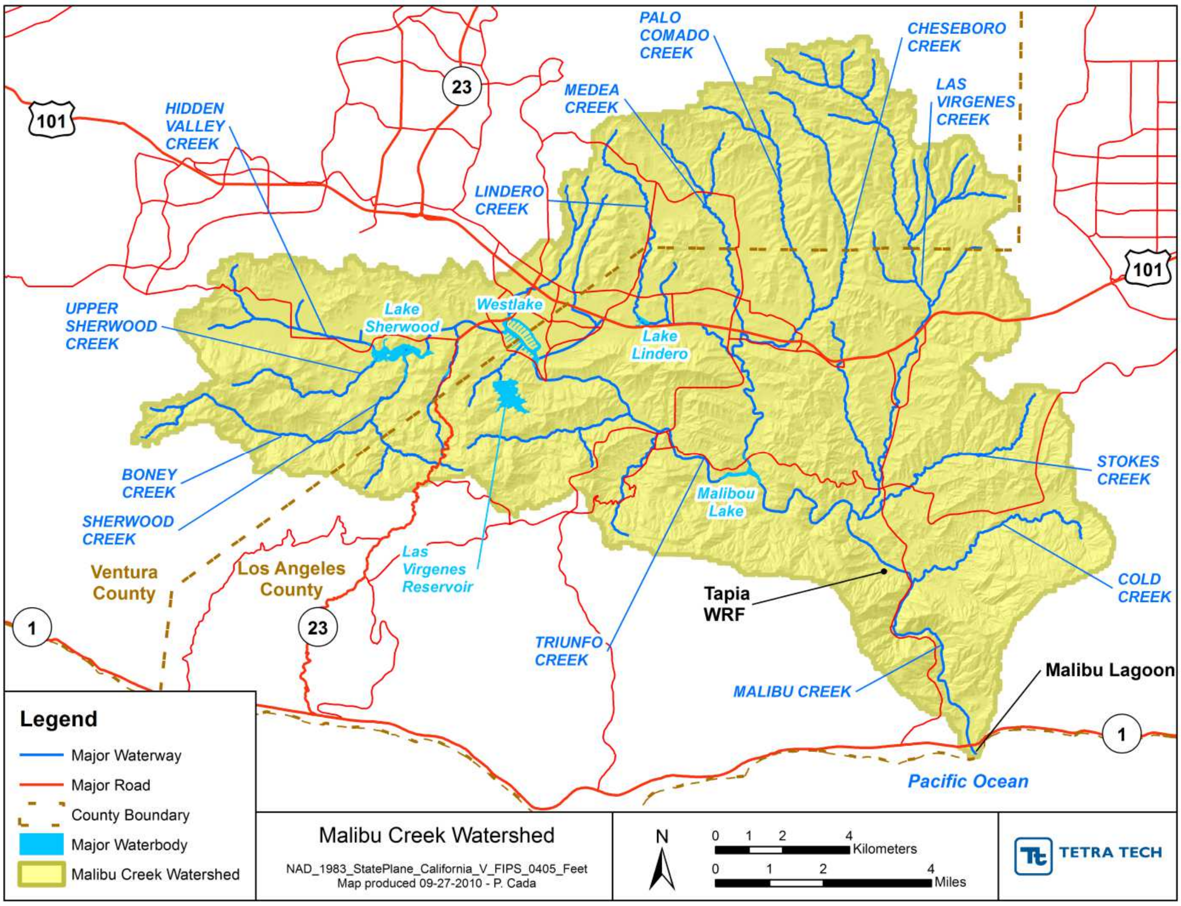

Figure 1-1. Malibu Creek Watershed

1.1 REGULATORY BACKGROUND

Section 303(d) of the Clean Water Act (CWA) requires that each State "shall identify those waters within its boundaries for which the effluent limitations are not stringent enough to implement any water quality objective applicable to such waters." The CWA also requires states to establish a priority ranking for waters on the 303(d) list of impaired waters and establish Total Maximum Daily Loads (TMDLs) for such waters.

The elements of a TMDL are described in 40 Code of Federal Regulations (CFR) 130.2 and 130.7 and Section 303(d) of the CWA, as well as in the United States Environmental Protection Agency (USEPA) Region IX's Guidance for Developing TMDLs in California (USEPA, 2000). A TMDL is defined as the "sum of the individual waste load allocations for point sources and load allocations for nonpoint sources and natural background" (40 CFR 130.2) such that the capacity of the waterbody to assimilate pollutant loads (the loading capacity) is not exceeded. A TMDL is also required to account for seasonal variations and include a margin of safety to address uncertainty in the analysis (CWA 303(d)(1)(C) (USEPA, 2000).

States must develop water quality management plans to implement the TMDL (40 CFR 130.6). USEPA has oversight authority for the 303(d) program and is required to review and either approve or disapprove the TMDLs submitted by states. In California, the State Water Resources Control Board (SWRCB) and the nine Regional Water Quality Control Boards (Regional Boards) are responsible for preparing lists of impaired waterbodies under the 303(d) program and for preparing TMDLs, both subject to USEPA approval. If USEPA disapproves a TMDL submitted by a state, or if a state does not develop a TMDL in a timely manner, USEPA is required to establish a TMDL for that waterbody. The Regional Boards hold regulatory authority for many of the instruments used to implement the TMDLs, such as National Pollutant Discharge Elimination System (NPDES) permits and state-specified Waste Discharge Requirements (WDRs).

As part of its 1996 and 1998 regional water quality assessments, the Los Angeles RWQCB (LARWQCB) identified over 700 waterbody-pollutant combinations in the Los Angeles Region where TMDLs would be required (LARWQCB, 1996, 1998). These are referred to as "listed" or "303(d) listed" waterbodies or waterbody segments. A 13-year schedule for development of TMDLs in the Los Angeles Region was established in a consent decree approved between USEPA and several environmental groups on March 22, 1999 (Heal the Bay Inc. et al. v. Browner et al. C 98-4825 SBA). Under the consent decree, USEPA must establish these TMDLs by March 24, 2013. For the purpose of scheduling TMDL development, the consent decree combined the more than 700 waterbody-pollutant combinations into 92 TMDL analytical units.

1.2 ELEMENTS OF A TMDL

Guidance from USEPA (1991) identifies several elements of a TMDL. Sections 2 through 10 of this document are organized such that each section describes data and background information (Sections 4, 6, 7, and 8) or one of the TMDL elements, including the analysis and findings of these TMDLs for that element. Additionally, implementation and monitoring recommendations are provided in Section 11. TMDL sections are as follows:

- **Section 2: Problem Statement.** Presents the data used to add the waterbody to the 303(d) list, and summarizes existing conditions using that evidence along with any new information acquired since the listing. This element identifies portions of the waterbody that fail to support all designated beneficial uses; the criteria designed to protect those beneficial uses (collectively, the beneficial uses and water quality objectives are the water quality standards [WQS]); and, in summary, the evidence supporting the decision to list, such as the number and severity of impact observed.
- **Section 3: Numeric Targets.** Sets numeric targets based upon the numeric and narrative water quality objectives described in the Los Angeles Region Water Quality Control Plan (Basin Plan) and the existing USEPA established 2003 Nutrient TMDL for Malibu Creek Watershed.
- **Section 5: Source Assessment.** Describes and identifies the potential point sources and nonpoint sources of sediment and impact to Malibu Creek and Lagoon.
- **Section 9: Linkage Analysis.** Provides an analysis of the relationship between sources and the water quality impairment. This TMDL completed a detailed stressor identification or causal assessment to comprehensively evaluate the critical stressors causing the impairment. The linkage analysis

addresses the critical conditions, loading, and water quality parameters. Allocations are designed to protect the waterbody from conditions that exceed the applicable numeric target. The allocations are based on critical conditions to ensure protection of the waterbody under all conditions.

- **Section 10: TMDLs and Pollutant Allocations.** Identifies the quantitative load, concentration based allocations and in this case, the necessary numeric biological response numeric targets that need to be achieved to ensure protection of the identified beneficial uses in Malibu Creek and Lagoon.
- **Section 11: Implementation.** Not considered a required element of a TMDL established by USEPA; this section contains recommendations to the State regarding implementation and monitoring for this TMDL.

1.3 Physical Setting

The Malibu Creek watershed, located about 35 miles west of Los Angeles, California, drains and area of 109 square miles (Figure 1-1). The watershed extends from the Santa Monica Mountains and adjacent Simi Hills to the Pacific Coast of Santa Monica Bay at Malibu State Beach (formerly Surfrider Beach). Malibu Lagoon, currently about 31 acres in size, occupies the area behind the beach at the mouth of Malibu Creek. The entire watershed lies within Level 3 sub-ecoregion 6 (Southern and Central California Chapparal) within aggregate nutrient ecoregion 3 (Xeric West; USEPA, 2000c).

1.3.1 Malibu Creek and Tributaries

The Malibu Creek watershed includes the cities of Agoura Hills, Westlake Village, Calabasas, Thousand Oaks, Hidden Hills, and a portion of Malibu and Simi Valley and has a total population of nearly 100,000. Nearly two-thirds of the watershed is in Los Angeles County, while the remaining portion is in Ventura County. Historically, there is little flow in the summer months; much of the natural flow that does occur in the summer in the upper tributaries comes from springs and seepage areas.

Malibu Creek has several major tributaries and together these make up the Malibu Creek watershed. These tributaries include streams draining to Lake Sherwood, which discharges to Potrero Creek. This creek then reaches Westlake Lake and flow moves down Triunfo Creek to its confluence with Lobo Canyon Creek, which becomes Malibu Creek. Medea Creek, Las Virgenes Creek, and Cold Creek are other major tributaries. Medea Creek and Malibu Creek form Malibou Lake. Further downstream Las Virgenes Creek joins Malibu Creek at Malibu Creek State Park. Eventually the creek empties into the 13-acre Malibu Lagoon (see Section 1.3.2 for more details on the Lagoon). The major tributaries of Medea and Las Virgenes Creeks are described below along with Malibou Lake, which is a major impoundment in the watershed.

Medea Creek has a total length of 7.56 miles. Land use in the Medea Creek subwatershed contains a mix of open space area and residential and commercial uses. Lower Lindero Creek eventually flows to Medea Creek. Medea Creek also receives drainage from the subwatersheds associated with Palo Comado Creek and Cheseboro Creek and eventually drains into Malibou Lake.

Malibou Lake receives the drainage from most of the subwatersheds in the upper portion of the watershed. The lake has a drainage area of 64 square miles which represents almost 60% of the entire watershed. Water flows from Triunfo and Medea Creek into the 69-acre lake. The lake was constructed in 1922 for swimming, boating and fishing by members and guests of the Malibou Lake Mountain Club, Ltd. Malibou Lake has mud bottom that is dredged on a continual basis because of sediment loadings from upstream sources. The outflow from the lake discharges into Malibu Creek.

Malibu Creek also receives flow from Las Virgenes Creek. Las Virgenes Creek is an eleven mile creek with a 12,456-acre drainage area. Land cover in the Las Virgenes Creek subwatershed is predominantly open, with some residential and commercial/industrial land. Malibu Creek is a 10-mile creek that runs from Malibou Lake to Malibu Lagoon (see Section 1.3.2). The predominant land cover in the Malibu Creek subwatershed is open. The Tapia Water Reclamation Facility (Tapia WRF) is located in this subwatershed and contributes significant flow in the winter months.

About 50 square miles of the watershed (nearly half of the total area) is parkland or conserved land. Some of the protected areas include Peter Strauss Ranch, Cheseboro Canyon, Cold Creek Canyon Preserve, Tapia Park, and Malibu Creek and Lagoon State Parks. The watershed contains a wide variety of diverse habitats including coastal strand, oak and riparian woodlands, chaparral, coastal sage scrub, native grasslands, sulfur springs, and brackish water Lagoon. It is home to several threatened, endangered, or endemic plants and animals. These include the southern steelhead trout, tidewater goby, California brown pelican, California least tern, red-legged frog, San Fernando Valley spineflower, Malibu baccharis, and the arroyo chub, an endemic minnow, which is a California species of special concern.

1.3.2 Malibu Lagoon

Malibu Lagoon is located in the City of Malibu, Los Angeles County at the mouth of Malibu Creek. The wetland acreage includes 2/3 mile of the creek corridor east of the Pacific Coast Highway and the wetland habitat acreage is approximately 92 acres. The historic wetland size has been documented and estimated to be several times its present size; the wetland had extended through the Civic Center area to the Pepperdine University property. Malibu Lagoon is surrounded by a chaparral ecosystem and experiences Mediterranean-type climate with mild, wet winters and hot, dry summers. Annual precipitation ranges from an average of 13.2 in falling over the coast and 25.4 in falling over the mountains.

Early historical accounts of the Chumash Indians, who arrived into the Malibu area more than 20,000 years ago, and ship activities, suggest the Lagoon remained open through the summer. Prior to 1900's, the Lagoon was described as having been relatively pristine, until the construction of the Rindge railroad line in 1908 that resulted in filling in portions of the Lagoon. In 1929, Caltrans used the site as a dumping ground during the construction of the Pacific Coast Highway. Road construction in and around the Lagoon continued throughout the years, including filling additional areas of the Lagoon to construct baseball fields and parking for beach access (Ambrose et al. 1995). The Lagoon is bounded by the public beaches on the south side, the Malibu Colony residential development and a golf course on the west side, the Pacific Coast Highway and expanding commercial development on the north side, and the historical Adams House Museum in the eastern adjacent area. The California Department of Parks and Recreation (CDPR) currently has land management and ownership responsibility of the Malibu Lagoon and adjacent lands.

Malibu Lagoon is a valuable coastal wetland, providing critical habitat for the federally endangered tidewater goby and southern steelhead trout, and a diverse number of shorebirds; the Lagoon is a critical stop over on the Pacific Flyway for migratory birds (Shifting Baseline, 2011; Jones & Stokes, 2006; Moffatt & Nichol, 2005).

Malibu Lagoon has undergone major changes in recent history due to major road construction, nearby development and upstream anthropogenic activities (Jones & Stokes, 2006; Moffatt & Nichol, 2005). Since 1929, Malibu Lagoon had been used as a dump site for fill material by Cal Trans during the construction of the Pacific Coast Highway (PCH). By the late 1970's the site was completely filled and housed two baseball fields (Jones & Stokes, 2006; Moffatt & Nichol, 2005). The impact from the previous construction activities led to loss of native species, increasing urban runoff, and excessive nutrient inputs.

In 1983, the California Department of Parks and Recreation (DPR) restored Malibu Lagoon by creating three channels and re-vegetating with native salt marsh plants (Jones & Stokes, 2006; Moffatt & Nichol, 2005). Malibu Lagoon underwent a restoration which included the removal of construction rubble, excavation of buried fill to create channels, thus increasing the main Lagoon depth, and planting of native vegetation. Then, in 1996, the California Department of Transportation (DOT) implemented restoration actions to mitigate the Malibu Lagoon/PCH bridge replacement; this restoration effort was mainly focused on the enhancement of tidewater goby (fish species) habitat, re-vegetation of native species (i.e., California bunchgrasses) and removing non-native plant species (i.e., Myoporum, black mustard, and hottentot fig) from the Lagoon. The Parks and Recreation Department has maintained the site as a wildlife habitat since the first restoration effort. Additional restoration efforts included the re-introduction of the endangered tidewater goby, additional excavation of tidal channels to improve tidal circulation, creation of islands and areas for to support bird and tidewater goby habitat (Trim 1994). Malibu Lagoon is home to many endangered and threatened species, including the California brown pelican, California least tern, double-crested cormorant, California gull, western snowy plover, elegant tern, tidewater goby, and the steelhead trout. In spite of these efforts, the continual development activities adjacent and upstream of the Lagoon continue to impact the ecological viability and health of the benthic community.

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2. Problem Statement

This section describes the beneficial uses identified in the Water Quality Control Plan (Basin Plan) and discusses the applicable water quality objectives for each beneficial use. It also includes information to describe the basis for each listing.

2.1 WATER QUALITY STANDARDS

California state water quality standards include of the following elements: 1) beneficial uses, 2) narrative and/or numeric water quality objectives (WQOs) and numeric water quality criteria, and 3) an antidegradation policy. In California, beneficial uses are defined by the Regional Boards in the Basin Plans. Numeric and narrative objectives are specified in each region's Basin Plan, designed to be protective of the beneficial uses.

2.1.1 Beneficial Uses

The Los Angeles Region Basin Plan lists the beneficial uses of Malibu Creek and Lagoon and major tributaries, which determine the applicable water quality criteria (Los Angeles Board, 1995).

Table 2-1 summarizes the beneficial uses designated for Malibu Creek and Lagoon and tributaries. These waterbodies are designated to provide municipal water supply, water recreation, ecological habitat uses, and the support of rare, threatened, or endangered species.

Table 2-1. Beneficial Uses for Malibu Creek, Lagoon and Major Tributaries (Los Angeles Board, 1995)

Waterbody	Malibu Creek	Malibu Lagoon	Las Virgenes Creek	Upper Medea Creek	Lower Medea Creek
Municipal and Domestic Supply (MUN)	P*		P*	P*	I*
Agricultural Supply (AGR)					
Industrial Process Supply (PROC)					
Industrial Service Supply (IND)					
Groundwater Recharge (GWR)					I
Freshwater Replenishment (FRSH)					
Navigation (NAV)		E			
Hydropower Generation (POW)					
Contact Water Recreation (REC1)	E	E	Em	Im	Em
Non-contact Water Recreation (REC2)	E	E	E	I	E
Aquaculture (AQUA)					
Warm Freshwater Habitat (WARM)	E		E	I	E

Waterbody	Malibu Creek	Malibu Lagoon	Las Virgenes Creek	Upper Medea Creek	Lower Medea Creek
Cold Freshwater Habitat (COLD)	E		P	P	
Inland Saline Water Habitat (SAL)_					
Estuarine Habitat (EST)		E			
Marine Habitat (MAR)		E			
Wildlife Habitat (WILD)	E	E	E	E	E
Preservation of Biological Habitats of Special Significance (BIOL)					
Rare, Threatened, or Endangered Species (RARE)	E	Ee	E	E	
Migration of Aquatic Organisms (MIGR)	E	Ef	P		
Spawning, Reproduction, and/or Early Development (SPWN)	E	Ef	P		
Shellfish Harvesting (SHELL)					
Wetland Habitat (WET)	E	E	E	E	E

Notes:

P Potential beneficial use.

E Existing beneficial use.

I Intermittent beneficial use.

Ee One or more rare species utilize all ocean, bays, estuaries, lagoons and coastal wetlands for foraging and/or nesting.

Ef Aquatic organisms utilize all bays, estuaries, lagoons and coastal wetlands, to a certain extent, for spawning and early development. This may include migration into areas which are heavily influenced by freshwater inputs.

* Beneficial use designated under SB 88-63 and RB 89-03. Some designations may be considered for exemptions at a later date.

m Access prohibited by Los Angeles County DPW in the concrete-channelized areas.

The WARM and COLD aquatic life uses are most relevant to this TMDL. The WARM use is specifically defined as “Uses of water that support warm water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.” The COLD use is defined as “Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancement of aquatic habitats, vegetation, fish, or wildlife, including invertebrates” (Los Angeles Board, 1995).

2.1.2 Water Quality Objectives

Water quality objectives for the Malibu Creek watershed have been established at the federal, state, and regional levels. These objectives support aquatic life by addressing toxicity, nutrients, dissolved oxygen, algae, sediment, and other related constituents. Objectives are primarily based on the California Toxic Rule (CTR) (40 CFR 131 – 65FR 31682, May 18, 2000) and the Los Angeles Basin Plan (Los Angeles

Board, 1995). The Los Angeles Basin Plan defines narrative and numeric WQOs to protect beneficial uses of water and prevent nuisances within a specific area.

The SWRCB is in the process of developing biological objectives (bio-objectives) for California's freshwater streams and rivers and expects to adopt the new objectives in spring of 2014 (see http://www.waterboards.ca.gov/plans_policies/biological_objective.shtml for detailed information on the process and status). Bio-objectives will provide narrative or numeric benchmarks to protect aquatic life beneficial uses and will include comparisons to reference sites. Several Advisory Groups have been developed to facilitate this process.

Given that the statewide bio-objectives are not yet finalized, the applicable narrative objectives for aquatic life within Malibu Creek include those that relate to toxicity, eutrophication, dissolved oxygen, and sediment and include the following:

- **Bioaccumulation:** The Basin Plan states that "toxic pollutants shall not be present at levels that will accumulate in aquatic life to levels which are harmful to aquatic life or human health."
- **Biochemical Oxygen Demand (BOD):** The Basin Plan states that "waters shall be free of substances that result in increases in the BOD which adversely affect beneficial uses."
- **Sediment:** The Basin Plan narrative sediment criteria were established to prevent impacts to spawning habitat, benthic organisms, and larval fish as well as other impacts. The Basin Plan states that "waters shall not contain suspended or settleable material in concentrations that cause nuisance or adversely affect beneficial uses."
- **Temperature:** The Basin Plan states that "the natural receiving water temperature of all regional waters shall not be altered unless it can be demonstrated to the satisfaction of the Regional Board that such alteration in temperature does not adversely affect beneficial uses." The Basin Plan also specifies numeric criteria as noted in Table 2-2.
- **Turbidity:** The Basin Plan states that "watersheds shall be free of changes in turbidity that cause nuisance or adversely affect beneficial use" and also specifies numeric criteria as noted in Table 2-2.
- **Toxicity:** The Basin Plan states that "all waters shall be maintained free of toxic substances in concentrations that are toxic to, or that produce detrimental physiological response in human, plant, animal, or aquatic life."

The numeric criteria most applicable to the protection of aquatic life in the Malibu Creek watershed are presented in Table 2-2, along with the nitrate-nitrogen criterion that is most relevant to drinking water uses. Ammonia objectives are defined as a function of pH and temperature and metals objectives are defined as a function of hardness. The equations used to calculate these objectives are explained in more detail below. Numeric criteria for other toxins are outlined in the CTR 40 CFR 131.38 (USEPA, 2000a).

Prior to the establishment of the 2003 Malibu Creek Watershed Nutrient TMDL, the only numeric nutrient criterion specified for the waters of Malibu Creek Watershed, other than the ammonia limit, was the human health-based criterion of 10 mg/L for nitrate nitrogen. The 2003 USEPA-established TMDL set nutrient criteria for "total" nitrogen (specified as the sum of nitrate plus nitrite nitrogen) and total phosphorus based on best available information at the time (USEPA, 2003). These are also presented in Table 2-2. Since 2003, a significant amount of additional data and analyses have been completed. California is closer to establishing statewide approach for setting nutrient criteria based on the Nutrient Numeric Endpoint (NNE). A specific NNE technical document is currently being completed for Malibu Creek Watershed. Based on this draft NNE document specific for Malibu Creek Watershed and other additional monitoring in Malibu Creek and Lagoon, there is strong evidence that the nutrient limits should be revisited. These values are discussed in the numeric targets section along with the proposed new numeric targets (Section 3).

Table 2-2. Selected Numeric Water Quality Criteria Applicable to the Malibu Creek Watershed (Los Angeles Board, 1995)

Constituent	WQO	Notes
Ammonia	30-day average and one-hour acute objectives expressed as functions of temperature and pH; four-day maximum average concentrations shall not exceed 2.5 times the 30-day average objective.	See Equation 2-1 through Equation 2-4
Nitrate-Nitrogen	10 mg/L	Specific objective for the Malibu Creek watershed
Dissolved Oxygen	For WARM: Mean annual concentration > 7 mg/L; instantaneous > 5 mg/L; as a result of waste discharges: > 5 mg/L For COLD: > 6 mg/L For COLD and SPWN: > 7 mg/L	Objectives differ by beneficial use for waters receiving waste discharges
pH	As a result of waste discharges: between 6.5 and 8.5, and no change > 0.5 units from natural conditions	Objective defined for waters receiving waste discharges
Temperature	For WARM: no change > 5 degrees F above natural temperature and < or equal to 80 degrees F at all times; For COLD: no change > 5 degrees F above natural temperature	Objectives differ by beneficial use; for Malibu Lagoon, stricter regulations may be induced for individual dischargers under the CA Thermal Plan (SWRCB, 1972)
Total Dissolved Solids	2,000 mg/L	Specific objective for the Malibu Creek watershed
Turbidity	Natural turbidity 0 to 50 NTU: increases shall not exceed 20 percent Natural turbidity >50 NTU: increases shall not exceed 10 percent	
Chlorophyll-*a*	150 mg/L for streams and Lagoon	Consistent with USEPA, 2003
Algae cover	30% Floating algae 60% Bottom algae	Consistent with USEPA, 2003
Nitrate plus Nitrite Nitrogen	1.0 mg/L summer (April 15 –November 15) 8.0 mg/L winter (November 16- April 14)	Consistent with USEPA, 2003
Total Phosphorus	0.1 mg/L summer (April 15 –November 15) only	Consistent with USEPA, 2003

The Basin Plan expresses ammonia targets as a function of pH and temperature because un-ionized ammonia (NH_3) is toxic to fish and other aquatic life. In order to assess compliance with the standard, pH, temperature, and ammonia must be determined at the same time. The toxicity of ammonia increases with increasing pH and temperature; therefore, ammonia targets depend on the site specific pH and temperature as well as the presence or absence of early life stages (ELS) of aquatic life.

A December 2005 Amendment to the Basin Plan assumes that ELS are present in any waterbody designated as COLD (Los Angeles Board, 2005a). The 30-day average target concentrations (criterion continuous concentration (CCC)) of ammonia for waterbodies with ELS absent and present can be calculated using Equation 2-1 and Equation 2-2, respectively. The four-day maximum average concentration shall not exceed 2.5 times the 30-day average objective, while the one-hour acute level, with ELS absent and present, can be calculated with Equation 2-3 and Equation 2-4, respectively (USEPA, 1999).

Equation 2-1. 30-day Average Total Ammonia Concentration for Waterbodies with ELS Absent

$$\text{30-day Average Concentration (mg/L)} = \left(\frac{0.0577}{1+10^{7.688-pH}}+\frac{2.487}{1+10^{pH-7.688}}\right)\cdot 1.45\cdot 10^{0.028\cdot(25-MAX(T,7))}$$

Equation 2-2. 30-day Average Total Ammonia Concentration for Waterbodies with ELS Present

$$\text{30-day Average Concentration (mg/L)} = \left(\frac{0.0577}{1+10^{7.688-pH}}+\frac{2.487}{1+10^{pH-7.688}}\right)\cdot MIN\left(2.85, 1.45\cdot 10^{0.028\cdot(25-T)}\right)$$

Equation 2-3. Acute Criteria for Total Ammonia-Nitrogen for Waterbodies with ELS Absent (USEPA, 1999)

$$Acute\ Limit\ (mg/L) = \left(\frac{0.41}{1+10^{7.204-pH}}\right)+\left(\frac{58.4}{1+10^{pH-7.204}}\right)$$

Equation 2-4. Acute Criteria for Total Ammonia-Nitrogen for Waterbodies with ELS Present (USEPA, 1999)

$$Acute\ Limit\ (mg/L) = \left(\frac{0.267}{1+10^{7.204-pH}}\right)+\left(\frac{39.0}{1+10^{pH-7.204}}\right)$$

2.1.3 Antidegradation

State Board Resolution 68-16, "Statement of Policy with Respect to Maintaining High Quality Water in California," known as the "Antidegradation Policy," protects surface and ground waters from degradation. Any actions that can adversely affect water quality in all surface and ground waters must be consistent with the maximum benefit to the people of the state, must not unreasonably affect present and anticipated beneficial use of such water, and must not result in water quality less than that prescribed in water quality plans and policies. Furthermore, any actions that can adversely affect surface waters are also subject to the federal Antidegradation Policy (40 CFR 131.12). The proposed TMDLs will not degrade water quality, and will in fact improve water quality as they will lead to meeting the water quality standards.

2.2 Basis of Listing in Malibu Creek Watershed

Use assessments of Malibu Creek and Lagoon have identified a wide range of water quality impairments. The 2002 Section 303(d) (Los Angeles Board, 2002) list of impaired waters identifies Malibu Creek as impaired by total selenium, total aluminum, nitrite-nitrogen, and sedimentation, while Malibu Lagoon was listed as impaired by sedimentation. An earlier listing for coliform bacteria had been recently removed after completion of a TMDL. The 2008 list (Los Angeles Board, 2008) shows Malibu Creek as impaired by poor benthic macroinvertebrate bioassessments, excess coliform bacteria, fish barriers (fish passage), invasive species, nutrients (algae), scum/foam (unnatural), sedimentation/siltation, selenium, sulfates, and trash. The 2008 list also indicates that Malibu Lagoon is impaired for benthic community effects, coliform bacteria, eutrophic conditions, swimming restrictions, viruses (enteric), and pH.

A number of these identified impairments have been addressed through TMDLs:

- A coliform bacteria TMDL for Malibu Creek was approved by USEPA on 1/1/2002 (USEPA, 2002).
- A nutrient/eutrophication TMDL for both the creek and Lagoon was approved by USEPA on 3/21/2003. Allocations are based on loading targets of 1 mg/L total nitrogen and 0.1 mg/L total phosphorus (USEPA, 2002).
- A coliform bacteria TMDL for Malibu Lagoon was approved on 1/1/05.
- Swimming restrictions and enteric viruses in the Lagoon are addressed in a TMDL approved 1/10/06.
- A trash TMDL for the creek and Lagoon (although the Lagoon was not listed for trash) was approved on 6/26/2009.

This study addresses some, but not all, of the remaining impairments in the main stem of Malibu Creek and Malibu Lagoon for which TMDLs have not been completed, in accordance with the Consent Decree in the case Heal the Bay, Inc. and Santa Monica Baykeeper, Inc. vs. USEPA in US District Court for the Northern District of California. The 8/16/2010 Stipulation to Modify Amended Consent Decree in this case discusses three “pairings of Water Quality Limited Segments (WQLSs) and pollutants” for which TMDLs will be completed for Malibu Creek (WBID CAR4042100019990201132825, which is the main stem from the Lagoon up to Malibou Lake) and Malibu Lagoon by 3/24/2013:

1. Malibu Creek benthic-macroinvertebrate bioassessments
2. Malibu Creek sedimentation/siltation
3. Malibu Lagoon benthic community effects

The stipulation removes from the Consent Decree the requirement to complete sedimentation TMDLs for Malibu Creek tributaries Medea Creek, Las Virgenes Creek, and Lindero Creek.

The 2002 303(d) Fact Sheet discusses sedimentation as impaired, stating that “Malibu Creek Watershed, including Malibu Creek, Las Virgenes Creek, Triunfo Creek, and Medea Creek, is proposed to be listed in the 2002 305(b) water quality assessment as “Partially Supporting (Impaired)” due to excessive sedimentation. Regional Board staff and James M. Harrington, Staff Environmental Scientist of California Department of Fish and Game, evaluated the data and concluded that the Malibu Creek watershed, with the exception of Cold Creek, is impaired by sedimentation based on both the biological assessment of the macroinvertebrate stream community assemblage and the physical habitat data. Harrington states, ‘All of the monitoring sites within the Malibu Creek watershed (except for the upper reaches of Cold Creek) show typical signs of ecological impairment due primarily to sediment (and nutrient enrichment)…and low physical habitat scores reflect the influence of heavy sediments in causing reduced habitat availability and reduced habitat quality for macroinvertebrates… It is my opinion that Malibu Creek is impaired by excessive sedimentation” (Letter from Harrington to the Regional Board dated December 6, 2001).

The 2008 integrated report for the Los Angeles Region states “The water quality chemistry and bioassessment data provide a substantial basis that benthic macroinvertebrate populations are impacted by a wide range of anthropogenic stressors.” The report from the 2005 Malibu Creek Bioassessment

Monitoring Program (Aquatic Bioassay, 2005) examined eight sites in the Malibu Creek watershed, providing both Index of Biotic Integrity (IBI) and physical habitat scores (including substrate complexity, embeddedness, consolidation, and percent fines). Four of the eight sites (including Malibu Creek above the Lagoon – the only station on the main stem included in that survey) showed physical habitat as optimal or suboptimal and, for these four sites, "stressors other than habitat conditions may have impacted these sites." There are many other potential causes of the poor IBI scores (including excess nutrients, metals, organics, and exotic species).

Basis of the 303(d) listing for benthic community impacts in Malibu Lagoon

Malibu Lagoon was originally included in the 1998 listing for benthic community effects impairment.

According to California State Water Resources Board, Los Angeles Region (Personal Comm. LB Nye, August 9, 2012), the basis of the impairment listing for benthic community impacts in Malibu Lagoon was due to one of the few documented survey of the benthic community, in Chapter 6 of "Enhanced Environmental Monitoring Program at Malibu Lagoon and Malibu Creek" (Ambrose et al., 1995). This discussion provides a summary of the benthic invertebrate results and analyses provided in the report; the sampling method and other details are not provided in this TMDL, and instead further interest should be directed to the Chapter 6 of the report itself.

A total of three different invertebrate groups were surveyed in the 1993-1994 sampling effort, including zooplankton (small floating species in the water), infauna (species living in the Lagoon sediment), and large invertebrates (e.g., shrimp, crabs). A total of 17 benthic invertebrate taxa were collected, including the mud-flat crab, the introduced oriental shrimp, two polychaete families and other crustacean and bivalve taxa. The most abundant zooplankton taxon were the copepods; other common taxa included ostracods, nauplii, polychaetes, trochophores, nemerteans, and nematodes. According to Ambrose et al. (1995), the distribution and abundance of these floating species in the water column was influenced by the transitory and shallow environment of Malibu Lagoon. Copepods, ostracods and benthic invertebrate larvae were the most common zooplankton species, as would be expected in shallow Lagoon waters.

Infauna inhabiting the sediments of coastal lagoons typically includes clams, shrimp, crustaceans, worms, among others. Benthic infauna is a highly diverse group with hundreds of species. A typical southern California coastal Lagoon with appropriate tidal flushing should support between 100-200 infaunal species (Zedler et al., 1992; Peterson, 1977). In contrast, coastal lagoons without tidal flushing will see significantly reduced species richness (Nordby and Covin, 1988). The only bivalve crustacean collected was the California jackknife clam, *Tagelus californianus*; a total of 352 live clams were collected. The polychaete *Polydora nuchalis* was also collected. Approximately 99% of the clams were collected at the tidal creek site (S-6B), which had finer sediments than other sites sampled in the Lagoon. At sandier substrates, the clams were not collected or had few individuals (n=3 at 3 sites), suggesting that sandy substrates were not suitable habitat for jackknife clam burrows. There was some indication that peak abundances of the clams coincided with summer breaching events and the first significant precipitation event in 1993. Mud crab burrows and mud crabs were observed in the Lagoon, specifically at trap stations with the steepest banks. The exotic and introduced oriental shrimp was first collected at Malibu Lagoon in September 1987 during a fish survey (Dillingham, 1989). During the 1993-1994 sampling period, a total of 1,125 oriental shrimp were collected across all sampling periods and sites; the majority of the shrimp were collected furthest from the mouth of the Lagoon. The study stated that one major contributing factor to the high shrimp abundances observed was due to the presence of construction debris, which likely provided habitat shelter for the invertebrates.

The observations and results of the 1993-1994 sampling effort for benthic invertebrates suggest that Malibu Lagoon ranks "poorly at this trophic level when compared to less disturbed southern California estuaries" (Ambrose et al., 1995).

In 2010, supporting information for the 2010 integrated report against delisting this listing for Malibu Lagoon stated that readily available data and information, and weight of evidence, conclude there is "sufficient justification against removing this water segment-pollutant combination from the section 303(d) list." This conclusion is based on the staff findings that:

1. The Malibu Lagoon Restoration Feasibility Study Final Alternatives Analysis describes restoration measures for Malibu Lagoon. These proposed restoration efforts, if fully implemented, are anticipated to correct the conditions which allow the negative indicator species to thrive.
2. The Regional Board "decided against moving the benthic community effects listing in Malibu Lagoon from the TMDL required portion of the 303(d) list to the being addressed by action other than TMDL portion of the 303(d) list." The source of impairment is indicated as hydromodification.

2.3 IMPAIRMENT CONCLUSIONS

Many different datasets were evaluated to characterize and confirm impairments. These data include water quality, biological, and habitat data. Detailed analyses are presented in Sections 7 and 8. The remainder of this section summarizes these findings and how they relate to the impairment assessments.

Water quality data were analyzed. Exceedances of the dissolved oxygen criteria were observed at monitoring stations on Malibu Creek (12.2% exceedance frequency at station MC1 and 11.7% exceedance frequency at MC-12 [Table 7-2]). Turbidity values were generally low (most samples were assumed to be collected during dry weather); however, they were about an order of magnitude above the reference sites (Section 7.4.2). In addition USEPA collected wet-weather turbidity data on Malibu Creek (Section 7.4.3). This study found that for average typical ranges of flows in the Creek, there is a good relationship between turbidity and suspended solids. An annual load was estimated and it was an order of magnitude greater than the estimated load from mass emission station F-130, likely due to the particularly greater flow events observed in the sampling period 2011-2012, but suggesting that large sediment loads can be transported downstream of Malibu Creek during years with more frequent and larger magnitude storm events.

Nutrient concentrations exceed targets established in the Malibu Creek nutrient TMDL (USEPA, 2003) at station MC-1, especially for nitrate-N and orthophosphate-P (Table 7-7) during both winter and summer periods (Section 7.5). Sampling by other groups for various nutrient species provides similar insights. In addition, Heal the Bay has collected algal coverage data for 2005-2010. These data indicate that the mat algae cover is above the 2003 nutrient TMDL threshold and the temporal trend does not show any decline over time (see Section 8.3). In Malibu Lagoon, elevated concentrations for the biologically-available nutrients such as Nitrogen Oxide (NOx), and Ammonium (NH_4) were observed (Moffatt &Nichol, 2005; 2NDNATURE, 2010) along with the presence of excessive algae leading to anoxic conditions (Section 8.2).

The biological data are presented several ways for streams and the estuary (Section 8. In freshwater, a summary of Heal the Bay Southern California Benthic Index of Biotic Integrity (SC-IBI) results for the main stem of Malibu Creek shows that 41 of 44 samples (93 percent) are rated as either poor or very poor on the SC-IBI scale (Section, 8.1.3, Table 8-2, and Figure 8-2). Results for several tributaries (Medea Creek, Triunfo Creek, and Las Virgenes Creek) were also mostly poor or very poor; however, other tributaries showed much better results (Table 8-3 and Table 8-4). Samples collected by LVMWD showed similar results on the main stem and on Las Virgenes Creek (Table 8-6) and SC-IBI results based on USEPA sampling were also low. When considering all available SC-IBI scores, the lowest median scores are found in the main stem and in the lower portions of tributaries Triunfo Creek, Medea Creek, and Las Virgenes Creek (Figure 8-2).

As an additional line of evidence, the O/E ratio was also calculated, where O is the number of taxa observed in a sample and E is the expected number of taxa (see Section 8.1.4). The O/E scores, which are the site specific percent of taxa expected in the absence of disturbance, varied by site location with some scoring close to reference expectation (approximately > 0.8) and others scoring close to zero. In general, O/E scores were weakly correlated with SC-IBI scores, which explained about 35-37% of the variability based on either a linear or polynomial fit (Figure 8-4).

Benthic results were compared with various water quality indicators to identify any correlations. Overall, stations with low median IBI scores are also those stations that are downstream of significant amounts of urban development (Figure 8-10). It was also found that nitrate-N concentrations are elevated at stations downstream of high levels of development (Section 7.4), further supported by the findings that median IBI scores are better than poor only at stations with average nitrate-N concentrations less than 1 mg/L (which is the target specified in the nutrient TMDL) (Figure 8-11) (note: the relationships with O/E were less conclusive). The benthic results were also compared with percent imperviousness, demonstrating a strong negative correlation between the bioscores and percent upstream impervious area (Figure 8-16 and Figure 8-17). Overall, the analyses suggest that imperviousness and urban development are significant indicators of biological condition in the Malibu Creek Watershed.

While there is no metric for comparison, benthic macroinvertebrate data in Malibu Lagoon were also summarized. USEPA collected data during winter 2010 and spring 2011 that showed less than 20 total taxa, which still indicates an impaired system, and Malibu Lagoon Restoration Monitoring in 2006-2007 showed similar results (Section 8.2). This is well below a threshold of 40 taxa for a healthy community of benthic invertebrates (Section 3.2).

Comprehensive evaluation of the available data confirm impairments for benthic macroinvertebrates and benthic community effects in Malibu Creek and Malibu Lagoon, respectively. The sedimentation listing in Malibu Creek is confirmed by both the turbidity data analyses in which results were an order of magnitude above reference sites as well as the calculated 38 percent change in sedimentation rate from natural conditions (Section 10.2.2). Multiple stressors were evaluated related to these impairments. The key stressors impacting the biota (both directly and indirectly) are sedimentation and nutrient loading, as summarized in Section 9. In addition, nutrient data from the last 10 years suggest that the nutrient concentration numeric limits from the 2003 TMDL are not quite stringent enough to attain beneficial uses and that new targets should be set year-round and reduced to address the benthic-macroinvertebrate and benthic community effects impairments in Malibu Creek and Lagoon, respectively.

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3. Numeric Targets

Numeric targets represent quantitative vales that result in attainment of the water quality standards. Since USEPA's assessment of the all available data and studies demonstrate that the impairment is a result of multiple interacting stressors, this TMDL identifies multiple numeric targets for the most significant pollutants. The targets are assigned based on response targets and comparisons with natural conditions, which are specific measures directly associated with the biotic impairment and sedimentation that can be measured and assessed (e.g., SC-IBI).

The key stressors impacting the biota (both directly and indirectly) are sedimentation and nutrient loading, as summarized in Section 9. Excessive levels of sedimentation cause suboptimal habitat, and are also associated with the movement of sediment-associated nutrients and toxics. Excess nutrient loading causes overgrowth of algae including the development of macro-algal mats, which also directly impair the habitat available for benthic macroinvertebrates, while indirectly contributing to exceedances of DO and pH criteria. Numeric targets associated with these stressors are presented below for Malibu Creek and Lagoon, while the analyses supporting the selection of these targets are documented in Sections 7 through 10 (as well as several associated appendices).

Prior to the establishment of the 2003 Malibu Creek Watershed Nutrient TMDL, numeric nutrient criteria did not exist for the waters of Malibu Creek Watershed. The 2003 USEPA-established TMDL set nutrient criteria for total nitrogen (nitrate-nitrite) and total phosphorus based on best available information at the time. These are presented in Table 2-2. Since 2003, a significant amount of additional data and analyses have been completed. California is closer to establishing statewide approach for setting nutrient criteria based on the Nutrient Numeric Endpoint (NNE). A specific NNE technical document is currently being completed for Malibu Creek Watershed. Based on this draft NNE document specific for Malibu Creek Watershed and other additional monitoring in Malibu Creek and Lagoon, there is strong evidence that the nutrient limits should be revisited.

3.1 MALIBU CREEK AND TRIBUTARIES NUMERIC TARGETS

Numeric targets for Malibu Creek and its major tributaries were identified from several sources. These include the Basin Plan, the 2003 nutrient TMDL (USEPA, 2003), NNE Analyses (Appendix F), and additional data analyses (Sections 7 and 8) and are discussed below in the context of this TMDL.

In the 2003 TMDL, USEPA utilized the reference waterbody approach to develop numeric targets for impaired streams and lakes within the Malibu watershed based on USEPA guidance (USEPA, 2000a; 2000b; 2003). For streams, the reference approach involves using relatively undisturbed stream segments to serve as examples of background nutrient concentrations (USEPA, 2000a). The 2003 TMDL evaluated data from three locations upstream of the Tapia treatment plant with long-term data sets (Upper Malibu Creek (R9), Middle Malibu Creek (R1) and Lower Las Virgenes Creek (R6)). The concentrations for both nitrogen and phosphorus at the Upper Malibu Creek and Middle Malibu Creek stations were much lower than at the Las Virgenes Creek station. Data from stations R9 and R1 were believed to be more appropriate for setting target values using the reference approach. Based on data from these stations, the proposed targets in the 2003 Nutrient TMDL were 1.0 mg/l for total nitrogen and 0.1 mg/l as a target for total phosphorus for the summer period (USEPA, 2003).

In this TMDL addressing sedimentation and benthic community impairments, USEPA believes data from the last 10 years suggest that the nutrient concentration numeric limits from the 2003 TMDL are not quite stringent enough to attain beneficial uses and that new targets should be set year-round and reduced. Specifically, Heal the Bay has collected algal coverage data for 2005-2010. These data indicate that the mat algae cover is above the 2003 nutrient TMDL threshold and the temporal trend does not show any decline over time (see Section 8.3). In addition, monitoring stations on Malibu Creek demonstrate excursions of the summer and winter nutrient targets from the 2003 nutrient TMDL (see Section 7.5). These analyses support the conclusion that additional nutrient concentration targets are needed.

To identify new nutrient targets, two methods were evaluated: the NNE Analyses and a reference-based approach. The California NNE approach is a risk-based approach, with ultimate focus on supporting designated uses (Appendix F). The analysis for both stream and lake sites suggest that the TMDL criteria (USEPA Region IX, 2003) for the Malibu Creek watershed of 1 mg/L nitrate plus nitrite N and 0.1 mg/L total phosphorus (from April 15 to November 15) may not be adequate to support uses. An application of this tool using site-specific data yields a median TN concentration of 0.24 mg/L for Malibu Creek with a corresponding TP goal of 0.0033 mg/L for the summer period; however, the method estimates that impairment can be addressed by meeting either the TN or TP target. As an alternative approach, when evaluating data at the potential reference sites (Section 7.5.4), the available data suggest that natural reference conditions in the Malibu watershed can be approximated as having a central tendency for the summer period of around 0.7 mg/L total N and 0.14 mg/L total P outside the Modelo formation, and around 1.3 mg/L total N and 0.6 mg/L total P within the Modelo formation.

In summary, the numeric targets for this TMDL that apply to Malibu Creek and tributaries are as follows:

- **SC-IBI**: The SC-IBI scores at stations MC-1, MC-12, and MC-15 should obtain a median value of 40 or better, consistent with at least a "Fair" ranking (Ode et al., 2005). Scores less than 40 result in a determination of impairment, and a score of 40 also separates the impacted sites on the Malibu Creek main stem from the reference sites (see Section 8.1.2). The evaluation should be based on a median over a minimum of 4 years to account for significant year-to-year variability in individual measurements.
- **SC-O/E**: The O/E scores provide a second line of evidence to complement the IBI. O/E should equal at least the 10^{th} percentile of the model reference distribution. Similar to the SC-IBI, the evaluation should be based on a median over a minimum of four years to account for year-to-year variability.
- **Benthic Community Diversity**: Based on the benthic metrics, an additional target was established related to species diversity. Specifically, a diverse and rich population of multiple benthic macroinvertebrate species should be observed in Malibu Creek and the tributaries feeding into the main stem.
- **Benthic Algal Coverage**: Algal coverage targets were established in the USEPA (2003) nutrient TMDL based on Biggs (2000) recommendations of: no more than 30 percent cover for filamentous (floating) algae greater than 2 cm in length and no more than 60 percent cover for bottom algae greater than 0.3 cm thick. Ongoing studies by SCCWRP suggest these targets should be protective of goals established in the draft CA NNE framework. The NNE framework suggests that, for support of the COLD beneficial use, maximum benthic chlorophyll *a* density should be constrained to be less than 150 mg/m^2 and ideally less than 100 mg/m^2 (referred to as the BURC II/III and BURC I/II boundaries).
- **Dissolved Oxygen**: Consistent with the 2003 Nutrient TMDL, the target for the mean annual dissolved oxygen concentration is 7 mg/L for all waters in the Malibu watershed. The Basin Plan standard for waters designated as WARM is that no single determination be below 5.0 mg/l as a result of waste discharges. This target applies to most tributaries, including Lower Medea Creek. A more restrictive target of 7 mg/L is required for Las Virgenes Creek, Upper Medea Creek, and Malibu Creek to protect existing and potential uses associated with cold-water fisheries and spawning. Recognizing that diel fluctuations in DO are a natural occurrence, we propose that 7.0 mg/L minimum for waters with uses associated with cold water fisheries and spawning (Las Virgenes Creek, Upper Medea Creek, and Malibu Creek) be interpreted as an average daily value.

- **Natural Sedimentation Rate**: In the absence of an appropriate reference site or watershed, a reasonable sedimentation rate to protect the health of the Malibu Creek watershed is determined by evaluating the natural capacity of flow to move sediment in the Malibu Creek Watershed. Analyses estimated that a 38 percent reduction in channel sediment transport is required to achieve natural loading rates (Section 10.2). The reduction goal can be converted to a load basis by examining sediment transport at the LACDPW F-130 mass emissions station (see Section 10.2.2).
- **Nutrient Concentrations**: Based on the analyses described above, nutrient targets in Malibu Lagoon were established for several specific parameters based on the reference system approach: total nitrogen (organic plus inorganic nitrogen) targets are 0.6 mg/L in the summer and 1.0 mg/L in the winter; and total phosphorous targets are 0.1 mg/L in the Creek, major tributaries and in the Lagoon throughout the year.

3.2 MALIBU LAGOON NUMERIC TARGETS

Several sources were also used to identify numeric targets for Malibu Lagoon, including the Basin Plan, the 2003 nutrient TMDL (USEPA, 2003), and additional data analyses (Sections 7 and 8). These sources are discussed below including how they apply to this TMDL.

In the 2003 TMDL, nutrient targets for the Lagoon were derived from the USEPA/NOAA guidance for estuaries (NOAA/EPA, 1988). The targets are 1.0 mg/l for nitrogen and 0.1 mg/l phosphorus for the summer period. We used the high-end range for these values because of the uncertainty regarding which factors are limiting algal abundances. For comparison, average Lagoon values during the summer were 1.39 mg/l for nitrogen and 0.49 mg/l (Ambrose et al., 2000). The average winter concentrations measured by Ambrose et al. were 4.0 mg/l for nitrogen and 0.63 mg/l for phosphorus.

The average winter concentrations described in the Ambrose et al. (2000) report reflect concentrations of an already impaired Lagoon; this observation is highlighted by data collected since 2000. Consequently, this TMDL reduces the numeric target limits set in the 2003 nutrient TMDL. Specifically, total nitrogen (organic plus inorganic nitrogen) targets are 0.6 mg/L in the summer and 1.0 mg/L in the winter, and total phosphorous targets are 0.1 mg/L (apply year-round).

Malibu Lagoon currently shows elevated concentrations for the biologically-available nutrients such as Nitrogen Oxide (NOx), and Ammonium (NH_4) (Moffatt &Nichol, 2005; 2NDNATURE, 2010). The presence of excessive algae lead to greater consumption of the available dissolved oxygen during decomposition, and thus lead to anoxic conditions that impact the survival of the flora and fauna in the Lagoon (Section 8.2). In addition, USEPA collected data during winter 2010 and spring 2011 that showed less than 20 total taxa, which still indicates an impaired system, and Malibu Lagoon Restoration Monitoring in 2006-2007 showed similar results (Section 8.2).

Because baseline data for Malibu Lagoon (prior to the significant impacts in the Lagoon) were not available and reference site data from another similar seasonally tidal coastal Lagoon were also not available, this TMDL based its determination on the best available information and the strong conclusion that we should expect to see greater species and taxa richness from a healthy benthic community in Malibu Lagoon. Consequently, based on our review of other coastal estuaries, we should expect to see a doubling of the species and taxa richness within a ten year time frame. Our best example and most comparable coastal estuary in size and physical behavior is Los Peñasquitos Lagoon in San Diego County. The best indication of the expected increase in benthic infaunal richness was the observed data before and after extended mouth closure due to anthropogenic activities. Los Peñasquitos Lagoon saw approximately three-fold increase of taxa richness (from around 11 to 34). Similarly, San Dieguito, although a much larger estuary, saw a six-fold increase in taxa richness after more natural tidal flushing actions were implemented (from 7 to 42). In Batiquitos Lagoon, a ten year monitoring period following the restoration of the tidal flushing resulted in greater benthic infauna abundance and diversity (Merkel &

Associates 2009). In addition, they found that the later post-restoration monitoring years, less dominant organisms were observed more regularly, but in small numbers.

The average taxa richness observed during the three sampling periods in Malibu Lagoon over a 15 year time span (1995-2010) was 16 taxa. During the 1995, 2006/07 and 2010/11 sampling periods, the average taxa richness observed was 17, 13.5, and 18.5, respectively. For this TMDL, the numeric target and benthic invertebrate taxa richness goal is set at 35. USEPA believes this is a reasonable target for the rationale provided above, and because this reflects the recently restored restoration of Malibu Lagoon in summer 2012. This Lagoon restoration was comprehensive, cost approximately $7M, and was designed to increase tidal flushing to all zones of the Lagoon, remove the excessively anoxic sediment, particularly in the back sloughs of the Lagoon. These actions should provide the best foundation for building and restoring the benthic community in the Malibu Lagoon. As such, based on our knowledge of coastal estuaries in general, the long-term impaired conditions in the Lagoon observed in the last 20 years, a doubling of the benthic infaunal taxa richness is achievable and should provide for improvement and protection of the beneficial use. This is comparable to the approach taken in the Chesapeake Bay TMDLs addressing benthic community impairments due to nutrient and sedimentation unbalance.

In summary, the numeric targets for this TMDL that apply to the Malibu Lagoon are as follows:

- **Benthic Community Diversity**: Achieve a goal of increasing species richness in Malibu Lagoon with multiple functional groups. USEPA believes that by setting a target of species richness of 35 in 15 years will lead to a healthy community of benthic invertebrates.
- **Dissolved Oxygen**: Consistent with the 2003 Nutrient TMDL, the target for the mean annual dissolved oxygen concentration is 7 mg/l for all waters in the Malibu watershed, including Malibu Lagoon. A more restrictive target is required for Malibu Lagoon to protect existing and potential uses associated with cold-water fisheries and spawning. The Basin Plan standard for waters designated as WARM is that no single determination be below 5.0 mg/l as a result of waste discharges. Recognizing that diel fluctuations in DO are a natural occurrence, we propose that 7.0 mg/l minimum for waters with uses associated with cold water fisheries and spawning be interpreted as an average daily value.
- **Nutrient Concentrations**: Based on the analyses described above, nutrient targets were established for several specific parameters in Malibu Lagoon: total nitrogen (organic plus inorganic nitrogen) targets are 0.6 mg/L summer and 1.0 mg/L winter, and total phosphorous targets are 0.1 mg/L (apply year-round).

4. Geographic Information and Analysis

Geographic analyses provide a foundation to interpret data analyses and to represent sources and conditions in the watershed. This section presents the geographic data evaluated (see also Appendix A) and associated characterization of the Malibu Creek watershed. Appendix B provides additional background on watershed characterization.

4.1 Inventory of Spatial Data

Spatial data for the Malibu Creek watershed region were obtained from several different sources. In many cases, the original source data were modified for specific applications to the Malibu Creek watershed. For example, the Southern California Association of Governments (SCAG) land use and land cover data from 1990, 2005, and 2008 were clipped to the watershed boundaries and simplified through aggregation of the numerous SCAG classes into broader descriptions. Some spatial data were available in tabular format (e.g., latitude and longitude) and then transformed into Geographic Information System (GIS) spatial coverages. Appendix A includes the description of the different spatial datasets assembled to support subsequent work within the watershed.

4.2 Jurisdictions

Seven municipalities have jurisdictional boundaries within the Malibu Creek watershed (Figure 4-1). Five of the municipalities are within Los Angeles (LA) County and two are within Ventura County. Westlake Village and Agoura Hills jurisdictional areas (both in LA County) are found exclusively within the watershed. The majority of the watershed is outside of existing incorporated municipal jurisdictional boundaries. As of 2010, all areas within the watershed are covered by municipal stormwater permits for LA and Ventura counties, except for state roads, which are covered by Caltrans' permit (see Section 5.1.2).

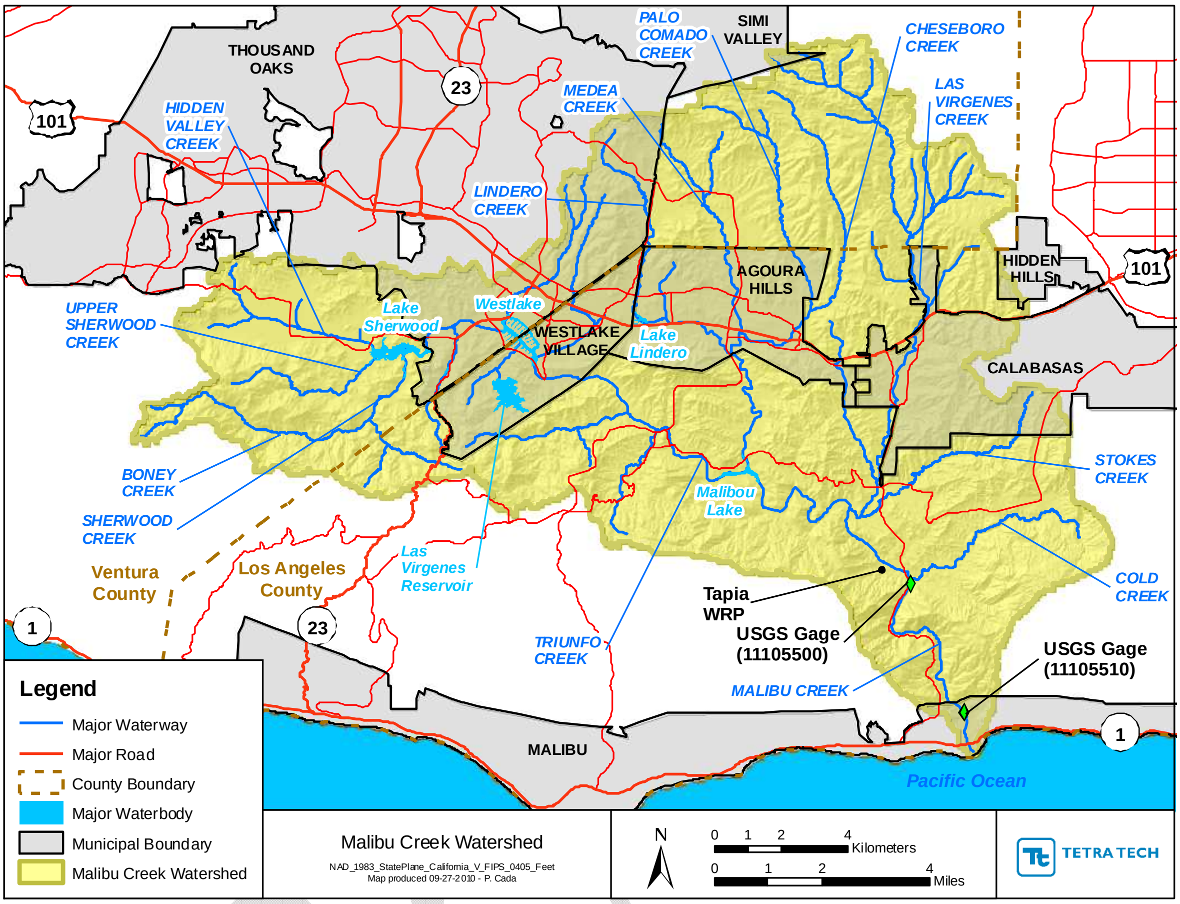

Figure 4-1. Municipal Jurisdiction Boundaries within the Malibu Creek Watershed

4.3 Topography

Located in the Peninsular Range physiographic province, the Malibu Creek watershed is bordered by the Santa Monica Mountain range to the west and Simi Hills to the north. As shown in Figure 4-2, most of the headwater areas are located in Ventura County and many of these areas drain to lakes before converging to form Malibu Creek in the lower watershed. Elevations in the watershed range from sea level at the Malibu Lagoon and Santa Monica Bay to over 900 meters (2,953 feet) in the Santa Monica Mountains and Simi Hills. The watershed elevation and topography shown in Figure 4-2 is based on a 10-meter Digital Elevation Model (DEM) obtained from United States Department of Agriculture (USDA).

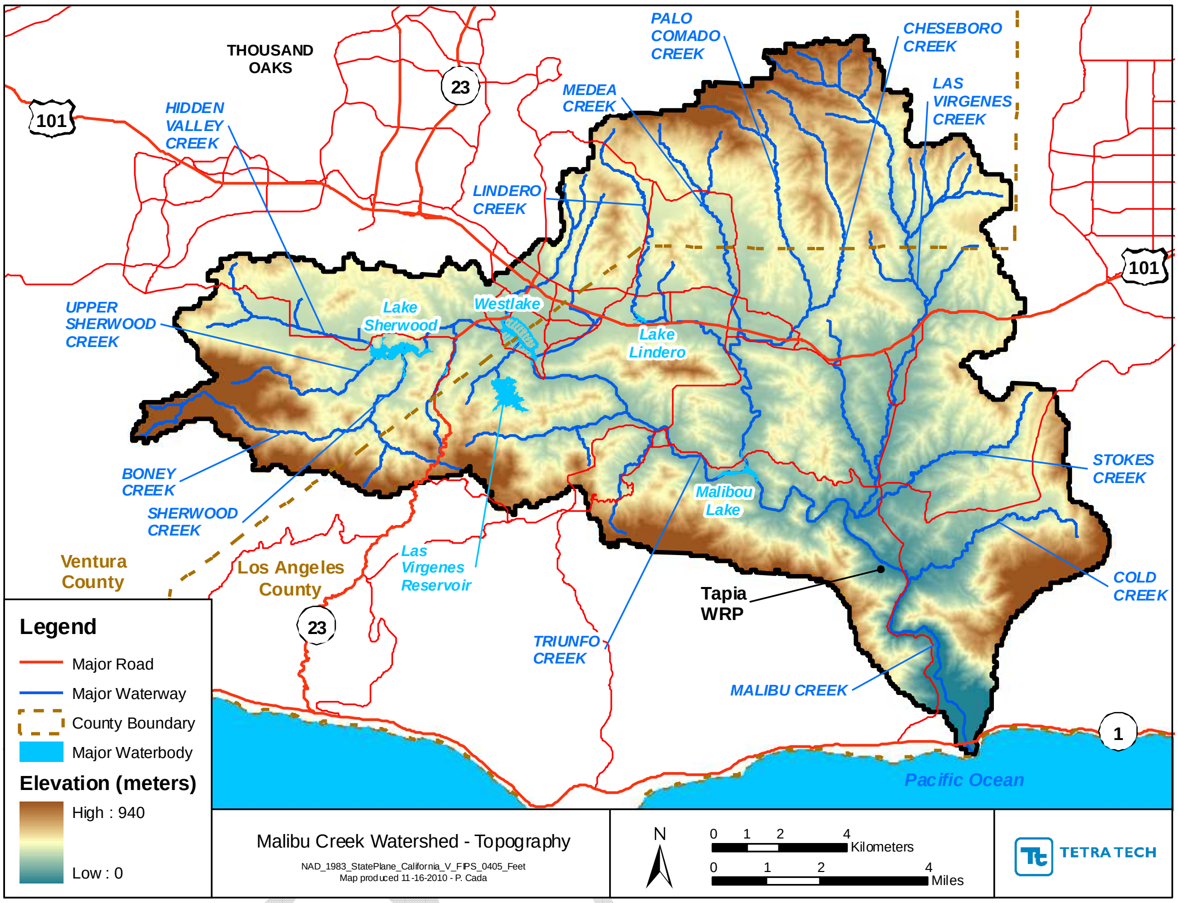

Figure 4-2. Topography of the Malibu Creek Watershed

Malibu Lagoon occupies a small prism at the confluence of Malibu Creek with the Pacific Ocean at Malibu Beach (Figure 4-3). Like most southern California estuaries, Malibu Lagoon is open to the ocean on an intermittent basis, with mouth closures due to coastwise sand transport. The image from October 2011 shows a small outflow occurring at the eastern end of the beach. The morphology of the current Lagoon is constrained by the Pacific Coast Highway, the Malibu Civic Center, and areas of fill (including a golf course) between the Pacific Coast Highway and the beach.

Figure 4-3. Malibu Lagoon in October 2011

4.4 Geology and Soils

Malibu Creek flows from and through the Santa Monica Mountains, a region of active deformation and topographical change. The dynamic nature of this landscape plays an important role in shaping conditions in the stream and Lagoon – and includes naturally enhanced rates of erosion and sediment delivery.

Meigs et al. (1999) estimated that uplift rates on the south flank of the Santa Monica Mountains were approximately 0.5 millimeters per year (mm/yr), while erosion, represented in normalized form as denudation rate, was also on the order of 0.5 mm/yr. This results in sediment yields that are noticeably greater than yields from surrounding portions of southern California. Warrick and Mertes (2009) examined the issue in detail for the Western Transverse Range (Santa Clara, Ventura, and Santa Ynez Mountain drainages), and found that areas with highest sediment yields consistently have weakly consolidated bedrock (Quaternary-Ploicene marine formations) and are associated with the highest rates of tectonic uplift. These areas generated sediment yields on the order of 5,000 tons per square kilometer per year ($t/km^2/yr$), but yields from other portions of the range without Quaternary-Pliocene marine formations were still on the order of 1,000 $t/km^2/yr$. Geology in the basin in the Santa Monica Mountains is mostly non-marine in nature, but does include some areas of Eocene and Cretaceous marine sediments.

Significant exposures of Triassic age marine sediments are found in the area immediately north of the 101 Freeway where the Monterey formation (known locally as the Modelo formation; Figure 4-4) is present at the surface. The Monterey/Modelo formation is an important source of petroleum. Information from Las Virgenes Municipal Water District (LVMWD) (2011) suggests that the source of very high levels of sulfate, phosphate, metals, and total dissolved solids is due to drainage originating from the Modelo formation (the report also indicates that other Miocene marine formations may also contribute to elevated solute levels). USEPA reviewed the submitted data, conducted additional evaluation of the information, and examined multiple maps describing the Modelo formation north of Liberty Canyon Creek and the portions near Malibou Lake.

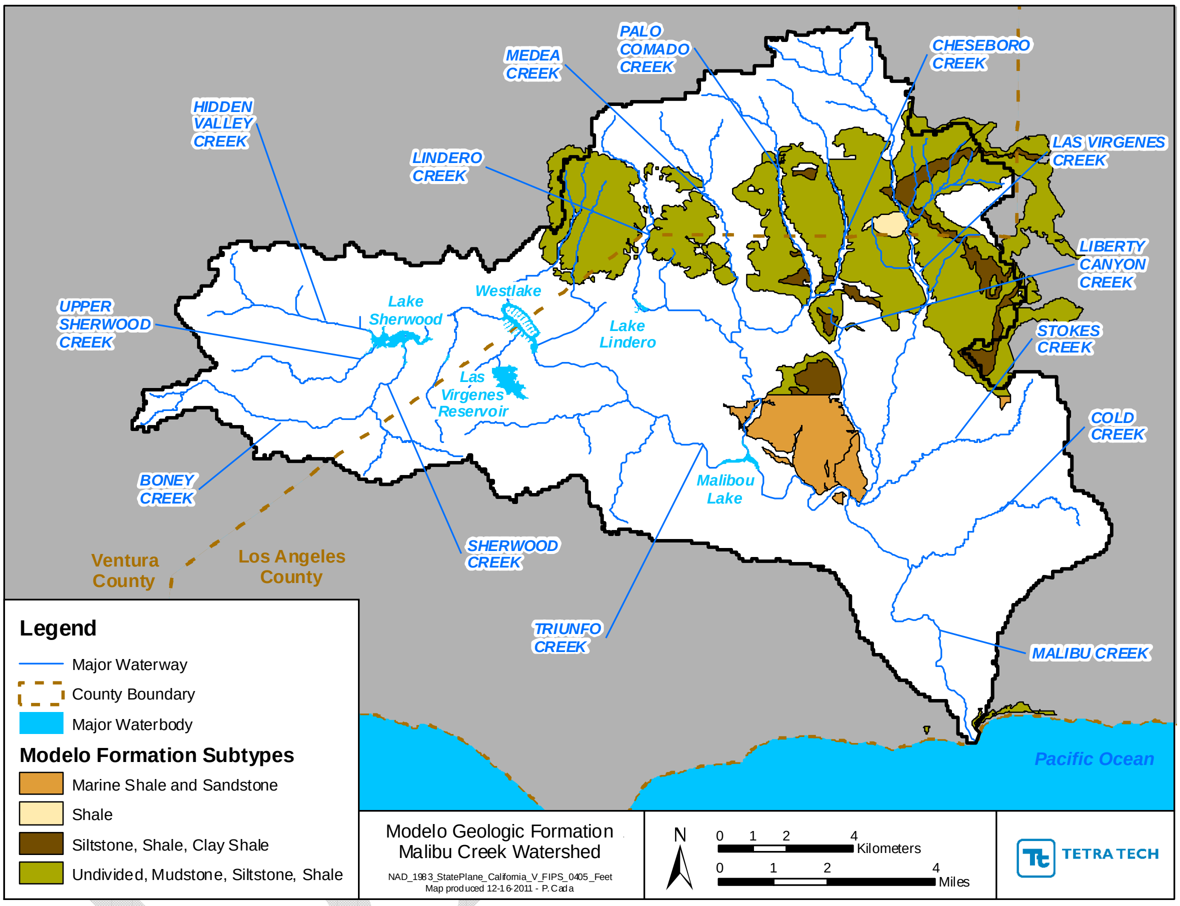

Figure 4-4. Location of the Modelo Formation in the Malibu Creek Watershed

Source: California Geological Survey, 2009

Soils in the watershed generally reflect the underlying glacial geology derived from sandstone, shale, or metavolcanic parent material. Soil data was obtained from the National Resource Conservation Service's (NRCS) Soil Survey Geographic (SSURGO) and State Survey Geographic (STATSGO) (for a portion missing SSURGO coverage in northwest LA County) databases. The watershed consists primarily of shallow soils with slow infiltration rates (Group D) on hillsides and mountains with slopes of 30-75 percent and fine-grained soils derived from marine sediments in the flatter central part of the watershed (Group C).

The Hydrologic Soil Group (HSG) classification is a means for grouping soils by similar infiltration and runoff characteristics during periods of prolonged wetting. Typically, clay soils that are poorly drained have lower infiltration rates, while well-drained sandy soils have the greatest infiltration rates. The Soil

Conservation Service (SCS, 1986) has defined four HSG categories for soils as listed in Table 4-1. The distribution of HSGs in the watershed is 56 percent "D," 24 percent "C," 7 percent "B," a fraction of a percent of "A" near the watershed outlet (11 acres), and 13 percent described as "Water or Rock" (Figure 4-5).

Table 4-1. SCS Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	Soils with high infiltrations rates. Usually deep, well-drained sands or gravels. Little runoff.
B	Soils with moderate infiltration rates. Usually moderately deep, moderately well-drained soils.
C	Soils with slow infiltration rates. Soils with finer textures and slow water movement.
D	Soils with very slow infiltration rates. Soils with high clay content and poor drainage. High amounts of runoff.

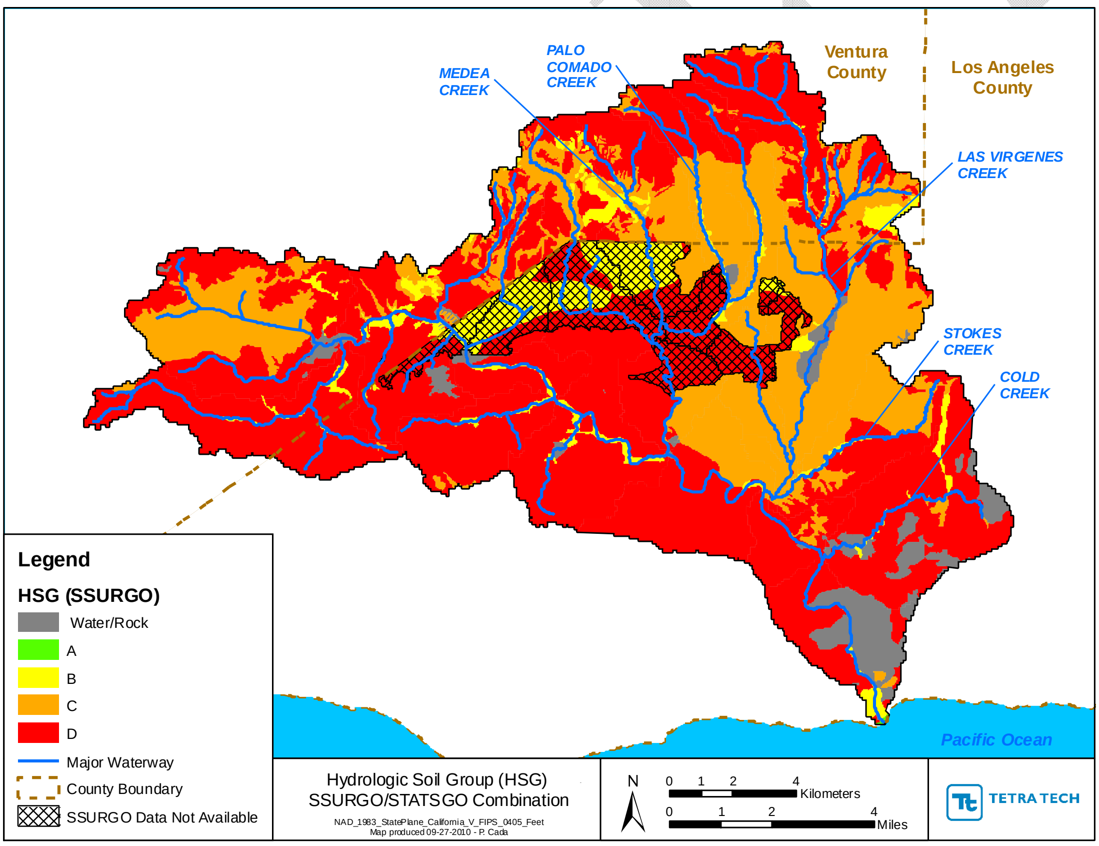

Figure 4-5. Hydrologic Soil Groups – Malibu Creek Watershed (STATSGO and SSURGO)

4.5 LAND USE/LAND COVER

A number of land use/land cover (LU/LC) GIS products are available for the Malibu Creek watershed. The National Land Cover Data (NLCD) provides a useful overview, but has limitations in urban areas.

The U.S. Forest Service LANDFIRE dataset (www.landfire.gov) provides a high level of detail about vegetation, but does not represent development. The strongest GIS product for representing developed land uses is the SCAG land use data, which documented land use in 1990, 1993, 2001, 2005, and 2008. Land use is classified using a modified Anderson system, with up to three levels of detail represented by a 4-digit number. In all, there are over 100 distinct classes.

There appear to be some discrepancies between the 2005 and 2008 SCAG land use coverages, and the 2008 results do not always match aerial imagery. The 2008 approach incorporates regional planning data and apparently classifies some small areas that are still in an under- or undeveloped status as highly developed land uses.

4.5.1 Analysis of Land Use and Land Cover

To simplify the SCAG data, the original land use and land cover classes were aggregated into more general categories. The generalized SCAG land use was then intersected with the study area boundary for 1990, 2005, and 2008 data to perform a change analysis. The results of the LU/LC analysis are shown in Table 4-2 and Figure 4-6 and Figure 4-7. Most notably, areas of barren and undeveloped SCAG LU/LC had the largest decrease while Single Family Residential (SFR) (<0.5 acres) and office increased the most between 1990 and 2008.

For areas designated as “Undeveloped” by SCAG, the LANDFIRE Existing Vegetation Type (EVT) dataset was used to supplement the SCAG data in Figure 4-6 and Figure 4-7. The 2005 coverage is shown as it appears to be more accurate than 2008. The 25 different LANDFIRE land cover types in the watershed were aggregated into seven more general land cover descriptions (Table 4-3).

Table 4-2. Land Use and Land Cover Composition and Change Analysis (SCAG, 1990, 2005, 2008)

Land Use/Land Cover Description	1990 (SCAG) Area (acres)	1990 (SCAG) Percent (%)	2005 (SCAG) Area (acres)	2005 (SCAG) Percent (%)	2008 (SCAG) Area (acres)	2008 (SCAG) Percent (%)	Percent Composition Change 1990-2008
Agriculture	1,299	1.9%	1,252	1.8%	932	1.3%	-0.5%
Barren	1,213	1.7%	371	0.5%	346	0.5%	-1.2%
Commercial	403	0.6%	549	0.8%	717	1.0%	0.4%
Industrial	557	0.8%	658	0.9%	953	1.4%	0.6%
Institutional	405	0.6%	513	0.7%	885	1.3%	0.7%
Multifamily	948	1.4%	1,051	1.5%	922	1.3%	0.0%
Office	428	0.6%	579	0.8%	1,574	2.2%	1.6%
Open Water	444	0.6%	469	0.7%	522	0.7%	0.1%
Orchards	95	0.1%	162	0.2%	162	0.2%	0.1%
Park – Irrigated	564	0.8%	688	1.0%	523	0.7%	-0.1%
SFR <0.5 ac	4,225	6.0%	4,938	7.0%	5,048	7.2%	1.2%
SFR >0.5 ac	2,495	3.6%	3,798	5.4%	2,830	4.0%	0.5%
Transportation (CALTRANS)	406	0.6%	406	0.6%	406	0.6%	0.0%
Undeveloped and Park - Non-irrigated	56,704	80.8%	54,751	78.0%	54,367	77.5%	-3.3%
TOTAL	70,186	100%	70,185	100%	70,187	100%	N/A

N/A = not applicable

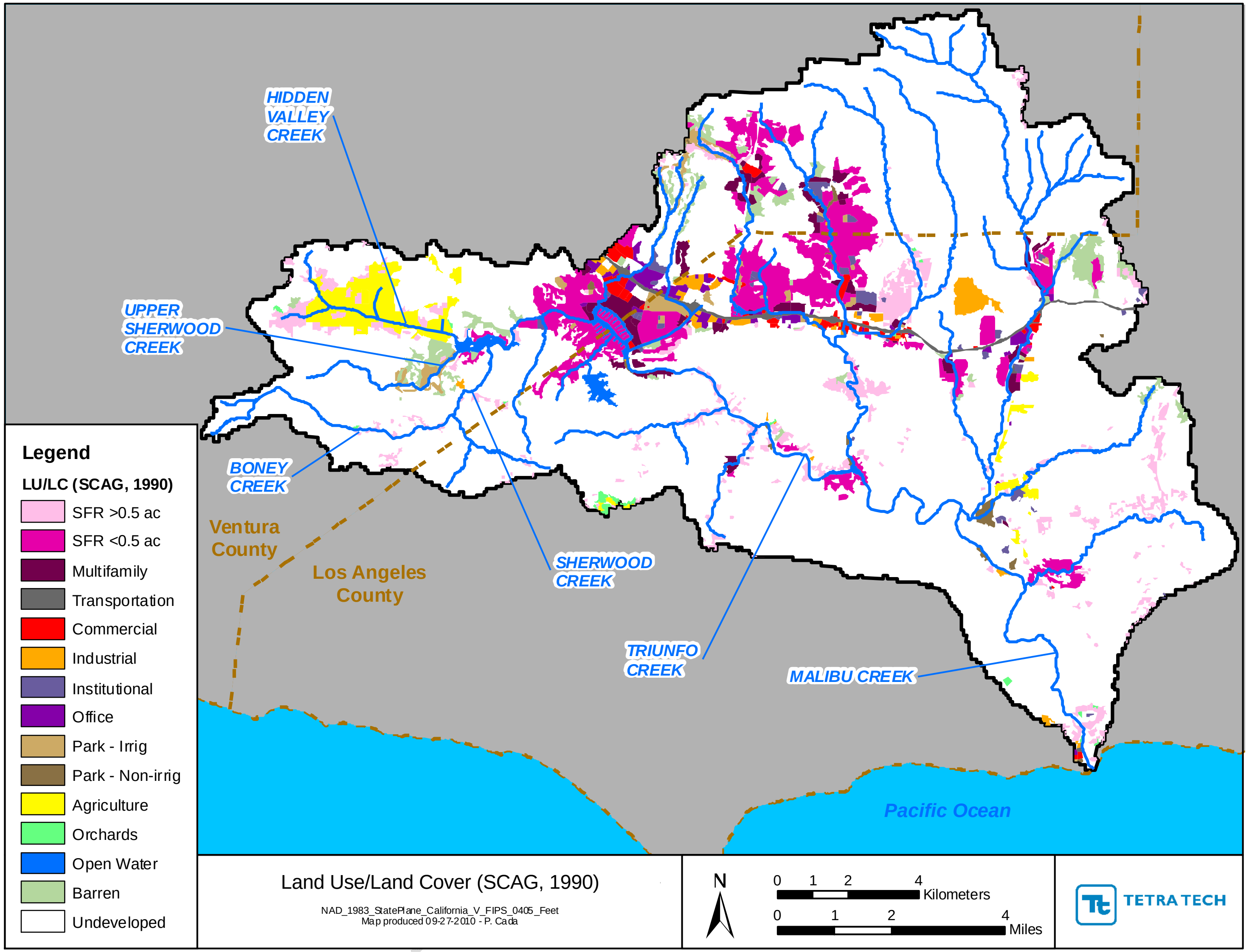

Figure 4-6. Land Use and Land Cover (SCAG, 1990) – Malibu Creek Watershed

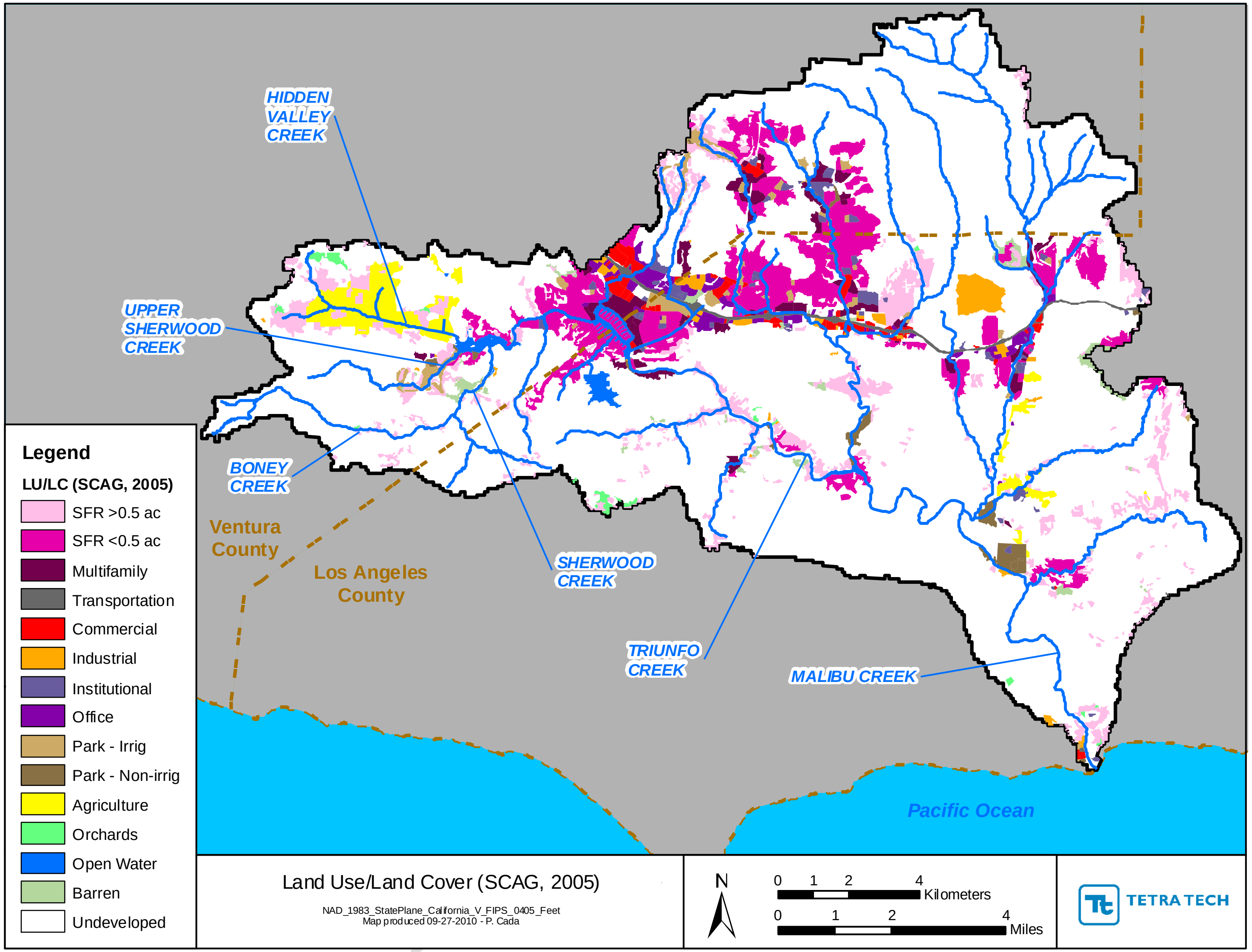

Figure 4-7. Land Use and Land Cover (SCAG, 2005) – Malibu Creek Watershed

Table 4-3. Land Cover within "Undeveloped" SCAG class (LANDFIRE, 2007)

Land Cover Description	Percent of Undeveloped Land (SCAG)		
	1990	2005	2008
Open Water	0.04%	0.03%	0.02%
Barren/Developed	2.64%	1.59%	1.87%
Herbaceous – Grassland	8.32%	8.11%	8.27%
Sparsely Vegetated	0.53%	0.39%	0.39%
Shrubland (Chaparral/Scrub)	71.05%	72.02%	71.77%
Sparse Tree Canopy (Savannah)	11.77%	12.07%	11.93%
Open Tree Canopy (Woodland)	5.64%	5.79%	5.75%

4.5.2 Impervious Surfaces

Impervious surfaces encourage direct runoff, rather than infiltration of precipitation. The impervious area in a watershed is thus an important factor in determining the amount and timing of runoff, streamflow characteristics, and pollutant loading.

Impervious surfaces in the watershed include buildings, parking lots, roads, sidewalks, and other features. Determination of an average percent impervious for the aggregated SCAG LU/LC categories (Table 4-2) can assist with the identification and prioritization of environmental stressors. The most recent impervious surface assessment available was created by the Multi-Resolution Land Characteristics Consortium (MLRC) for the NLCD in 2001 (Figure 4-8). The locations of Heal the Bay biological monitoring stations are also shown in this figure to support subsequent discussions of the relationship of bioscores and impervious areas.

An average percent impervious for each of the aggregated SCAG LU/LC categories was calculated using the SCAG LU/LC 2001 data and the NLCD 2001 impervious surface coverage (Table 4-4). The resulting impervious fraction estimates are generally lower than the estimates of percent impervious by land use provided in the Los Angeles County Hydrology Manual (LACDPW, 2006). The Los Angeles County Department of Public Works (LACDPW) estimates are for countywide design purposes and are suspected not to be representative of the specific existing land uses in the Malibu Creek watershed, where overall development is much less intense than in LA County as a whole.

It is assumed that the average impervious value for each LU/LC category derived in Table 4-4 can also be applied to the earlier (1990) and more recent (2005 and 2008) coverages of the SCAG LU/LC. The resulting analysis shows that imperviousness in the watershed increased from 3,694 to 4,878 acres between 1990 and 2008; however, this still constitutes only a small portion of the total watershed area (6.95 percent) – primarily because undeveloped land still predominates.

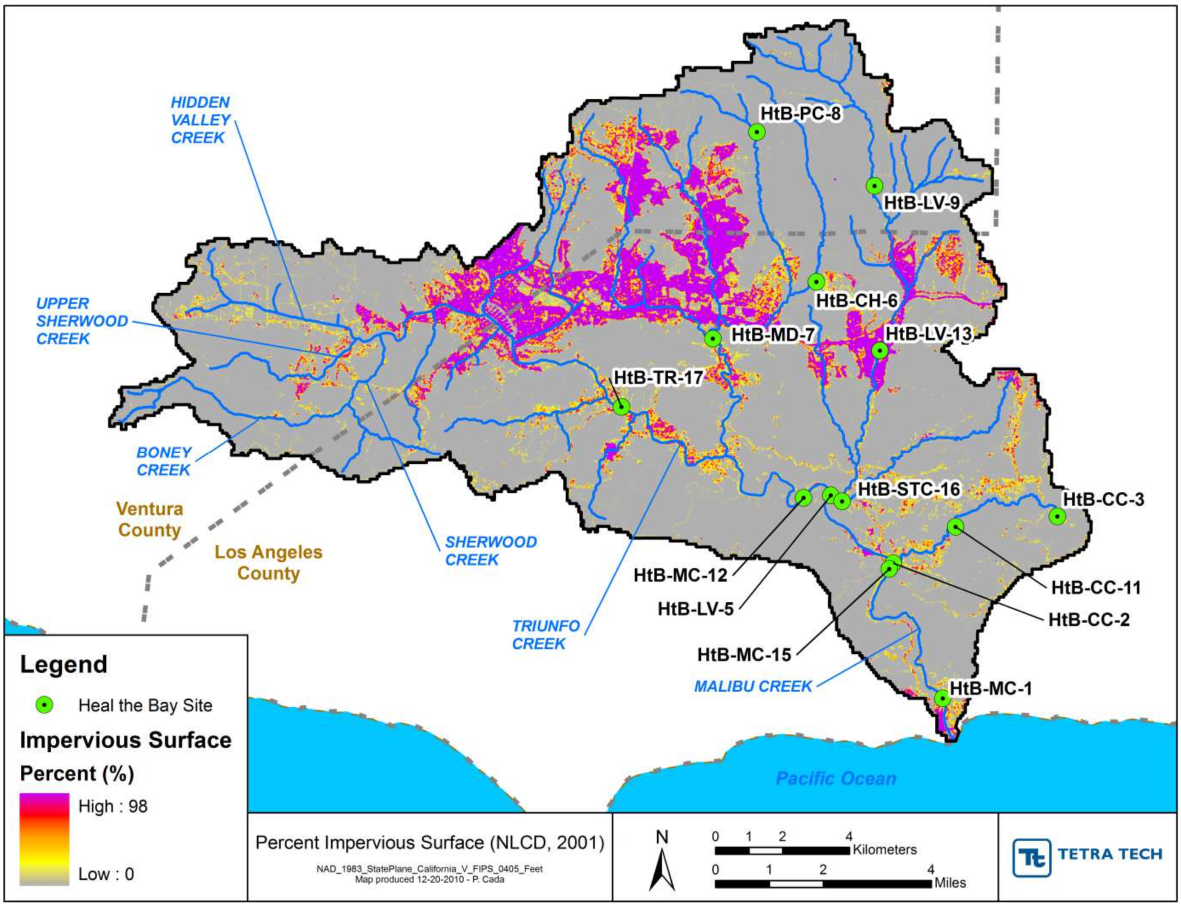

Figure 4-8. Percent Impervious Surface (NLCD, 2001) – Malibu Creek Watershed

Table 4-4. Malibu Watershed Imperviousness by SCAG LU/LC Categories

LU/LC Description	Average Imperviousness (%)	Impervious Area 1990 (acres)	Impervious Area 2005 (acres)	Impervious Area 2008 (acres)
Agriculture	1	15	14	10
Barren	7	87	27	25
Commercial	51	209	284	365
Industrial	28	156	185	268
Institutional	28	111	141	248
Multifamily	39	374	415	363
Office	46	197	266	723
Open Water	2	9	9	11

LU/LC Description	Average Imperviousness (%)	Impervious Area 1990 (acres)	Impervious Area 2005 (acres)	Impervious Area 2008 (acres)
Orchards	3	3	5	5
Park - Irrigated	7	41	50	38
SFR <0.5 ac	34	1,459	1,704	1,738
SFR >0.5 ac	11	286	436	325
Transportation	49	178	178	200
Undeveloped and Park – Non-irrigated	1	568	563	559
Watershed Total (ac)		3,694	4,279	4,878
Percentage Impervious		5.26%	6.10%	6.95%

Note: There are some discrepancies in the classification of developed land in the commercial, industrial, institutional, and multifamily categories between the 2005 and 2008 SCAG coverages.

4.6 Fire History and Conditions

Fire activity in a watershed can significantly impact the hydrologic response. Severe burns, particularly in natural areas, such as forest or grassland, remove vegetation that holds soil in place and reduce the amount of water lost through evapotranspiration. Floods and massive debris loads are common following extensive fires. These impacts diminish over subsequent years as vegetation is reestablished.

Fire history data were obtained in spatial format from the California Department of Forestry and Fire Protection through 2010 (http://frap.cdf.ca.gov/data/frapgisdata/download.asp?spatialdist=1&rec=fire). The data were reviewed to determine the timing and extent of years with major fire events (defined as a year with events that burned at least 1,500 acres within the watershed). Appendix B presents a summary of these results.

4.7 Hydrography

4.7.1 Drainage Network

Hydraulic routing of water in the Malibu Creek watershed includes both the natural drainage network and water management infrastructure. Detailed stormwater network lines were obtained only for the LA County portion of the watershed (Figure 4-9). It is likely that there is above- and below-ground stormwater infrastructure in the Lake Sherwood, Westlake, and greater Thousand Oaks areas within Ventura County; however, no available GIS coverages were identified.

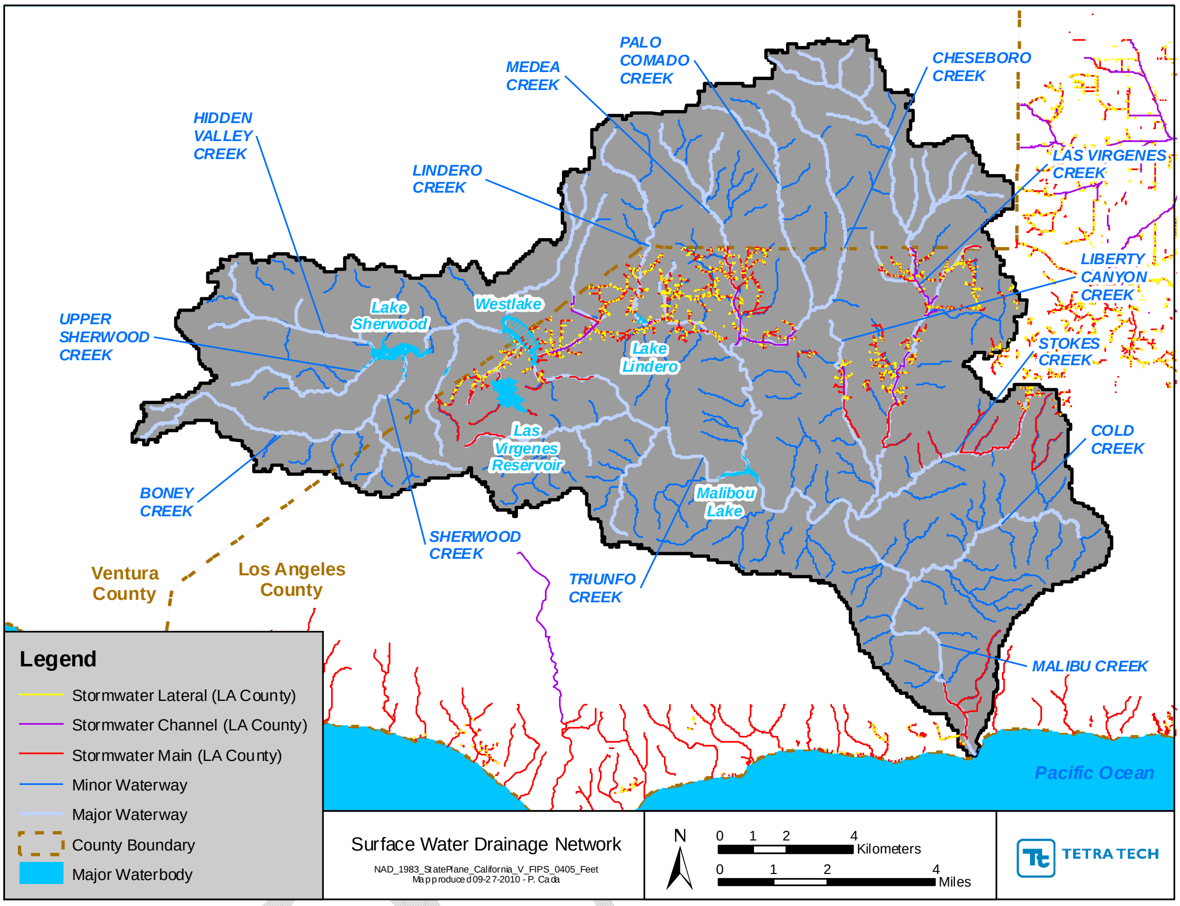

Figure 4-9. Surface Drainage Network – Malibu Creek Watershed

4.7.2 Subwatershed Delineation

There are several programs and automated GIS tools available in the public domain that can be used to generate watershed boundaries from a DEM. The tool selected for this project was developed using Environmental Systems Research Institute's (ESRI) Model Builder and available from the ESRI Support Center.[1] The tool involves several steps of DEM processing that produce a stream network layer and watersheds sized based on user specifications.

Several data sources were used to inform the aggregation of catchments into subwatersheds. They included major breaks in hydrography (i.e., stream order), LU/LC as shown by the 2008 SCAG data, monitoring stations, and point sources. GIS layers of stormwater infrastructure were not available for the Ventura County portion of the watershed. The stormwater network coverages in LA County were reviewed but did not result in any modifications to the delineation. The delineation process resulted in an average subwatershed size of 5.22 mi^2 (Figure 4-10).

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[1] http://support.esri.com/index.cfm?fa=downloads.geoprocessing.filteredGateway&GPID=16

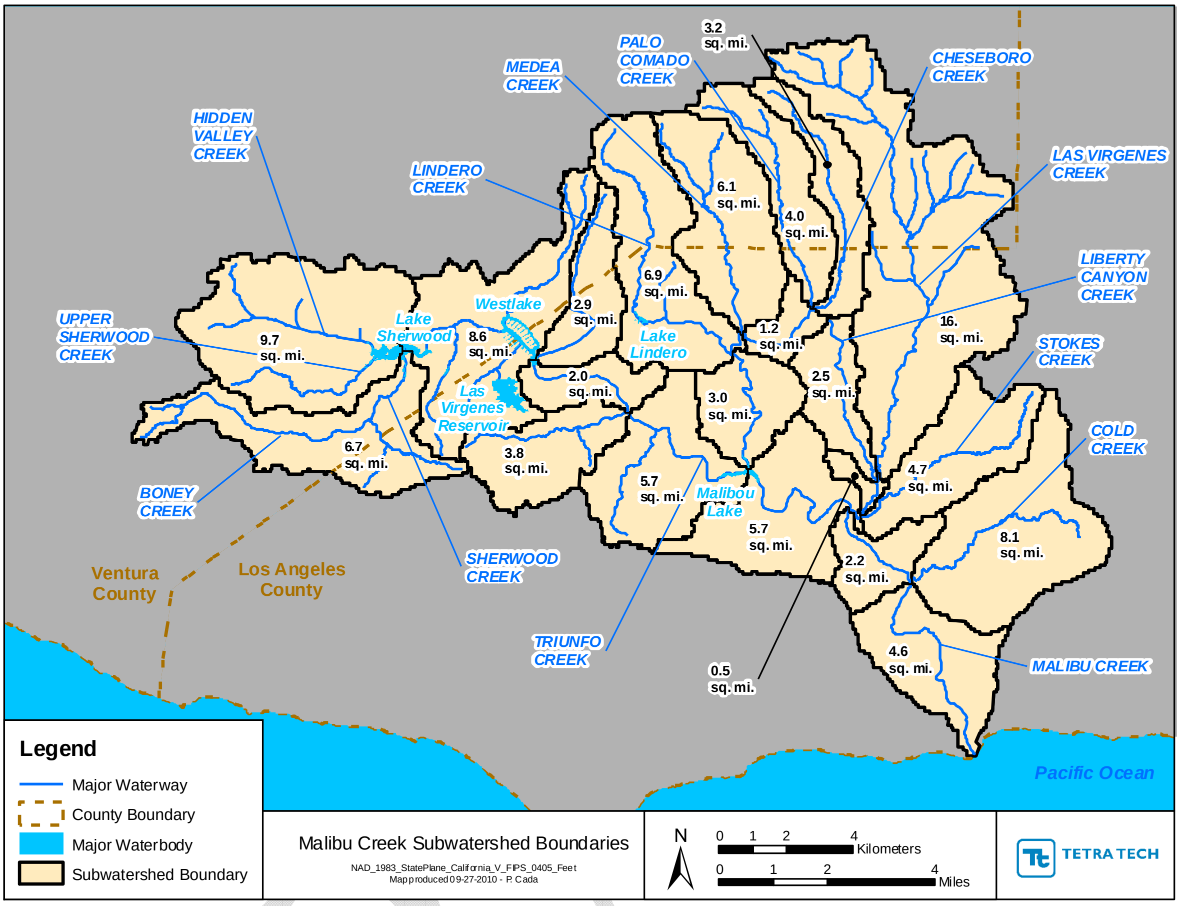


Figure 4-10. Malibu Creek Subwatersheds

5. Source Assessment

This section identifies the potential sources of pollutants that discharge into the impaired waterbodies. In general, pollutants can enter surface waters from both point and nonpoint sources. Point sources include discharges from a discrete human-engineered outfall. These discharges are regulated through NPDES permits. Nonpoint sources, by definition, include pollutants that reach surface waters from a number of diffuse land uses and activities that are not regulated through NPDES permits. Specific sources for point and nonpoint sources in the Malibu Creek watershed are presented below.

5.1 Point Sources of Pollution

NPDES permits in the watershed include municipal separate storm sewer system (MS4) permits, a California Department of Transportation (Caltrans) stormwater permit, and general or individual NPDES permits.

5.1.1 Permitted Facilities

The only facility with a permitted wastewater discharge to Malibu Creek or its tributaries is the Tapia Water Reclamation Facility (TWRF). TWRF is operated under a Joint Powers Authority between Las Virgenes Municipal Water District (located in western LA County) and Triunfo Sanitation District (located in eastern Ventura County). The facility is along Malibu Canyon Road in unincorporated LA County. Constructed at a low point in the Malibu Creek watershed, it allows wastewater to flow by gravity to the treatment facility (see Figure 4-1). It was built in 1965 with a capacity of 0.5 million gallons per day (MGD) and has been expanded several times – in 1968 to a capacity of 2 MGD; in 1972 to a capacity of 4 MGD; in 1984 to a capacity of 8 MGD; in 1986 to a capacity of 10 MGD; and in 1994 to its current capacity of 16 MGD. TWRF began water recycling in 1972 and currently treats an average of 9.5 MGD of wastewater (http://www.lvmwd.com/index.aspx?page=72). The plant was upgraded from secondary to tertiary treatment in 1984.

TWRF applies state-of-the-art technology to transform wastewater into high-quality recycled water that is used to irrigate public and commercial landscaping such as golf courses, school grounds, highway medians, and parks. During the hot summer months, irrigation consumes all the recycled water Tapia produces. When excess effluent is produced, TWRF discharges both to Malibu Creek and to Arroyo Calabasas, a tributary of the Los Angeles River. The main discharge to Malibu Creek occurs about 0.3 miles upstream from the confluence with Cold Creek and about 5 miles upstream from Malibu Lagoon. LARWQCB Order No. 97-135 contained a provision prohibiting discharges from TWRF to Malibu Creek from May 1st to November 1st each year, except under certain conditions.

"Implementation of the prohibition under Order No. 97-135 was subject to further discussions among the Regional Board, National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Game. After discussions among these departments, it was concluded that TWRF should apply for an incidental "take" permit as required by Endangered Species Act §10(a)(1)(B). It was also recommended that a minimum flow of 2.5 cubic feet per second (ft^3/sec) be maintained throughout the year to sustain endangered species. Also, extreme weather conditions in the winter of 1998 caused the Lagoon to remain open for an extended period. Heavy rains at that time also resulted in more runoff into the Malibu Creek and Lagoon and created a condition resulting in less demand for reclaimed water during the period the discharge prohibition was in effect" (Los Angeles Board, 2005b). To address these issues, revisions were made in 1998 through Order 98-030, which directed that TWRF shall "not discharge as otherwise permitted by these requirements to Malibu Creek at any of its discharge points commencing either: (a) May 1st of each calendar year, or (b) the first natural closure of Malibu Lagoon by sand buildup, whichever is later, through and including October 31st of each calendar year." Exceptions are provided for storm events, plant upsets, or "the existence of minimal streamflow conditions that require flow augmentation in Malibu Creek to sustain endangered species." The discharge prohibition is based on a finding that "that unseasonable freshwater inputs from Tapia and other sources cause the Lagoon to flood and/or breach when it otherwise would not."

In 1999, Order No. 99-142 modified the discharge prohibitions to Malibu Creek to extend from April 15 to November 15. When discharges occur in the winter, the current permit limits are 8 mg/L total inorganic nitrogen (N) in accordance with the Malibu Watershed nutrient TMDL (USEPA, 2003) and 3 mg/L total phosphorous (P) (added to NPDES permit by LARWQCB based on plant performance). The TMDL limits represent an approximately 43 percent reduction in inorganic N loads relative to the 1997-1999 time period, with no reduction in P concentrations. Tentative limits have also been developed for a suite of metals, organic compounds, and other pollutants. This order also excluded the incidental take permit requirement previously required (and subsequently remanded by the SWRCB) and was substituted with an exception for flows necessary to sustain endangered steelhead trout (2.5 ft^3/sec).

Most of the effluent generated by TWRF is used for irrigation during the summer months. At the time of the nutrient TMDL, effluent irrigation and sludge injection were estimated to contribute 9 percent of the annual nitrogen load and 6 percent of the annual phosphorus load to the Malibu Creek watershed. Sludge disposal in the watershed has since ceased, and the TMDL assigned a load allocation of zero to effluent irrigation based on a requirement that applications not exceed agronomic rates.

5.1.2 Stormwater

Stormwater runoff in the Malibu Creek watershed is regulated through the Los Angeles County MS4 permit, the Ventura County MS4 permit, and the statewide stormwater permit issued to Caltrans. The permitting process defines these discharges as point sources because the stormwater is discharged from the end of a stormwater conveyance system.

5.1.2.1 Municipal Stormwater

USEPA also regulates urban stormwater discharges through NPDES permits. These permits apply to stormwater runoff that is transported through regulated MS4s and discharged into waterbodies. To prevent harmful pollutants from being washed or dumped into an MS4, operators must obtain a NPDES permit and develop a stormwater management program.

An MS4 is defined as a conveyance or system of conveyances that is: (1) Owned by a state, city, town, village, or other public entity that discharges to waters of the U.S., (2) Designed or used to collect or convey stormwater (including storm drains, pipes, ditches, etc.), (3) Not a combined sewer, and (4) Not part of a Publicly Owned Treatment Works (sewage treatment plant).

USEPA has extended coverage under the MS4 permitting program in two phases. Phase I, issued in 1990, requires medium and large cities or certain counties with populations of 100,000 or more to obtain NPDES permit coverage for their stormwater discharges. Phase II, issued in 1999, requires regulated small MS4s in urbanized areas, as well as small MS4s outside the urbanized areas that are designated by the permitting authority, to obtain NPDES permit coverage for their stormwater discharges. Each regulated MS4 is required to develop and implement a stormwater management program (SWMP) to reduce the contamination of stormwater runoff and prohibit illicit discharges. Because a NPDES permit is applied, stormwater discharges from a regulated MS4 are subject to wasteload allocations for point sources under the TMDL program, rather than load allocations for nonpoint sources.

Los Angeles City and County were covered under Phase I of the stormwater program. The municipalities within Los Angeles County (except for the City of Long Beach) and the unincorporated areas of the county are covered under a unified MS4 permit under California Regional Water Quality Control Board, Los Angeles Region, Order No. 01-182, NPDES Permit No. CAS004001. The LA County Flood Control District serves as Principal Permittee.

The Malibu Creek watershed also includes areas within unincorporated Ventura County and the City of Thousand Oaks (within Ventura County). These areas are covered by the new MS4 permit for Ventura County (Order R4 2010-0108, NPDES Permit No. CAS004002, July 8, 2010), which unifies MS4 coverage for that county with the Ventura County Watershed Protection District as Principal Permittee.

5.1.2.2 Caltrans

The county MS4 permits do not directly cover runoff from state highways, which are covered under a separate permit. Caltrans is responsible for the design, construction, management, and maintenance of the State highway system, including freeways, bridges, tunnels, Caltrans' facilities, and related properties. Caltrans' discharges consist of stormwater and non-stormwater discharges from State-owned rights-of-way. Before July 1999, stormwater discharges from Caltrans' stormwater systems were regulated by individual NPDES permits issued by the Regional Water Boards. On July 15, 1999, the State Water Board issued a statewide permit (Order No. 99-06-DWQ) which regulated all stormwater discharges from Department-owned MS4s, maintenance facilities and construction activities.

5.1.2.3 Summary

The distribution of watershed land area by MS4 jurisdiction is an important input to the TMDL allocation of loads (see Section 10). This analysis is provided in Table 5-1, in which the land uses described in Section 4.5 are summarized by jurisdiction along with associated impervious areas.

Table 5-1. Land Use Distribution by MS4 Jurisdiction

Land Use	Los Angeles County		Ventura County		Caltrans	
	Total area (ac)	Impervious area (ac)	Total area (ac)	Impervious area (ac)	Total area (ac)	Impervious area (ac)
Agriculture	250	3	671	8	0	0
Barren	257	20	64	5	0	0
Commercial	238	247	114	118	0	0
Industrial	612	239	73	29	0	0
Institutional	452	176	185	72	0	0
Multifamily	323	210	236	153	0	0
Office	245	209	605	515	0	0
Open Water	316	7	195	4	0	0
Orchards	84	2	73	2	0	0
Park - Irrigated	169	13	316	25	0	0
SFR <0.5 ac	1,975	1,037	1,335	701	0	0
SFR >0.5 ac	1,925	250	580	75	0	0

Land Use	Los Angeles County		Ventura County		Caltrans	
	Total area (ac)	Impervious area (ac)	Total area (ac)	Impervious area (ac)	Total area (ac)	Impervious area (ac)
Transportation (Caltrans)	0	0	0	0	206	200
Undeveloped*	33,076	344	20,731	216	0	0
Total	39,924	27,55	25,180	1,922	206	200

Note: Based on SCAG 2008 land use with additional interpretation of Caltrans transportation land use areas from state-owned roads coverage. Non-state-owned roads are embedded within the other land uses.

5.2 Non-Point Sources of Pollution

A nonpoint source is a source that discharges via sheet flow or natural discharges, as well as agricultural stormwater discharges and return flows from irrigated agriculture. Nonpoint sources include areas that do not drain to a storm drain system, agricultural flows, and onsite wastewater disposal (note: equestrian sources that may contribute invasive species and nutrients from excrement may also occur in the watershed; however, their loading is expected to be intermittent and minimal). However, the entire watershed is covered by MS4 permits and flows from properties that drain directly to the creeks without passing through an organized stormwater conveyance represent minimal amounts of impervious area. These areas are considered to be an insignificant contributor to the overall loading to the creek, but are presented below to characterize their potential impact.

5.2.1 Agricultural Sources

932 acres of the Malibu Creek watershed are designated as agricultural (1.3 percent) according to the SCAG 2008 land use layer (Table 4-2). These areas are generally located along Hidden Valley Creek or Malibu Creek (Figure 4-7) and can be sources of nutrients and sediment to the receiving waters. Vineyards are also located in the watershed; however, comparison with the agricultural and orchard categories in the land use layer does not show overlap with the know vineyard locations (Goepel et al., 2012).

5.2.2 Onsite Wastewater Disposal

Regional Board Staff reviewed past studies and also conducted independent modeling estimates of nitrogen mass loadings from onsite wastewater disposal systems (OWDS) into Malibu Lagoon (Lai, 2009). Specifically, three previous studies were evaluated (Stone Environmental, 2004; Questa, 2005; Tetra Tech, 2002) and summarized by Lai (2009). These results are summarized in Table 5-2. In addition, the in-Lagoon nitrogen concentrations predicted from the mass loading associated with the Stone Environmental and Tetra Tech studies are shown in Figure 5-1. This figure also compares the results with actual nitrogen concentration data (note: the 13 pounds per day [lbs/day] line is associated with the nitrogen numeric target of 1.0 mg/L in the nutrient TMDL [USEPA, 2003]).

In addition to the previous studies, the Regional Board estimated nutrient loadings using a numerical model and a spreadsheet model. Regional Board staff estimated mass loading into the Lagoon of 34.9 lb/day using the spread sheet method and showed that this would produce a nitrogen concentration in the Lagoon water of 2.9 mg/L (Table 5-2 and Figure 5-1). The use of another three-dimensional groundwater flow and solute transport model (Questa, 2005) showed an estimated mass loading of 30.2 lb/day, which resulted in a Lagoon water nitrogen concentration of 2.5 mg/L (Table 5-2 and Figure 5-1). According to the measured data during 1995-1999 (Sutula et al., 2004) and 2002-2003, the nitrogen concentration in the Lagoon water is increasing. As such, the resulting nitrogen concentration of 2.9 mg/L for 2008-2009 falls within the trend of measured data from 1995 to 2003. Thus, the mass loading into the Lagoon of 34.9 lb/day is considered to be an appropriate and reasonable estimate.

In summary, the Regional Board analysis concluded that estimates between 30-40 lbs/day of nitrogen are loaded to the Lagoon from OWDS, which exceeds the nutrient TMDL load allocation and results in excursions of the TMDL numeric target from the previous nutrients TMDL (USEPA, 2003).

Table 5-2. Comparisons of Estimated Nitrogen Mass Loading to Malibu Lagoon (Lai 2009)

	Stone Report (2004)[b]	Questa Report (2005)[b]	Tetra Tech Report (2002)[c]	Staff Estimate (Spreadsheet Method)[d]	Staff Estimate (Numerical Model Method)[e]
1.Wastewater Flow Rate from Commercial OWDS (gal/day)	62,166	100,000	75,000	127,241	127,241
2.Concentration in Commercial Wastewater (mg/L)	50	50	59.2	3 - 110	3 – 110
3.Mass Loading from Commercial OWDS (lbs/day)	25.94	41.73	37.05	42.1	42.1
4.Wastewater Flow Rate from Residential OWDS (gal/day)	126,121	126,121	54,800	139,300	139,300
5.Concentration in Residential Wastewater (mg/L)	20	20	59.2	45	45
6.Mass Loading from Residential OWDS (lbs/day)	21.05	21.05	27.07	52.3	52.3
7.Mass Loading from OWDS (lbs/day)	46.99	62.78	64.12	94.4	94.4
8.Ratio of Mass Loading[a]	0.36	0.32	0.50	0.37	0.32
9.Mass Loading to Malibu Lagoon (lbs/day)	17	20	32	34.9	30.2

Notes: [a] the ratio of mass loading entering Malibu Lagoon versus mass loading from OWDS, i.e., value of row 9 divided by value of row 7.

[b] the nitrogen loads were assumed to be mostly nitrate in the OWDS and the model only simulated the nitrate in the Stone and Questa Modeling Reports.

[c] 50 percent of nitrogen loads from the OWDS were assumed to enter the Malibu Lagoon.

[d] The nitrogen mass loading from OWDS was estimated based on the commercial load from each OWDS and the residential load with an average concentration of 45 mg/L for OWDS. Staff estimated the nitrogen mass loading to Malibu Lagoon by using the spread sheet method.

[e] the nitrogen mass loading based on the commercial load from each OWDS and the residential load with an average concentration of 45 mg/L from OWDS were used in the model. Staff estimated the nitrogen mass loading to Malibu Lagoon by using Questa numerical model results.

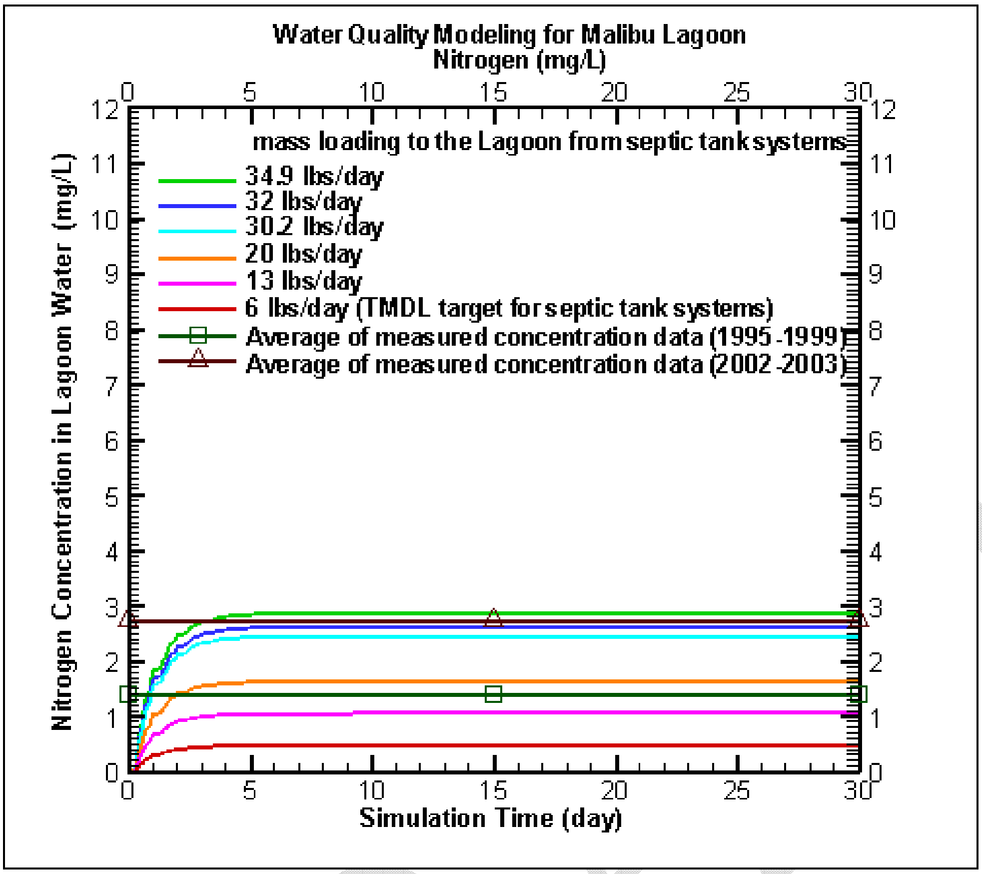


Figure 5-1. Nitrogen concentrations in Malibu Lagoon Resulting from Different Mass Loadings (Lai, 2009)

6. Flow Data and Analysis

The hydrology of the Malibu Creek watershed has changed significantly over the years due to urbanization, the importation of water, the construction of reservoirs, and the discharge of wastewater to Malibu Creek. Most of these changes began in the mid-1960s when urban development accelerated. Urbanization of portions of the upper watershed increased the amount of impervious surfaces, greatly increasing runoff and peak flows during storms and reducing infiltration to soils and groundwater. The resulting increases in runoff and stream flows in turn increased erosion rates, both over the land surface and in the stream channels, causing significant sedimentation in the reservoirs. Approximately 20,000 acre-feet of water per year is currently imported into the watershed (NRCS, 1995; Abramson et al., 1998). Much of this is used for landscape irrigation, which subsequently enters the waterways through shallow groundwater flows or runoff into storm drains. Other portions of this water are used in homes and end up at the Tapia Water Reclamation Facility, where, after treatment, much of it is re-used for irrigation at various locations in the watershed.

These changes have increased both storm flows and base flows in the watershed. The NRCS (1995) study estimated that base flows in Malibu Creek have increased by an order of magnitude over pre-development conditions, from about 200 to 2,000 acre-feet per year. Stream flows during storms have almost doubled, from about 11,900 to over 21,000 acre-feet per year (NRCS, 1995). As a result, the average annual flow had more than doubled by 1995, from about 12,000 to 27,000 acre-feet (NRCS, 1995). Some of this (about 4,000 acre-feet) was due to discharges from the Tapia WRF that has since been curtailed. About 3,000 acre-feet of the increased flow is associated with runoff from lawn and home use, and about 500 acre-feet with septic tank seepage (NRCS, 1995).

The Malibu Creek watershed contains 11 major streams and several other less important tributaries. Prior to development in the watershed, many of these streams were intermittent to ephemeral, except for Las Virgenes Creek, lower Medea Creek, and Cold Creek, which were perennial to intermittent (NRCS, 1995). However, as a result of irrigation with imported and reclaimed water, most of the larger tributaries and all of the main reaches from Westlake Lake to Malibu Lagoon generally have flows all year long (NRCS, 1995). It is assumed that additional development since this 1995 study has resulted in even higher flows.

6.1 Stream Flow Gaging

Stream flow monitoring along Malibu Creek is limited to the two gage locations shown in Figure 6-1. The flow gage near Crater Camp (USGS 11105500; LACDPW F-130) contains the longest period of record. USGS operated this gage between February 1, 1931 and September 30, 1979, after which LACDPW took over operation and continues to monitor the gage to the present. (Records through the end of WY 2009 have been released as of this writing.) The second flow gage in the Malibu Creek watershed is USGS 11105510, an active gage located near the mouth of the river, upstream of the Lagoon. This gage has only been in operation since December 6, 2007.

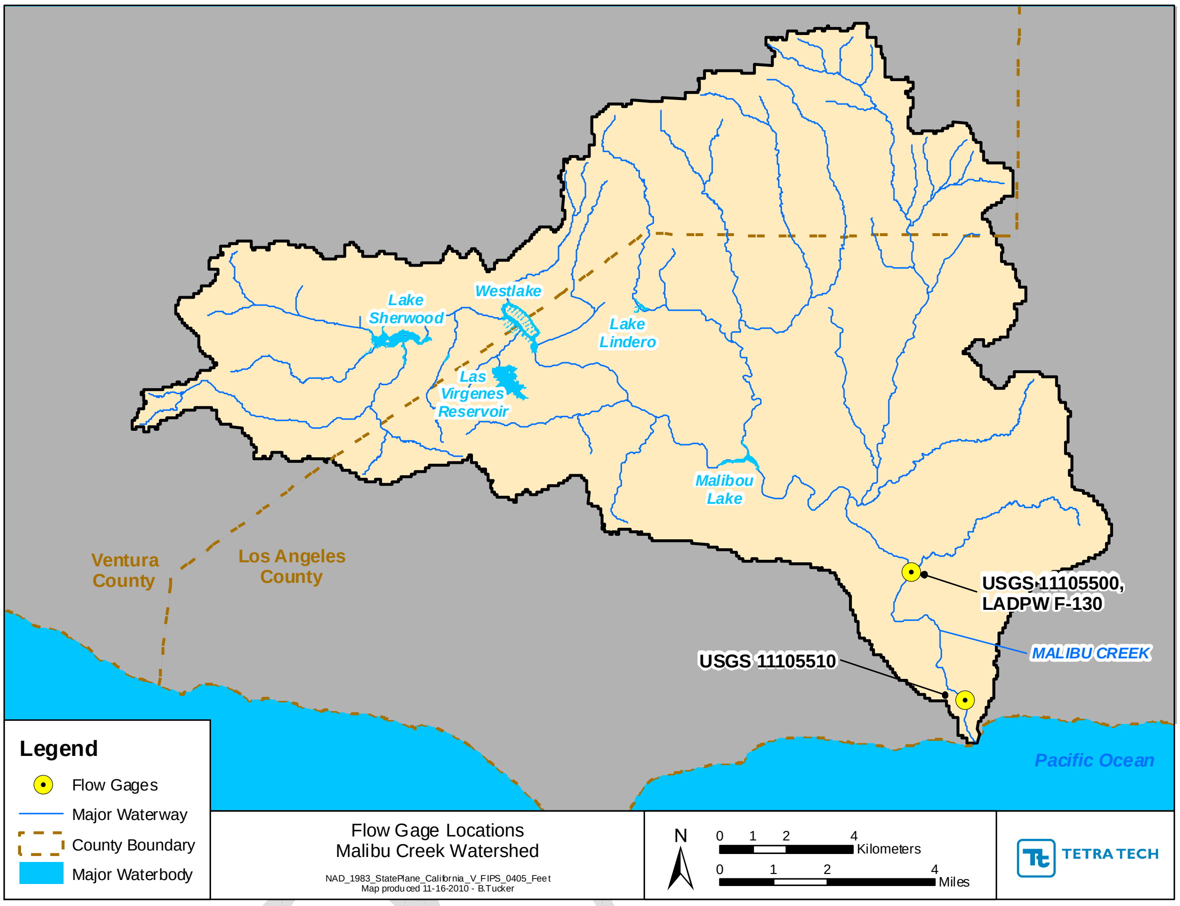


Figure 6-1. Locations of Flow Gages

Figure 6-2 and Figure 6-3 show the daily flow time-series for the two flow gage sites, with Figure 6-3 showing both gages for the common period of record. A logarithmic scale is used on the plots; values that fall at or below 0.01 cubic feet per second (cfs) represent zero reported flow. Flows at the two gages match fairly well in the winter; however, during the summer period flow at the upstream F-130 gage remains around 1 cfs, while flow at the downstream USGS gage drops to near zero. The difference is presumably due to evaporation and uptake by riparian vegetation, such as the non-native giant reed, *Arundo donax*.

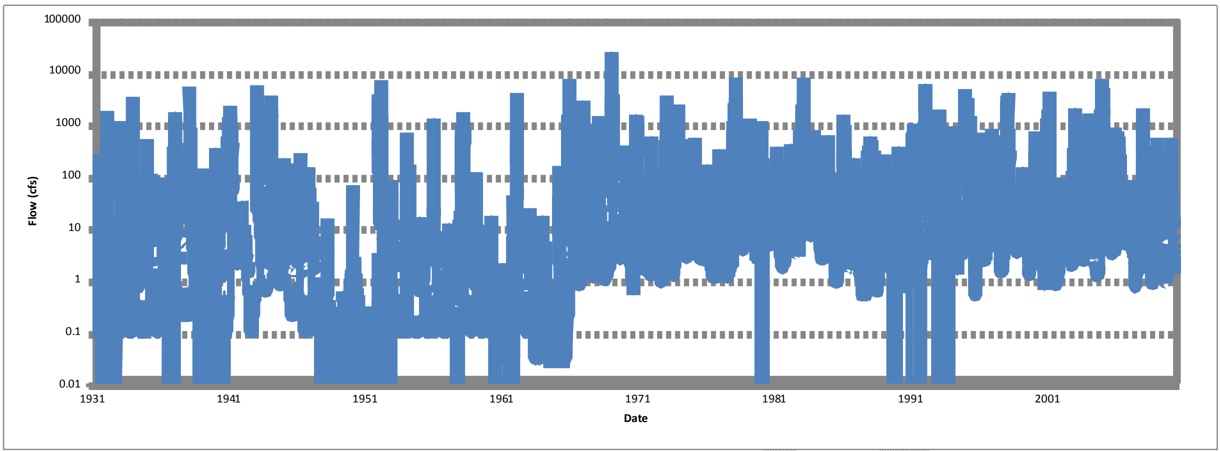


Figure 6-2. Daily Flow Time-Series for USGS 11105500/LACDPW F-130 Gage

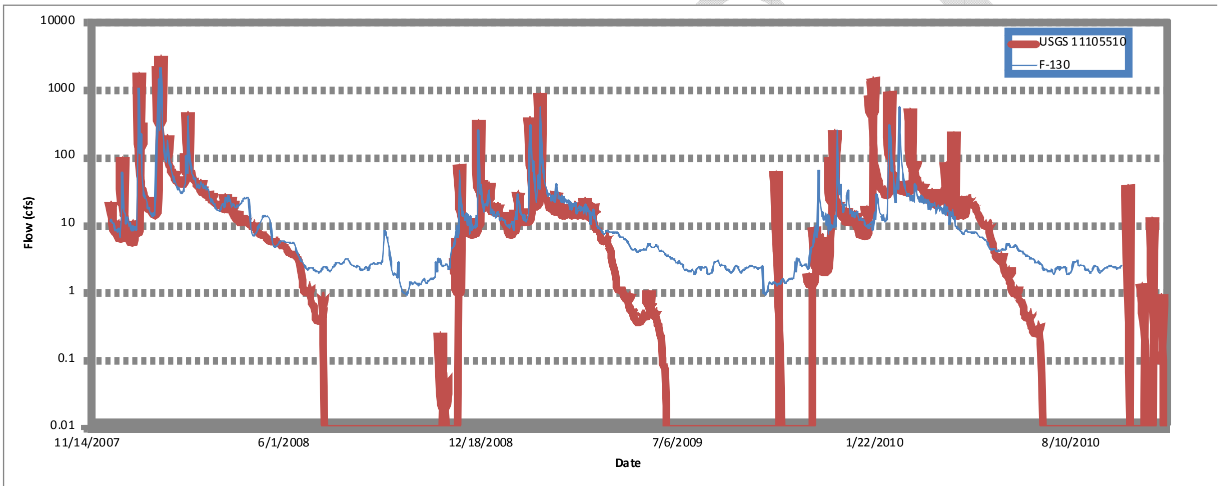


Figure 6-3. Daily Flow Time-Series for USGS 11105510 Gage

Table 6-1 provides a statistical summary of the daily flow data, and Table 6-2 shows the monthly averages to demonstrate the extreme seasonal variability in this stream.

Table 6-1. Statistical Summary of Daily Flow Data (cfs)

Gage	Dates	Min	Q25	Median	Q75	Max	Mean
USGS 11105500, LACDPW F-130	4/1/1931 – 9/30/2010	0	0.8	3.9	11.7	24,200	29.4
USGS 11105510	12/6/2007 – 9/6/2010	0	0.01	3.6	19.0	3,010	31.2

Table 6-2. Monthly Flow Averages (cfs)

Month	USGS 11105500/F-130, 1931-2010		USGS 11105510, 2007-2010	
	Mean Flow	Median Flow	Mean Flow	Median Flow
Jan	82.7	10.3	183.9	18.0
Feb	100.9	16.7	97.7	52.0
Mar	80.1	17.1	29.9	24.0
Apr	25.4	9.6	19.7	16.0
May	10.1	5.1	6.4	5.8
Jun	6.9	3.1	1.5	1.0
Jul	3.4	2.0	0.1	0.0
Aug	2.4	1.5	0.0	0.0
Sep	2.7	1.5	0.0	0.0
Oct	3.7	1.5	2.2	0.0
Nov	10.6	2.9	3.3	0.1
Dec	26.4	6.1	27.4	13.5

As shown in the figures and data summary, long-term flow in Malibu Creek is characterized by extreme seasonal fluctuation between near-zero base flows during the summer/fall and large peak events during the winter. Based on observed flows from the recent gage (Dec. 2007-present), monthly median flows between July and October are zero while median flows between December and April range between 13.5 cfs and 52.0 cfs. Observed flow data from the long-term gage portrays a significant increase in base flow between the pre-1966 monitoring period and the post-1992 period. In part this may be due to agricultural diversions in the earlier period, but imported water has also contributed to the base flow increase. Predevelopment measurements show that the historical base flow during summer was on the order of 0.18 cfs (NRCS, 1995), but by the 1990s the summer base flow had reached about 4 cfs. The NRCS (1995) study estimated that summer runoff from watering lawns and washing driveways in the upper watershed accounted for about 2.4 cfs of the base flows. About 7.4 cfs of runoff is generated, but about two-thirds of that is lost through evapotranspiration (NRCS, 1995).

6.2 IHA Change Analysis

The Indicators of Hydrologic Alteration (IHA) tool (Nature Conservancy, 2008) was used to compare differences in hydrologic regimes between two time periods and assess how these changes are related to impacts on instream sediment loading and biological health. IHA is used to summarize long periods of daily hydrologic data into a much more manageable series of ecologically relevant hydrologic parameters. As a result, Tetra Tech targeted hydrologic indicators that best represent the impacts on sediment loading and the health of benthic macroinvertebrate communities.

Flows were analyzed at the LACDPW monitoring gage on Malibu Creek below Cold Creek (Gage F130), the same location as the earlier USGS gage on Malibu Creek at Crater Camp (11105500). This gage is located downstream of most of the development in the watershed, as well as the Tapia discharge. IHA was used to do a pre- post-analysis. For the pre-impact period, daily flows were used for Water Years 1932-1965 (10/1/1931 – 9/30/1965) available on the USGS NWIS website. The pre-impact period was limited to 1965 because this is when the Tapia discharge and related development came online. The post-impact period used flows for Water Years 1992 to 2009 (10/1/1992 to 9/30/2009) provided by LACDPW as representative of current conditions.

Figure 6-4 shows separate flow duration curves for the pre- and post-periods. Note the significant increase in overall flow during the later monitoring periods, apparently reflecting the combination of the Tapia discharge and use of imported water in the basin. The overall mean flow for the two monitoring periods doubled from 17 cfs during the pre-impact period to 47 cfs during the post-impact period; an increase of 180 percent.

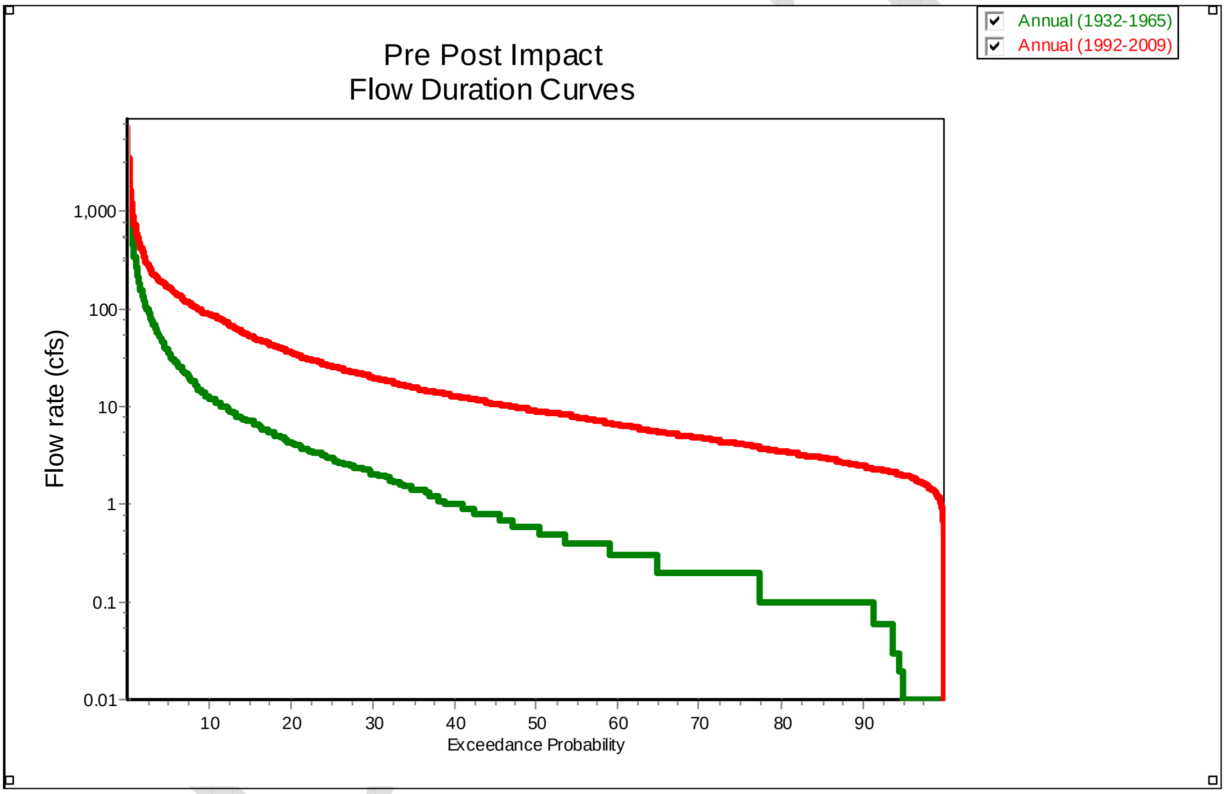


Figure 6-4. Annual Flow Duration Curves for Pre-Post Monitoring Periods on Malibu Creek

The basic IHA flow indicators are divided into five groups; each one representing a different set of hydrologic statistics and related influence on the stream ecosystem. Subsets of the 33 total IHA parameters are shown in Table 6-3, separated by impact period. The specific ecosystem influences associated with each of the parameter groups are shown in Table C-1 of Appendix C. (Note that Tetra Tech used the non-parametric analysis option in IHA.)

Table 6-3. Pre- and Post-Impact Median Results for Selected IHA Flow Parameters

Parameter Group	Parameter	Pre-Period	Post-Period	% Change
Magnitude of monthly water conditions	Median flow in April	3.5 cfs	21.5 cfs	505%
	Median flow in Nov.	0.2 cfs	6.7 cfs	3,237%
Magnitude and duration of annual extreme water conditions	Annual minima, 30-day median	< 0.1 cfs	2.4 cfs	2,310%
	Annual maxima, 30-day median	25.3 cfs	129 cfs	410%
	Number of zero-flow days	0.007	0.08	918%
Timing of annual extreme water conditions	Julian date of annual 1-day max.	275	278	1.0%
	Julian date of annual 1-day min.	40.5	40	11%
Frequency and duration of high and low pulses	# of low pulses within each water year (< 0.2 cfs)	4	0	-100%
	# of high pulses within each water year (> 3 cfs)	3.5	3	-14%
Rate and frequency of water condition changes	Rise rate: mean of all positive differences between consecutive daily values	0.25	0.40	62%
	Fall rate: mean of all negative differences between consecutive daily values	-0.40	-0.66	64%

The statistical results show a significant increase in the magnitude of annual flows between the pre- and post-impact periods. As shown in Figure 6-5, the median 1-day maximum flows increase from 179 cfs to 860 cfs (an increase of 380 percent). The median monthly flows increase between 505 percent and 3,237 percent between the pre- and post-impact monitoring periods and the annual 30-day maximum values increase by 410 percent. Not only do the median peak flows significantly increase during the post-impact period as expected from the increased development and imperviousness in the watershed, but the median low-flows also increase (+2,310 percent for the 30-day rolling median) as a result of wastewater discharges, use of imported water, and likely reductions in stream diversions.

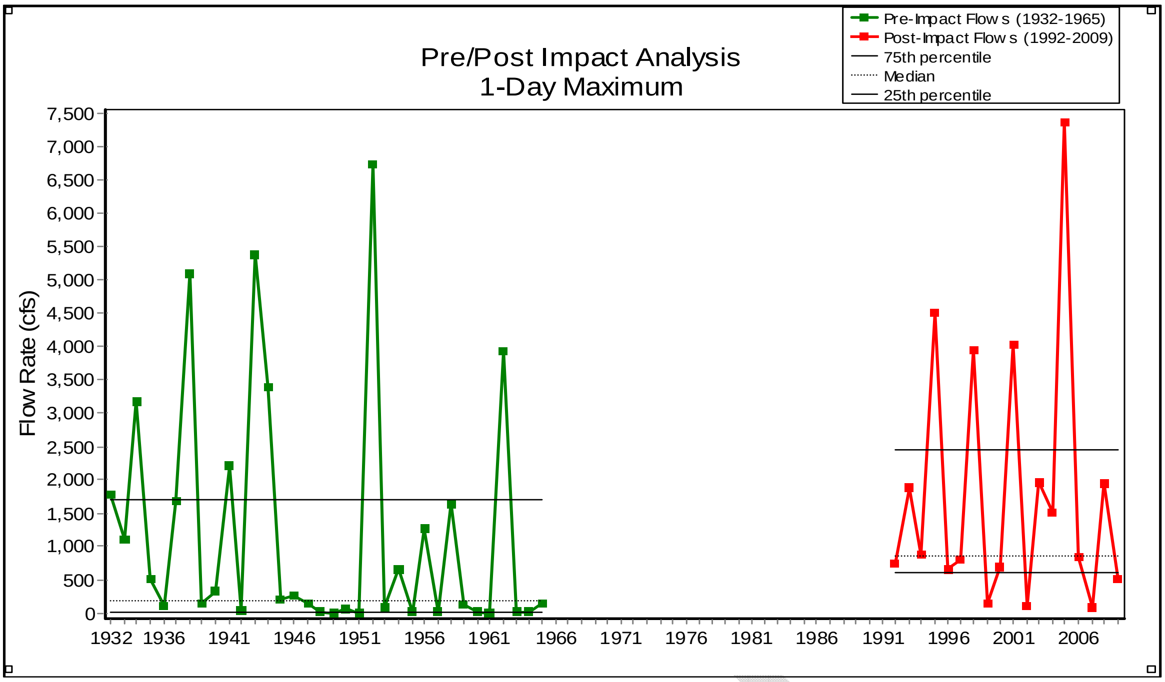


Figure 6-5. Pre/Post Comparison of Median Daily Maximum Flows on Malibu Creek

A key feature of the IHA is the evaluation of Environmental Flow Components (EFC). The program categorizes all daily flows as one of the following: extreme low flows, low flows, high flow pulses, small floods, and large floods. For Malibu Creek, extreme low flows are zero flows under pre-impact conditions. The dividing line between low flows (base flows) and high flows is set at 3cfs by the analysis, while the small flood minimum peak flow is 179 cfs and the large flood minimum peak flow is 4,505 cfs.

The EFC median low flows by month are shown in Figure 6-6 and reveal a dramatic change associated with use of imported water in the basin. Selected EFC parameters are shown in Table 6-4. The table includes a “Significance Count.” To calculate this, the software program randomly shuffles all years of input data and recalculates (fictitious) pre- and post-impact medians 1,000 times. The significance count is the fraction of trials for which the deviation values for the medians were greater than for the real case. Thus a low significance count (minimum value is 0) means that the difference between the pre- and post-impact periods is highly significant, and a high significance count (maximum value is 1) means that there is little difference between the pre- and post-impact periods. The significance count can be interpreted similarly to a p-value in parametric statistics. The IHA guide to the interpretation of EFC statistics is shown in Table C-2 of Appendix C.

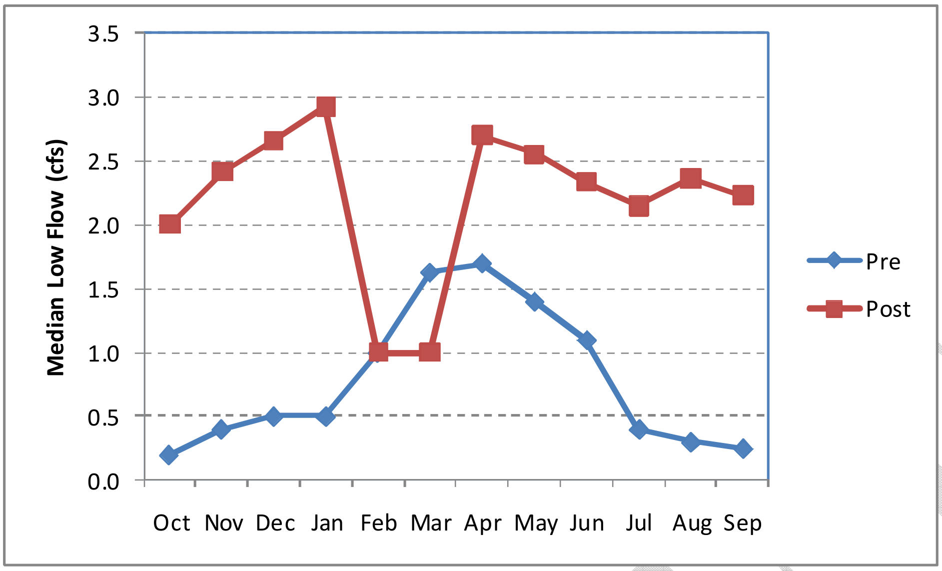


Figure 6-6. EFC Median Low Flows by Month

Table 6-4. Pre- and Post-Impact Median Results for IHA EFC Parameters

EFC Parameter	Pre-Impact	Post-Impact	Significance Count
Extreme low peak (cfs)	< 0.1	NA	
Extreme low timing (Jday)	274	NA	
Extreme low freq. (/yr)	4	0	0.07007
High flow pulse peak (cfs)	7.25	3.779	0.05506
High flow pulse timing (Jday)	53.5	272.5	0.03904
High flow pulse rise rate	4.175	0.95	0.2032
High flow pulse fall rate	-2.771	-0.6505	0.1972
Small flood peak (cfs)	1180	1697	0.4605
Small flood timing (Jday)	37	46	0.2943
Small flood rise rate	177.1	18.48	0.1862
Small flood fall rate	-16.7	-11.71	0.3333
Large flood peak (cfs)	5370	7360	0.00
Large flood timing (Jday)	62	9	0.00
Large flood rise rate	169.7	86.57	0.5856
Large flood fall rate	-44.62	-8.635	0.1922

There is a dramatic change in extreme low flow frequency: In the pre-impact period the median number of days with zero flow was four per year, whereas none occur in the post-impact period. This change may decrease the ability of the system to purge invasive species.

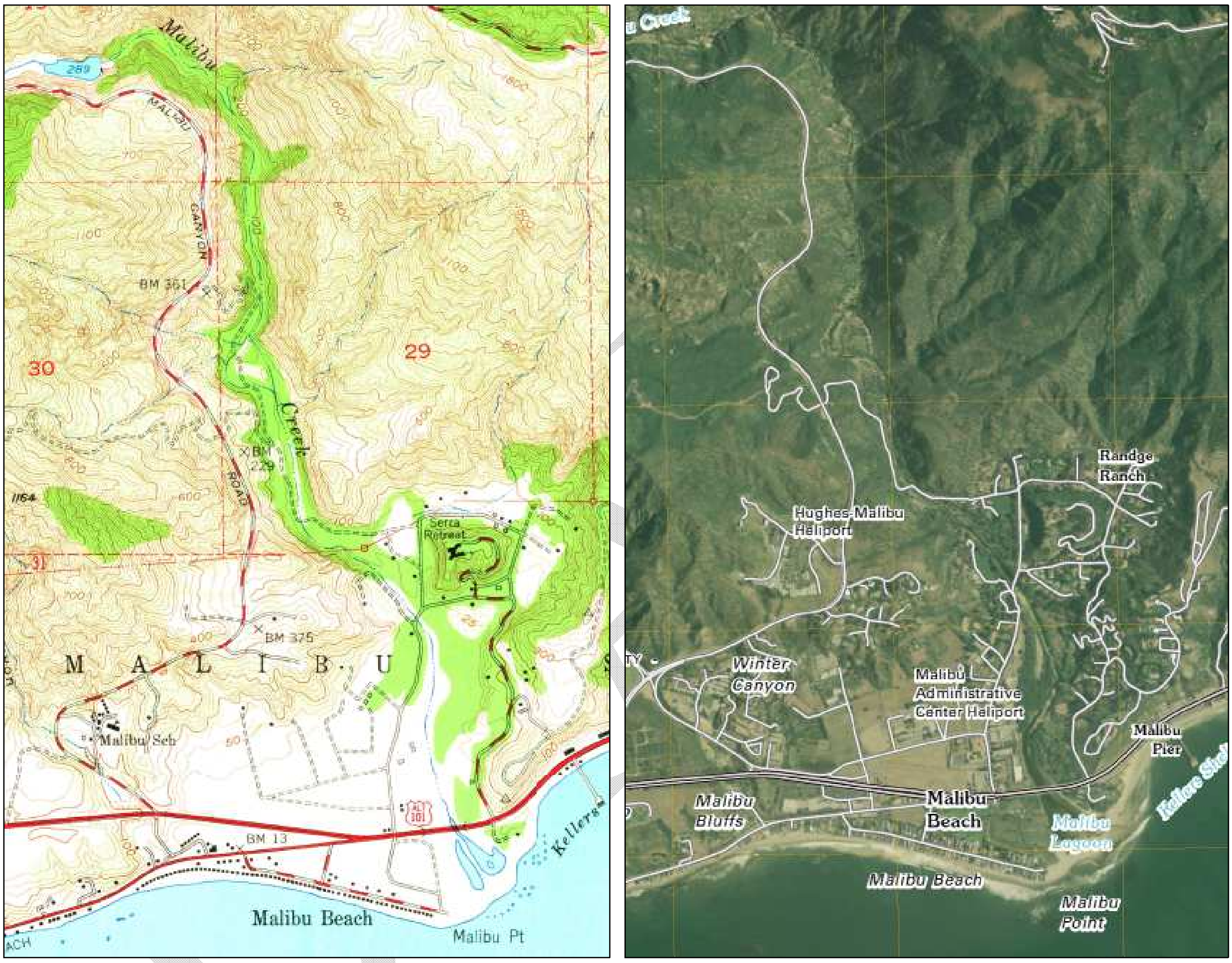
In general, the rates-of-flow rise and fall do not show statistically significant differences, nor is there much difference in small floods. More significant (< 10 percent) are the changes in high flow pulse (e.g., above base flow) peak and timing and large flood peak and timing. The high flow pulses are smaller and occur later in the year post-impact, while the large flood peaks are greater and occur earlier in the year. Both of these factors are likely to be associated with shaping the physical conditions and morphology of the streambed, while the changes in large floods can also have important consequences for the physical habitat of the floodplain.

6.3 MALIBU LAGOON MORPHOLOGY

The geologic history of Malibu Lagoon is described in Ambrose and Orme (2000) and Moffatt & Nichol (2005). The form of the Lagoon represents a dynamic balance between sea level rise since the last ice age and high sediment supply due to uplift of the Santa Monica Mountains. In general, the Lagoon has been aggrading over time in concert with sea level rise of approximately 1.8 mm/yr. An image of the Lagoon prior to major disturbances is available from the 1903 topographic map of Calabasas Quadrangle (Figure 6-7). The map shows the Lagoon as closed, with a small area of open water. It is likely that ranching activities since the 1860s had increased sediment supply prior to this map.

Figure 6-7. Malibu Lagoon, Detail from 1903 USGS 1:24,000 Map of Calabasas Quadrangle
(http://ims.er.usgs.gov/gda_services/download?item_id=5500825&quad=Calabasas&state=CA&grid=15X15&series=Map GeoPDF)

As described by Ambrose and Orme (2000), a railway was constructed across the Lagoon in 1908 and transformed into the Pacific Coast Highway in 1929. The western portions of the Lagoon were largely drained between 1920 and 1949 and large portions converted to truck farming. A variety of building projects followed, constraining the natural footprint of the Lagoon. The 1950 map of the same area shows the reduced footprint of the Lagoon and constraint by roads and ongoing building projects (Figure 6-8; left panel). A 2009 revision shows even more constraints on the Lagoon morphology (Figure 6-8; right panel). These constraints have increased aggradation in the remaining footprint of the Lagoon, much of which was noted as being above MSL in 2005 (Moffatt & Nichol, 2005). As a result, the Lagoon is much smaller and fresher than was likely the case under natural conditions – occupying only the eastern portion of its original extent.



1950 **2009 Digital Map**

Figure 6-8. Malibu Lagoon, Detail from USGS 1:24,000 Malibu Beach Quadrangle

The Lagoon is naturally a highly dynamic system in which substantial aggradation occurs in cycle with major floods that open the barrier beach and scour out accumulated sediments. Floods in 1938 and 1998 deepened the Lagoon and increased water volume on a temporary basis.

Natural breaching of the Lagoon barrier would occur primarily in response to winter storms. Alterations to the hydrology of the system have affected this natural cycle. Extensive use of imported water in the basin has extended flows into the dry season, which, in conjunction with reduced storage in the Lagoon, tends to result in overtopping of the beach during the summer. To prevent flooding, mechanical breaching of the beach during summer has been used.

No detailed record of intentional and natural breaching of the barrier beach has been located. Some information may be gleaned from a series of aerial photographs available at [www.coastalcalifornia.org.](www.coastalcalifornia.org)

(These are subject to copyright and are thus not reproduced here.) Based on these photographs and information provided in Ambrose and Orme (2000) and Moffatt & Nichol (2005), the following partial chronology can be constructed:

1972 [day not stated]	*Beach open at center, shallow channel*
1979 Oct.	*Open at center with full ocean exchange*
1997-1998 Winter	*Fully open to the sea with deepening of Lagoon by 0.5 to 1 m due to major flood event*
1999-2004	*Largely closed and aggrading*
2002 October	*Photography shows beach fully closed*
2004 October	*Open at west end of beach*
2005 June	*Closed*
2006 September	*Small overflow channel at west end of beach*
2008 September	*Closed*
2010 September	*Closed*
2011 October	*Small overflow channel at east end of beach*

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7. Water Quality Data and Analysis

In this section, all available water quality data collected and evaluated are provided; this TMDL conducted analyses of the data to provide context and background information regarding key stressors and impairments. These data are summarized and described in detail below.

7.1 SOURCES OF DATA

Water quality in the Malibu Creek watershed has been monitored by a variety of agencies over time. Much of this monitoring is summarized in a recent report by the Joint Powers Authority of the Las Virgenes Municipal Water District and the Triunfo Sanitation District (LVMWD, 2011). Additional analyses were conducted and are of potential relevance to biotic impairment in Malibu Creek.

The most significant sources of water quality monitoring data (other than bacterial data) are the Heal the Bay Stream Team, LVMWD, the Malibu Creek Watershed Monitoring Project (MCWMP), and the LACDPW. These data are discussed below and summarized in Appendix A.

7.1.1 Heal the Bay Stream Team Water Quality Sampling

The Heal the Bay Stream Team is a citizen volunteer monitoring project that has collected a limited suite of conventional water quality data in the Malibu Creek watershed and elsewhere since 1998. Although data are collected by volunteers, the team is led by a dedicated Heal The Bay Water Quality Monitoring Coordinator; in addition, the project involves significant training and supervision with adherence to established protocols and procedures. The early years of this effort (1998 – 2002) are described in detail in the dissertation of Luce (2003). Sampling sites were on Malibu Creek and its tributaries. They also included potential reference sites outside of the watershed (Figure 7-1, sites with prefix “HtB”). These include three sites on the Malibu Creek main stem: HtB-MC1, just above the Lagoon near the mouth of Malibu Creek, HtB-MC15 below the confluence with Cold Creek and also below the Tapia discharge, and HtB-MC12, upstream of Las Virgenes Creek and upstream of the Tapia Discharge.

Consistent with the discussion in Luce (2003), site SC-14 on Solstice Creek and LCH-18 on Lachusa Creek were selected as the most appropriate reference sites for the Malibu main stem. These sites are at similar elevation (but slightly lower stream order), but have few or no impacts due to development. Luce also treated the Arroyo Sequit station (AS-19) as a potential reference site; however, this site is subject to some development impacts including roads, equestrian uses, and at least one septic system upstream of the sampling station. Therefore, it is not treated as a primary reference site in this assessment.

7.1.2 LVMWD Sampling

LVMWD has conducted sampling in Malibu Creek since 1971 in conjunction with their discharge permit. These sites are indicated by prefix “LVMWD” on Figure 7-1. The sampling sites focused on discharge points to the local creeks and downstream impacts and have consistently addressed bacteria, general physical parameters, and inorganic nutrients. In 2005, monitoring for heavy metals and organic compounds was added to the routine monitoring to address the California Toxics Rule.

7.1.3 Malibu Creek Watershed Monitoring Program

The MCWMP was a multi-agency effort conducted under a Proposition 13 grant from February 2005 through February 2007 with the aim of establishing baseline water quality throughout the watershed. The sampling sites appear without prefix on Figure 7-1 (e.g., “LV1”).

7.1.4 Los Angeles County Mass Emissions

As part of its MS4 permit, LACDPW conducts sampling at seven mass emissions stations, one of which is collocated with stream gage F130, in Malibu Creek just below the confluence with Cold Creek (coincident with HtB-MC15 on the map). This targets wet and dry events with the intention of estimating mass loading past the monitoring station.

Figure 7-1. Monitoring Sites in the Malibu Creek Watershed and Adjacent Reference Sites

7.1.5 USEPA 2010-2011 Creek and Lagoon Monitoring

As part of the effort to more fully evaluate the condition of the Creek and Lagoon, USEPA collected and analyzed additional sampling data in Winter 2010 and Summer 2011. Monitoring included samples collected for water quality, macroinvertebrate community and physical habitat, which are discussed in this section and the next section on biological and habitat data.

7.2 DISSOLVED OXYGEN AND TEMPERATURE DATA ANALYSES

Malibu Creek has existing aquatic life beneficial uses of WARM, COLD, and SPWN, which are respectively associated with minimum DO criteria of 5, 6, and 7 mg/L. Samples from the Malibu Creek main stem generally meet these criteria , but not all the time. The Stream Team sampling provides a large database of samples. These are compared to the two reference sites in Table 7-1.

Table 7-1. Stream Team Dissolved Oxygen Sample Summary Malibu Creek Mainstem and Potential Reference Sites, 1998-2010

Site		MC-1	MC-12	MC-15	Solstice (14)	Lachusa (18)	Applicable Criteria
Sample Count		117	70	25	72	61	
DO (mg/L)	Average	10.90	9.38	9.09	9.30	9.93	> 7 mg/L
	Min	2.81	2.6	2.8	7.05	7.06	
	Max	19.68	12.92	18.14	16.17	13.28	

The SPWN criterion of 7 mg/L and the COLD criterion of 6 mg/L or better are met in the reference sites, but not always in the main stem. There are also frequent high values in the main stem, attributable to algal photosynthesis. A box plot of the DO samples (Figure 7-2) shows that the minimum DO criterion is met most of the time, although more than 12 percent of the samples at MC-1 were less than 7 mg/L (MC-15 is omitted from the box plot because the number and period of record of samples is limited). As shown in Table 7-2, less than 10 percent of the DO samples in the main stem fall below the COLD criterion; however, no excursions have been measured at the reference sites.

Table 7-2 does suggest high levels of DO stress in some of the tributaries. For example, samples at the Las Virgenes LV-9 station were less than 6 mg/L 71 percent of the time.

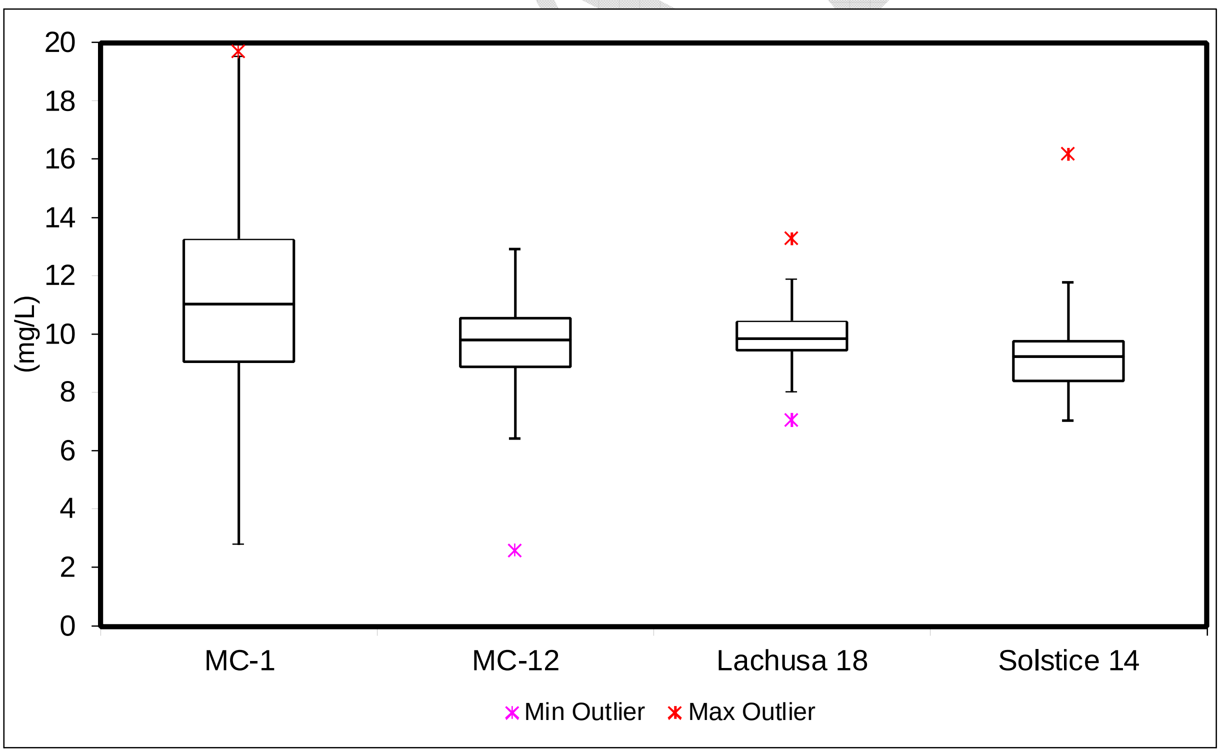


Figure 7-2. Box Plot of Stream Team DO Samples from Malibu Creek and Reference Sites

Table 7-2. Frequency of Low DO Samples at Malibu Creek Stream Team Stations, 1998-2010

Station	Description	< 7 mg/L	<6 mg/L	<5 mg/L
HtB-MC-1	Malibu Creek, Cross Creek Rd.	13.60%	9.30%	7.10%
HtB-MC-12	Malibu Creek at Malibu Creek State Park	12.70%	7.80%	5.30%
HtB-SC-14	Solstice Creek. National Park Service Area, upstream of bridge	0%	0%	0%
HtB-LCH-18	Lachusa Creek	0%	0%	0%
HtB-CC-2	Cold Creek at Piuma Rd	11.40%	8.90%	4.40%
HtB-CC-3	Cold Creek at Stunt Rd	4.40%	3.00%	0.90%
HtB-LV-5	Las Virgenes Creek at Malibu Creek State Park	4.70%	2.40%	2.00%
HtB-CH-6	Cheseboro Creek, Agoura Hills	11.20%	5.00%	3.60%
HtB-MD-7	Medea Creek, Cornell at Kanan Rd.	11.60%	2.20%	0%
HtB-PC-8	Palo Comado Creek	33.30%	22.10%	15.50%
HtB-LV-9	Las Virgenes Creek	79.60%	71.00%	38.10%
HtB-CC-11	Cold Creek	18.40%	13.30%	11.10%
HtB-LV-13	Las Virgenes Creek, Lost Hills Rd east of Malibu Hills Rd. Apartments	19.90%	4.30%	0%
HtB-MC-15	Malibu Creek, Malibu Canyon Rd. upstream of LA County Stream Gauge	14.70%	11.30%	9.20%
HtB-STC-16	Stokes Creek Outlet	0%	#N/A	0%
HtB-TR-17	Triunfo Creek, Corner of Kanan Rd. at Troutdale upstream of bridge	36.80%	23.80%	17.50%
HtB-AS-19	Arroyo Sequit, up Mulholland Highway 1.1 miles	8.20%	6.50%	0%

The DO samples in the main stem do not seem to show a clear trend over time, although observations less than 5 mg/L appears a little more frequent in recent years (Figure 7-3).

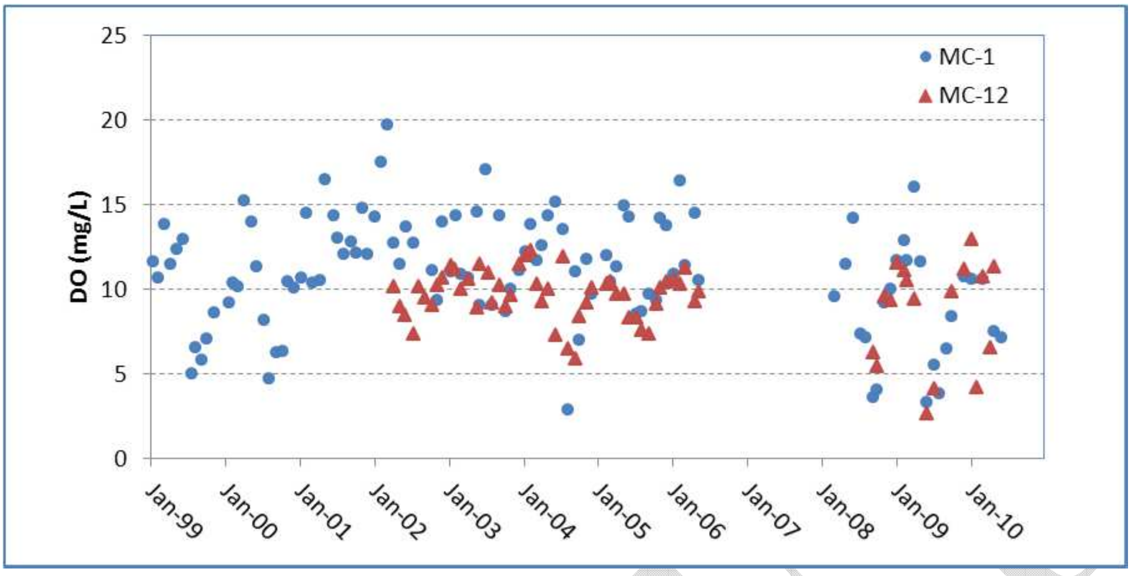


Figure 7-3. DO Concentration versus Time at Malibu Creek Stream Team Stations 1 and 12

Dissolved oxygen concentrations in shallow flowing streams are strongly affected by temperature, as water temperature is a major determinant of the saturation DO concentration. The wider range of DO concentrations observed in the Malibu Creek main stem compared to the reference stations may be due to greater variability in temperature. Average temperatures at the Malibu Creek sites followed the general pattern at the reference sites; however, stream temperature appears to have been impacted by the characteristics of the watershed (Figure 7-4). The MC-12 site was approximately 4 °C cooler during the winter and 4 °C warmer in the summer than the reference sites. The MC-1 site has temperatures that are similar to the reference sites during the winter months but elevated relative to the reference sites by about 2-3 °C during the summer. The temperature patterns in Malibu Creek likely reflect a combination of effects, including (1) the watershed drains inland areas that are expected to have higher summer air temperatures than reference sites in the coastal strip, (2) the various impoundments in the watershed may further increase summer water temperatures, and (3) effects of development, including the presence of concrete channels and reduced riparian cover, can lead to increased stream heating. The elevated summer temperatures in Malibu Creek also likely exacerbate algal growth problems.

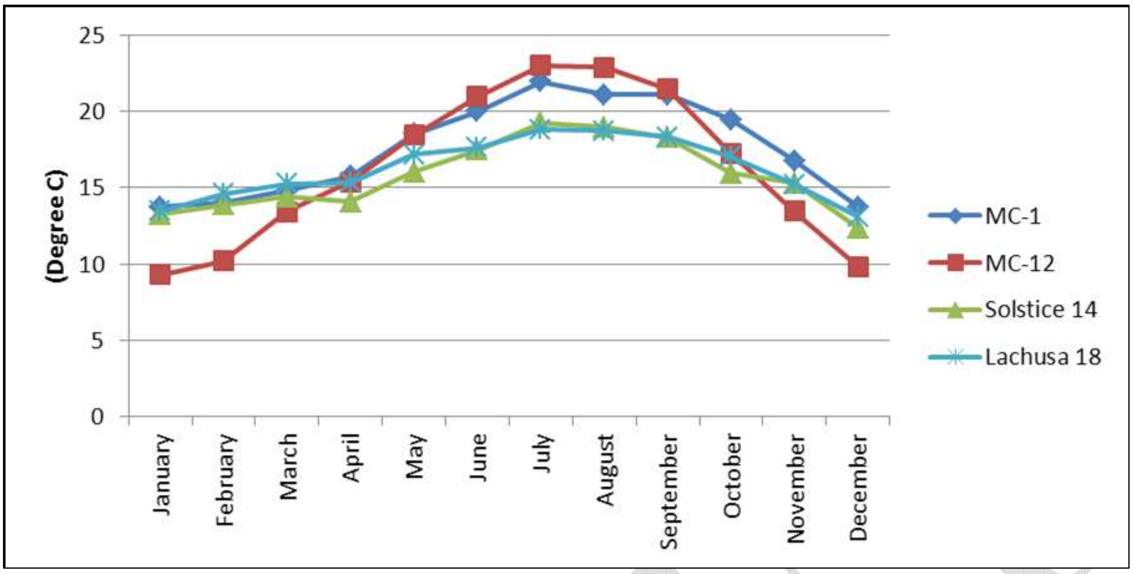


Figure 7-4. Average Stream Temperatures in Malibu Creek and at Stream Team Reference Sites

Occasional low DO is a source of stress to biota in Malibu Creek. Unfortunately, the Heal the Bay sampling is not conclusive for analysis of the DO status of the Creek because many locations in the Creek contain high densities of benthic algae. These algae create oxygen during daytime photosynthesis and consume oxygen during overnight respiration, resulting in a diurnal pattern in which DO concentrations tend to be lowest around dawn. Single grab samples, as reported by Heal the Bay, are thus of limited use in evaluating the full range of DO experienced by biota over the course of the day. Further, the Heal the Bay database does not show the time of sample collection. Other researchers (e.g., Gilbert, 2009) have demonstrated the existence of strong daily cycles of DO concentration in Malibu Creek, which could result in acute stress to the benthic community.

Although only limited data are available on daily cycles of dissolved oxygen in the watershed., low DO is known to occur in some locations with slow-moving pooled water. The State of the Watershed Report (Sikich et al., 2012), states the following: "24-hour samples taken by the Santa Monica Mountains Resource Conservation District (RCD) at three sites within the watershed show that some areas experience significantly decreased dissolved oxygen concentrations during the early morning hours. Continuous monitoring provides a better assessment of actual DO levels since time of day is taken into account for each location. DO at some of the RCD sites was highly variable throughout the day, dropping far below the 7 mg/L standard for waters designated as COLD… and SPAWN… in Malibu Creek, and below the 5mg/L standard for waters designated as WARM… in the remaining tributaries of 5 mg/L." Sikich et al. then present a figure, described as "Continuous monitoring DO profiles for the Lunch and Start Pools in lower Malibu Creek, 2010 Water Quality Monitoring Final Progress Report, Resource Conservation District of the Santa Monica Mountains. Data graphed were collected between August 11, 2009 and September 1, 2009. Start Pool is approximately 250m upstream of Site 1 (outlet of Malibu Creek) and Lunch Pool is approximately 720m upstream of Start Pool." This figure is reproduced below (Figure 7-5).

Note that the Start Pool sonde recorded about 8 hours below 2 mg/L, a condition that would be fatal to many aquatic organisms. Thus, there are at least some locations where low DO is a significant problem in the watershed; however, the spatial extent of such conditions is not known. Severe diurnal depression of DO is less likely to occur in shallower, faster flowing reaches of the stream.

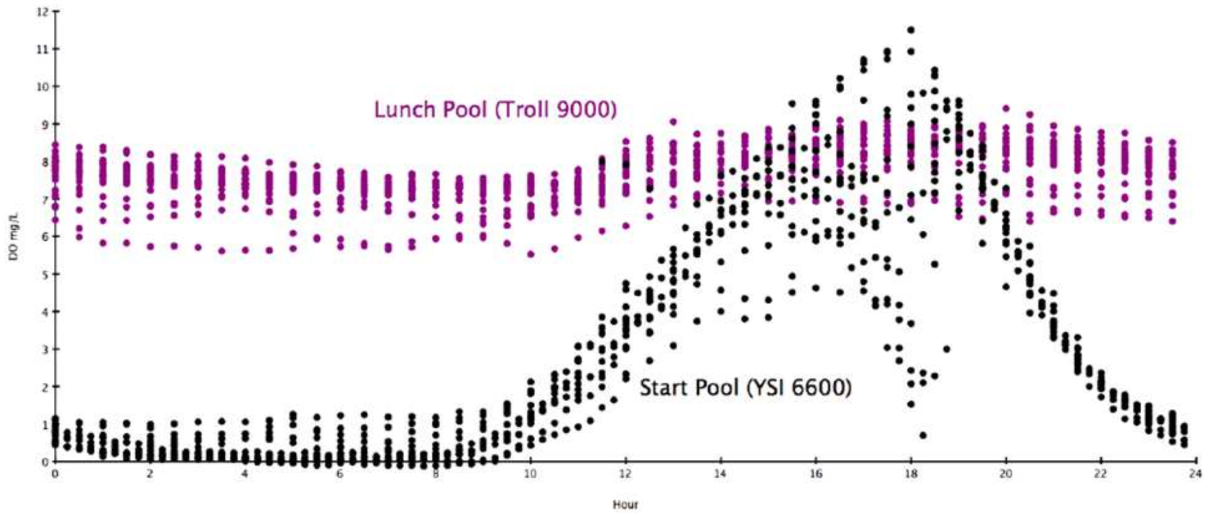


Figure 7-5. Dissolved Oxygen Profiles in Lower Malibu Creek Pools (from Sikich et al., 2012)

Sikich et al. also discuss low DO within Malibu Lagoon (citing Briscoe et al., 2002, and Ambrose et al., 1995): "The Malibu Lagoon suffers low Dissolved Oxygen (DO) levels, a condition that threatens aquatic life. In a 2005 study, pre-dawn dissolved oxygen concentrations averaged 1.15 ± 0.12 mg/L SE, significantly below Basin Plan thresholds Concentrations below 5 mg/L threaten aquatic life survival, and periods of low dissolved oxygen and low species diversity have been recorded in the Lagoon since the early 1990s. For this reason, along with extensive sedimentation and eutrophication, a comprehensive planning effort was initiated in the late 1990s and early 2000s to restore the Malibu Lagoon, with the primary objectives of improving water quality through increased circulation and enhancing Lagoon habitat for birds, fish and invertebrates."

7.3 CONDUCTIVITY AND DISSOLVED SOLIDS DATA ANALYSES

Malibu Creek is characterized by brackish water, with median specific conductance greater than 1,800 µS/cm in the lower creek below the LA County gaging station and higher concentrations, typically greater than 3,000 µS/cm, in the northern headwaters above the 101 freeway (LVMWD, 2011). Stream Team conductivity sampling for the main stem stations and reference sites is shown in Table 7-3. Results from the MCWMP MAL station are similar to those reported for MC-1, with an average of 1,862 µS/cm.

Table 7-3. Stream Team Conductivity Sample Summary, 1998-2010

Site		MC-1	MC-12	MC-15	Solstice (14)	Lachusa (18)	Applicable Criteria
Sample Count		117	70	25	72	61	
Conductivity (µS/cm)	Average	1,877	2,287	2,151	1,185	1,505	~2,985 (based on TDS of 2,000 mg/L)
	Min	13	903	1,030	368	16	
	Max	3,690	15,500	3,080	1,424	1,702	

There is no water quality criterion for electrical conductivity applicable to Malibu Creek. Elevated conductivity and total dissolved solids (TDS) are primarily due to ionic salt content of the water. There is a TDS standard of 2,000 mg/L as a specific objective for the Malibu Creek watershed in the Basin Plan.

The relationship between TDS and conductivity depends on the specific ions involved, their molecular weight, and their valence. However, a standard rule of thumb is that TDS is approximately equal to 0.67 times conductivity for a typical ionic content. This suggests that a conductivity of 2,985 µS/cm could be an informative screening criterion for Malibu Creek. Conductivity measurements occasionally exceed this value in the Malibu Creek main stem (0.7 percent at MC-1 and 4.7 percent at MC-12), but not in the reference sites (Figure 7-6).

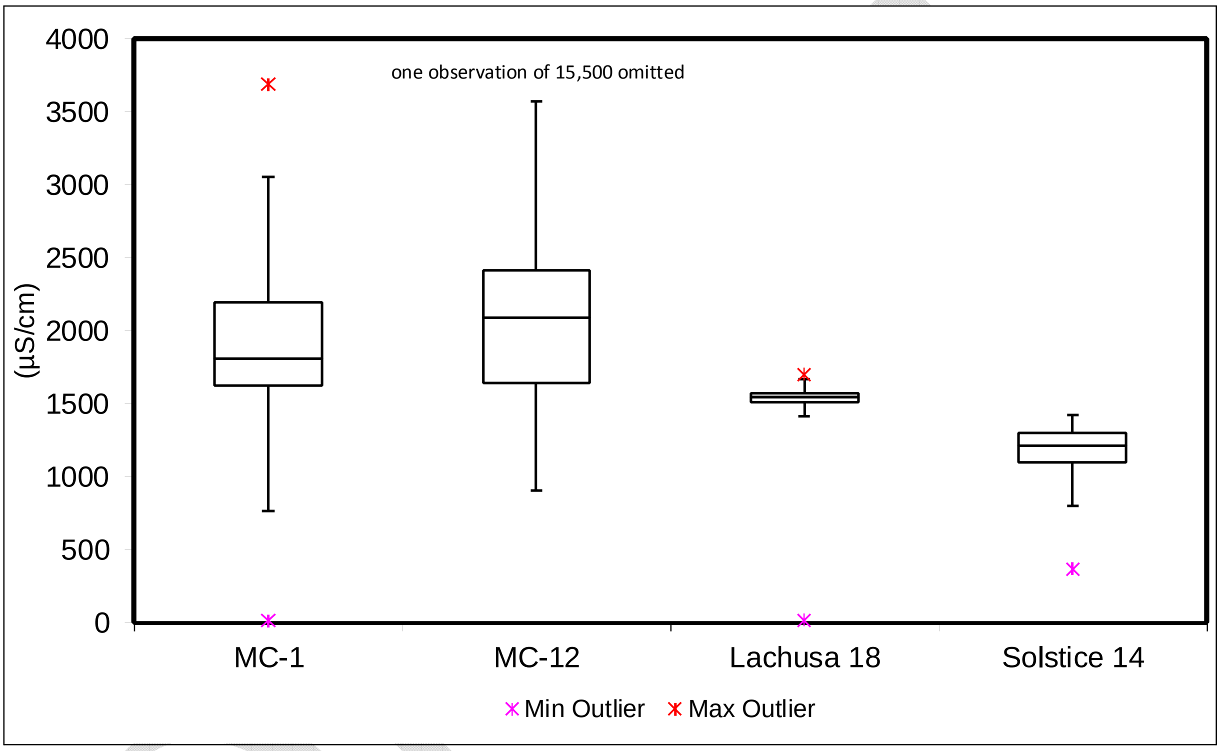


Figure 7-6. Box Plot of Conductivity Measurements from Malibu Creek and Reference Sites

7.4 Suspended Solids and Turbidity Data Analyses

7.4.1 Suspended Solids

Monitoring of suspended solids in Malibu Creek is limited, and this parameter is not collected by the Stream Team. MCWMP samples from station MAL have an average TSS of 3.6 mg/L, based on two wet weather samples in the database.

The mass emissions station monitoring shows that high suspended solids concentrations do occur. The maximum reported concentration is 3,196 mg/L and the 90th percentile value is 394 mg/L. LACDPW has performed trend analysis on total suspended solids data collected at the Malibu Creek mass emissions station. The most recent analysis (LACDPW, 2010) detected a decreasing trend that was not statistically significant at the 5 percent level (Figure 7-7). The trend does reflect one extremely high outlier observed during a storm event in 2006.

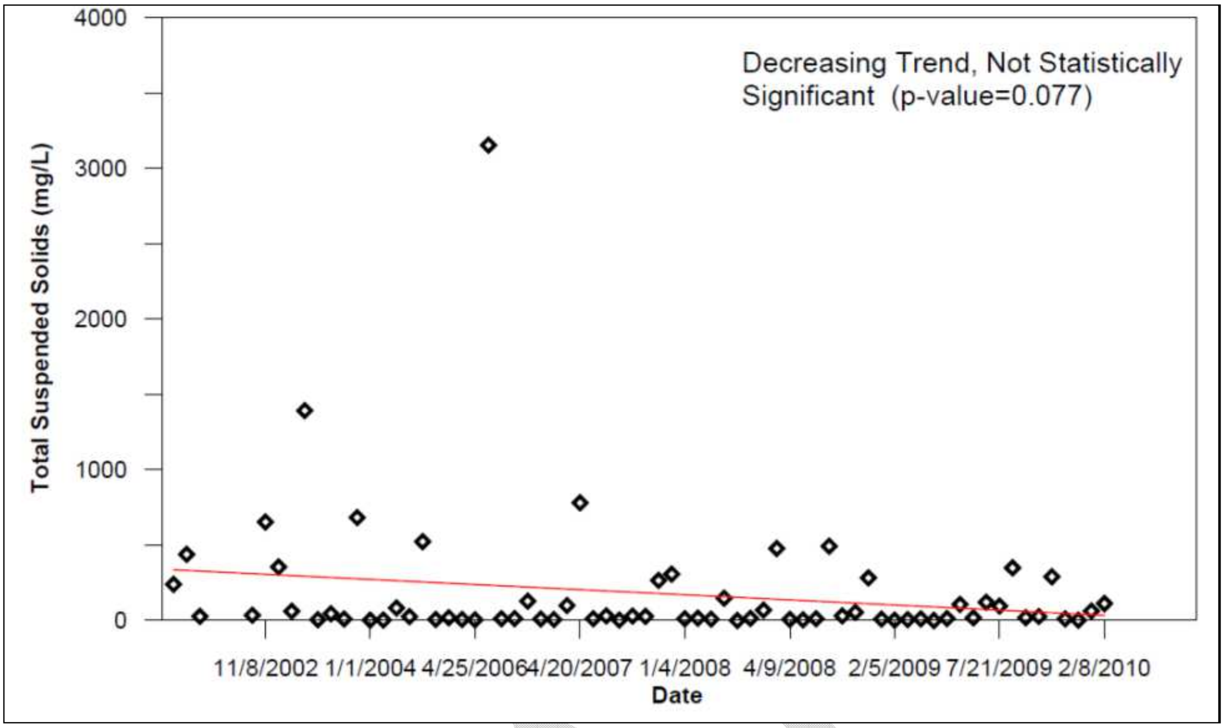


Figure 7-7. Malibu Creek Total Suspended Solids Concentration versus Time (from LACDPW, 2010)

7.4.2 Turbidity

The water quality standards for turbidity are based on elevation relative to natural conditions: A 20 percent increase above background is the maximum allowed. The turbidity values reported in Heal the Bay sampling are generally low (Table 7-4). Heal the Bay samples monthly throughout the year, encompassing both wet and dry seasons, but not specifically targeting specific conditions.. Turbidity in the main stem of Malibu Creek is clearly greater than at the reference sites (Figure 7-8).

Table 7-4. Stream Team Turbidity Sample Summary, 1998-2010

Site		MC-1	MC-12	MC-15	Solstice (14)	Lachusa (18)	Applicable Criteria
Sample Count		117	70	25	72	61	
Turbidity (NTU)	Average	1.94	1.31	2.62	0.75	0.27	≤ 20% above background
	Min	0	0.03	0	0	0	
	Max	40	14.9	35.5	39.5	3.1	

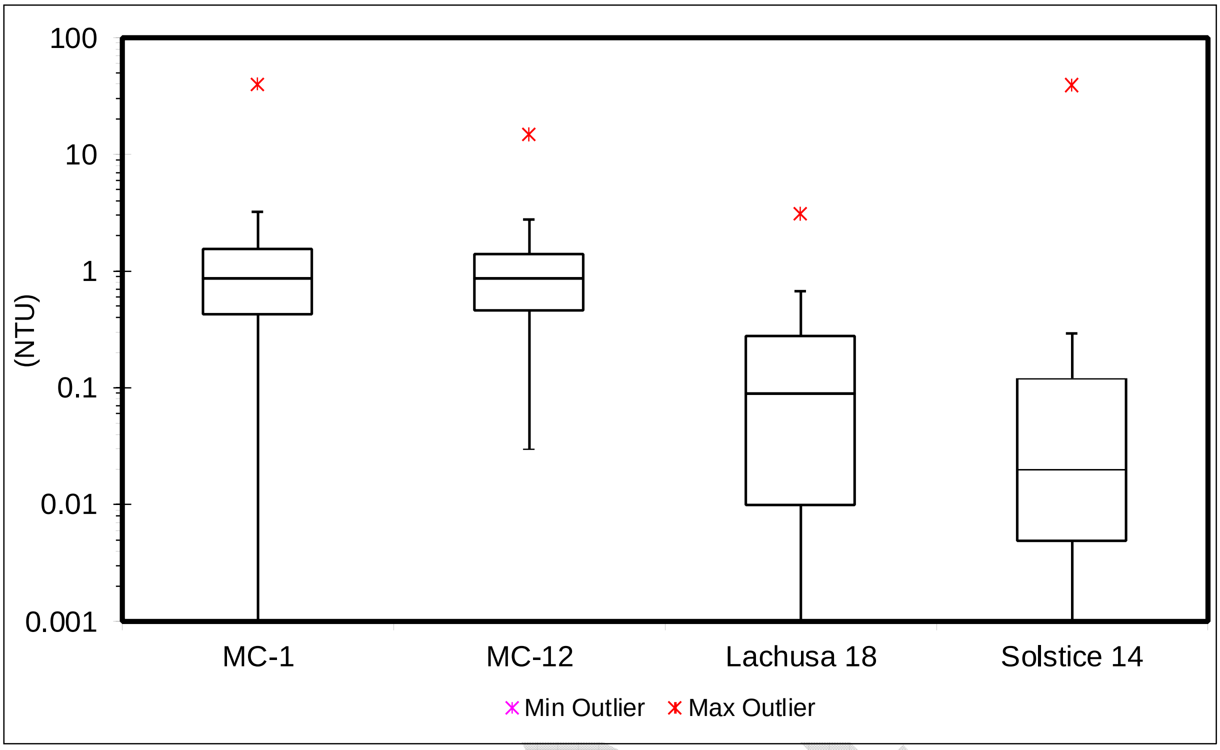


Figure 7-8. Box Plot of Turbidity Measurements from Malibu Creek and Reference Sites

Average reported turbidity values are compared by month in Table 7-5 and Figure 7-9. For most months, average turbidity at the reference sites is on the order of 0.1 NTU, while that in the main stem is on the order of 1 NTU.

Table 7-5. Average Monthly Turbidity in Malibu Creek, Stream Team Data

	MC-1		MC-12		Lachusa 18		Solstice 14	
Month	Average	Count	Average	Count	Average	Count	Average	Count
January	0.89	9	1.52	5	0.15	3	0.02	4
February	5.63	10	4.47	6	0.21	4	7.12	6
March	5.57	11	2.80	6	0.71	6	0.22	7
April	1.23	10	0.61	7	0.08	7	0.11	7
May	1.41	10	0.51	6	0.17	5	0.24	7
June	1.01	10	0.80	5	0.28	5	0.16	5
July	1.13	9	0.71	5	0.29	4	0.15	6
August	1.03	8	1.05	4	0.24	4	0.04	6

Month	MC-1		MC-12		Lachusa 18		Solstice 14	
	Average	Count	Average	Count	Average	Count	Average	Count
September	1.38	8	0.90	6	0.09	5	0.20	5
October	0.79	9	0.47	6	0.15	5	0.17	5
November	1.01	10	0.88	6	0.05	4	0.01	6
December	1.29	10	0.85	6	0.67	5	0.24	5

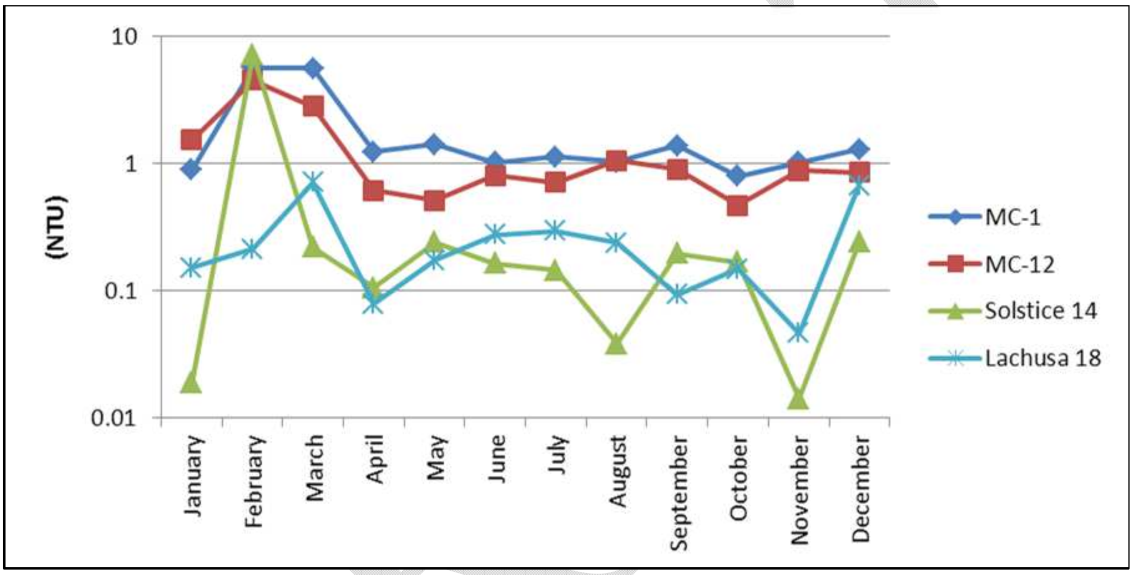


Figure 7-9. Monthly Average Turbidity in Malibu Creek and Stream Team Reference Sites

7.4.3 USEPA Analysis of TSS and Turbidity Relationship

Between February 16, 2011 and April 25, 2012, USEPA completed turbidity and suspended sediment sampling at Malibu Creek site MC-1. A multiparameter datasonde with real time web available data was deployed at the site on lower Malibu Creek during this time period; this was connected to an automatic sampler, set to trigger on pre-set turbidity measurements. The goal of this sampling effort was to determine if a relationship between turbidity and suspended sediment transport in the Creek could be established.

A water quality monitoring station was established on February 16, 2011 on Malibu Creek, about 250 meters northwest and upstream from the Cross Creek Road Bridge. The USGS Gaging Station 11105510 on Malibu Creek is located just upstream of that bridge. Discharge data used in our analysis came from that gaging station. The gaging station collects discharge and stage data on a 15 minute interval. The monitoring station included a multiparameter water quality datasonde, a datalogger, a cell phone modem for real time access to the data, and an automated composite sampler. During the original set up, the sampler was programmed to collect samples when turbidity was > 20 NTUs.

On March 20, 2011 a flood event of about 9000 CFS occurred in the watershed and the equipment was damaged. During the remainder of the monitoring period, the turbidity trigger was set to >50 NTU to avoid spurious sample collection, that did not correspond to real rain/sediment transport events.

The station collected 27,128 data points during the deployment. During the same time period, the USGS gaging station collected 39,273 data points out of a possible 39,399. After review of all the data, data of questionable quality was removed from the data set, based on USEPA's best professional judgment. Since the turbidity sensor was occasionally impacted by debris or dirt, resulting in spurious values, some values were removed resulting in a total of 26,913 turbidity values collected. Turbidity values were assessed with other indicators of flow (i.e., increases in depth or discharge, rainfall at the local meteorological stations, or decreases in conductivity). The subsequent load estimates were made with both the raw turbidity and the edited turbidity values.

Rainfall data from two nearby CIMIS weather stations (Camarillo and Santa Monica) was used to assess the potential for turbidity events in the data analysis described below. During the deployment period, rainfall data indicate that there were 17 potential rainfall events that may have generated storm related turbid flows. Due to sampler damage and non-triggering turbidity levels, only three of the rainfall events led to successful collection of samples (i.e., concurrent data pairs).

For the three successfully sampled events there were 54 samples generated where there are concurrent measurements of turbidity, SSC and flow. The samples span the range of flows from 9.8 CFS to 1660 CFS. Of the 39,273 readings recorded during the deployment period, only 67 (0.17%) were > 1660 CFS. The flow in the creek was between 9.8 CFS and 1660 CFS 42% of the time. Storm flows that generate high turbidity and solids transport are very rare at flows lower than those that were sampled. This data set includes values that represent the typical ranges of flows in the system, with the exception of really large events. The impact of really large events is difficult to characterize,and may be very significant in terms of material moved.

Figure 7-10 shows the linear relationship based on the 50 concurrent data pairs used in the analysis of the SSC-Turbidity relationship. This final linear relationship and does not included data with low turbidities and was based on a best fit line drawn. This result shows that for average typical ranges of flows in the Creek, there is a good relationship between turbidity and suspended solids, and suggests that turbidity can be an excellent surrogate for suspended solids concentration in Malibu Creek.

Use of this equation provides an estimate of 2,366,713 kg or 2,608 English tons of suspended sediment during the 68.3 percent of the time period successfully sampled between 2/16/11 and 4/25/12, most of it within the large event of 3/25/12. Total loads were evidently much higher, as the very large event of 3/20/11 was not successfully sampled.

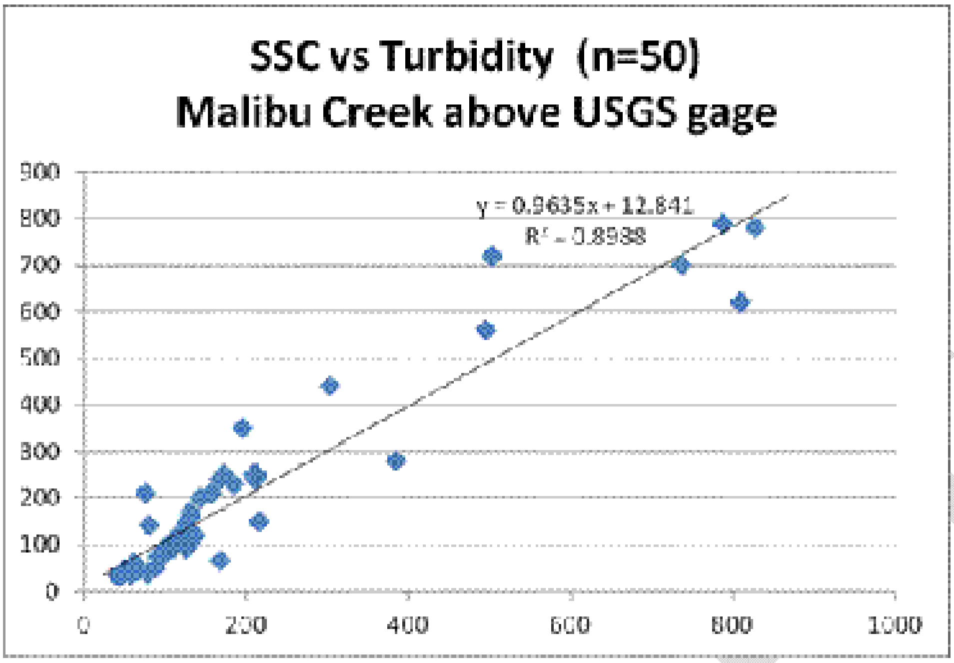


Figure 7-10. Linear relationship between suspended sediment concentration and turbidity at Malibu Creek above the USGS gage station

Further investigation of the turbidity concentration from a representative non-impacted portion of the watershed could better inform the change in sediment loading overtime.

7.5 Nutrients Data Analyses

The majority of sampling for nutrients in Malibu Creek has primarily been focused on inorganic nutrient species only. This can be problematic in areas of high algal density since algae may control the observed inorganic nutrients, rather than the inorganic nutrients controlling the algal density; for this reason, Dodds et al. (2002, 2006) found that total nitrogen (TN) and total phosphorus (TP) are better predictors of benthic algal response than the inorganic forms. In Malibu Creek streams, we find algal response is better indicated by TN and TP.

Heal the Bay stream monitoring includes only inorganic nutrients. Results for the main stem Malibu stations are shown in Table 7-6. Concentrations are higher below Tapia (MC-1 and MC-15), as reflected by samples collected during discharge periods and before the prohibition on summer discharges.

Table 7-6. Heal the Bay Stream Team Malibu Creek Mainstem Nutrient Sample Summary, 1998-2010

Site		MC-1	MC-12	MC-15	Applicable Criteria
Sample Count		117	70	25	
NOx-N (mg/L)	Average	2.46	0.08	2.18	<1 mg/L in main stem, 4/15-11/15 (TMDL); <8 mg/L winter
	Median	0.35	0.03	1.27	
	Min	0	0	0.04	

	Max	13.05	0.86	6.84	
	Excursions of summer target	7.69%	0%	30.8%	
	Excursions of summer target 2005+	0%	0%	30.8%	
	Excursions of winter target	12.5%	0%	0%	
Total Ammonia as N (mg/L)	Average	0.17	0.07	0.30	pH dependent (1.2 – 28 mg/L)
	Median	0.06	0.05	0.09	
	Min	0	0	0	
	Max	7.05	0.5	2.57	
PO_4-P (mg/L)	Average	1.82	0.27	1.51	<0.1 mg/L in main stem, 4/15-11/15 (TMDL)
	Median	1.42	0.27	0.65	
	Min	0.33	0.03	0.17	
	Max	5.46	0.51	5.12	
	Excursions	27.69%	92.68%	100%	
	Excursions 2005+	16.67%	95.00%	100%	

Median concentrations at other Heal the Bay stations are summarized in Table 7-7. The sites with the highest nitrate concentrations (LV5, MD7, LV13, MC15) are all downstream of developed areas. Seven of the sites (CC3, CH6, PC8, LV9, SC14, LCH18, and AS19) drain relatively undisturbed areas, including the Lachusa and Solstice Creek stations (LCH18, SC14) proposed as reference sites by Heal the Bay. Median nitrate-N concentrations at these undisturbed sites range from 0.01 to 0.03 mg/L. Only Solstice Creek (SC14) reports a median greater than 0.01, and Sikich et al. (2012) report that nitrogen concentrations at this site are influenced by a leaking septic system. Two of the undisturbed sites (CH6 on Cheseboro Creek and LV9, on upper Las Virgenes Creek) predominantly drain the Modelo formation, but do not show elevated nitrate-N concentrations. In contrast, for orthophosphate-P, there appears to be a clear difference for sites that drain the Modelo formation: The undisturbed sites that do not drain the Modelo formation have median orthophosphate-P concentrations that range from 0.06 to 0.14 mg/L, while the two that do drain the Modelo formation have median orthophosphate-P concentrations of 0.44 and 0.55 mg/L.

Table 7-7. Heal the Bay Median Nutrient Concentrations at Other Stations

Station	Nitrate-N (mg/L)	Ammonia-N (mg/L)	Orthophosphate-P (mg/L)
Htb_CC2	0.43	0.030	0.24
HtB-CC3	0.010	0.010	0.06
HtB-LV5	4.24	0.040	0.44
HtB-CH6	0.005	0.030	0.42
HtB-MD7	0.74	0.090	0.39

Station	Nitrate-N (mg/L)	Ammonia-N (mg/L)	Orthophosphate-P (mg/L)
HtB-PC8	0.005	0.030	0.13
HtB-LV9	0.005	0.020	0.55
HtB-CC11	0.02	0.030	0.15
HtB-LV13	1.22	0.070	0.69
HtB-SC14	0.030	0.030	0.080
HtB-MC15	1.23	0.090	0.65
HtB-STC16	0.45	0.060	0.38
HtB-TR17	0.15	0.040	0.32
HtB-LCH18	0.010	0.030	0.12
HtB-AS19	0.010	0.030	0.14

As noted above, inorganic nutrient concentrations alone does not appear to reveal the full potential for nutrient-induced algal growth. The best evidence for the spatial distribution of TN concentrations in the watershed is from the MCWMP sampling (which did not include TP). This includes one station from the main stem (MAL) (located downstream of the Tapia winter discharge) and results from several other stations in Table 7-8. The CC station is in a relatively undisturbed area and shows consistently low median inorganic N concentrations (0.01 in both summer and winter); however the median total N concentration is 0.06 in summer and 0.56 in winter. Most of the remaining stations are influenced by development and/or agriculture, although LV1 is upstream of most anthropogenic influences (and downstream of HtB-LV9). Concentrations of inorganic N at LV1 are higher than at HtB-LV9, with inorganic N in the 0.3 – 0.35 mg/L range and total N in the 1.22 to 1.73 mg/L range The reasons are unknown, but the presence of unstable stream banks and illegal dump sites above this station (Sikich et al., 2012) are possible contributing factors

Table 7-8. MCWMP Nutrient Sampling at Selected Stations, Median Results by Season, 2005-2007

Station	TN (mg/L)		Inorganic N (mg/L)		Inorganic P (mg/L)	
	SUMMER	WINTER	SUMMER	WINTER	SUMMER	WINTER
MAL	0.49	3.27	0.04	2.12	0.21	0.50
CC	0.06	0.56	0.01	0.01	0.05	0.04
MED1	0.84	0.75	0.01	0.01	0.09	0.09
MED2	0.67	0.96	0.03	0.08	0.12	0.09
LV1	1.33	1.73	0.30	0.35	0.07	0.11
LV2	3.36	4.51	3.01	3.19	0.22	0.19

Additional monitoring of total N concentrations in the watershed has been conducted by LACDPW at the mass emissions station on Malibu Creek, downstream of the Tapia WRF discharge. This monitoring has focused on winter wet weather events, with relatively small amounts of sampling during the summer dry period.

Time series of total N at this station show that forms other than nitrate-N may constitute a significant amount of total N (Figure 7-11). The overall statistics are elevated by the Tapia winter discharges, with total N concentrations during the non-discharge period since 2005 in the range of 1.6 to 1.9 mg/L (Table 7-9).

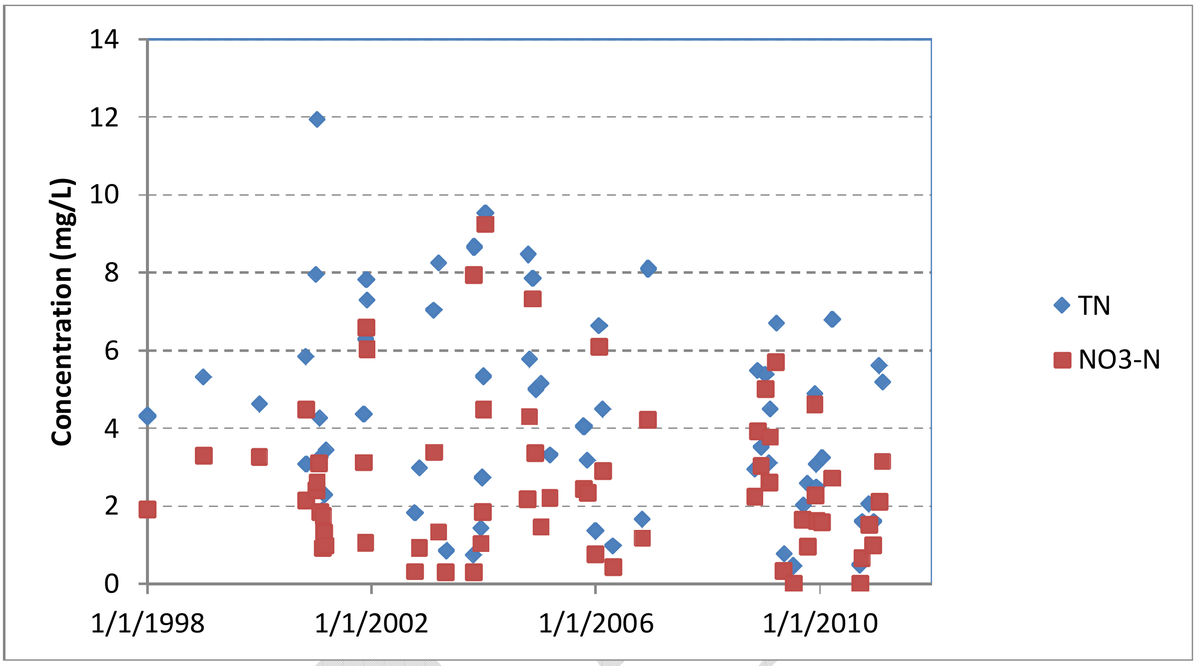


Figure 7-11. Total and Nitrate-N Monitoring at LACDPW Mass Emissions Station

Table 7-9. Total and Nitrate-N Statistics at LACDPW Mass Emissions Station on Malibu Creek

	Count	TN, median	NO_3-N, median	TN, average	NO_3-N, average
All Data	64	4.15	2.23	4.32	2.65
Non-discharge period (Apr. 15 – Nov. 15)	21	2.59	1.17	3.02	1.82
Discharge period (Nov. 16- Apr. 14)	43	4.88	2.60	4.95	3.05
Non-discharge period, 2005-2011+	11	1.65	0.95	1.89	1.11

Additional inorganic nutrient sampling at multiple stations in the watershed is summarized in LVMWD (2011); however, the LVMWD sampling does not include total N or total P.

Total nutrient concentrations are also available from a special study conducted in 2001 and 2002 reported by Busse et al. (2003, 2006). Busse et al. classified sites as Reference (minimal human impact), Rural, or one of several developed categories (Residential, Commercial, Multiple, Horse, Golf), along with sites upstream and downstream of Tapia. Several of the stations correspond to Heal the Bay sampling sites; however, georeferencing information has not been obtained. Samples were taken in August and October 2001 and June and August 2002. The reference sites, as well as several of the other sites, show inorganic N as a small fraction of total N.

Table 7-10. Total and Inorganic Nutrient Statistics from Busse et al. (2003)

Site	Sample Count	Total N (mg/L)	Inorganic N (mg/L)	Total P (mg/L)	Inorganic P (mg/L)
Reference Sites					
Cold Creek, Mountains Restoration Trust Lands	4	0.666	0.025	0.070	0.026
Palo Comado Creek, Santa Monica Mountains National Recreation Area	2	0.371	0.010	0.028	0.008
Rural Sites					
Cold Creek at Piuma Road	2	0.441	0.266	0.076	0.028
Cold Creek off Cold Canyon Road	2	0.546	0.073	0.037	0.019
Developed Sites					
Medea Creek at Conifer St. in Agoura Hills	4	0.566	0.070	0.130	0.096
Lindero Creek near Falling Star Lane	2	0.839	0.222	0.112	0.026
Lindero Creek at Lindero Country Club	2	1.525	0.422	0.144	0.085
Triunfo Creek off Triunfo Canyon Road	2	0.394	0.022	0.098	0.028
Medea Creek close to Chumash Park	4	1.000	0.455	0.143	0.074
Medea Creek south of Agoura Road	1	1.418	0.427	0.087	0.092
Las Virgenes Creek at the intersection of Lost Hills and Las Virgenes Road in Calabasas	1	2.748	2.828	0.296	0.268
Downstream Sites					
Malibu Creek, Malibu State Park, above Tapia	2	0.564	0.043	0.118	0.058
Malibu Creek, upstream of gaging station, below Tapia	3	1.060	0.473	0.211	0.165

7.5.1 Nitrate plus Nitrite N Trends

The 2003 nutrient TMDL established targets for nitrate plus nitrite N of less than 1 mg/L in the Malibu Creek main stem for the period of April 15 to November 15 and less than 8 mg/L for the remainder of the year. There is also a numeric objective for nitrate N of 10 mg/L in the Basin Plan. Examination of the full Stream Team data set (all years and all seasons) shows that concentrations are clearly elevated at the downstream station, MC-1, while concentrations upstream of Tapia at MC-12 are not much different from the reference sites (Figure 7-12). Indeed, MC-12 concentrations have not been noted in excess of the 1 mg/L target, yet mat algal coverage remains high (see below, Section 8.3). Time series at MC-1 for the year and for the 4/15-11/15 period show a decrease in the frequency of high concentration events over time (Figure 7-13). It should be noted, however, that excess periphyton growth can occur at concentrations less than 1 mg/L (e.g., Dodds and Welch, 2000).

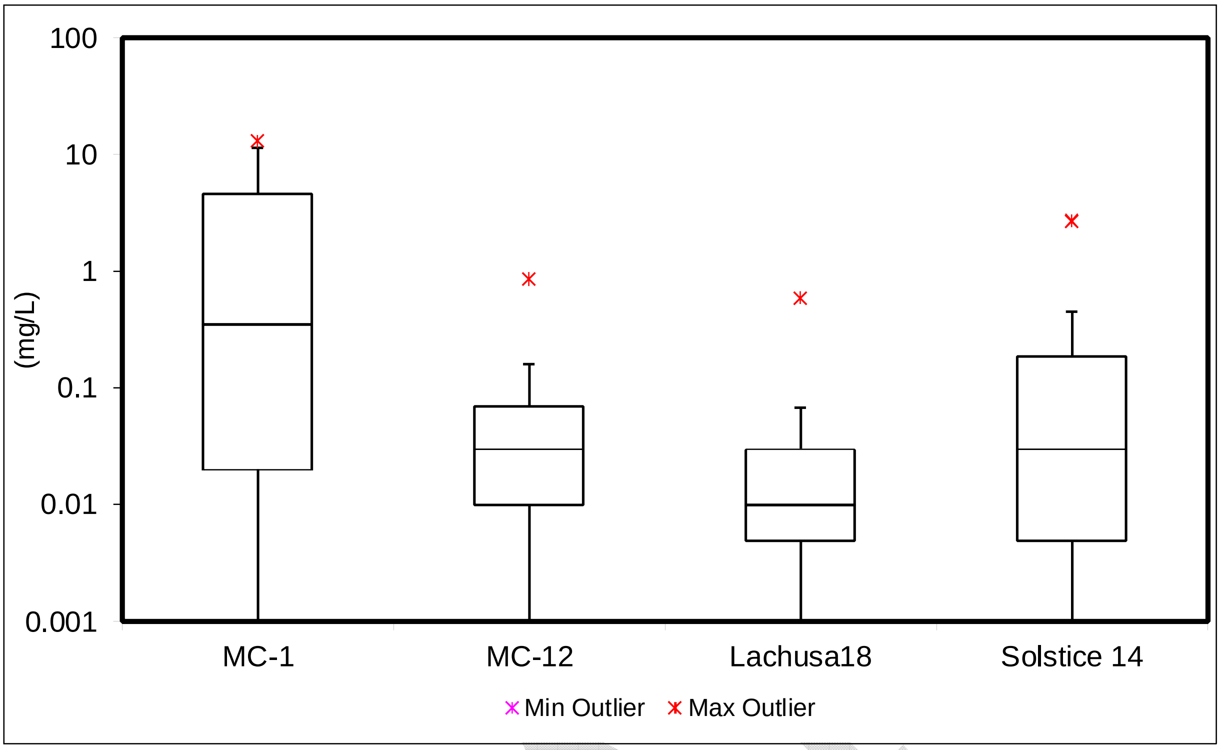


Figure 7-12. Boxplot of Nitrate plus Nitrite-N Measurements from Stream Team Malibu Creek and Reference Sites (All Years and All Seasons)

Results reported by LVMWD (2011) suggest that the median nitrate-N concentration is about 1.0 mg/L upstream of the Tapia discharge and 1.90 mg/L downstream.

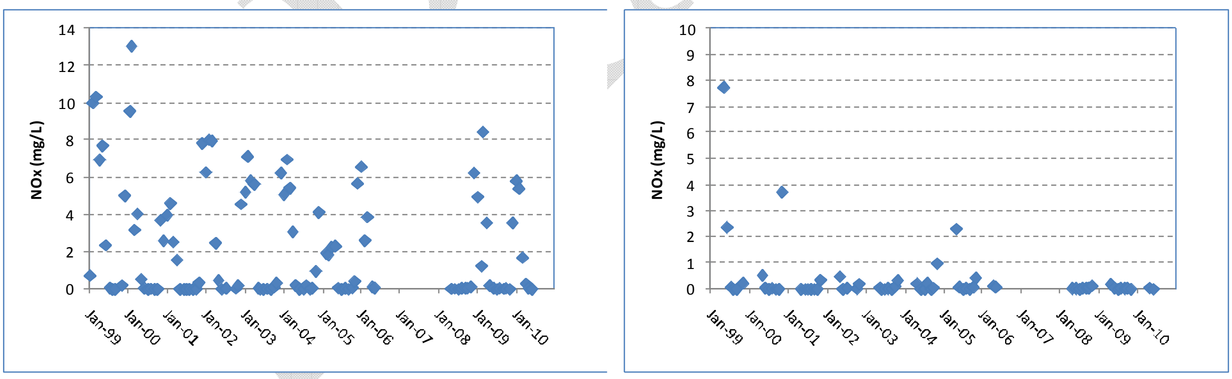


Figure 7-13. Time Series of Nitrate plus Nitrate N at Station MC-1 for the Full Year (left) and for April 15 – November 15 (right)

LVMWD (2011) suggests that nitrate concentrations in the watershed are naturally elevated in runoff due to the Monterey/Modelo formation, and notes the elevated concentration in Las Virgenes Creek (median of 2.88 mg/L). Figure 7-14 compares average nitrate-N concentrations at stations with significant amounts of data. The highest concentrations are indeed found in the stations in the Modelo formation; however, at LV-9 and CH-6, both of which drain portions of the Modelo Formation, the nitrate-N (and also the ammonia-N) concentrations are near zero. It is noteworthy that these two stations are upstream of most high density development in the watershed, whereas the other Modelo formation stations are downstream of high density development areas.

At Las Virgenes Creek, station LV-9, upstream of development, had an average nitrate-N concentration of 0.009 mg/L; station LV-13, in the midst of the development near highway 101, had an average of 1.26 mg/L; and LV-5, downstream station showed an average of 4.25 mg/L. It appears that the elevated nitrate concentrations are influenced by the amount of development upstream, and not necessarily due to the Modelo Formation. Concentrations in the main stem represent a mix of concentrations at the upstream stations and appear to be influenced by the high concentrations at LV-5.

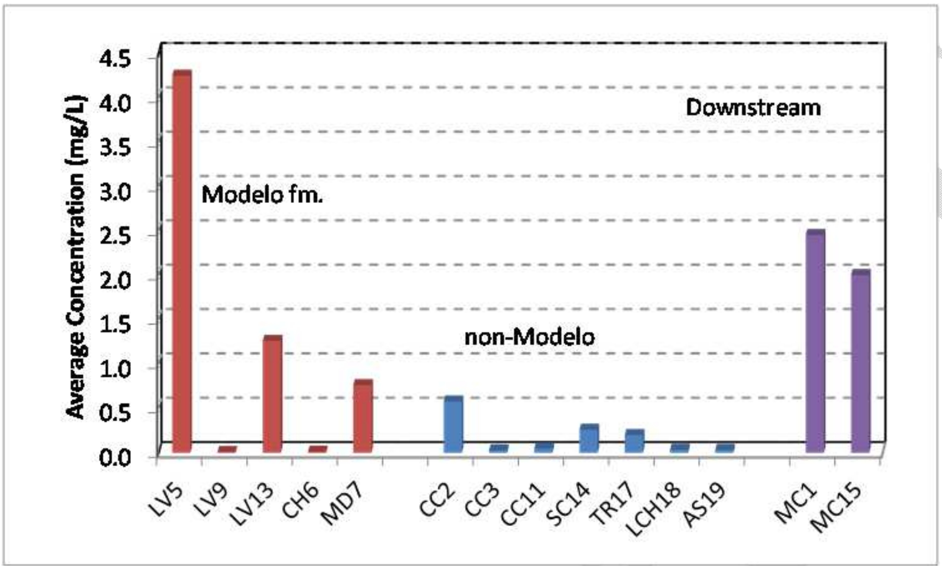


Figure 7-14. Average Nitrate-N Concentrations at Stream Team Sampling Sites

Results from MCWMP sampling provide similar insights. Both stations LV1 and LV2 drain the Modelo formation, but LV2 is downstream of development while LV1 drains open space. Summer median inorganic N concentration was 0.30 at LV1; the LV2 concentration was 3.01 (Table 7-8), suggesting that the increased inorganic N concentrations are more associated with development than with geology. The undeveloped CC station also showed low nitrogen concentrations.

7.5.2 Ammonia N Trends

Ammonia concentrations are generally low in the Malibu Creek main stem, with a few high outliers. The main stem stations may be slightly elevated relative to the reference sites (Figure 7-15). The acute criteria for ammonia are pH dependent. Comparing each observation to the corresponding acute criterion concentration (including recent data from MC-15) revealed no excursions of the acute ammonia criterion.

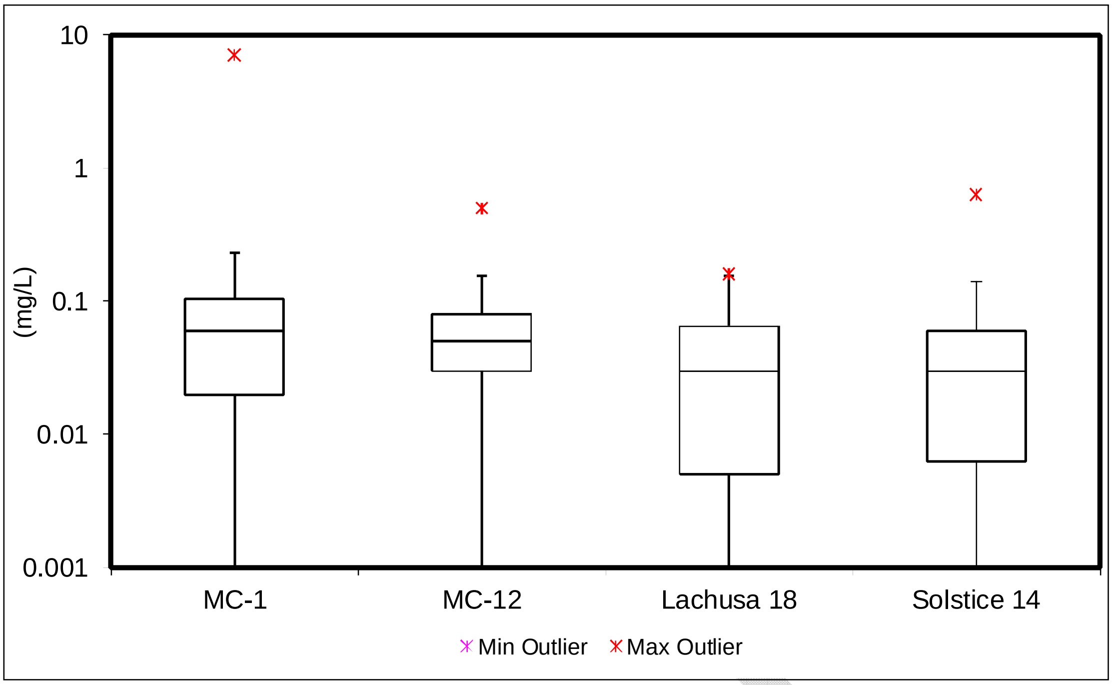


Figure 7-15. Boxplot of Ammonia as N Measurements from Malibu Creek and Stream Team Reference Sites

7.5.3 Orthophosphate as P Trends

As with nitrate N, the 2003 nutrient TMDL established a target concentration for total P. This is 0.1 mg/L, applicable from April 15 through November 15. Heal the Bay does not monitor total P, but instead reports PO_4-P. Average concentrations of PO_4-P (all time periods) in the Stream Team sampling are greater than 1 mg/L at both MC-1 and MC-15, downstream of the Tapia discharge, and are clearly elevated compared with the reference stations (Figure 7-16). Concentrations at MC-12, upstream of Tapia, are more similar to the reference sites, suggesting that winter and historic summer loading from Tapia continues to affect concentrations of orthophosphate in Malibu Creek. Time series of observations at MC-1 during the summer TMDL period show little decline with time and continue to be frequently above 1 mg/L (Figure 7-17).

LVMWD (2011) shows somewhat lower orthophosphate concentrations in lower Malibu Creek with an overall median of 0.48 mg/L; but this is still above the target. Average concentration during summer 2009 at MC-1 was 1.16 mg/L. In general, the 2003 Nutrient TMDL targets have not been achieved. PO_4-P concentrations in lower Malibu Creek are highly elevated, and typically higher than the inorganic N concentrations, suggesting that phosphorus is not limiting algal growth. The high nutrient concentrations present at MC-1 suggest that both phosphorus and nitrogen are present at concentrations that likely promote algal growth. This matches well with the results from USEPA's physical habitat assessment, which showed a high percentage of algal cover in the stream at MC-1.

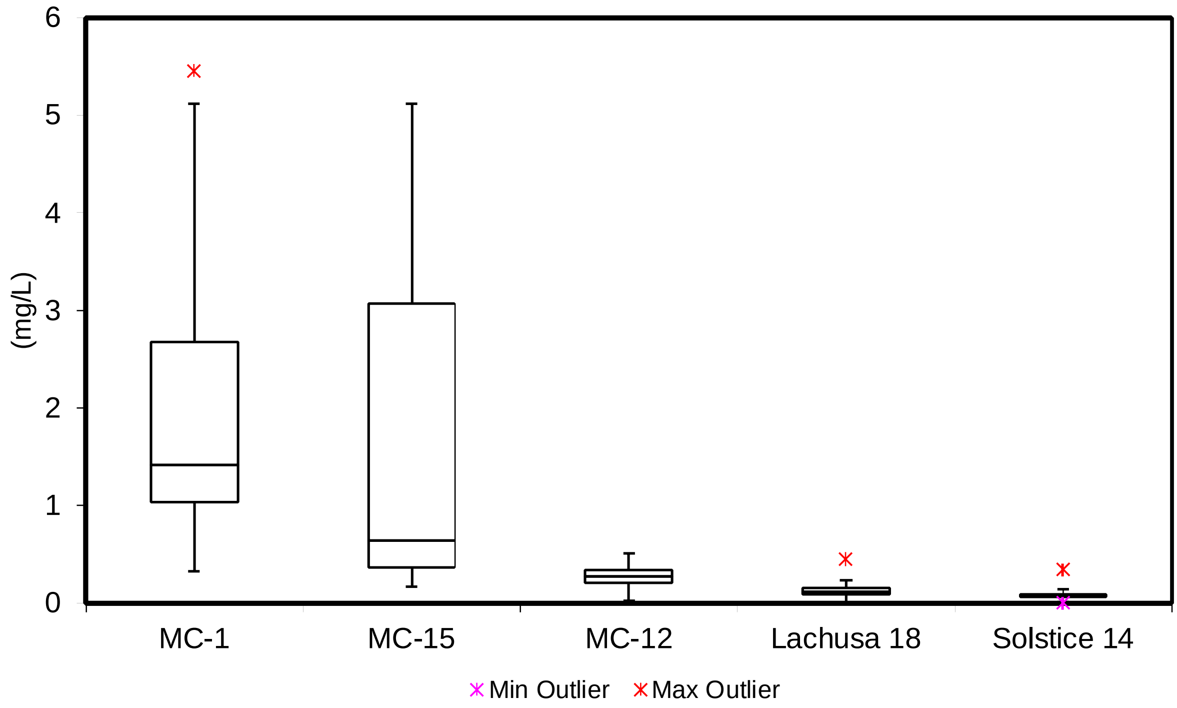


Figure 7-16. Boxplot of PO_4-P Measurements from Malibu Creek and Stream Team Reference Sites

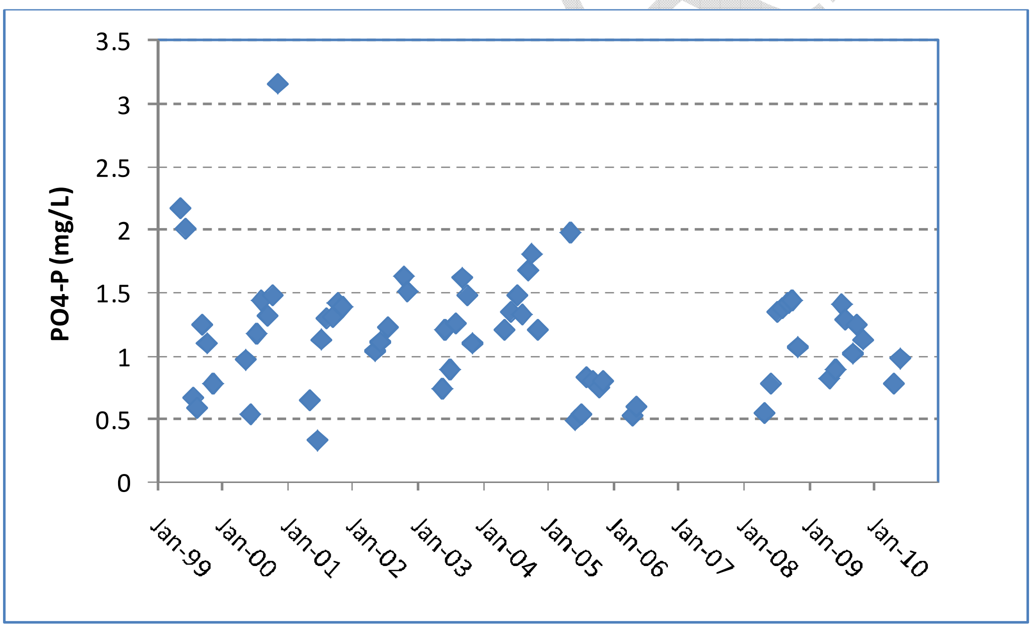


Figure 7-17. Time Series of PO_4-P Concentrations at MC-1 during the Summer (4/15-11/15) TMDL Period

As with nitrate-N, LVMWD (2011) suggests that elevated P concentrations in the watershed are mainly due to runoff from the Modelo formation. Average PO_4-P concentrations in the lower main stem are compared to concentrations in upstream stations monitored by the Stream Team in Figure 7-18. Some of the observed concentrations in the Modelo formation tend to be higher than those in areas of other geology. In the Stream Team data, there does not appear to be a strong correlation between concentration and intensity of development. MCWMP data do show that orthophosphate concentrations are higher at LV2 than at LV1, while the median at LV1 appears only slightly elevated relative to the CC station (undeveloped, not draining the Model formation). Concentrations of orthophosphate in the lower main stem are much higher than those seen at any of the upstream stations – likely due to continued cycling of phosphorus previously discharged to the system and stored in stream sediments. However, the considerably elevated concentrations at MC1 and MC15 indicate that the Modelo formation is not the only cause of elevated orthophosphate concentrations in the watershed. Note that CH6, a relatively un-impacted site draining the Modelo formation, shows average orthophosphate concentrations of 0.42 mg/L. Overall, the average phosphate concentrations are elevated four-fold at those sites draining the Modelo formation, elevated near twenty-fold at the sites downstream of Tapia's discharge, and hovering around the criterion level at the non-Modelo formation sites (Figure 7-18). These observations suggest that phosphate concentrations are consistently elevated in the water and a large contributing source of energy for primary production.

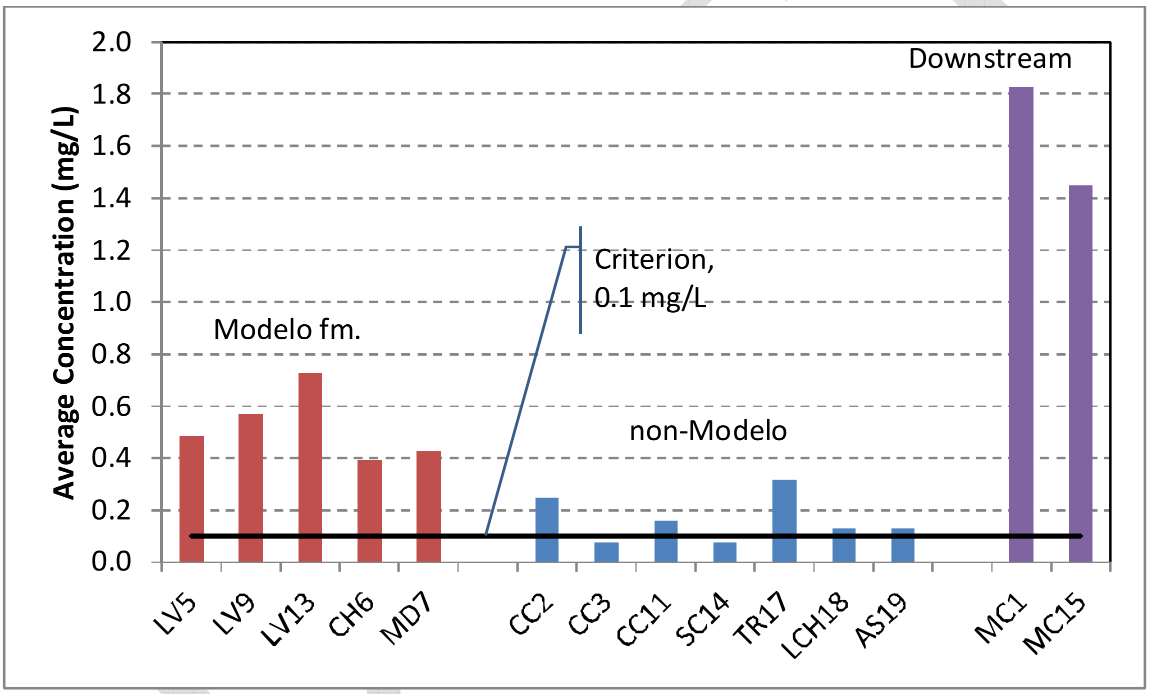


Figure 7-18. Average PO_4-P Concentrations at Heal the Bay Monitoring Sites

7.5.4 Nutrient Reference Conditions in the Malibu Creek Watershed

The Malibu Creek watershed is clearly affected by elevated nutrients. However, in some circumstances nutrients may be elevated due to natural geological conditions, such as drainage from marine sediments. A detailed review of the natural or reference conditions helped define the minimum level of nutrient enrichment that is attainable in the watershed,

Similar to the 2003 Nutrient TMDL, USEPA utilized the reference waterbody approach to develop numeric targets for impaired waterbodies within the Malibu watershed. This approach is described in USEPA guidance (USEPA, 2000a, 2000b). For streams, the reference approach involves using undisturbed stream segments to serve as examples of background nutrient concentrations (USEPA, 2000b). USEPA assessed the natural background or reference conditions for nutrients in the Malibu watershed are based on the best available data and information. Although available data exists to determine the best approximation of the natural background levels of TN and TP, there is some uncertainty due to observations that eutrophic systems, such as Malibu Creek Watershed (with high total N and total P), may show low inorganic N and/or inorganic P concentrations if more bioavailable forms of nutrients are already rapidly taken up by algae (as they become available through the decay of organic matter). Thus, primarily examining the inorganic N or P concentrations may not capture the excessive concentrations already converted to organic forms (i.e., algae). This trend has been observed in this watershed when extensive algal coverage was observed in conjunction with very low nitrate concentrations.

Malibu Creek watershed has unique geology, with many areas of marine sediments with the Modelo formation. For nitrate-N, median concentrations at potential reference sites without significant anthropogenic disturbance appear to be less than 0.03 mg/L and mostly less than 0.01 mg/L for many sites both in and outside the Modelo formation, although there appear to be higher concentrations at the MCWMP LV1 station (median 0.30 and 0.35 mg/L in summer and winter, respectively, perhaps increased by the presence of illegal dump sites and unstable stream banks in this reach) (Table 7-11). In contrast, sites downstream of development tend to have higher concentrations of both nitrate and total N.

The median total N concentration at the MCWMP LV1 station (draining the Modelo formation) is 1.33 mg/L in summer and 1.73 mg/L in winter. Reference sites reported by Busse et al. (2003) on Cold Creek and Palo Comado Creek appear to have lower total N concentrations (averages of 0.67 and 0.37 mg/L). Unfortunately, the total N concentration at other potential reference sites has not been monitored and is not known. For comparison, the survey of nutrient data for Level 3 ecoregion 6 (Southern and Central California Chaparral and Oak Woodlands, which includes the Malibu watershed; USEPA, 2000d) suggests reference conditions of 0.155 mg/L nitrate plus nitrite N and 0.518 mg/L total N. Interestingly, averaging the TN concentrations from Cold and Palo Comado Creek together results in 0.52 mg/L, exactly the recommended reference condition for a Level3 ecoregion 6 area.. The data in Busse et al. (2003) suggest that the inorganic N to total N ratio at reference sites may be has high as 38. Thus, a nitrate-N concentration on the order of 0.01 – 0.03 mg/L would correspond to a total N concentration in the range of 0.38 to 1.1 mg/L Thus, natural total N concentrations for the Malibu watershed could be as low as about 0.03 mg/L if the nitrate N concentration is less than 0.01 mg/L (Table 7-11). Our detailed discussion provided earlier suggests strongly that the presence of Modelo formation has little to no effect on inorganic and organic nitrogen levels in this Watershed.

However, for phosphorus, the Modelo formation may result in somewhat elevated levels for reference conditions. Only inorganic P has been monitored at potential reference sites, except for the results in Busse et al. (2003). Median orthophosphate P concentrations at potential reference sites outside the Modelo formation appear to be 0.14 mg/L or less (with average total P concentrations of 0.07 mg/L or less at Busse's reference sites); however, the reported median concentrations at relatively undisturbed stations within the Modelo formation are as high as 0.55 mg/L – suggesting that nitrogen is likely the limiting nutrient for algal growth under natural conditions within this watershed, with P typically present at concentrations in excess of algal growth requirements based on a typical ratio of plant cell concentration of 7.2:1 N:P on a mass basis (Table 7-11). However, it should be re-iterated that considerably elevated concentrations at MC1 and MC15 suggest the Modelo formation is not the only cause of elevated orthophosphate concentrations in the watershed. Although there is some indication that Modelo formation leads to somewhat elevated TP concentrations, the substantial elevated orthophosphate levels downstream of Tapia's discharge (more than twenty-fold) suggest that phosphorus concentrations are consistently elevated in the water Creek and a consistent source of available energy for algal production.

In sum, evidence to date indicate that natural reference conditions for the Malibu Creek watershed have a central tendency for the summer period of between 0.52 - 0.67 mg/L total N and 0.07 mg/L total P outside the Modelo formation, and around 1.30 mg/L total N and 0.55 mg/L total P within the Modelo formation (assuming that most phosphorus would be present as orthophosphate in areas of significant P surplus).

Table 7-11. Summary of observed nutrient concentrations at reference sites in Malibu Creek Watershed

Site/Source	TN (mg/L)	NO_3-N (mg/L)	TP (mg/L)	PO_4-P (mg/L)
Reference Sites		<0.03		
w/o Modelo		0.01-0.03	0.07	<0.14
w/ Modelo		0.01-0.03	0.55	
LV1 (Modelo) summer*	1.33	0.30		
LV1 winter*	1.73	0.35		
Cold Creek	0.67			
Palo Comado Creek	0.37			
Level 3 Ecoregion (USEPA, 2000d)	0.518	0.155		

*There is good indication that this elevated level at LV1 is affected by illegal dump sites nearby and unstable stream banks in the reach (Busse et al. 2003).

7.6 PESTICIDES DATA ANALYSES

Brown and Bay (2005) conducted additional studies of organophosphorus pesticides in the Malibu Creek Watershed, sampling two dry and two storm events in 2002-2003. Diazinon was the only organophosphorus pesticide detected in any of the creek samples, with measurable amounts in most of the dry-weather samples from Medea Creek, and both of the stormwater samples from Malibu Creek. Concentrations of diazinon in some samples exceeded the California Department of Fish and Game chronic criterion by up to a factor of 14 in Medea Creek. Concentrations within the Malibu Creek main stem did not appear sufficiently high to be a significant source of toxicity.

8. Biological and Habitat Data and Analysis

Analysis of biological and habitat data provide additional information regarding benthic impairments. These data are described in detail below.

8.1 MALIBU CREEK MAIN STEM AND TRIBUTARIES

8.1.1 Inventory of Biological and Habitat Data

Biological and habitat data have been collected in Malibu Creek by Los Angeles County Flood Control District, Heal the Bay, Inc., LVMWD, and others. The County, the water district, USEPA, and SCCWRP have also collected biological data in Malibu Lagoon. An inventory is provided in Appendix A. For Malibu Creek, biological sampling locations are shown in Figure 8-1 (below) and Table 8-1. In the case of Los Angeles County Flood Control District (Weston, 2011), fixed sites were monitored through 2008 and randomized sites in 2009 and 2010. Only the fixed sites are shown in the table and figure.

Table 8-1. Biological Sampling Sites in Malibu Creek Watershed

Site ID	Location	Organization	Slope
HtB-AS-19	Arroyo Sequit	Heal the Bay	3.7%
HtB-CC-11	Cold Creek	Heal the Bay	4.6%
HtB-CC-2	Cold Creek	Heal the Bay	1.9%
HtB-CC-3	Cold Creek	Heal the Bay	11.1%
HtB-CH-6	Cheseboro Creek	Heal the Bay	2.2%
HtB-LCH-18	Lachusa Creek	Heal the Bay	6.6%
HtB-LV-13	Las Virgenes Creek	Heal the Bay	1.7%
HtB-LV-5	Las Virgenes Creek	Heal the Bay	1.8%
HtB-LV-9	Las Virgenes Creek	Heal the Bay	1.7%
HtB-MC-1	Malibu Creek near mouth	Heal the Bay	0.5%
HtB-MC-12	Malibu Creek above Las Virgenes Creek	Heal the Bay	9.5%
HtB-MC-15	Malibu Creek below Cold Creek	Heal the Bay	3.5%
HtB-MD-7	Medea Creek	Heal the Bay	1.2%
HtB-PC-8	Palo Comado Canyon	Heal the Bay	2.9%
HtB-SC-14	Solstice Creek	Heal the Bay	3.7%
HtB-STC-16	Stokes Creek	Heal the Bay	3.9%
HtB-TR-17	Triunfo Creek	Heal the Bay	0.5%
HV	Hidden Valley Creek	Malibu Creek WMP	0.1%

Site ID	Location	Organization	Slope
LC	Liberty Canyon Creek	Malibu Creek WMP	2.1%
LIN1	Lindero Creek	Malibu Creek WMP	0.9%
LIN2	Lindero Creek	Malibu Creek WMP	2.8%
LV1	Las Virgenes Creek	Malibu Creek WMP	1.2%
LV2	Las Virgenes Creek	Malibu Creek WMP	1.6%
MAL	Malibu Creek near Mouth	Malibu Creek WMP	1.7%
MED1	Medea Creek	Malibu Creek WMP	1.3%
MED2	Medea Creek	Malibu Creek WMP	1.2%
PC	Potrero Creek	Malibu Creek WMP	0.5%
TRI	Triunfo Creek	Malibu Creek WMP	1.0%
LVMWD R-11	Malibu Lagoon	LVMWD	NA
LVMWD R-4	Malibu Creek	LVMWD	0.5%
LVMWD R-3	Malibu Creek	LVMWD	1.0%
LVMWD R-13	Malibu Creek	LVMWD	0.3%
LVMWD R-2	Malibu Creek	LVMWD	<0.1%
LVMWD R-1	Malibu Creek	LVMWD	0.5%
LVMWD R-9	Malibu Creek	LVMWD	0.3%
LVMWD R-7	Las Virgenes Creek	LVMWD	1.6%
LACo_15	Medea Creek	LA Co. FCD	2.1%
LACo_16	Las Virgenes Creek	LA Co. FCD	1.2%
LACo_17	Cold Creek	LA Co. FCD	4.4%
LACo_18	Triunfo Creek	LA Co. FCD	0.8%
EPA-1	Malibu Creek	USEPA	2.5%
EPA-2	Malibu Creek	USEPA	2.0%
EPA-3	Malibu Creek	USEPA	0.8%
EPA-4	Las Virgenes Creek	USEPA	0.6%

In this table, stream gradient is evaluated as far as revealed by the 10 meter (m) DEM (as well as a 3 m DEM available for the coastal area only) by using the following procedure:

1. Buffer each monitoring point by a circle with radius of 1,000 feet.

2. Determine stream elevations at the upstream and downstream locations where the stream crosses the circle
3. Divide by the stream reach length (from National Hydrography Dataset [NHD]) to get the gradient

These results are shown in Table 8-1 and suggest several of the sites are essentially low gradient (less than 1%), including the lower Malibu Creek site. The gradient estimates should, however, be used with caution because the DEM, even at 10 m resolution, may not resolve the stream surface elevation very well. Also, the results do not match up very well with the percent gradient results given for the MCWMP sites in the 2005 report (which says, for instance, that the lower Malibu Creek site had a 3 percent gradient). Those results were obtained by an inclinometer over a thalweg distance of 100 m, and are less precise (the 2005 report shows percent gradient as whole integers of 1, 2, or 3 percent only).

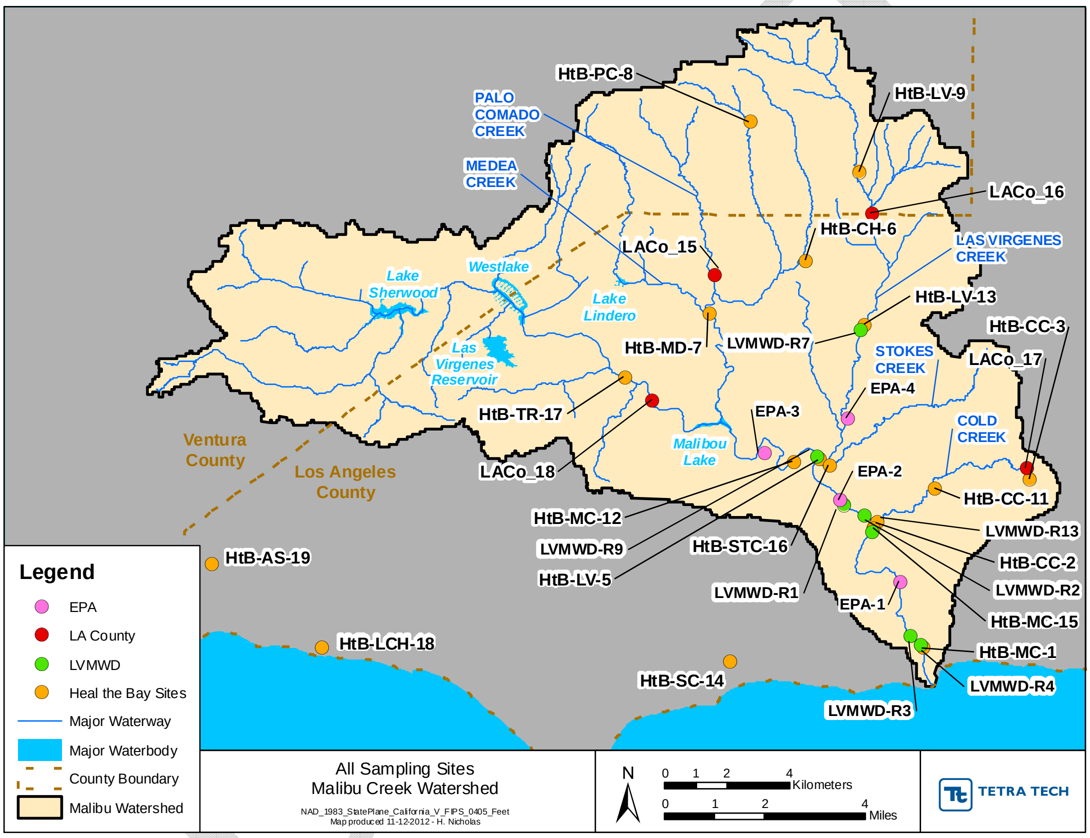


Figure 8-1. Benthic Macroinvertebrate Sampling Sites in the Malibu Watershed

8.1.2 Stream Benthic Macroinvertebrate Data

The main stem of Malibu Creek is listed as impaired based on poor benthic macroinvertebrate bioassessments. Sedimentation is also listed as impaired in Malibu Creek, and is closely linked to the condition of macroinvertebrate communities and their habitats.

A variety of organizations have collected benthic macroinvertebrate samples in the Malibu Creek watershed. The longest period of record and broadest spatial coverage is provided by data collected by Heal the Bay since 2000 (see Luce, 2003, for description of site selection and methods). Other large datasets have been developed by LVMWD and Los Angeles County. USEPA also collected macroinvertebrate samples from Malibu Creek and the Lagoon in 2010 and 2011.

This report focuses first on those samples collected from the main stem, as that was the original intent of this TMDL. However, many of the tributaries of Malibu Creek, such as Medea Creek and Triunfo Creek, have also shown poor to very poor bioscores. The results from the tributaries are examined for additional evidence as to the causes of low bioscores in the main stem.

8.1.3 SC-IBI Scores

Benthic macroinvertebrate data were collected according to SWAMP protocols and converted to bioassessment scores using the SC-IBI (Ode et al., 2005). The raw data are counts of individuals and measures of richness for taxonomic groups. These are converted to an IBI using a scoring system based on seven component metrics that were selected because they demonstrated correlation to disturbance variables and were non-redundant. Metric scores from zero to 10 are assigned to each of the seven metrics, which are then summed (with a maximum score of 70) and normalized to a scale of zero to 100. Ode et al. (2005) used a statistical criterion of two standard deviations below the mean score from un-impacted reference sites to establish a value of SC-IBI as an impairment threshold. The final category rankings are 0-19 = "very poor," 20-39 = "poor," 40-59 = "fair," 60-79 = "good," and 80-100 = "very good."

The reference sites defining the SC-IBI are based on two Omernik Level III ecoregions in coastal California: chaparral and oak woodlands (ecoregion 6) and southern California mountains (ecoregion 8). Since the majority of the reference sites considered in the SC-IBI study (Ode et al. 2005) showed moderate to high gradients, some concerns regarding the applicability of the scoring for low gradient stream sites (e.g., those with a slope of 1 percent or less) have been raised. Recently, Mazor et al. (2010) demonstrated that the SC-IBI yields reasonably consistent results in low gradient sites, although sensitivity to gradients in land cover was poor. Another important consideration raised is that standard sampling methodologies often fail to return the requisite sample size of at least 500 individuals for low gradient sites. However, as shown above in Table 8-1, analysis of DEM data (3 m for the coastal region and 10 m elsewhere) demonstrates that the majority of sampling sites on the Malibu Creek main stem had slopes equal to or greater than 1 percent. Furthermore, all the Heal the Bay samples from the main stem appear to have achieved the requisite sample size of 500.

Heal the Bay Benthic Data

A summary of Heal the Bay SC-IBI results for the main stem of Malibu Creek (Table 8-2 and Figure 8-2) shows that 41 of 44 samples (93 percent) are rated as either poor (yellow) or very poor (red) on the SC-IBI scale. The next table shows Heal the Bay SC-IBI results from selected sites in Malibu Creek tributaries and nearby Solstice and La Chusa Creek (some stations with only one or two samples are omitted). Medea Creek, Triunfo Creek, and Las Virgenes Creek show a preponderance of poor or very poor results, while other streams showed much better results.

Table 8-2. Heal the Bay SC-IBI Bioscores for Mainstem Malibu Creek, 2000 - 2011

Station	Spring 2000	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003	Winter 2005	Spring 2006	Fall 2006	Spring 2008	Spring 2009	Spring 2010	Spring 2011	Median (n>5)
MC1	16	24		39	19		26	23	26		26	21	30	6		25
MC1B			26													
MC12		23			33	27	21	31	20		17		17	3	13	21
MC12A			20	37												
MC13		39	23													
MC15					40	24	34	23			17		19	6	16	24
MC8	36	37														
MC8B		23														
MC9	33	17	24	43												
MC20										3						
MC21										4		29				

Note: SC-IBI scores rated as "poor" are shown in yellow; scores rated as "very poor" are shown in red.

Table 8-3. Heal the Bay SC-IBI Bioscores for Selected Tributaries to Malibu Creek and Nearby Streams, 2000 - 2011

Station	Spring 2000	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003	Fall 2003	Winter 2005	Spring 2006	Fall 2006	Spring 2008	Spring 2009	Spring 2010	Spring 2011	Median (n>5)
Cold Creek																
CC2	36		46	73	53		44		27/36	31/42			27	20	19	40
CC3	80	76	92	76	83	80	84	64	61	73		67	79/80	82	66	76
CC11	54	46	56	54	49		40			47			57	37/43	67	54
Las Virgenes Creek																
LV5	29	34	33	33	39	26	20	29	17/19	14/17			26	10		29
LV9					59	26	46		34	34			42	39	49	41
LV13					26	24	21	27	11	18			8	13		20
Medea Creek																
MD7	23	26	19	34	23		9	9	10	20			19	14		19
Solstice Creek																
SC14				87	76	76	67	70	63	60		56	69	49	59	67
SC22										64			53	44/46	58	58
Arroyo Sequit																
AS19				70	72	66	72	70	64	57		50	70	70	64	70
Cheseboro Creek																
CH6			59	57	64		49		54	43				34		54
La Chusa Creek																
LCH18				73	72	76	54	61	54	11			57	47	51	56
Triunfo Creek																
TR17	20		19		19		4		0	20			18	3	11	18

Note: SC-IBI scores rated as "poor" are shown in yellow; scores rated as "very poor" are shown in red.

LA Flood Control District Benthic Data

The Los Angeles County Flood Control District has conducted bioassessment in the watershed since 2003, with results obtained through 2010 (Weston, 2011). Fixed stations were used through 2008, with a switch to randomized stations in 2009. The fixed station sampling locations did not include Malibu Creek main stem (see Table 8-1 and Figure 8-2 below). However, in 2009 and 2010 there were randomized samples from the main stem. In 2009 a sample was collected at a site below Cold Creek, near Heal the Bay station MC-15. This yielded an SC-IBI bioscore of 29. In 2010 a sample was collected in the main stem just upstream of the confluence with Las Virgenes Creek, yielding an SC-IBI bioscore of 17. Both results are generally consistent with the results reported by Heal the Bay. Results for Los Angeles County's fixed stations are summarized in Table 8-4.

Table 8-4. Los Angeles County SC-IBI Bioscores for Fixed Samples Sites in the Malibu Creek Watershed

Location	Station	2003	2004	2005	2006	2007	2008	Median
Las Virgenes	LACo_16			39	24	29	23	26
Cold Creek	LACo_17	60	74	70	76	74	79	74
Triunfo Creek	LACo_18	31		29	26	27	21	27
Medea Creek	LACo_15	4	7	10	6	3	10	6

Note: Weston (2011) reports raw results on a 0 – 70 scale; these have been renormalized to the 0 – 100 scale for consistency with other sampling efforts. SC-IBI scores rated as "poor" are shown in yellow; scores rated as "very poor" are shown in red.

Additional benthic macroinvertebrate data were collected in spring and fall 2005 by Aquatic Bioassay (2005). Samples near MC-1 (location MAL) yielded SC-IBI bioscores of 33 and 17 in the spring and fall samples, respectively.

LVMWD Benthic Data

LVMWD has also collected benthic macroinvertebrate data since 2006 in connection with the Tapia WRF permit. The LVMWD sampling stations are summarized in detail in Table 8-5 (from Aquatic Bioassay, 2011) and are also shown on Figure 8-2 below. LVMWD's station R-4 approximately coincides with Heal the Bay station MC-1.

Table 8-5. Malibu Creek Watershed LVMWD Benthic Macroinvertebrate Sampling Stations

Station ID	Name	Position from TWRF Outfall	Distance (m) from TWRF Outfall	Latitude (N)	Longitude (W)	Elev. (ft)
R-11	Malibu Lagoon	Downstream	7470	34.03378	118.68291	3
R-4	Malibu Creek	Downstream	6290	34.04365	118.68488	26
R-3	Malibu Creek	Downstream	5860	34.04622	118.68847	44
R-13	Malibu Creek	Downstream	930	34.07642	118.70230	458
R-2	Malibu Creek	Downstream	150	34.08105	118.70500	468
R-1	Malibu Creek	Upstream	560	34.08423	118.71202	478

Station ID	Name	Position from TWRF Outfall	Distance (m) from TWRF Outfall	Latitude (N)	Longitude (W)	Elev. (ft)
R-9	Malibu Creek	Upstream	2500	34.09798	118.72170	495
R-7	Las Virgenes Creek	Upper Watershed	7650	34.13485	118.70682	721

SC-IBI scores reported by LVMWD have all been in the "poor" or "very poor" category (Table 8-6; see also Figure 8-2 below).

Table 8-6. SC-IBI Scores from LVMWD Stations

Season	Year	R-4	R-3	R-13	R-2	R-1	R-9	R-7
Fall	2006	24.3	20.0	25.7	17.2	22.9	Dry	24.3
Spring	2007	5.7	8.6	31.5	15.7	8.6	12.9	12.9
Spring	2008	22.9	14.3	11.4	8.6	1.4	2.9	2.9
Spring	2009	11.4	14.3	11.4	14.3	18.6	5.7	11.4
Spring	2010	23.0	13.0	27.0	9.0	19.0	7.0	14.0
Spring	2011	15.7	11.4	8.6	24.3	18.6	15.7	11.4

Note: SC-IBI scores rated as "poor" are shown in yellow; scores rated as "very poor" are shown in red.

USEPA 2010-2011 Benthic Data

USEPA conducted benthic macroinvertebrate sampling of Malibu Creek main stem to provide additional data and support (Table 8-7). USEPA sampled at five sites with two sites overlapping previous sampled stations by Heal the Bay and LVMWD. USEPA sampled at three additional reference sites along the main stem to enhance our knowledge of the reference conditions specifically along the main stem. There are a number of reference sites in other parts of the watershed, but limited sampling was conducted along Malibu Creek main stem.

Site MC1 is the same site sampled by HTB, located just upstream of the USGS mass emission station in the private residential Serra Retreat Community. MC EPA-1 is located upstream of MC-1 and downstream of Tapia WTP discharge along Malibu Canyon Road Hwy. Sites MC EPA-2 and EPA-3 are located in Malibu Creek State Park downstream of Triunfo and Medea Creeks, tributaries to Malibu Creek main stem. Malibu State Park is an expansive park, covering approximately 7,000 acres.

Both these sites were the best available reference sites for the main stem with no visible anthropogenic activities nearby. However, these sites are still strongly impacted by development activities upstream. For example, USEPA sited an additional site, MC EPA-4, upstream of MC EPA-3, along Las Virgenes Road which is outside of the State Park but adjacent to a large development community.

Table 8-7. Benthic metrics, abundance and S-IBI scores for the USEPA Sampling stations conducted in Spring 2011

	MC EPA#1	MC EPA#2	MC EPA#3	MC EPA#4	MC1
EPT Index (%)	56	6	1	33	48
EPT Taxa	7	4	2	4	6
Percent Chironomidae	11	5	17	9	16
Percent Dominant Taxon	22.1	80.9	80.7	23.1	23.4
Percent EPT Taxa	26	19	10	16	19
Percent Grazer Taxa	0	0	0	0	0
Percent Intolerant	1	1	0	0	2
Percent Mollusca	15	81	0	23	9
Percent Non-Insecta Taxa	33	29	35	28	29
Percent Oligochaeta Taxa	4	5	5	4	3
Percent Predator Taxa	19	24	20	20	29
Percent Collectors	56	13	96	56	53
Percent Scrapers	16	82	0	23	10
Percent Shredders	0	0	0	0	0
Percent Predators	5	1	1	4	9
Percent Tolerant	31	88	3	50	29
Taxonomic Richness	27	21	20	25	31
Tolerance Value	6.13	7.71	6	6.79	6.18
Total Abundance (#/sample)	12,460	13,114	3301	5923	10702
S-IBI scores*	20	17	20	3	13

* Based on the calculation of biological metrics from a group of 500 organisms from a composite sampled collected at each stream reach. The 500 organisms were used to compute the seven biological metrics used in computing the IBI score.

For the two sites in Malibu Creek State Park, a single dominant taxon was accounted for over 80% of the individuals collected whereas the other three sites outside of the park had approximately a fifth of the individuals as a single dominant taxon. The percentage of the highest tolerant species was observed in the State Park at MC-EPA2. The other site further upstream in Malibu State Park had the lowest percentage of tolerant species (3%); this site also had the highest percentage of collectors (96%). Taxonomic richness were comparable at all sites. These results indicate that the benthic community along the Malibu Creek main stem were all of poor condition and the sites located in the State Park did not fare better, likely due to the strong impact of the upstream development. This matches well with our analyses of the upstream development and impervious surface discussion. These data further confirmed the impaired condition of the benthic macroinvertebrate community along Malibu Creek. Other data also confirms that the impaired condition show tributaries flowing into Malibu Creek are also impaired, particularly those sites that are downstream of development of discharge.

Water quality taken at the time of the benthic macroinvertebrate sample collection showed that specific conductivity measurements were over 1.800 mmcho at all sites.

USEPA's sampling of the main stem of Malibu Creek also showed low SC-IBI scores. All five sites sampled by USEPA in May 2011 showed SC-IBI scores of "very poor" to "poor" conditions, with a S-IBI score of 20 as the highest value sampled at MC EPA-1 and MC EPA-3. Site MC-EPA4, located upstream and outside of the Park, but immediately downstream of a large residential development, showed the lowest SC-IBI score of 3.

Conclusion

Based on the similar trends of "poor to very poor" conditions observed from different data sets, USEPA concludes the evidence shows that Malibu Creek is impaired for benthic macroinvertebrate community.

While the current TMDL effort addresses only the Malibu Creek main stem downstream of Malibou Lake, it is informative to examine SC-IBI scores in the context of the whole watershed. Median scores for 2000-2010 are summarized in Figure 8-2, with land use overlain. Within the watershed, the median scores range from a low of 6 to a maximum of 78, with the highest score appearing in the unimpacted headwaters of Cold Creek. The lowest median scores are found in the main stem and in the lower portions of tributaries Triunfo Creek, Medea Creek, and Las Virgenes Creek. The tributary stations with low scores are upstream of the impaired portions of the Malibu Creek main stem and are also downstream of developed areas of the watershed, while stations upstream of developed areas had higher scores. This suggests that impairment in the Malibu Creek main stem may be associated with stressors (hydraulic and/or chemical) that originate within the developed areas of the watershed as well as other factors, such as geology.

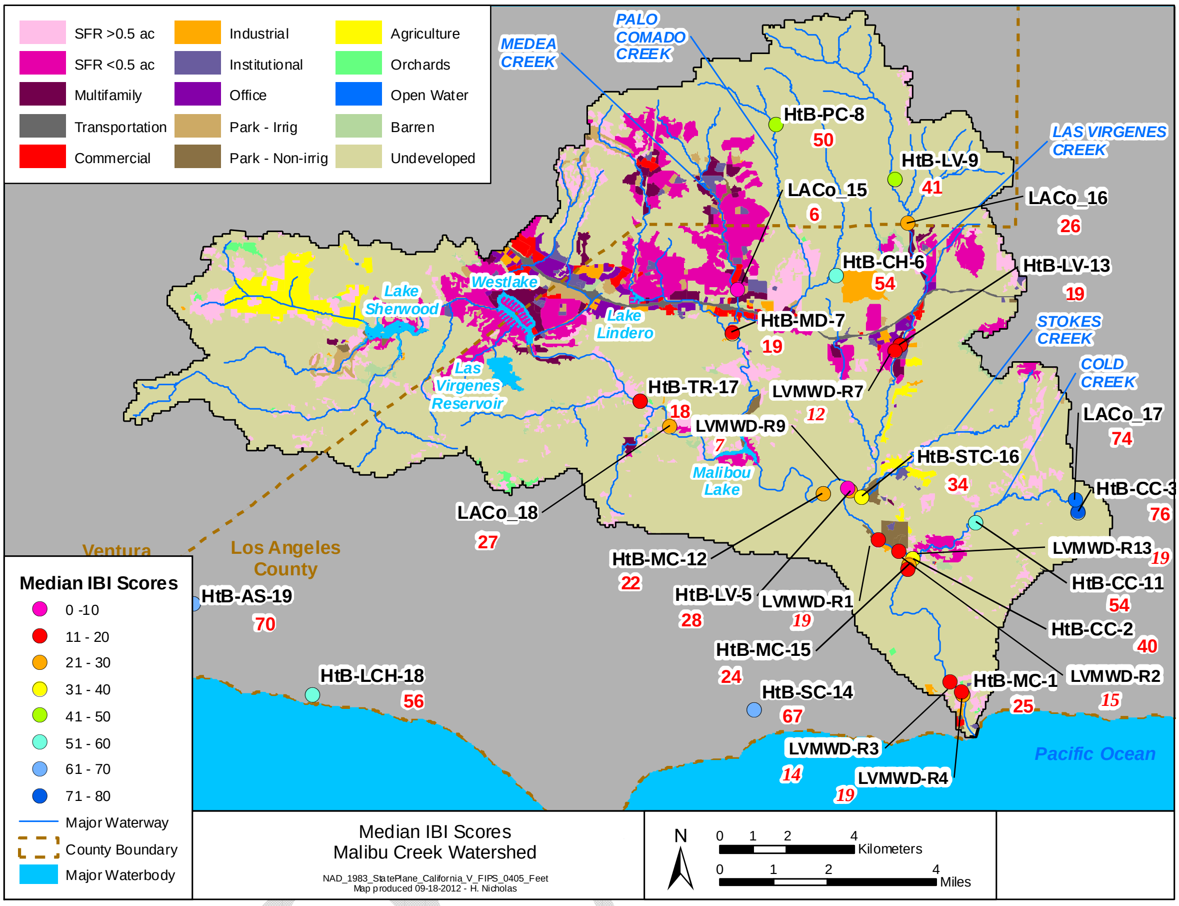


Figure 8-2. Median SC-IBI Scores (2000-2011) for the Malibu Creek Watershed and Adjoining Reference Stations

While extremely useful, the SC-IBI category rankings are not necessarily representative of the unique physical and geological situation of Malibu Creek. Another line of evidence can be developed by comparing results in Malibu Creek to results from undisturbed streams within the same immediate region. If appropriate undisturbed reference sites are available they should reveal important information on the biological potential of the local streams in the absence of human disturbance.

Selection of appropriate reference sites is challenging for Malibu Creek. Biological potential is influenced by a variety of factors including elevation (and associated micro-climate characteristics), gradient, and background geology. Heal the Bay identified La Chusa Creek (MC-18) and Solstice Creek (MC-14) as appropriate minimally disturbed reference sites for the Malibu main stem. These stations have the advantage of being at similar elevations to the Malibu main stem stations and are similarly proximate to the ocean. However, they differ in geology as they do not drain the Modelo formation marine sediments and have significantly lower conductivity than the Malibu main stem. To help rectify this problem, comparison can also be made to Cheseboro Creek (HtB CH-6). This station is in the upper watershed, but, unlike most other upper watershed stations, is minimally impacted by development. Cheseboro Creek does drain the Modelo formation and typically has conductivity values greater than 3,500 µs/cm (and is thus saltier than the Malibu Creek main stem). This station is, may appear less than ideal as a reference site because Heal the Bay SWAMP physical habitat sampling in 2010 showed that the substrate was 90% fines/sand and 10% bedrock, with no gravel or cobble, and only 64 percent of the banks were stable. However, perhaps in this Watershed and with the unique geology, this site is appropriate to use as basis for comparison with impacted sites; furthermore, this station does achieve acceptable SC-IBI scores.

SC-IBI scores show a clear difference between these sites, but little trend over time. A graphical comparison is provided by box and whisker plots, in which the central box represents the interquartile range, with a central line indicating the median or 50th percentile (Figure 8-3). The whiskers extend to 1.5 times the interquartile range above and below the third and first quartile values, while outliers beyond this range are shown as individual points. The SC-IBI comparison is depicted in Figure 8-3, showing no overlap in interquartile ranges between the Malibu Creek main stem stations and the reference sites. Interestingly, there is very little difference between the three main stem sites, even though they represent different stream gradients (0.5 to 9.5 percent) and include stations both upstream and downstream of the Tapia discharge. Further, the Cheseboro Creek station, draining the Modelo formation, typically exhibits IBI scores above the impairment threshold and much higher than are seen in the Malibu Creek main stem. Together, these observations suggest that (1) the Tapia discharge is not the single factor causing the observed impairment in the Malibu Creek main stem, and (2) high conductivity and other pollutants associated with the Modelo formation are also not sufficient to explain the impairment and seem to cause, at most, an incremental reduction to potential IBI scores.

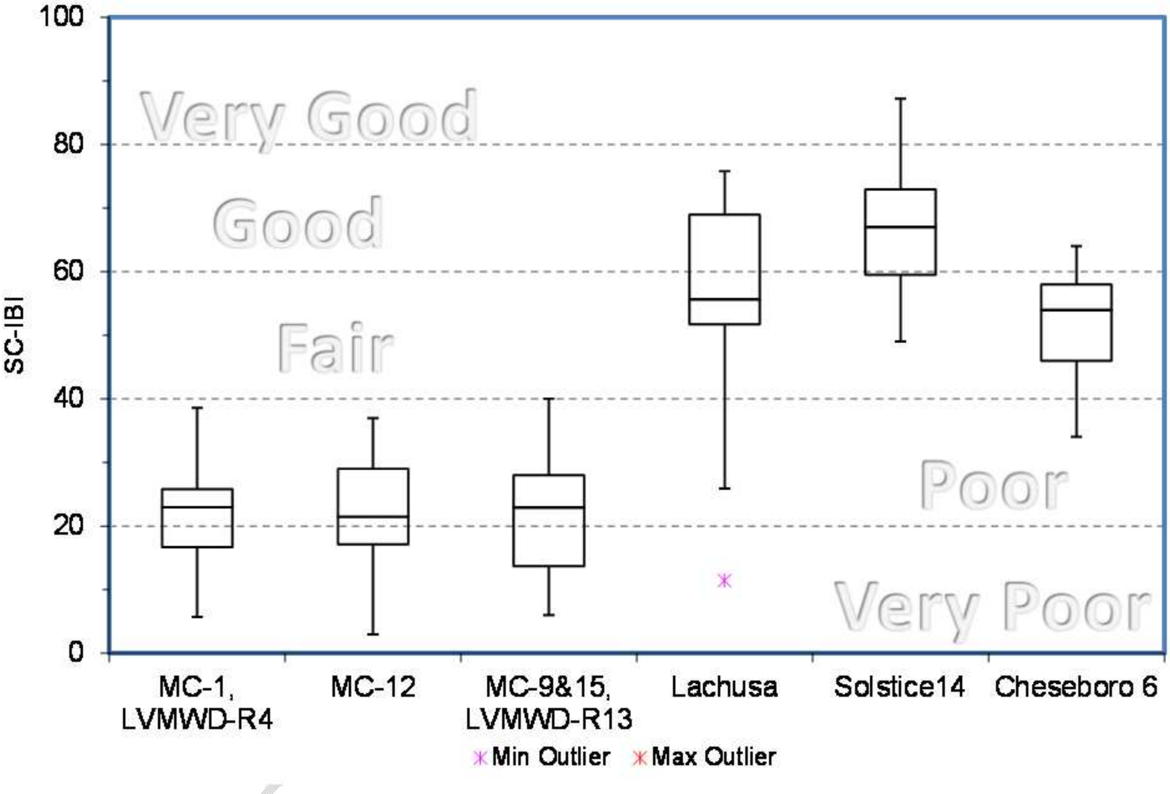


Figure 8-3. Comparison of SC-IBI Distribution for Malibu Creek to Local Reference Sites, 2000-2011

8.1.4 O/E Analysis of Benthic Macroinvertebrate Data

In keeping with the SWRCB current efforts to define appropriate numeric biological objectives for the entire state, USEPA conducted additional calculations. Benthic macroinvertebrate data can be evaluated in multiple ways. This TMDL reviewed the most common approach of using the IBI approach to determine the condition of the benthic macrobenthic community (Section 8.1.3).

USEPA also evaluated an alternative to the IBI approach, which is the use of the O/E ratio, where O is the number of taxa observed in a sample and E is the expected number of taxa (see Appendix D for a detailed discussion of the O/E process). This involves building a statistical model to predict the assemblage that would be expected at any sampled site if that site were in reference condition. The predicted model is derived from evaluating the assemblage at established reference sites. The O/E model can be applied to any site, and the difference between the expected and observed assemblages indicates the site impairment.

In general, O/E refers to the specific percent of taxa expected in the absence of disturbance. E is a function of physical habitat predictors and is derived using an approach developed in Great Britain (Moss et al., 1987; Wright, 1995; Clarke et al., 2003) known as the River Invertebrate Prediction and Classification System (RIVPACS). RIVPACS-type models have been developed for southern California, as described below. The O/E presentation provides a useful addition to the IBI-based scoring.

8.1.4.1 O/E Methods

We estimated O/E scores for each Malibu Creek watershed site where such estimates were possible. (Note that this is a subset of the samples for which IBI scores are available, as raw taxa data were not available for all samples.) We took existing benthic macroinvertebrate data supplied by Heal the Bay, LVMWD, and from USEPA and condensed them into a sample-by-species matrix. Samples were assigned unique site-date identifiers. We resolved taxonomic resolution using an operational taxonomic unit cross-walk table provided by the California Department of Fish and Game (CDFG) for their O/E models. We used the models with chironomid taxa identified to tribe, so taxa were resolved to that operational taxonomic unit (OTU) list. We then collected physical habitat predictors needed for the O/E models through communication with CDFG experts and Dr. Charles Hawkins at Utah State University, who maintains a site for calculating the CA O/E index values. These predictors for California include mean annual precipitation and mean annual temperature (both obtained from PRISM), percent sedimentary geology, watershed area, and latitude and longitude. The Malibu sites all fall within a small area, so the range among samples of latitude, longitude, and average annual temperature is small, while wide variability is present in the other predictors (Table 8-8).

Table 8-8. Range of O/E Model Predictors for Malibu Watershed

Predictor	Minimum	Maximum	Average
Precipitation (mm/yr, from PRISM)	34.2	58.4	40.9
Average Temperature (C, from PRISM)	17.2	18.2	17.9
Percent Sedimentary Geology	1.8%	100%	64.1%
Watershed Area	1.4	282.6	122.0
Latitude (DD)	34.033	34.195	34.094
Longitude (DD)	-118.932	-118.587	-118.730

We extracted those predictors using GIS for all sites within the Malibu Creek Watershed for which we had invertebrate samples. The predictors were then matched to the invertebrate samples.

California is described in three O/E modeling regions. We ran the O/E models identified as CA_R2_NONMIDGES, corresponding to those regions of California with mean monthly temperature >

9.3 degree C, and mean annual precipitation < 895 mm, which is comparable to the Malibu Creek Watershed. O/E was estimated with models run using the software available on the Western Center for Monitoring & Assessment of Freshwater Ecosystems website (http://www.cnr.usu.edu/wmc/htm/predictive-models/predictivemodelsoftware) for this Region 2 model .

Output generated include verification that modeled sites were within the experience of the model; in other words, the conditions are consistent with those that can be predicted based on the calibration dataset. More detail on O/E models can be found on the Western Center website (http://www.cnr.usu.edu/wmc) under the predictive models primer.

8.1.4.2 O/E Results for Entire Watershed

All of the sites from the Malibu Creek Watershed and adjoining sites that were modeled were within the experience of the model (values of P for Pass in Table D-1 of Appendix D). This means that reliable macroinvertebrate predictions could be generated for each site.

In terms of O/E scores, which is the site specific percent of taxa expected in the absence of disturbance, these varied by site location with some scoring close to reference expectation (approximately > 0.8) and others scoring close to zero (See Appendix D for predicted data).

In general, O/E scores were weakly correlated with SC-IBI scores, which explained about 35-37% of the variability based on either a linear or polynomial fit (Figure 8-4). This means that there was some disagreement between the two scores. This was especially true for sites scoring poor (P) or very poor (VP) for the southern California IBI score, but ranged between 0.9 to 0.1 for O/E scores. More agreement between the IBI and O/E scores were observed for those sites in the fair, good (G) and very good (VG) categories. These observations suggest that both biological approaches were successful at identifying the fair to very good sites. However, for "poor to very poor" sites, other variabilities also are critical to explaining the differences observed between the two approaches.

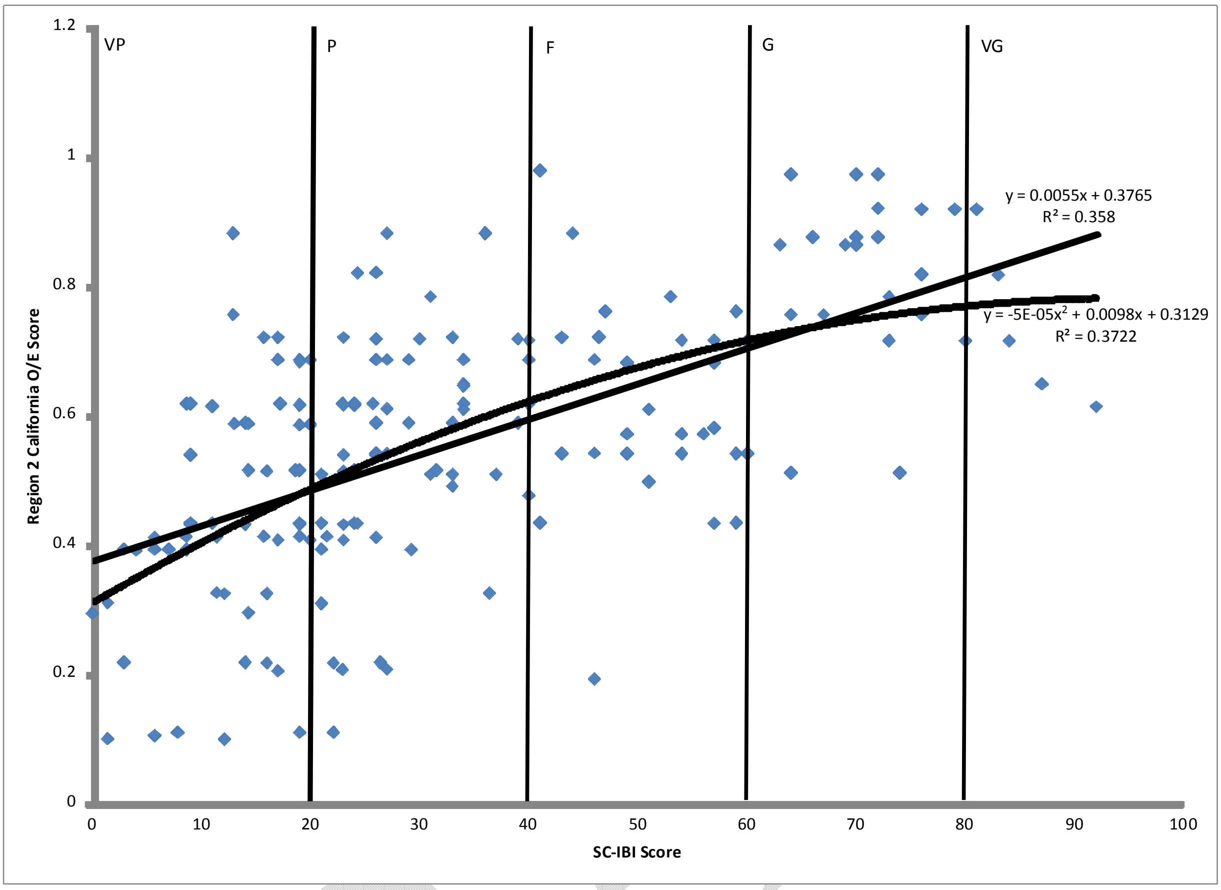


Figure 8-4. Plot of Individual SC- IBI scores vs. Region 2 California O/E scores (p>0.5) for the Malibu Creek Watershed Sites

While there are correlations between the two scores, there are also significant discrepancies. For example, the winter 2005 sample at MC-1 received a high O/E score (0.82) but a "poor" IBI score (26) on an original sample of 484 individual organisms rarefied to 300 for the O/E analysis. In contrast, the winter 2000 sample from Cold Creek had a fair IBI of 46, but a very low O/E of 0.19 (based on a sample size of only 30 organisms). The discrepancies between the two metrics are likely due to the probability basis of the O/E approach which evaluates the likelihood of observing different taxa within a sample of fixed size.

8.1.4.3 O/E for Malibu Mainstem and Reference Sites

The Malibu Creek main stem stations are of particular interest for the TMDL. O/E results for these stations are compared to the Lachusa and Solstice Creek reference sites in Figure 8-5. This appears to tell a rather different story from the IBI scores: For O/E there does not appear to be a significant difference between the Malibu main stem MC-1, MC-9, and MC-15 stations and the reference sites. In contrast, the IBI scores showed a strong difference.

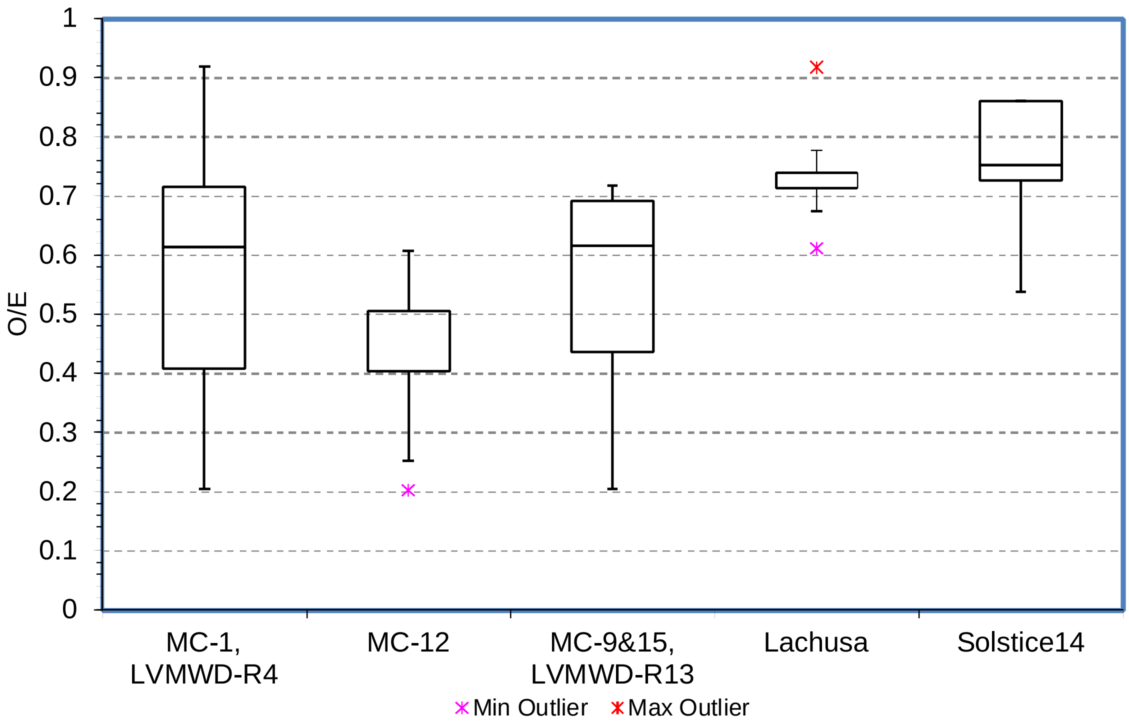


Figure 8-5. Comparison of O/E Distribution for Malibu Creek to Local Reference Sites, 2000-2010

8.1.5 Additional Analyses of Benthic Macroinvertebrate Data

It is of interest to examine some of the component metrics used to form the SC-IBI. This was done for the two main stem stations with the most data (MC-1 and MC-12). LVMWD-R4 results were added to those from nearby Heal the Bay station MC-1 for this analysis. Ode et al. (2005) identified the component "EPT taxa count" (Figure 8-6) as a particularly strong indicator of impairment (with < 10 taxa indicating impairment in the southern California mountains). This metric has a strong relationship to most sources of impairment, including nutrients and sedimentation. For Malibu Creek, the main stem stations have much lower EPT taxa counts than the La Chusa and Solstice potential reference stations; however, the EPT taxa count at Cheseboro Creek (which has elevated conductivity but little urban development) is similar to the downstream Malibu Creek stations. Thus, the EPT taxa, but not the overall IBI, may be sensitive to the high conductivity associated with marine sedimentary geologic formations in the watershed.

Coleoptera taxa and Trichoptera taxa appear to be strongly sensitive to urbanization and channel modification, but not to nutrients (Ode et al., 2005). Coleoptera taxa are included as a component in the SC-IBI, with an impairment threshold at < 2 (which leaves limited leverage with which to distinguish Malibu Creek from the reference sites). Trichoptera taxa are not a component metric within the SC-IBI, but also appear to show good discrimination relative to the reference sites with low conductivity (Figure 8-7).

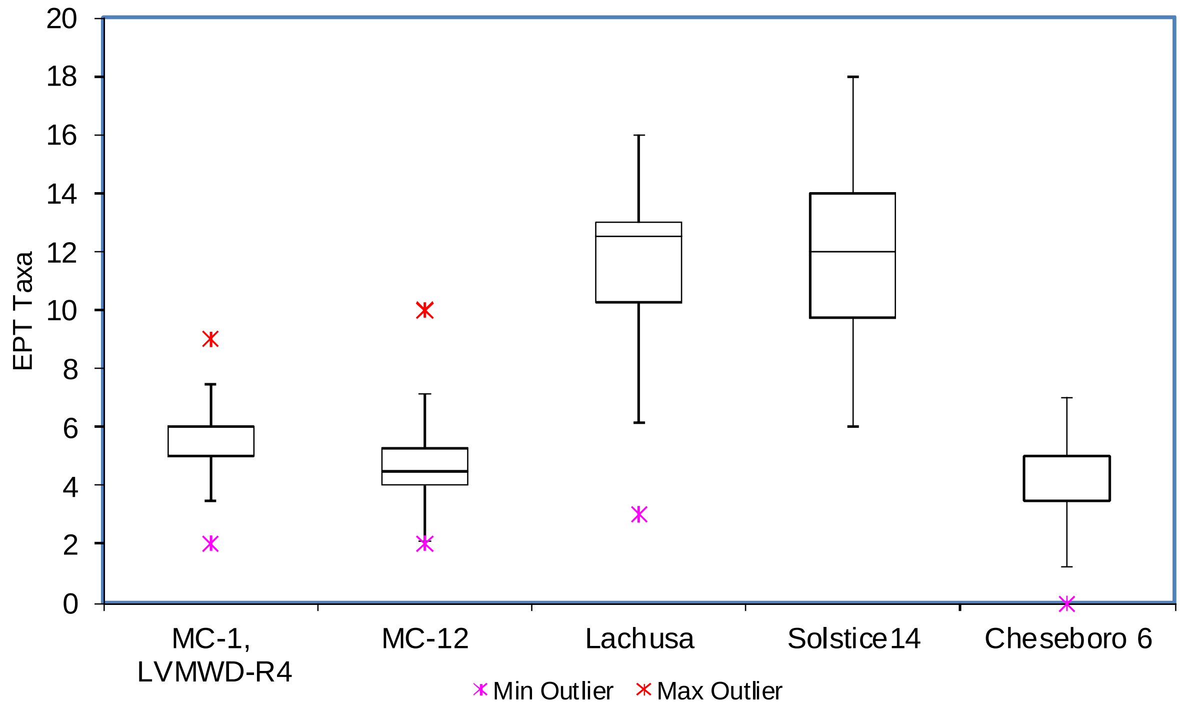


Figure 8-6. Comparison of EPT Taxa Count for Malibu Creek to Local Reference Sites

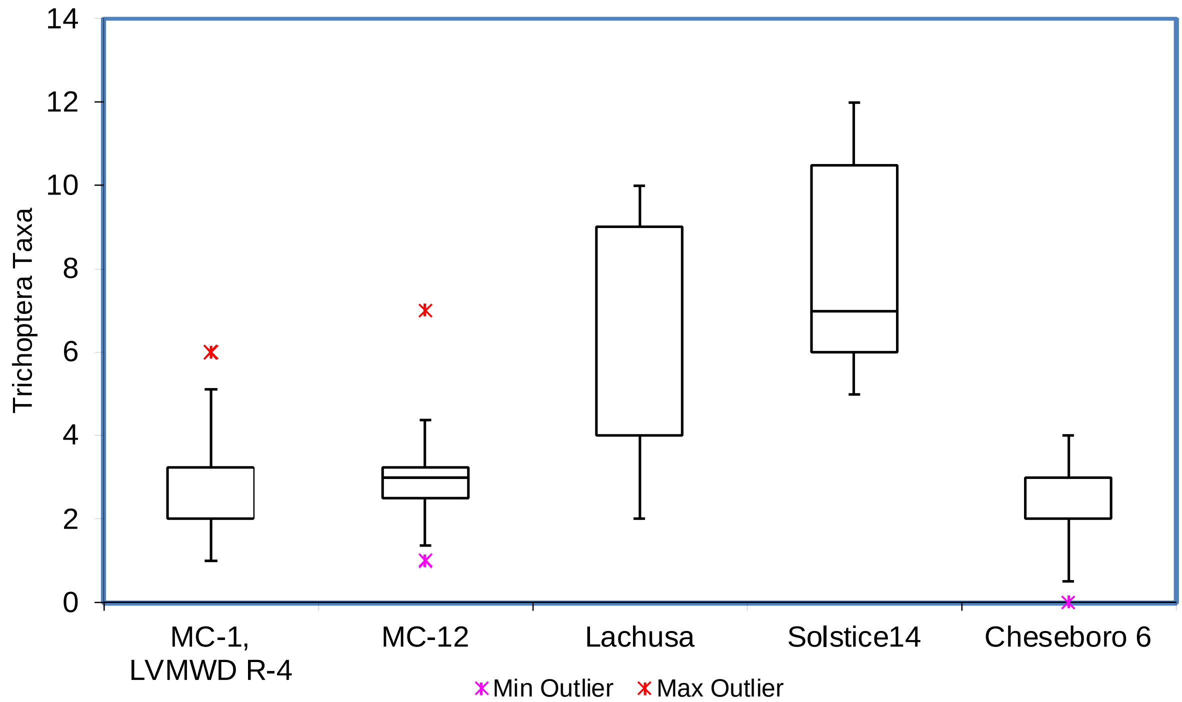


Figure 8-7. Comparison of Trichoptera Taxa Count for Malibu Creek to Local Reference Sites

The SC-IBI scores vary from year to year. There does not appear to be any clear trend over time at the MC-1 station and nearby LVMWD R-4 station (Figure 8-8) and the median has remained around 20 - 25. A notable anomaly in the MC-1 results is the low score for spring 2010. In contract, the R-4 station reported a more typical result for 2010, but yielded a very low score for 2007. Low values were also obtained by Heal the Bay in the Spring 2010 at MC-12 and MC-15 (3 and 6, respectively) while reference site scores dropped from 69 to 49 at AC-14 and from 57 to 47 at Lachusa. The 2010 results might thus be affected by weather or some other confounding factor.

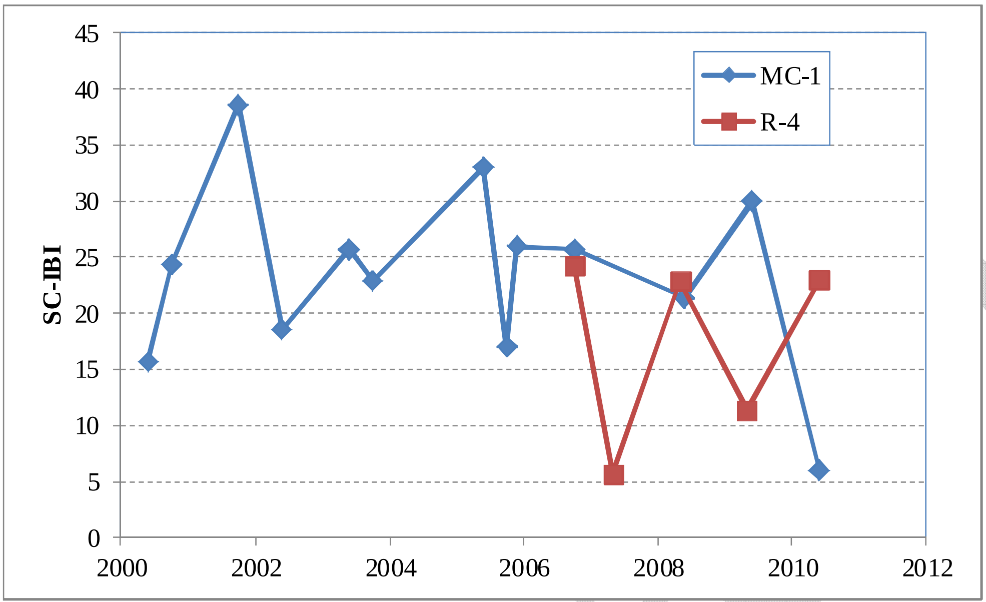


Figure 8-8. SC-IBI Scores over Time at Malibu Creek near Mouth (MC-1 and LVMWD R-4)

LVMWD (2011) suggests that low IBI scores are primarily due to high sulfate levels derived from the Modelo formation, which is exposed in the northern tributaries of Malibu Creek north of highway 101 (refer to Figure 4-4 above). LVMWD also notes that sulfur-seeps and springs within the Modelo formation support sulfur-reducing microbial communities that reduce sulfate to hydrogen sulfide gas (H_2S). H_2S is toxic to most forms of aquatic life, but is likely to be quickly oxidized, reducing the likelihood of impacts except in the immediate area of sulfur seeps.

Heal the Bay does not monitor sulfate, but does report conductivity, which provides a good surrogate for identifying the contribution of loads from the marine Modelo formation.

Figure 8-9 shows the correlation between median IBI and median conductivity for sites with at least five samples from 2000 through 2010 (water quality data were not yet available for 2011). Higher conductivity values clearly distinguish the sites within the Modelo formation. Further, there appears at first to be a weak negative correlation ($R^2 = 0.30$) between conductivity and IBI. The simple linear regression slopes and R^2 values are presented for comparative purposes only and are not intended to be predictive as correlation does not imply causation. Note that the main stem stations (MC) as well as Triunfo Creek (TR17) have intermediate conductivity, yet very low bioscores. In contrast, the Cheseboro Creek station (CH6) is in the Modelo formation and has high conductivity, but has a median IBI score nearly as high as the Lachusa reference station.

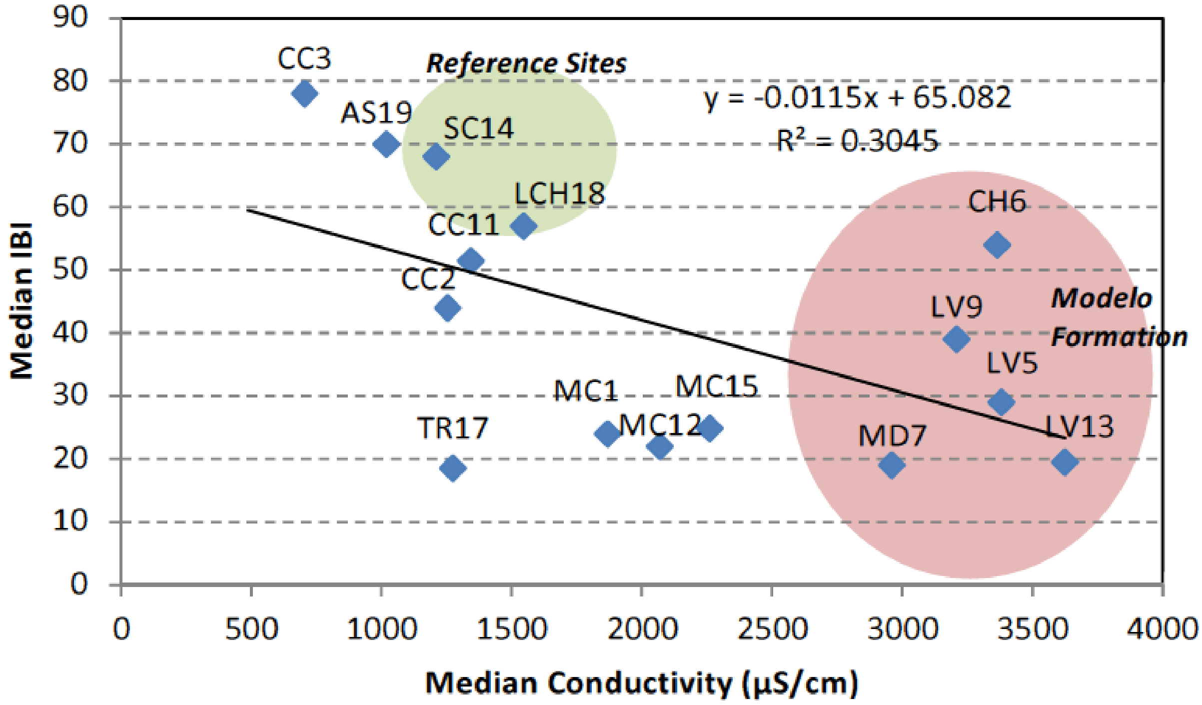


Figure 8-9. Correlation of Median IBI Scores with Median Conductivity

Note: Sites with at least five observations, 2000 – 2010. Median shown for MC-1 combines LVMWD R-4 samples; median shown for MC-15 combines LVMWD R-13 samples.

The apparent correlation of IBI and Modelo formation drainage may be confounded because the outcrops of this formation are located just north of the 101 highway corridor where most of the high density development occurs; the results appear to correlate better with the presence of upstream high density development (refer to Figure 4-7) than with Modelo formation drainage (Figure 8-10). Note that the Cheseboro station (CH6) is in the Modelo formation, but has little upstream development (and relatively high IBI scores), while the Triunfo station (TR17) exhibits low conductivity, but has plentiful amounts of upstream development (and very low IBI scores).

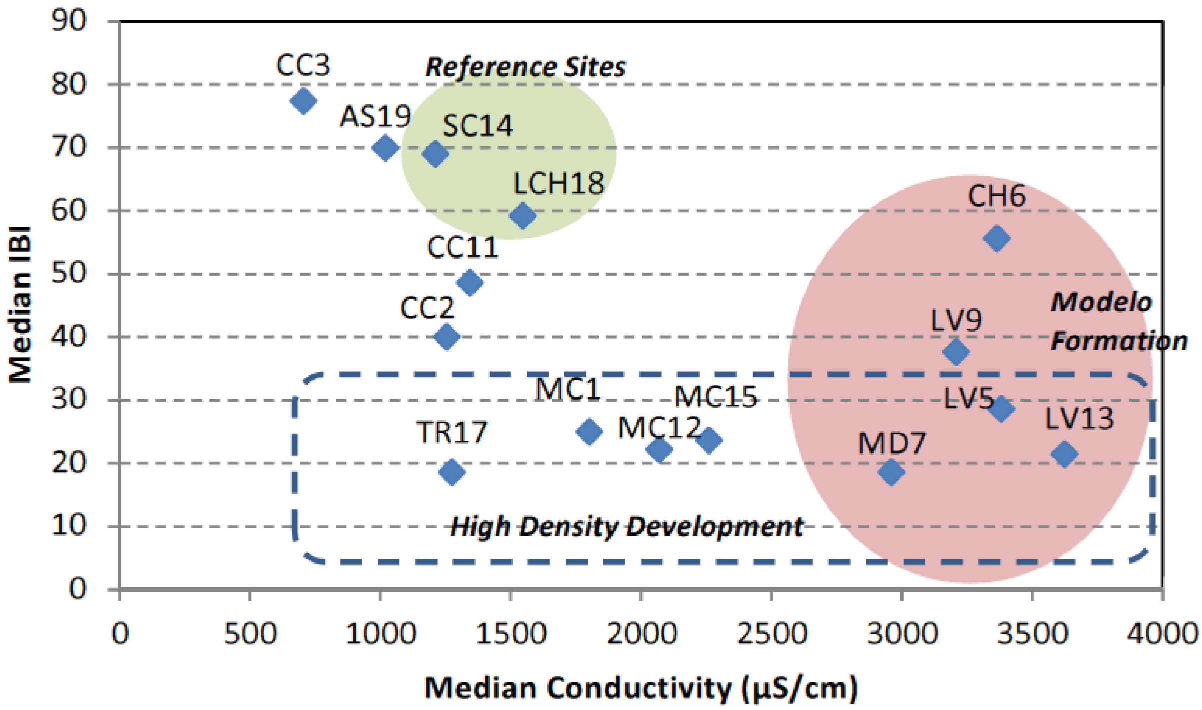


Figure 8-10. Correlation of Median IBI Scores with Upstream High Density Development

Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD R-4 samples; median shown for MC-15 combines LVMWD R-13 samples.

Median IBI scores at LV-13 and MD-7, downstream of the Modelo formation outcrops, are lower than those in the undeveloped areas of the Modelo formation (CH-6, LV-9), and also lower than those in streams that do not drain the Modelo formation at all (AS-19, CC-2, CC-3, CC-11). IBI scores are relatively high (median 56) at CH-6, within the Modelo formation, and low (median 19) at TR-17, with only a small fraction of its drainage in the Modelo formation. Notably, stations with low median IBI scores are also those stations that are downstream of significant amounts of urban development, which might explain the different responses seen at CH-6 and MD-7. As noted in Section 7.4, nitrate-N concentrations are also elevated at stations downstream of high levels of development.

Figure 8-11 shows that median IBI scores greater than 30 are only found at those stations that have an average nitrate-N concentration less than 1 mg/L (which is the target specified in the nutrient TMDL). This suggests that nutrient impacts may be one critical factor depressing benthic biotic health in the system. The correlation could also arise from the fact that elevated nutrients are found downstream of developed areas and not due to a causal relationship.

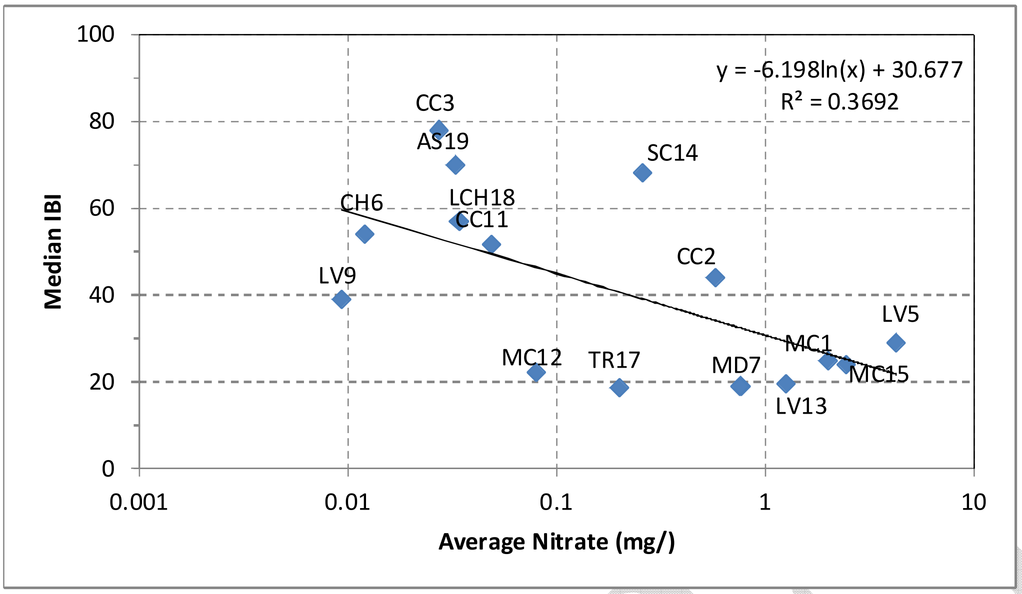


Figure 8-11. Correlation of Median IBI Scores with Average Nitrate-Nitrogen Concentration
Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD R-4 samples; median shown for MC-15 combines LVMWD R-13 samples.

Luce (2003) conducted multiple regression analyses of the relationship of IBI and other benthic macroinvertebrate measures to various habitat and chemical variables in the Heal the Bay data. She reported that the most significant correlations of benthic macroinvertebrate metrics were to substrate embeddedness (negative), percent canopy cover (positive), and conductivity (negative). No significant correlation was found to percent fines, percent sand, or macroalgal cover (e.g., *Cladophora*); however, microalgal cover (e.g., periphytic diatoms) emerged as a significant variable (with positive coefficient) for the EPT index and percent filterers. The relationship to conductivity was significant and negative for most benthic macroinvertebrate indices (except percent dominant species and percent filterers). Luce associates all three of the primary explanatory variables (embeddedness, canopy cover, and conductivity) with urbanization, but also noted that elevated conductivity occurred at some sites that lacked impervious cover and "increased conductivity must therefore have some other source, such as the geology of the watershed…" As was discussed above, it appears most likely that IBI scores are responding primarily to urbanization and only to a lesser degree, if at all, to conductivity itself. It thus appears that conductivity enters these regressions primarily as a surrogate for urban stormwater input, as was also suggested by Walsh et al. (2001) for studies in Australia.

Correlations to O/E scores were also examined. O/E is negatively correlated with conductivity and the relationship is similar compared with SC-IBI and conductivity (Figure 8-12). The correlation to nitrate-nitrogen is much weaker (Figure 8-13) than the SC-IBI (Figure 8-11).

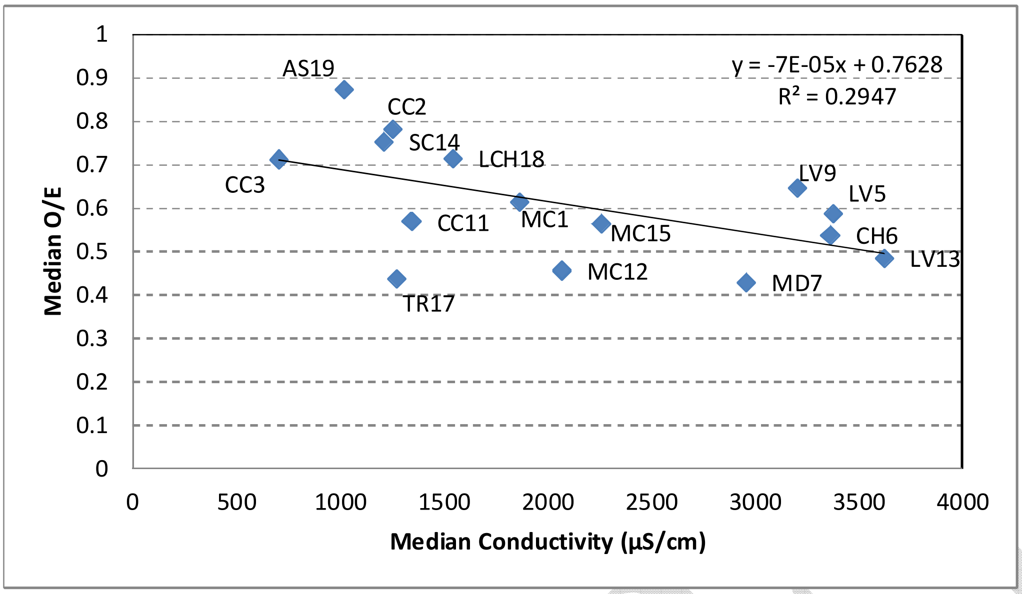


Figure 8-12. Correlation of Median O/E Scores with Median Conductivity.
Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD R-4 samples; median shown for MC-15 combines LVMWD R-13 samples.

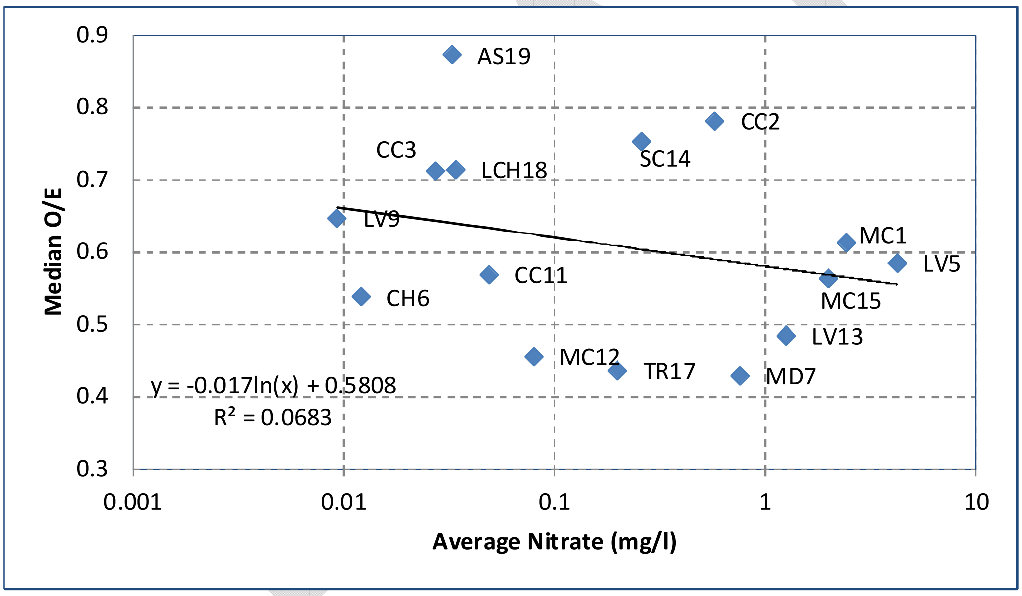


Figure 8-13. Correlation of Median O/E Scores with Average Nitrate-Nitrogen Concentration.
Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD R-4 samples; median shown for MC-15 combines LVMWD R-13 samples.

Bioscores were next compared to the fraction of total upstream area that is in sedimentary geology and the fraction of area that is impervious. For both SC-IBI and O/E, the median scores are essentially uncorrelated to percent sedimentary geology (Figure 8-14 and Figure 8-15). However, there is a strong negative correlation between bioscores and percent upstream impervious area (Figure 8-16 and Figure 8-17). The relationship to imperviousness is strongest for SC-IBI, which achieves an R^2 of over 69 percent. The regression line suggests that achieving an IBI of 40 would require cumulative upstream imperviousness of 3.3 percent or less. A similar level of imperviousness is also related to an O/E score of

0.5 or greater. These results suggest that imperviousness and urban development are significant indicators of biological condition in the Malibu Creek Watershed.

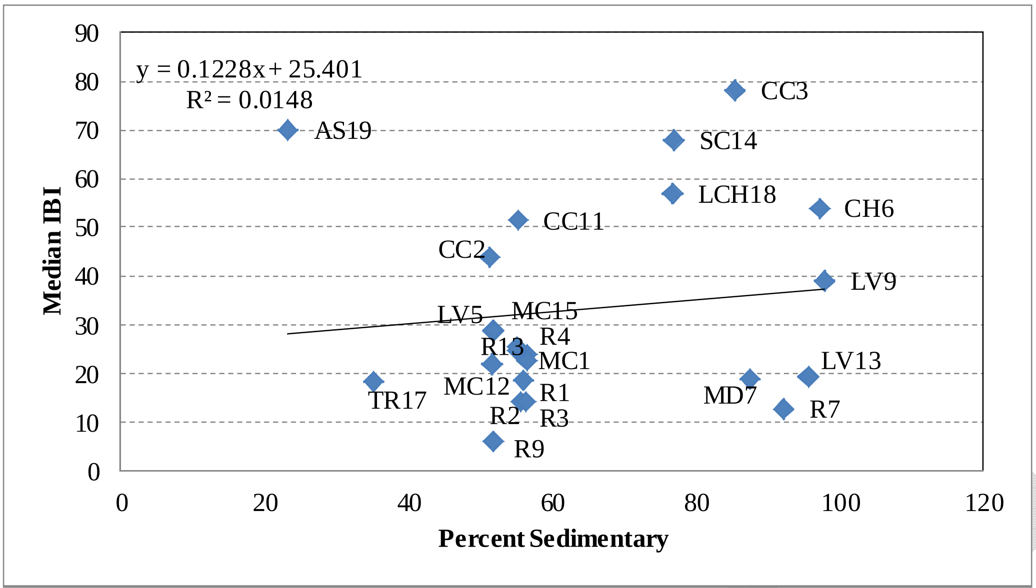


Figure 8-14. Correlation of Median IBI Scores with Percent Sedimentary Geology.
Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD R-4 samples; median shown for MC-15 combines LVMWD R-13 samples.

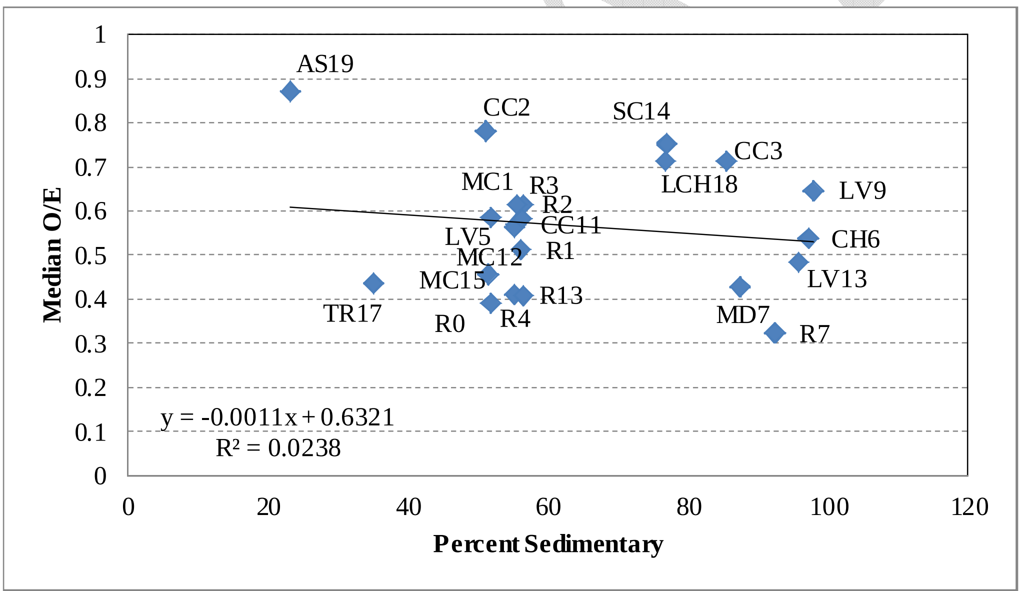


Figure 8-15. Correlation of Median O/E Scores with Percent Sedimentary Geology.
Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD R-4 samples; median shown for MC-15 combines LVMWD R-13 samples.

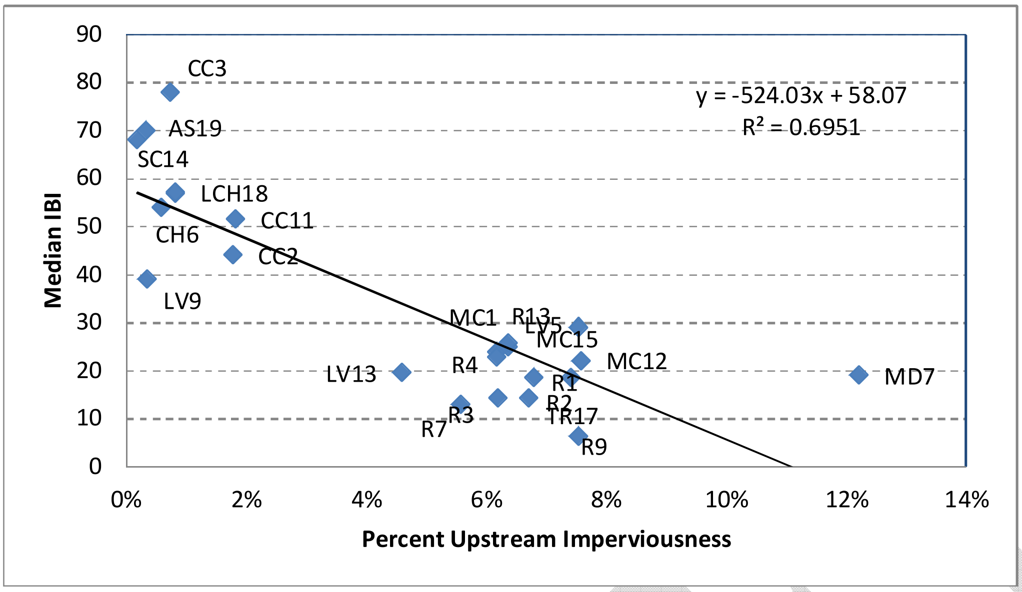


Figure 8-16. Correlation of Median IBI Scores with Percent Upstream Imperviousness.
Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD R-4 samples; median shown for MC-15 combines LVMWD R-13 samples.

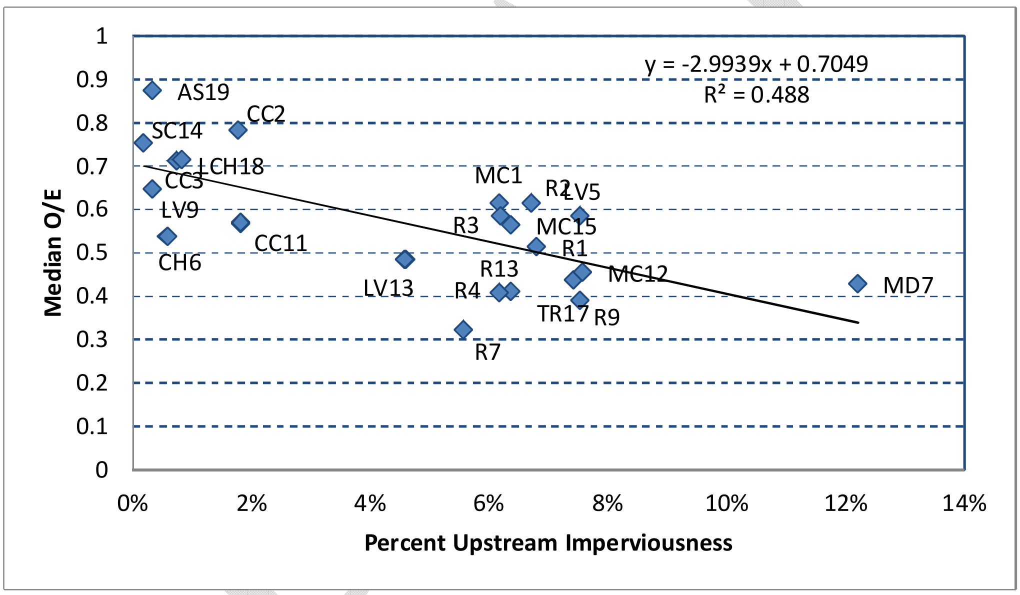


Figure 8-17. Correlation of Median O/E Scores with Percent Upstream Imperviousness.
Note: Sites with at least 5 observations, 2000 – 2010. Median shown for MC-1 combines LVMWD R-4 samples; median shown for MC-15 combines LVMWD R-13 samples.

8.2 Malibu Lagoon

Malibu Lagoon is naturally a lagoonal estuary with seasonal tidal influence. Historically, the beach barrier was beached by winter and spring runoff to allow for tidal exchange, and then restructure again and remain closed throughout summer and fall (Ambrose et al. 1995; Topanga-Las Virgenes Resources Conservation District 1989 and 1995). However, the impact of anthropogenic activities in the past has resulted in an altered pattern of Lagoon formation and breaching. Malibu Creek, which flows into the Malibu Lagoon, now receives year-round flow due to irrigation water, treated wastewater inputs and other urban related runoff. The year round flow creates higher summer water levels in the Lagoon and the sand barrier would artificially breach at times due to public recreational activity. In the past the sand barrier would be artificially breached to allow tidal exchange and clearing and release of nutrient buildup in the Lagoon. Although, this would temporarily improve water quality conditions, the life history of fish, such as the endangered tidewater goby, and the benthic community is directly affected.

Increasing urban development and decades of soil dumping have led to a dramatic loss of species in the Lagoon (Shifting Baseline, 2011; Jones & Stokes, 2006; Moffatt & Nichol, 2005), including benthic species such as crabs, shrimps, clams and other invertebrates that are a main component of the food chain for many fish and birds that are impacted by impaired conditions in Malibu Lagoon (Shifting Baseline, 2011; 2NDNATURE, 2010). Degraded by nutrient and bacteria pollution, as well as excessive sedimentation, these problems are exacerbated by poor circulation within the Malibu Lagoon's boundaries (Shifting Baseline, 2011; Jones & Stokes, 2006; Moffatt & Nichol, 2005; 2NDNATURE, 2010).

Due to low flushing, fine sediments accumulate in the tidal channels; these sediments are associated with greater nutrient loads that cause algae blooms, resulting in eutrophication (Shifting Baseline, 2011; Jones & Stokes, 2006; Moffatt & Nichol, 2005; 2NDNATURE, 2010). Eutrophication can be natural or caused by nutrient enrichment from anthropogenic activities. Malibu Lagoon currently shows elevated concentrations for the biologically-available nutrients such as Nitrogen Oxide (NOx), and Ammonium (NH_4) (Moffatt &Nichol, 2005; 2NDNATURE, 2010). Presence of excessive algae lead to greater consumption of the available dissolved oxygen during decomposition, and thus leading to anoxic conditions that impact the survival of the flora and fauna in the Lagoon.

Upstream runoff from residential areas and irrigation is estimated at a rate of 2,500--3,500 acre-ft annually. Multiple sources have estimated the seepage of septic tanks into the Lagoon, including an estimated rate of 500 acre-feet per year (Topanga-Las Virgenes Resources Conservation District 1995). The hydrologic flow and fate of dissolved or suspended material, such as nutrient, is complicated by the opening or closure of the mouth. Multiple factors influence the mouth condition, including erosion of sand from the mouth, large tidal flow, large freshwater input, long-shore sand transport and storm events. All of these factors can affect how the mouth and the hydrologic regime in the Lagoon will behave, which then impacts the biota that live in the Lagoon ecosystem.

Earlier dissolved oxygen levels showed stratification in the Lagoon and highly variable ranges. The diurnal dissolved oxygen levels surveyed in the morning between July 1993 and April 1994 at the westerly channel site showed a Lagoon bottom range between 2.6 mg/l to 10 mg/L and surface water range between 3.2 mg/L to 13.3 mg/L; the mid Lagoon site showed a bottom water range between 5.5 mg/L to 12.2 mg/L, and a surface water range between 6.2 mg/L to 16.8 mg/L (Ambrose et al. 1995). There were many occasions when the DO concentrations exceeded the basin plan water quality objective. Salinity concentrations from the Ambrose et al. (1995) report similarly showed stratification in the Lagoon and a wide range of salinity levels dependent on the flow of freshwater and opening of the mouth. Measurements of sediment in 1987 suggested the average rate of sedimentation since 1983 was 10 cm/year; this level of sedimentation is estimated to be nearly ten times the rate that would have occurred pre-European settlement periods (Topanga-Las Virgenes Resources Conservation District 1989).

In 1993 and 1994, Ambrose et al. (1995) collected benthic invertebrate data from Malibu Lagoon. Large and small infauna were collected from three sites in the Lagoon; a small clam gun was used to collect large infauna, a 10 cm deep sediment core was used to collect the small infauna, and zooplankton was sampled with a 153 um mesh plankton net. The largest proportion of infauna biomass was the collection of a single polychaete species. Other benthic invertebrates taxa collected included the California jackknife clam, two species of polychaetes, oligochaetes, ribbon worms, mud-flat clam, snails, crabs and the introduced oriental shrimp. Zooplankton species were dominated by copepods, ostracods and nematodes.

Malibu Lagoon continues to experience intense development and anthropogenic pressures both from the adjacent areas and upstream in Malibu Creek Watershed. The Watershed is highly modified by residential development, recreational reservoirs, and agriculture operations. In addition, the continuous discharge of water to the Lagoon year round from upstream sources and the past practice of mechanical breaching of the barrier beach during the summer and fall has disrupted the natural hydrologic cycle, altering the natural salinity and tidal cycles, which directly stresses the biotic community. The Lagoon also suffers from high nutrient concentrations seasonally.

8.2.1 Estuarine Benthic Biota

Estuarine invertebrates are found in the water, on vegetation, on the mud and in the mud (Lafferty 2005). Most species have the highest abundance in the summer and lowest abundance in winter and after high freshwater flows. In particular, the invertebrate community can be a useful indicator of the type of tidal inundation that an estuary receives. As mentioned earlier, invertebrates are particularly sensitive to variations in salinity (especially compared with fishes and birds). Sandoval and Lafferty (1995) found that the invertebrate community of estuaries with regular tidal influence is dominated by relatively *marine* species such as crabs, shrimp, polychaete worms, clams, mussels, and horn snails. In estuaries with variable salinity, these species are usually absent. Instead, aquatic insects, Marsh invertebrates are often inconspicuous, but they are a diverse group that includes benthic infauna and crustaceans in the lower marsh, and insects and spiders in the upper marsh (Josselyn, 1983; Zedler et al., 1992). A recent settlement plate survey done in Elkhorn Slough salt marshes found 25 different species of invertebrates including crustaceans, insects, spiders, snails, bivalves, and polychaetes (Griffith pers. comm.). Although not as species rich as adjacent tidal creeks, California salt marsh sediments can provide habitat for dense populations of oligochaetes and polychaete worms, while the lower elevation marsh surface is often dominated by gastropods, amphipods, isopods, and crabs (MacDonald 1969, Talley and Levin 1999, Williams and Desmond 2001). These species play important roles as detrital processors, algal grazers, and predators (Josselyn, 1983).

Data on benthic macroinvertebrates in Malibu Lagoon have been collected as part of the Bight 1998, Bight 2003, and Bight 2008 surveys (Ranasinghe et al., 2010). Researchers have also developed a benthic response index for California bays and estuaries (Smith et al., 2003; Ranasinghe et al., 2009). However, this is applicable only to haline and euryhaline communities. The majority of the samples obtained in Malibu Lagoon have been freshwater species (mostly larval beetles and flies), so the estuarine IBI is not applicable. On the other hand, the gradient within the Lagoon is essentially zero, so the stream-based SC-IBI for freshwater is also not applicable.

For Malibu Lagoon, aquatic life is "impaired by eutrophication resulting from excessive nitrogen loads" and direct input of inorganic nitrogen from onsite wastewater disposal systems is a concern (Callaway et al., 2009). The City of Malibu does not provide regional sewage collection or treatment, and high water tables decrease the efficiency of onsite wastewater treatment. The Malibu Creek Watershed nutrient TMDL assigned a load allocation of 6 lb/day of inorganic nitrogen; however, the Regional Board staff estimated that current loads from onsite wastewater disposal in the Civic Center area amount to 30-35 lb/day. As a result an amendment to the Water Quality Control Plan was made to prohibit new on-site wastewater disposal systems in the area. The evidence suggests, however, that existing loads may be sufficient to cause ongoing problems as the overall TMDL for total inorganic nitrogen in the summer season is only 27 lb/day.

Benthic community condition is a measure of the species composition, abundance and diversity of the sediment-dwelling invertebrates inhabiting surficial sediments. The benthic community measure is used to assess impacts to the primary receptors targeted for protection of aquatic life. Benthic community composition is a measure of the biological effects of both natural and anthropogenic stressors.

Southern California’s estuaries are categorized into seven different types: river mouth estuaries; canyon mouth estuaries; lagoonal estuaries; coastal dune-creek estuaries; bay estuaries; structural basin estuaries and artificial drain estuaries (Ferren et al. 1996). Malibu Lagoon is a lagoonal estuary defined by seasonally opened mouths, usually closed by sand bars most of the year, and brackish fringe-marshes rather than vegetated flats. Salinities can approach fresh water and the estuary can support fauna living in brackish to fresh water conditions (often fresh water input is due to wastewater discharge and agricultural or urban runoff) (Lafferty 2005).

An estuary is defined by its tidal influence, water source, water regime and unique composition of landforms (e.g., beds, bars reefs, levees, buoys, etc.). Salinity is another critical factor associated with habitat function. These include the amount and seasonality of freshwater input and the presence of a bar that can close off the mouth of the estuary from the ocean. Both of these features strongly influences habitat condition and the benthic community residing in the Lagoon because of regular periods of low salinity, high salinity, and tidal flushing that varies with the season (Lafferty 2005).

The Malibu estuarine Lagoon is no longer a natural system because the stream floods and storm waves are constrained by anthropogenic activities (Ambrose and Orme, 2000). The hydrologic inputs due to urban growth in the upper basin and the altered fire frequencies impact the lower basin by changing the magnitude and frequency of runoff and sediment delivery. There are many critical constrains on the physical system that has resulted in an altered estuarine Lagoon. These include road construction (Pacific Coast Highway (PCH) bridge and its approach ramps, the older Malibu Road, the Malibu Colony Road, Cross Creek Road and its upstream crossing – these impact drainage, constraining, diverting or ponding surface water and impeding exchange of subsurface water), variable upstream channelization and levee construction, riprap placed alongside Malibu Creek near the shopping center, and extensive areas of impermeable surface, which affect local hydrology, inhibiting infiltration, causing ponding or diversion of drainage into ditches and culverts. This results in a Malibu Colony area that is not mostly impermeable to direct precipitation and its impact on direct ocean-back water exchange.

During the flood of February 6, 1999, LACDPW data showed that 2,321 mg/L of suspended sediment was carried through Malibu Creek. Samples support that the Lagoon has higher sediment concentrations than stations farther upstream.

Infauna inhabiting the sediments of coastal lagoons typically includes clams, shrimp, crustaceans, worms, among others. Benthic infauna is a highly diverse group with hundreds of species. A typical southern California coastal Lagoon with appropriate tidal flushing should support between 100-200 infaunal species (Zedler et al. 1992; Peterson 1977). In contrast, coastal lagoons without tidal flushing will see significantly reduced species richness (Nordby and Covin 1988). During the 1993-94 sampling period, the basis of the impairment listing for Malibu Lagoon , only two families of polychaetes were observed; this is significantly fewer families than observed in Los Peñasquitos Lagoon (between 6 to 11 polychaete taxa), a southern California estuary similar in size to Malibu Lagoon and with frequently closed tidal flushing (Nordby and Covin 1988). Furthermore, the species richness for crustaceans and bivalves were also exceptionally low in Malibu Lagoon. In contrast, variability in benthic communities at Mugu Lagoon from 1969 to 1972 showed consistent community composition and little temporal variability in the population densities of the most abundant species of a sandy-bottom benthic community (Peterson 1977). Furthermore, 31 species were observed at Upper Newport Bay, 31 species at Tijuana Estuary and 52 species at Mugu Lagoon. These species richness observations indicate strongly that Malibu Lagoon, in comparison, has significantly lower species richness overall. Other coastal estuaries in southern California with poor tidal flushing also show similarly low invertebrate species richness, such as Los Peñasquitos Lagoon (n=20); San Dieguito (n=7), and Batiquitos Lagoon (n=9). These latter three Lagoon estuaries’ reported species richness in the 1970’s reflected long periods of prolonged mouth closure (Mudie et al. 1974 and 1976). After Los Peñasquitos and San Dieguito had been opened to the ocean (at least intermittently) in the 1990’s for a certain time period, the invertebrate species richness increased to

34 and 100, respectively. This compares well to the 100-200 types of invertebrate species observed for those coastal wetlands with good tidal flushing and ocean exchange.

8.2.2 Malibu Lagoon USEPA Sampling 2010-2011

USEPA conducted benthic invertebrate sampling at Malibu Lagoon during winter 2010 (November 8-9, 2010) and summer 2011 (May 24-26, 2011). To capture the largest range of benthic populations, USEPA applied four sampling methods to collect small infauna, large infauna, and invertebrates in the littoral zone and estuarine sediment at eight sites in Malibu Lagoon.

A total of 18 and 19 total taxa were collected in winter 2010 and spring 2011, respectively (Table 8-9 and Table 8-10). The spring 2011 sample collection resulted in near twenty times the total abundance collected in winter 2010 (230,621 individuals in spring compared with 12,104 individuals in winter across all eight sites). This is expected since spring season usually have greater diversity and abundance due to the climatic and flow conditions in the intertidal zone.

Sites S-02 and S-03 are located in the back sloughs where flow and circulation are limited; S-01 is located at C channel closest to the sand berm at the mouth; S-05 and S-06 are located on the eastern channel while S-07 and S-08 are located on the western channel of the Malibu Lagoon. For both winter and spring, the most abundant species collected was *Ostracoda Podocopida* species, a microscopic bivalve crustaceans commonly found in the littoral and sublittoral faunas of southern California (south of Pt. Conception). Podocopids are tolerant benthic species, crawling over or burrowing beneath the sediment surface, through the interstices of shelly sands and gravels, over rocks and plants, or through microalgae.

Located at the head of the estuary with consistent upstream freshwater flow, Site S-08 showed the most number of taxa collected. Sites S-02, located in the back channels with limited flow, and S-04, located closest to the Lagoon mouth in the central part of the Lagoon, showed the largest abundance (3,428 and 3,401, respectively; Table 8-9). However, the largest proportions of species sampled for S-02 and S-04 are podocopids and nematode round worms, both of which are highly tolerant species that can survive in highly impacted conditions. Sites S-02 and S-05 had the highest taxa richness collected. Similarly, S-05's largest proportion of species are podocopids and nematode round worms. Less tolerant species, such as a few of the aquatic and terrestrial insets had between 1-10 individuals. These results suggest strongly the poor benthic community diversity and abundance.

In spring 2011, Sites S-01, S-04, and S-05 (129,289; 40,904; and 43,610; respectively; Table 8-10) showed the significantly greater number of individuals collected. Note that these three sites are located closest to the sand berm and mouth. Site S-04 is located in the Lagoon mid-channel about 20 feet behind the san berm and mouth; S-05 is located along the eastern shore of the main Lagoon channel and about 50 m south of the PCH bridge/overpass. These three sites are located in the intertidal zones along the western shore, main channel and eastern shore of the Lagoon closest to the mouth. Also, we should note that over 97% of the abundance is from the Littoral Sweep method of sample collection. The different sampling methods will need to be further evaluated but the since the goal of this approach is similar to those used in the Malibu Lagoon Restoration Monitoring Plan, the results can be compared for the 2006 and 2007 benthic community data collected. The 2010 and 2011 sampling results, at least for density, was comparable to the density of invertebrates collected during the 1993-1994 sampling period, which showed that the infauna at Malibu Lagoon then was dominated by a single species of clam. Nordby and Zedler (1991) found that freshwater from sewage spills or winter rains lowered water salinities and had major impacts on the channel organisms of both southern California coastal wetlands. Benthic infaunal assemblages responded more rapidly to reduced salinity than did fishes, with continued salinity reduction leading to the extirpation of most species.

The Malibu Lagoon Restoration Baseline Monitoring efforts showed that the inorganic nitrogen species (nitrate, ammonia and SRP) were at extremely high levels in Spring 2007 (2NDNature, 2008). The 2006 and 2007 benthic sampling efforts in Malibu Lagoon conducted by 2NDNATURE showed a taxa richness of 24 and 34, respectively. The majority of taxa collected were similarly of those with high tolerance to varied conditions, and in this case, likely those species who can survive poor intertidal conditions (flow, circulation, DO, substrate characteristic). The sites with the greatest abundance of individuals (between 13,000 to 21,000) collected are sites located in the back channels where circulation is extremely limited and anoxic conditions have been observed and quantified (ML6, ML5, (ML4)S-02). In contrast, the 2007 sampling effort showed two orders of magnitude less abundance overall and the site with the most abundance (776) is located at ML-7 (same as S-01). It should be noted that in 2007, Malibu Creek Watershed experienced severe wildfires in October, which led to extensive damage and likely large influences to the nutrient loading and biogeochemical cycling within Malibu Lagoon. This likely impacted both the natural and anthropogenic conditions and the resulting biological and chemical responses.

Table 8-9. Benthic invertebrate species list, abundance and taxa richness collected during winter 2010 USEPA Malibu Lagoon sampling effort

Taxa List	S-01	S-02	S-03	S-04	S-05	S-06	S-07	S-08
ANNELIDA								
Oligochaeta	6	104	11	60	3	8	51	50
ARTHROPODA								
Atylus tridens					1			
Carinonajna bicarinata group						3		
Chironomidae	3	82	7	9	1	15	1	9
Coleoptera		1			1			
Copepoda - Calanoida sp.								2
Copepoda - Harpacticoda sp.			9	4		4		4
Ephydridae - Ephydra sp.		1						
Gammarus lacustris		1						
Hemiptera sp. 1	2	5	1					
Hemiptera sp. 2		2			1			
Holmesimysis costata				4				
Isopoda cf Flabillifera sp.					1			
Megalorchestia cf benedicti					1			
Ostracoda - Podocopida sp.	508	2,057	794	2,817	454	935	475	427
Palaemon macrodactylus								4
Traskorchestia traskiana	19	3	1	2	16	115	14	7
MISCELLANEOUS PHYLA								
Nematoda		1172	260	505	82	368	275	326
Abundance	538	3,428	1,083	3,401	561	1,448	816	829
Taxa Richness	5	10	7	7	10	7	5	8

Table 8-10. Benthic invertebrate species list, abundance and taxa richness collected during Spring 2011 USEPA Malibu Lagoon sampling effort

Taxa	S-01	S-02	S-03	S-04	S-05	S-06	S-07	S-08
ANNELIDA								
Oligochaeta	5,033	264	22	3016	1430	992	663	1612
Platynereis bicanaliculata						1		
MOLLUSCA								
Sacoglossa sp.				88	2	19		10
CRUSTACEA								
Arachnida sp.	1							
Coleoptera		10	1	118				
Collembola sp.	1							
Copepoda - Calanoida sp.	1		1	5		14	132	123
Copepoda - Harpacticoda sp.	2	83	4	32		1		
Decapoda sp. larvae								1
Diptera sp. midge	4	6	14	88	211	64	6	54
Eogammarus confervicolus	2	6	1	5	59	137	2	59
Hemiptera sp.	37	338	238		8	10	1	1
Insecta spp.	1	14	4	1	2			
Ostracoda sp.	124,139	5,443	2,983	37,428	41,768	914	158	1,756
Talitridae sp.	1	1						
Traskorchestia traskaian			1					
MISCELLANEOUS								
Chironomidae					1			
Chordata Juv.					0	1		
Nematoda	67	365	27	123	129	124	6	131
Abundance	129,289	6,530	3,296	40,904	43,610	2,277	968	3,747
Taxa Richness	12	10	11	10	9	11	7	9

8.2.3 Malibu Lagoon Restoration Monitoring 2006-2007

SMBRC collected a representative benthic macroinvertebrate survey by conducting a benthic grab sample and littoral sweep at a total of six sites during 2006 (Table 8-11) and five sites in 2007 (Table 8-12). In 2006, a total of 24 distinct taxa were observed and the combining sampling methods resulted in collecting a total of 65,302 individuals. Overwhelmingly, ostracods were the most abundant species collected at all sites (76% of total individuals). Sites ML-5 and ML-6 showed the most number of individuals collected (>21,000). The taxa richness ranged between 9-13 species per site. For every site, the littoral sweep of the pre-defined area resulted in more taxa and individuals collected. In 2007, a total of 34 distinct taxa were observed and the combining sampling methods resulted in a total of 2,274 individuals collected.

This is a significant difference between the two years, and likely due to the very different tidal exchange conditions observed between 2006 and 2007.

In fall 2006, the Lagoon was *open* for approximately two weeks prior to sampling, compared with a 1-150 day closure prior to sampling. The percent algal cover was significantly greater in fall 2007, between 14-38%, compared with 0-15% in fall 2006. The channel wetted width for Malibu Lagoon was also markedly different, between 75-135 ft in channel width in 2007, compared with 50-60 ft in channel width in 2006. The greater coverage of water over the intertidal zone and for extended period in 2007 likely flooded out some of the benthic invertebrate habitat and also modified the freshwater and saltwater balance.

Although the total abundance was higher in 2006, the total taxa richness was higher in 2007. Examination of the species composition showed that approximately 51% of the species composition was due to a Corisella species, a hemipteran aquatic insect that is highly tolerant to high chemical levels and physical disturbance (Foltz 2009). Approximately 25% of the species were due to ostracods and cyclopoids. The nutrient load (TN, TP and Organic Carbon) associated with sediment appear to decrease with increasing sand composition of the substrate. In conjunction to the increasing thickness of organic detritus as distance to the hydrologic connection of the main channel Lagoon decreasing support the critical role of tidal exchange; sites closer to hydrologic connection showed greater abundance and taxa richness in general. In 2006, better tidal exchange resulted in sites further away from the main channel of the Lagoon and mouth (back channel sites) with greater abundance; in these conditions, the floating microscopic bivalve crustacean ostracods dominated the species composition. In 2007, with very none to limited tidal exchange, sites right adjacent or in the main channel of the Lagoon had greater abundance; the highly tolerant Corisella aquatic insect dominated the species composition.

Table 8-11. Benthic community species collected for the Baseline Malibu Lagoon Restoration Monitoring Project in 2006 (2NDNATURE. 2008)

Insecta Taxa	ML2	ML4	ML5	ML6	ML7	ML8
Corisella sp.	0	0	0	3	0	0
Corixidae	61	19	903	2,058	1	58
Trichocorixa sp	13	3,859	251	1,018	1	42
Coleoptera *Berosus sp*	0	3	0	0	0	0
Coleoptera *Hygrotus sp*	0	0	13	4	0	0
Coleoptera *Ochthebius sp*	0	0	0	0	0	1
Diptera *Clunio sp*	0	1	0	0	1	0
Diptera *Cricotopus sp*	1	1	2	1	0	0
Diptera *Dasyhelea sp*	1	0	0	0	0	0
Diptera *Dolichopodidae*	0	0	5	0	0	0
Diptera *Ephydra sp*	190	189	144	51	3	0
Diptera *Tanytarsus sp*	1	0	0	0	0	0
Non-Insecta						
Nematoda	1015	1852	69	276	2	19
Oligochaeta	63	74	53	64	146	40
Polychaeta	0	0	0	0	0	2
Ophiuroidea	0	0	0	0	0	1

Insecta Taxa	ML2	ML4	ML5	ML6	ML7	ML8
Ostracoda	3,314	7,132	19,923	16,911	1,925	606
Amphipoda *Hyalella sp*	1	61	3	0	0	0
Cyclopoida *Cyclopoida*	118	27	2	0	2	25
Decapoda *Palaemonetes sp*	0	0	0	0	0	130
Hoplonemertea *Prostoma sp*	7	0	0	0	0	0
Hypsogastropoda *Hydrobiidae*	0	0	0	0	0	1
Hypsogastropoda *Tryonia sp*	56	543	279	1,438	207	14
Mytiloida *Mytilidae*	0	0	0	0	0	2
Abundance	4,841	13,761	21,647	21,824	2,288	941
Taxa Richness (Across all sites n=24)	13	12	12	10	9	13

Table 8-12. Benthic community species collected for the Baseline Malibu Lagoon Restoration Monitoring Project in 2007 (2NDNATURE, 2008)

Insecta Taxa	ML1	ML2	ML4	ML6	ML7
Collembola *Isotomidae*	3	0	0	0	2
Ephemeroptera *Callibaetis sp*	28	9	14	19	39
Odonata *Aeshna sp*	1	0	0	0	0
Odonata *Ischnura sp*	0	0	0	1	0
Odonata *Libellula sp*	0	0	0	1	0
Hemiptera *Abedus sp*	0	0	2	1	0
Hemiptera *Corisella sp.*	3	13	0	0	1
Hemiptera *Corixidae*	30	397	31	5	691
Hemiptera *Macrovellidae*	5	0	0	56	0
Hemiptera *Trichocorixa sp*	4	27	1	0	22
Coleoptera *Berosus sp*	5	2	8	0	3
Coleoptera *Enochrus sp*	0	0	0	2	0
Coleoptera *Ochthebius sp*	1	4	0	0	0
Coleoptera *Rhantus sp*	0	0	0	0	1
Coleoptera *Tropisternus sp*	1	0	2	0	1
Diptera *Anopheles sp*	0	1	1	11	6
Diptera *Apedilum sp*	3	2	0	4	0
Diptera *Atrichopogon sp*	1	0	0	0	0
Diptera *Chironomidae*	1	0	0	0	0
Diptera *Chironomus sp*	0	0	0	0	1
Diptera *Cricotopus sp*	7	0	0	10	12
Diptera *Culex sp*	0	0	0	1	0

Insecta Taxa	ML1	ML2	ML4	ML6	ML7
Diptera *Dicrotendipes sp*	0	1	0	0	2
Diptera *Ephydra sp*	0	0	0	0	4
Diptera *Goeldichironomus sp*	69	1	3	25	0
Diptera *Polypedilum sp*	1	0	0	0	0
Diptera *Tanypus sp*	0	0	0	0	2
Non-Insecta Taxa					
Nematoda	0	1	0	0	0
Oligochaeta	5	0	0	0	0
Ostracoda	2	151	0	88	1
Amphipoda *Hyalella sp*	2	3	33	1	0
Basommatophora	0	0	0	0	0
Physa/Physella sp	1	0	2	0	0
Cyclopoida					
Cyclopoida	264	0	0	108	4
Diplostraca					
Chydoridae	3	0	0	0	0
Abundance	440	612	97	333	792
Taxa Richness (Across all sites n=34)	22	13	10	15	16

8.3 STREAM BENTHIC ALGAL DATA

The nutrient impairment listing for the Malibu Creek watershed is based primarily on algal coverage. The TMDL (USEPA, 2003) establishes thresholds of 30 percent coverage for floating algae and 60 percent coverage for mat algae.

Coverage by mat or periphytic algae was (and continues to be) a noted problem in Malibu Creek and prompted the development of the nutrient TMDL. Growth of periphytic algae is controlled by a variety of factors, including nutrient availability, light availability, temperature, substrate condition, grazing, and flow-induced scour. Malibu Creek has a generally intact riparian canopy (Luce, 2003); however, nutrient concentrations are elevated, increasing the risk of excess algal growth (see Section 7.5).

Extensive data on total algal coverage between 1983 and 1999 was collected by the Tapia WRF and as summarized by USEPA (2003). Six sites on the main stem all had more than 10 percent of observations with greater than 30 percent algal coverage, as did one station in the Lagoon. SCCWRP (Busse et al., 2003) performed a detailed examination of algal conditions in 2001 and 2002, including measurements of benthic chlorophyll *a* densities, and concluded that most developed sites in the Malibu Creek watershed had chlorophyll *a* concentrations that "exceed suggested thresholds for acceptable levels." At most sites, algal biomass was not limited by nutrients, but rather by light availability and water current. Total nitrogen, total phosphorus, and total chlorophyll concentrations were all positively correlated with the proportion of upstream land covered by impervious surfaces (Busse et al., 2006). Byron and DuPuis (2002) examined 20 years of data on coverage by the attached alga *Cladophora glomerata* and also concluded that nutrient concentrations were not limiting algal growth in the creek. Instead, periphytic algae varied positively with light and negatively with winter-season scouring flows.

Luce (2003) reports multiple regression analyses of algal cover at Heal the Bay sampling sites for 1998 – 2002. She found positive correlations between nutrient concentrations and macroalgal cover, although the relationships were somewhat complex. Phosphate had a significant positive correlation to macroalgal cover in all seasons at sites with nitrate less than 0.1 mg/L, but not at sites with higher nitrate concentrations. Nitrate was positively correlated with macroalgal cover in the spring, but negatively correlated in the fall. Canopy cover did not appear strongly related to macroalgal density, except at sites with low nitrate where there was a negative relationship in the spring (increasing macroalgal density with decreasing canopy cover) and a positive relationship in the fall.

LVMWD (2011) suggests that high levels of algal growth in Malibu Creek are due to naturally elevated levels of phosphate and nitrate in drainage from the Modelo formation. The nature of these sediments may indeed enhance nutrient concentrations; however, that does not necessarily imply that current loading rates are natural, as loading from these areas may have been increased by altered flows and activities that increase erosion.

Given these studies, it is not clear if the existing nutrient TMDL targets – even if fully implemented – would be sufficient to significantly reduce algal coverage in Malibu Creek. Heal the Bay has continued to collect algal coverage data, which may be examined to evaluate whether conditions of excess algal growth that may adversely affect instream biota continue to be present. Averages of reported algal coverage for 2005-2010 at the two main stem sites with significant amounts of data are shown in Table 8-13. Both sites have average coverage of mat algae well above 50 percent and above the nutrient TMDL threshold (USEPA, 2003).

Table 8-13. Average Algal Cover in Malibu Creek, Heal the Bay Data for 2005-2010

Station	Floating Algae	Mat Algae
Site 1 – Malibu Creek near Mouth	27.5%	64.8%
Site 12 – Malibu Creek below Cold Creek	5.0%	83.7%

The data at these two stations from 1999 to 2010 are plotted against time in Figure 8-18 and Figure 8-19, along with a 12-point moving average to suggest temporal trend. Floating algae coverage clearly tends to be greater at Site 1, near the mouth, where gradients are lower (Figure 8-18). Mat algae concentrations are frequently very high at both stations, and do not show any declining trend with time (Figure 8-19). The recent trend for floating algae is below the 30 percent threshold presented in the nutrient TMDL, while mat algae is typically above the 60 percent nutrient TMDL threshold (USEPA, 2003).

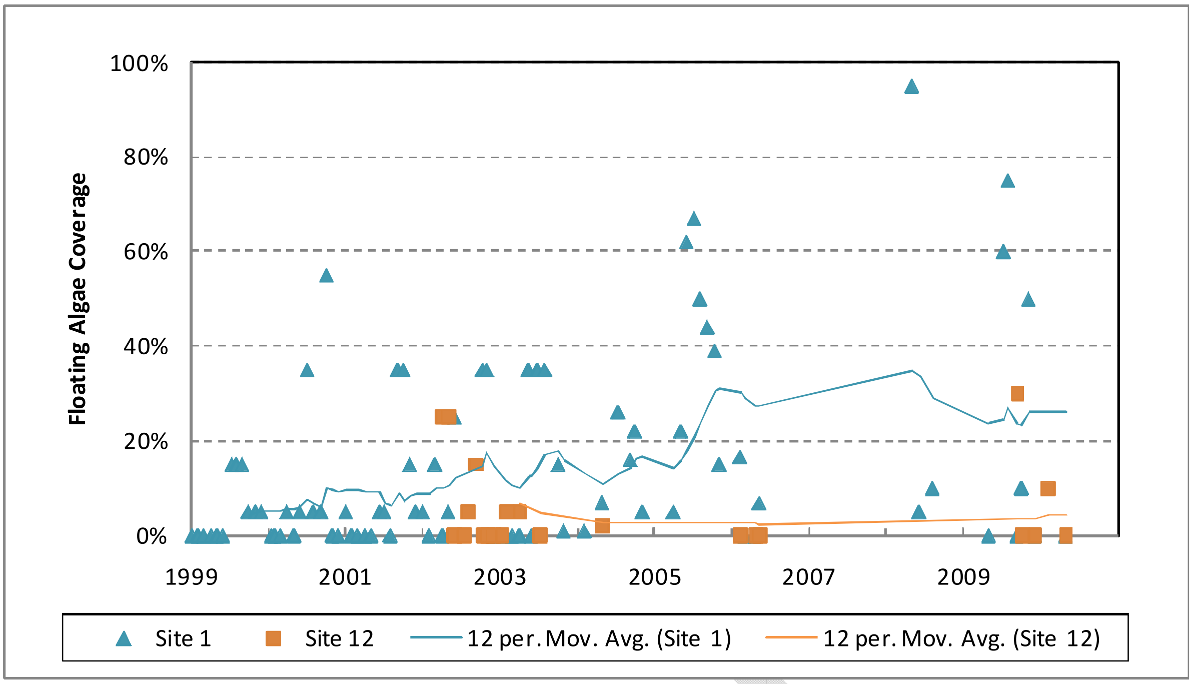


Figure 8-18. Temporal Trends in Floating Algae Coverage in Malibu Creek Mainstem

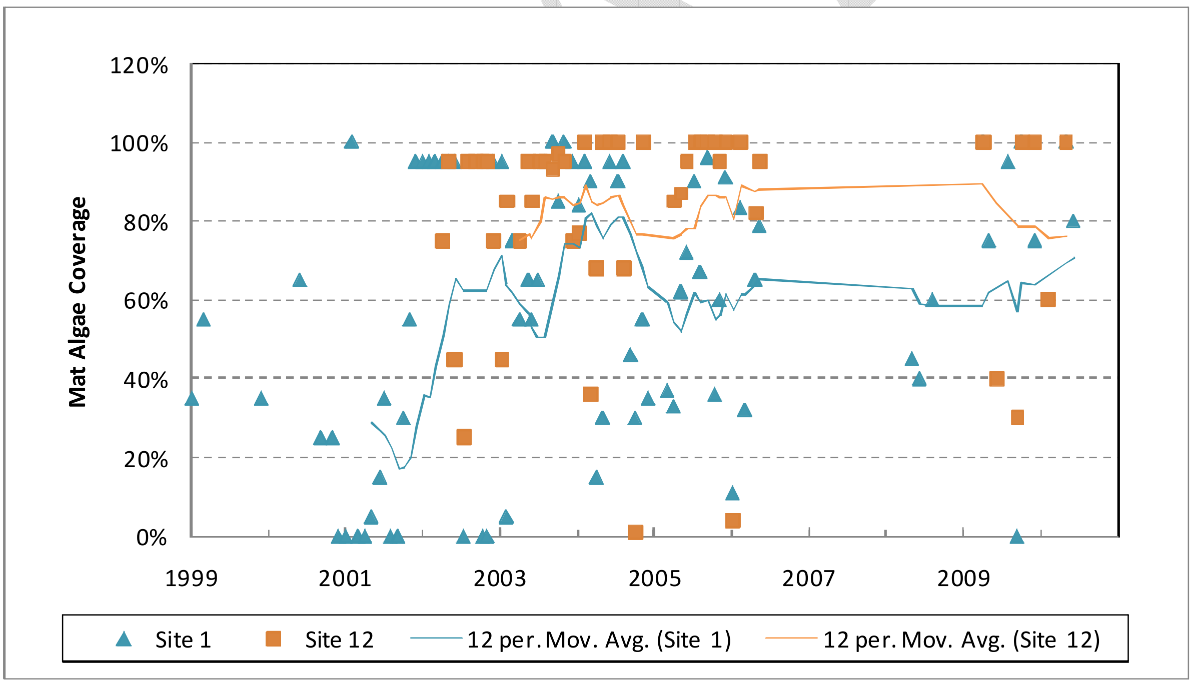


Figure 8-19. Temporal Trends in Mat Algae Coverage in Malibu Creek Mainstem

Box and whisker plots of the distribution of mat algae coverage at three main stem sites (also including Site 15, Malibu Creek below Cold Creek, for which smaller amounts of data are available) are provided in Figure 8-20 and compared to results for the two Heal the Bay reference sites (Site 14, Solstice, and Site 18, Lachusa). Mat algae coverage is clearly much greater in Malibu Creek than at the reference sites.

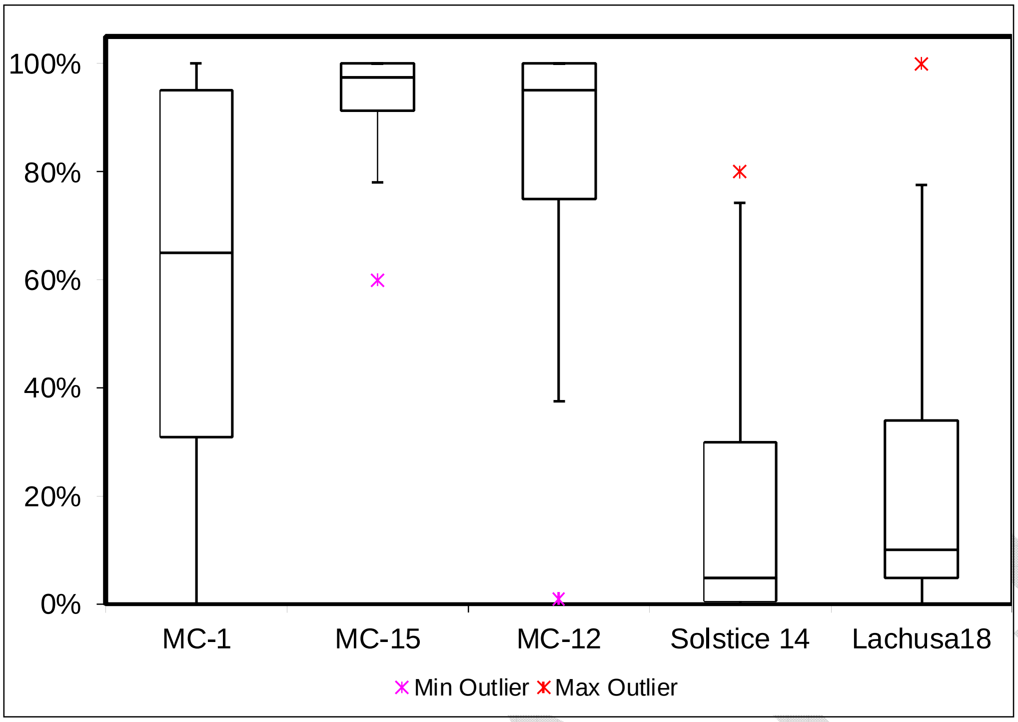
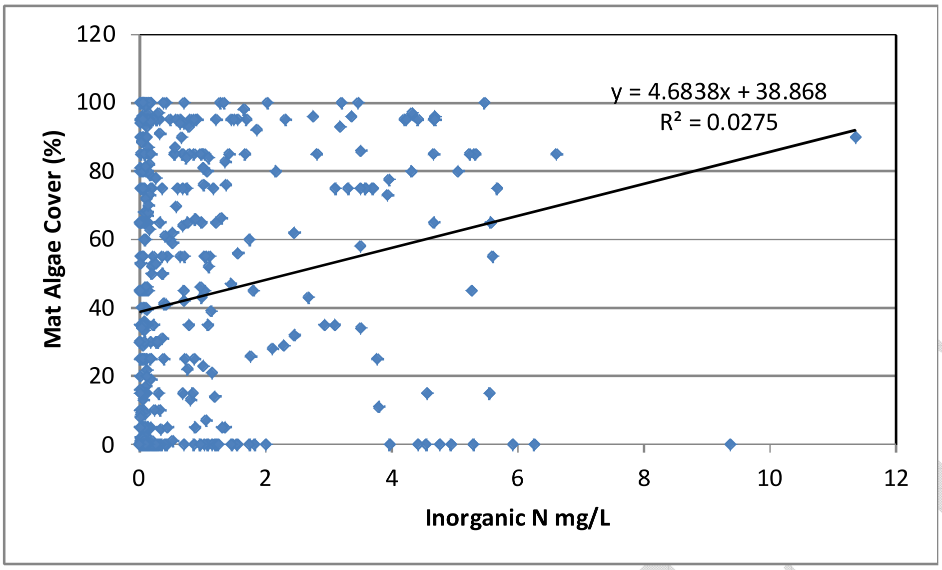


Figure 8-20. Box and Whisker Plots Comparing Mat Algae Coverage in Malibu Creek Mainstem to Reference Sites

An examination of all the Heal the Bay mat algae coverage data shows that there is almost no correlation between algae coverage and either inorganic N or inorganic P concentrations (Figure 8-21). Notably, 100 percent cover can occur at the lowest inorganic nutrient concentrations, while low cover is often found at high inorganic nutrient concentrations. In part, this may reflect control by light limitations and other factors; however, it also suggests that inorganic nutrient measurements may not provide a good indication of algal growth potential; instead total nutrient concentrations may be better at providing an indication of primary production.



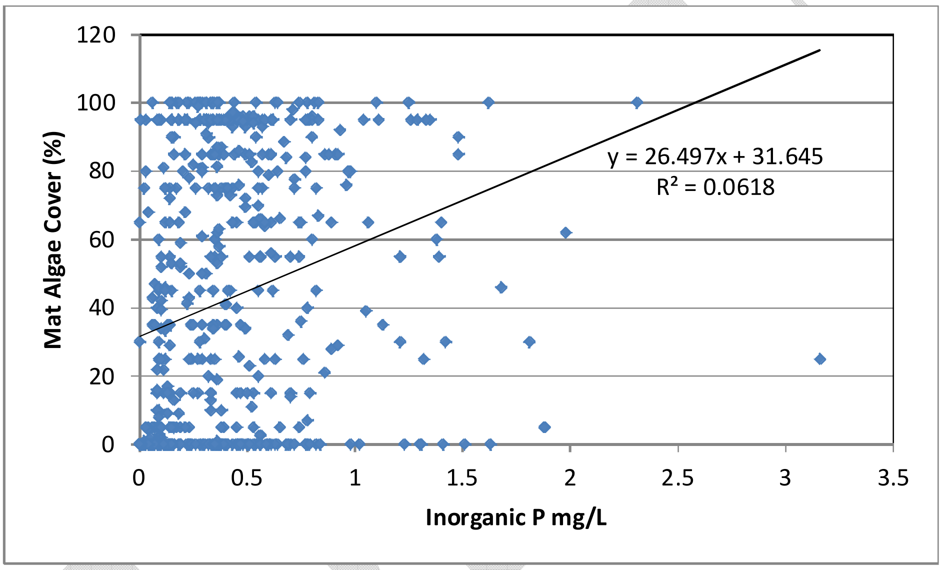


Figure 8-21. Correlation between Mat Algae Coverage (April 15 – November 15) and Inorganic Nutrient Concentrations in Heal the Bay Data

As described further in Appendix F, Busse et al. (2003) collected direct measurements of benthic algal density as mg/m^2 chlorophyll *a* during 2001 and 2002 at multiple sites in the Malibu Creek watershed. Maximum density was generally observed during the August 2002 survey and is summarized in Table 8-14. See Appendix F for further details on the sampling sites.

Table 8-14. Summary of Chlorophyll *a* and AFDM Data from the August 2002 Survey (Busse et al., 2003)

Waterbody	Land Use	Sub-Habitat	Benthic chlorophyll *a* (mg/m^2)	Benthic plus Planktonic chlorophyll *a* (mg/m^2)
Medea Creek	Residential 1	Sun Riffle	165.1	165.1
Medea Creek	Residential 1	Shade Riffle	50.0	50.0

Waterbody	Land Use	Sub-Habitat	Benthic chlorophyll *a* (mg/m^2)	Benthic plus Planktonic chlorophyll *a* (mg/m^2)
Medea Creek	Commercial 1	Sun Run	969.2	969.2
Medea Creek	Commercial 1	Sun Riffle	110.9	110.9
Medea Creek	Commercial 2	Sun Pool	133.1	413.0
Medea Creek	Commercial 2	Sun Run	73	123.5
Medea Creek	Commercial 2	Sun Riffle	66.9	66.9
Las Virgenes	Multiple 1	Shade Run	383.9	383.9
Las Virgenes	Multiple 1	Shade Riffle	504.0	504.0
Las Virgenes	Multiple 2	Sun Run	102.6	102.6
Las Virgenes	Multiple 2	Shade Run	531.1	531.1
Las Virgenes	Multiple 2	Shade Riffle	255.9	255.9
Malibu Creek	Below Tapia	Shade Run	341	341
Malibu Creek	Below Tapia	Sun Riffle	230.3	230.3
Malibu Creek	Below Tapia	Shade Riffle	258.1	258.1
Cold Creek	Reference 1	Sun Pool	75.0	75.0
Cold Creek	Reference 1	Shade Pool	6.5	6.5
Cold Creek	Reference 1	Sun Run	8.3	8.3
Cold Creek	Reference 1	Shade Run	3.2	3.2
Cold Creek	Reference 1	Sun Riffle	9.6	9.6
Cold Creek	Reference 1	Shade Riffle	16.2	16.2

Based on these analyses, the algae-related impairment in the Malibu Creek main stem has yet to be mitigated. Therefore, excess algal growth remains a potential stressor that could limit biological conditions in Malibu Creek. This excess algal growth does not appear to strongly affect DO concentrations in the creek, as excursions of the DO criterion exist, but are infrequent (see Section 7.2); however, excess growth of periphytic and attached algae can also have a direct deleterious impact on habitat suitability.

8.4 Invasive Species

The New Zealand mudsnail (*Potamopyrgus antipodarum*) was first documented in samples from the Malibu Creek watershed in 2005 (Abramson, 2009). This invasive species is of concern because it can reproduce by cloning and rapidly create massive colonies that disrupt the food web and displace native benthic macroinvertebrates. While New Zealand mudsnails have been documented in many western states, their presence was not known in the Santa Monica Bay watershed prior to the analysis of the 2005 samples.

Individual mudsnails are tiny (3-5 mm in length), but may reach densities of 500,000 organisms per square meter (Dorgelo, 1987). Unfortunately, they are easily transported from stream to stream by attaching themselves to shoes and boots, fishing gear, bicycle tires, boats, and animals.

The snail is a "nocturnal grazer, feeding on plant and animal detritus, epiphytic and periphytic algae, sediments and diatoms" (Benson and Kipp, 2008). "Because of their massive density and quantity, the New Zealand mudsnail can out-compete and reduce the number of native aquatic invertebrates that the watershed's fish and amphibians rely on for food" (Heal the Bay, 2011; http://sites.healthebay.org/news/2006/06_08_nzmudsnail/default.asp). The snail "colonies disrupt the food web by displacing native aquatic invertebrates that fish and amphibians rely on for food" and have been found on more than 70 percent of substrate samples in Malibu Creek (Abramson et al., 2009).

The mudsnails appear to be spreading in the Malibu Creek Watershed. Work by Heal the Bay has documented the spread beginning in 2006. In that year, the mudsnails were found at 14 of 44 sites (32 percent) in Media, Las Virgenes, and Malibu Creek proper – including sites on Malibu Creek above and below Cold Creek and near the mouth. In 2007 they were found at 20 of 56 sites (36 percent), including sites in Lindero and lower Solstice Creek (a reference site for Malibu Creek). The mudsnails had spread to Cold Creek and Triunfo Creek by 2008, and in 2009 were also found in Ramirez Creek.

Jim Harrington (unpublished) began examining the relationship between IBI scores and New Zealand mudsnail density in the samples and has not found a strong correlation. Mudsnails constituted only 3 percent of the biological sample in spring 2006 at MC-1 and 81 percent of the sample in Spring 2009, yet the IBI scores were 26 and 27, respectively. Anomalously low IBI scores in Spring 2010 also had low densities of mudsnails (from less than 1 percent at MC-1 to 13 percent at MC-15). To date, the available data do not confirm the New Zealand mudsnails as a primary stressor.

8.5 Toxicity Data

8.5.1 Malibu Creek

Water column toxicity in Malibu Creek has been frequently assessed at the mass emission station coincident with the stream gage downstream of the Tapia WRF. Bay et al. (1996) examined two stormwater samples in Malibu Creek using the 48-h red abalone larval development and 20-min purple sea urchin fertilization tests and found no toxicity. Subsequently, LACDPW has conducted two wet and two dry water column toxicity tests per year at the mass emissions station, using *Ceriodaphnia dubia* (water flea) survival and reproduction and *Strongylocentrotus purpuratus* (purple sea urchin) fertilization tests as part of their MS4 NPDES permit requirements. Annual results for the 2001-2002 through 2003-2004 seasons showed no water column toxicity in Malibu Creek. (There is no published report for 2004-2005). Subsequently, occasional toxicity has been observed. Through the 2009-10 season, sea urchin fertilization was impacted in 2006-2007, 2007-2008, and 2008-2009 wet weather samples, as well as a 2009-2010 dry weather sample, while *C. dubia* survival was impacted in the 2008-2009 wet weather samples and *C. dubia* reproduction was impacted in the 2005-2006 and 2007-2008 dry weather samples. In each case, the toxic effect apparently dissipated after holding the sample; therefore, the annual modeling reports attribute the cause to volatile chemicals.

Brown and Bay (2005) examined toxicity in eight dry weather and two stormwater samples from Malibu Creek at the HTB-01 station near the mouth. One out of eight dry weather samples showed acute toxicity (survival) and two out of eight showed chronic toxicity (reproduction) to *C. dubia*. The analysis was focused on organophosphorus pesticides and concluded that these were unlikely to be the causes of the observed toxicity, which was more likely related to sulfate and other total dissolved salts. Higher levels of toxicity were observed in Las Virgenes Creek (likely associated with salts) and Medea Creek (likely associated, at least in part, with diazinon).

8.5.2 Malibu Lagoon

Sediment toxicity in Malibu Lagoon has been examined with amphipod toxicity tests as part of the "Bight" sampling program conducted every five years. In both 1998 and 2003 no toxicity was reported for Malibu Lagoon (Bay et al., 2000; Bay et al., 2005). A total of seven sites were analyzed in Malibu Lagoon in 2003. Bight 2008 (Bay et al., 2011) did not include sediment toxicity results for Malibu Lagoon.

Additional sediment toxicity results for a sample collected in Malibu Lagoon in 1993 are reported in Anderson et al. (1998). This report confirms the absence of toxicity to amphipods. Mussel development tests apparently showed some impact from exposure to subsurface water, although the results are not discussed in the text.

8.6 Physical Habitat Information

Heal the Bay analyzed physical habitat quality scores using the Rapid Bioassessment Protocol (RBP) from 2000 through 2008. The RBP (Barbour et al., 1999) analyzes 10 different metrics for physical habitat. These metrics vary somewhat for high gradient and low gradient streams; the low gradient options are shown in parentheses below:

1. Epifaunal substrate/available cover
2. Embeddedness (or pool substrate)
3. Velocity/depth combination (or pool variability)
4. Sediment deposition
5. Channel flow status
6. Channel alteration
7. Frequency of riffles/bends (or channel sinuosity)
8. Bank stability
9. Bank vegetative protection
10. Riparian zone width

Each component receives a score from 0 to 20 and the individual scores are added to form a physical habitat score with a potential range from 0 to 200. Scores from 150 to 200 are considered optimal, those from 100 to 150 suboptimal, from 50 to 100 marginal, and below 50 poor. The range of results are shown in Table 8-15 and compared to reference sites in Figure 8-22 below. All average scores are either optimal or suboptimal. The averages for lower Malibu Creek (MC-1 and MC-15) are slightly lower than those for the reference sites, but the scores overlap substantially. Individual component metrics have not been provided for these data.

Table 8-15. Physical Habitat Scores (RBP) for Malibu Creek, Heal the Bay 2000 - 2008

Station	Count	Range	Average
MC-1 (Malibu Creek at Discharge)	6	123 – 151	142 (suboptimal)
MC-15 (Malibu Creek below Tapia WWTP)	6	122 – 159	142.2 (suboptimal)
MC-12 (Malibu Creek upstream of Bridge Rock Pool)	5	141 – 178	167.2 (optimal)
LCH18 (Lachusa Creek)	4	131 – 182	163.2 (optimal)
SC14 (Solstice Creek)	4	138 – 179	155.2 (optimal)
CH6 (Cheseboro Creek)	3	134 - 139	136.3 (suboptimal)

Las Virgenes Municipal Water District also reports RBP Physical Habitat Scores for their monitoring stations for 2006, 2008, 2009, and 2010 (Table 8-16 and Figure 8-22). The overall scores are somewhat lower than those at the Heal the Bay sites, and tend to be in the marginal to sub-optimal range. The sites with lower average RBP scores tend to have received poor or marginal ratings on the embeddedness, sediment deposition, and riffle frequency measures.

Table 8-16. Physical Habitat Scores (RBP) for Malibu Creek, LVMWD 2006 - 2010

Station	Count	Range	Average
R-13	4	128 – 155	145 (suboptimal)
R-2	4	101 – 117	111 (suboptimal)
R-1	4	73 – 119	92 (marginal)
R-9	3	84 – 106	98 (marginal)
R-4	4	74 – 120	91 (marginal)
R-3	4	91 – 136	112 (suboptimal)

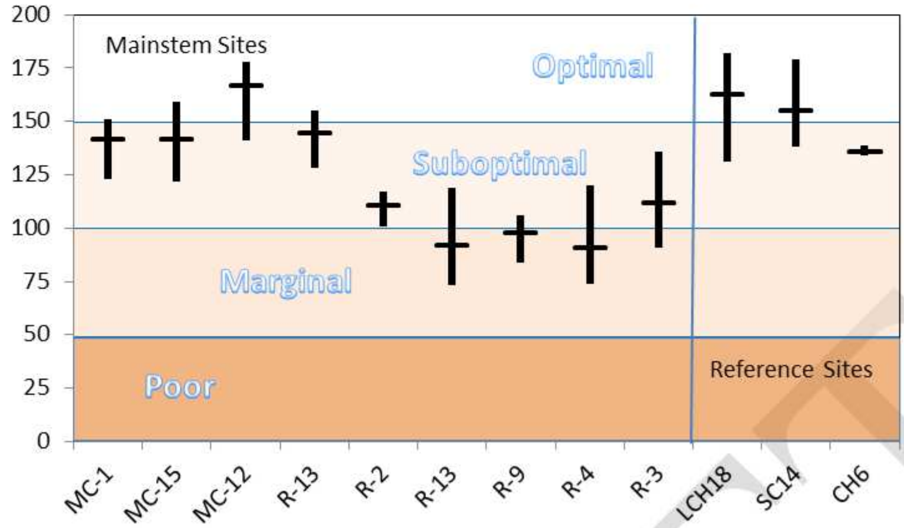


Figure 8-22. Range of Physical Habitat Scores at Malibu Creek Mainstem and Reference Sites

Note: Maximum, minimum, and average RBP Physical Habitat Scores from Heal the Bay and LVMWD sampling.

The 2005 Malibu Creek Bioassessment Monitoring Program Report (Aquatic Bioassay, 2005), conducted as part of the Malibu Creek Watershed Monitoring Program, provided data for eight sites in the Malibu Creek watershed. This included SC-IBI results and physical habitat scores (including substrate complexity, embeddedness, consolidation, and percent fines). For four of the eight sites (including Malibu Creek above the Lagoon – the only station on the main stem included in that survey) the physical habitat was rated as optimal or suboptimal. The report concludes that, for these four sites, "stressors other than habitat conditions may have impacted these sites." Only a few of the sites in the watershed studied in 2005 show physical habitat conditions that are rated as poor with evidence of excessive sedimentation, and all of these are on tributaries, not Malibu Creek proper. The Fish Migration Barrier study (Abramson and Grimmer, 2005) also shows good to excellent habitat quality along the main stem.

In 2009 and 2010, Heal the Bay collected SWAMP physical habitat measures and did not report RBP scores. An interpretation of these data is currently in preparation and not yet available to USEPA. However, preliminary analysis suggests that neither percent cobble embeddedness nor bank stability is strongly correlated with IBI scores at the Heal the Bay stations (Figure 8-23). This may be due to the nature of the geology of the naturally erodible soils in Malibu Creek Watershed.

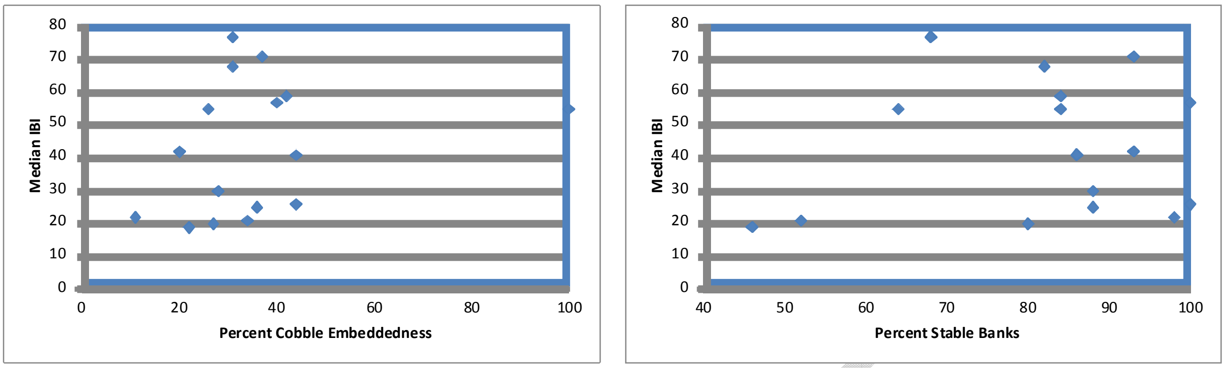


Figure 8-23. Relationship of SC-IBI to Percent Cobble Embeddedness and Percent Stable Banks at Heal the Bay Stations

Note: Physical habitat measures are as reported by Heal the Bay for 2009 – 2010; SC-IBI scores are the medians for 2000 - 2010

Los Angeles County also developed RBP physical habitat scores for their sampling at fixed sites during 2003 through 2008. These do not include stations on the main stem of Malibu Creek. Stations on Medea, Las Virgenes, and Triunfo creeks (all of which had poor to very poor SC-IBI scores), had physical habitat scores ranging from 85 to 141, which are in the marginal to sub-optimal range. The Cold Creek station, with better biota, had physical habitat scores ranging from 164 to 170.

In 2009, Los Angeles switched to randomized monitoring sites and substituted the SWAMP physical habitat procedure for the RBP methods (Weston, 2010, 2011). The physical habitat measures are summarized using the California Rapid Assessment Methodology (CRAM) score, which ranges from 25 to 100. While quality rankings have not yet been assigned to CRAM scores, they are useful for a relative comparison. Weston (2011) reported a correlation between CRAM score and SC-IBI with $R^2 = 0.546$, but the strength of this relationship is in large part due to concrete-lined channels that have low CRAM and low IBI.

In both 2009 and 2010 Los Angeles County included randomized sites on the Malibu Creek main stem. In 2009, site SMC01384 (Malibu Creek at Malibu Canyon Road) had a CRAM score of 83 relative to a range of scores across LA County of 27 to 85. Banks were reported as stable, and the site received a score of 14 out of 20 for sediment deposition. A 2010 site further upstream, SMC02152, Malibu Creek in Malibu State Park upstream of Las Virgenes Creek, yielded a CRAM score of 78 and was also noted as having stable banks and a sediment deposition score of 12 out of 20. Thus, CRAM does not appear to be a good predictor of SC-IBI at these Malibu Creek stations.

In summary, biota in the main stem of Malibu Creek do not appear to be strongly limited by physical habitat condition alone, although physical habitat is less than optimal and likely contributes to lower SC-IBI scores. Isham (2005) undertook a summary study of the relationship between IBI scores and physical habitat quality scores from monitored sites in Los Angeles, Orange, and San Diego counties. The reference sites had good IBI scores and good physical habitat scores. However, the urban sites showed consistently lower IBI scores regardless of physical habitat score, indicating "that there was virtually no relationship between macroinvertebrate community quality and physical habitat quality in the presence of urban runoff". Instead, urbanization appears to be associated with impaired IBI scores via other stressor-impact relationships.

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9. Linkage Analyses

The linkage analysis defines the connection between numeric targets and identified pollutant sources and may be described as the cause-and-effect relationship between the selected indicators, the associated numeric targets, and the identified sources. This provides the basis for estimating total assimilative capacity and any needed load reductions. For these TMDLs, a stressor identification was performed as the linkage analysis. Additional background information is provided in Appendix E, which summarizes some key studies in the watershed. A hypothetical linkage analysis example is presented in Appendix G to illustrate how this approach considers the multiple variables to determine the critical stressors and causes

The benthic macroinvertebrate communities in Malibu Creek and Estuary have been adversely affected, as shown by low bioscores. USEPA concludes that a TMDL is necessary to address the impacts. Since a single stressor was not identified as the source of the benthic community degradation during the listing of the impairment, USEPA conducted a detailed, and structured examination of the potential stressors to identify candidate causes of impairment. To accomplish this, the methodology outlined in USEPA's Stressor Identification Guidance (SIG) (USEPA, 2000b), which constitutes volume 1 of the Causal Analysis/Diagnosis Decision Information System (CADDIS; http://www.epa.gov/caddis/) is followed in this section.

9.1 Stressor Identification Process

The ability to accurately identify stressors and defend the evidence supporting those findings is a critical step in developing strategies that will improve the quality of aquatic resources. The SIG lays out a detailed and rigorous approach to identify stressors that cause biological impairment in aquatic ecosystems while providing a structure to organize the scientific evidence supporting the conclusions.

The Stressor Identification approach involves the following steps:

1. List Candidate Causes
2. Analyze Evidence
    a. Measurements of the candidate causes and responses
    b. Measurements of exposure at the site and measures of effects from laboratory studies
    c. Site measurements and intermediate steps in a chain of causal processes, and
    d. Cause and effect in deliberate manipulations of field situations or media
3. Characterize Causes
    a. Eliminate Alternatives
    b. Diagnostic Analysis
    c. Strength of Evidence Analysis
    d. Identification of Probable Cause

9.1.1 List Candidate Causes

The first step in investigating the potential causes of the degraded benthic macroinvertebrate community is to develop a list of potential causes. The benthic macroinvertebrate community may be stressed by degraded habitat, physical stressors, invasive species, or adverse water quality conditions. Habitat may be degraded by flow alteration, increased sedimentation, poor sediment quality or excess algal density that reduces favorable habitat conditions. The benthic macroinvertebrates population may also be reduced because of physical stressors that cause deviations from the natural conditions. Degraded water quality due to anthropogenic activities can also adversely impact the benthic macroinvertebrates population.

A conceptual model is developed, describing the pathways by which potentially controllable activities may impact the benthic macroinvertebrate community. Proximate and interacting stressors and stressor sources are identified. Proximate and interacting stressors (termed Major Stressors in this document) are conditions that occur at an intensity, duration, and frequency of exposure that results in a change in the ecological condition. Sources are origins of stressors that release or impose a stressor into a waterbody. This model guides the analysis and characterization.

9.1.2 Analyze Evidence

Analyzing evidence requires reviewing the potential relationships between candidate causes and observed impairments to determine if the causal pathway from source to impairment is complete. For a causal pathway to be considered complete, a source must be present and linked to a stressor, which must then be linked with the resulting impairment. Ideally, evidence from the site comprises the body of the weight of evidence supporting the causal relationship. In many cases, however, sufficient data may not be available from the site to support the entire causal pathway. Additional information from other, similar sites and from laboratory studies may be used to evaluate the strength of the causal relationship. For each potential stressor, this section asks the following questions:

1. Are there associations between measurements of the candidate causes and the observed impairment effects? Do the cause and effect occur at the same time or place? If the cause is not present, is the effect also not present? Is the intensity of the causal factor related to the magnitude of the effect?
2. Do studies performed elsewhere indicate a causal relationship between the candidate cause and the observed impairment effects?
3. Are there intermediate measurements that are associated with the causal mechanism that can proxy for measurements of the cause itself?
4. Does experimental mitigation or manipulation of the cause support a cause and effect relationship?

This section of the Linkage Analysis is inherently linked to the following section, Characterize Causes. The

9.1.3 Characterize Causes

The third step ("Characterizing Causes") evaluates the evidence previously assembled to reach a conclusion and state the levels of confidence in the conclusion. This step relies on three substeps: eliminate candidate causes for which case-specific evidence clearly shows that a necessary step in the causal pathway does not occur; diagnose candidate causes for which case-specific evidence clearly and specifically indicates a candidate cause; and finally, perform a strength of evidence analysis.

9.1.3.1 Eliminate

The first sub-step is to eliminate those alternatives in which the evidence does not support a significant role in the observed impairment. Elimination of potential causes requires care as the dominance of one cause may mask other sufficient causes. Only causes where lack of evidence for causality is unambiguous should be eliminated.

9.1.3.2 Diagnose

A further technique to narrow the list of candidate causes is to consider diagnostic analysis. Whereas the elimination step relies on negative evidence (e.g., an exposure pathway *is not* present), diagnostic analysis relies on positive evidence (e.g., a particular symptom *is* present). The diagnostic approach is most appropriate for stressor identification when organisms are available for examination, the candidate causes are familiar enough that protocols have been established, and there is a high degree of specificity in the cause, the effect, or both.

9.1.3.3 Strength-of-evidence Analysis

Strength of evidence analysis uses the information developed in the data analysis to determine if the candidate causes have a true effect on the benthic macroinvertebrates. The causal considerations for the strength of evidence analyses used three types of evidence: case-specific evidence, evidence from other situations or biological knowledge, and evidence based on multiple lines of evidence

In general, the strength of evidence analysis laid out in the Stressor Identification Guidance (USEPA, 2000b) follows principles derived from epidemiology ("Hill's Criteria").

The first four, case-specific considerations directly evaluate an observed case: *co-occurrence* (of cause and effect), *temporality* (the cause must precede the effect), *biological gradient* (the effect should increase with increasing exposure), and *complete exposure pathway* (the stressor must be able to reach the receptor).

The next four considerations combine information from the case at hand: *plausibility* (the degree to which a cause and effect relationship would be expected given known facts), *specificity* (the impact is associated with only one or a few potential causes), *analogy* (similarity to any well-established cases), and *predictive performance*.

The last two considerations evaluate the relationships among all of the available lines of evidence: *consistency* (agreement among all lines of evidence), and *coherency of evidence* (whether a conceptual or mathematical model can explain any apparent inconsistencies among the lines of evidence).

9.2 LIST CANDIDATE CAUSES

Unlike the simple hypothetical example presented in Appendix G, the various potential causes of impairment in Malibu Creek and Lagoon interact with one another in complex ways. Candidate causes (as identified in preceding sections) and key linkages to impaired biology are summarized in a site conceptual model in Figure 9-1. Note that only a few of the many interactions are explicitly shown in this figure. For example, turbidity can affect algal growth. The items shown at the top are the major candidate causes. These include both human activities and resulting stressor sources (top rows). These stressor sources are linked to responses through a variety of causal pathway steps and/or modifying factors (interacting stressors, modifying factors, and proximate stressors). For example, channel sedimentation is a proximate stressor impacting stream biology that itself is related to a number of stressor sources and human activities.

9.2.1 Major Stressors

Stressors are conditions that occur at an intensity, duration, and frequency of exposure that results in a change in the ecological condition (SIG); they can be either proximate or interacting, as shown in Figure 9-1. The list of candidate stressors below presents both proximate and interacting stressors to better separate and identify the likely causes of biological impairment in Malibu Creek and Malibu Lagoon. Based on the analyses in the preceding sections of this report, there are five major stressors that are potential causes of biological impairment in Malibu Creek and Estuary. These are:

A1. **Reduced Habitat Quality from Sedimentation**: Excess sedimentation is documented in Malibu Creek and Lagoon, and is a known cause of habitat degradation with likely adverse impacts on benthic macroinvertebrate. Wood and Armitage (1997) provide the following summary: “Fine sediment suspension and deposition affects benthic invertebrates in four ways: (1) by altering substrate composition and changing the suitability of the substrate for some taxa…; (2) by increasing drift due to sediment deposition or substrate instability…; (3) by affecting respiration due to the deposition of silt on respiration structures… or low oxygen concentrations associated with silt deposits…; and (4) by affecting feeding activities by impeding filter feeding due to an increase in suspended sediment concentrations…, reducing the food value of periphyton…, and reducing the density of prey items.” Sand deposition is also problematic as it provides an unstable substrate and can impede upstream migration or smother benthic communities.

Increased sedimentation can arise from both upland and in-channel sources; however, it is most strongly associated with changes in the flow regime that cause channel instability. Sediment related problems are frequently associated with areas in the watershed that has experienced large storm events, leading to very unstable banks (see evidence from USEPA physical habitat sampling); this likely led to soil detachment and sedimentation. Another significant source is likely from impervious areas and possibly lake discharge from Malibou Lake. Both of these sources would lead to increased runoff and heavy sedimentation from the already unstable banks, low embeddedness and poorly vegetated riparian areas along Malibu Creek main stem. The stressor may be something that either directly physically modified the benthic community or indirectly affected its habitat. Because the sediment-related habitat metrics have been low, sediment appear to be the most plausible cause of stress in Malibu Creek main stem.

The only point sources included in this watershed are the storm water MS4 discharges and the Tapia Water Reclamation Facility. Tapia does not appear to be a source of discharge leading to impacts from sedimentation due to the evidence from benthic macroinvertebrate scores and physical habitat data from upstream and downstream of Tapia’s discharge point. Agriculture in this watershed is minimal, with a small growing population of wineries and nurseries.

A2. **Reduced Habitat Quality from Excess Algal Growth**: Excess algal growth associated with nutrient enrichment has long been observed in the Malibu Creek watershed, resulting in USEPA Region 9 establishing nutrient TMDLs in 2003. USEPA’s TMDL document noted that “…the proliferation of algae can result in loss of invertebrate taxa through habitat alteration,” while algal mats “may result in eutrophic conditions where dissolved oxygen concentration is low…and negatively affect aquatic life in the waterbody…”

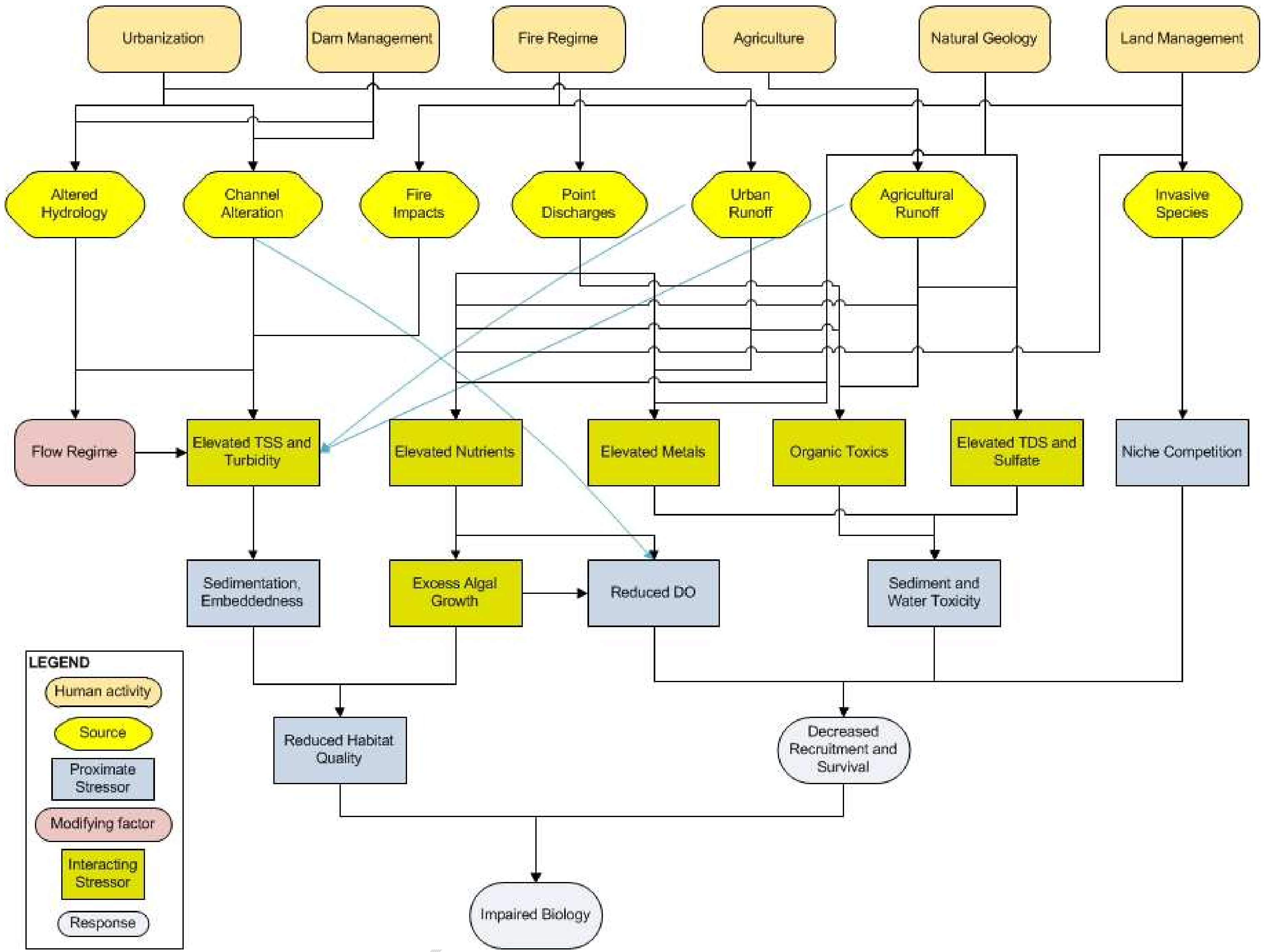

Figure 9-1. Conceptual Model of Candidate Causes of Impaired Biology in Malibu Creek and Lagoon

A3. **Reduced DO from Excess Algal Growth or Oxygen-demanding Wastes**: Low DO has been observed in both Malibu Creek and its tributaries, although observations of daytime DO meet the minimum DO criterion most of the time (Figure 7-2). Data show that early morning DO levels are well below the criterion for some pools in lower Malibu Creek. Additionally, Sikich et al. (2012) report that the Malibu Lagoon "suffers low Dissolved Oxygen (DO) levels…In a 2005 study [Briscoe et al., 2002], pre-dawn dissolved oxygen concentrations averaged 1.15 ± 0.12 mg/L SE, significantly below Basin Plan thresholds." As noted above, impaired DO may result from excess algal growth. It can also be caused by discharges of oxygen demanding wastes and is exacerbated by elevated water temperatures, which in turn may be linked to impervious surface runoff, impoundments, and removal of riparian vegetation. Regardless of the cause of low DO, benthic macroinvertebrates require adequate DO for survival, and low DO conditions are stressors that potentially cause biological impairment.

A4. **Toxicity from Metals or Organic Toxics**: Occasional water column toxicity has been reported for Malibu Creek since 2005 (Brown and Bay 2005). In Malibu Lagoon, two sediment sites out of eight exhibited toxicity (Meyers et al., 2001). A variety of substances, including various metals, ammonia, and organic chemicals such as pesticides, herbicides, and petroleum products can cause acute (e.g., lethality) and/or chronic toxicity (e.g., reduced reproductive success) in benthic macroinvertebrates. Toxicity is most often associated with anthropogenic loads (wastewater discharges, urban runoff); it some instances, it may also reflect natural conditions, caused by naturally elevated water column or sediment concentrations. For instance, sulfate and selenium concentrations may be naturally elevated in the Malibu basin due to its geology (LVMWD, 2011).

Stormwater in Malibu Creek often has elevated toxicant concentrations. Those increased pollutant levels have been shown at times to have deleterious effects based on toxicity tests in Malibu Creek (see Section 8.5.1). Also, monitoring data indicates that in about half the samples, selenium exceeded acute standards in
63 percent of the dry weather samples and chronic standards in approximately half the wet samples reported at LACDPW's mass emission station on Malibu Creek from 2003-2010. Sulfate acute and chronic standards were exceeded in approximately half of both the wet and dry samples. The toxicity analyses of Brown and Bay (2005) described in Section 8.5 suggest that sulfate and other dissolved salts were the likely cause of observed dry and wet weather toxicity.

A5. **Niche Competition from Invasive Species**: New Zealand mudsnails have been observed in Malibu Creek since 2005, and are spreading in the watershed. Abramson et al. (2009) report that the New Zealand mudsnail "colonies disrupt the food web by displacing native aquatic invertebrates that fish and amphibians rely on for food" and have been found on more than 70 percent of substrate samples in Malibu Creek. Other non-native invasive plants and animals are also reported in the watershed (Sikich et al., 2012). In general, invasive species impair native ecosystems by outcompeting native species for resources such as food or habitat and ultimately reducing species diversity (Strayer, 2010).

9.2.2 Major Stressor Sources

Sources are origins of stressors that release or impose a stressor into a waterbody. Seven groups of stressor sources are listed as potential causes of observed impairment for further evaluation:

B1. **Altered Hydrology**: Altered hydrology, in addition to changing the flow regime, causes increased erosion and sedimentation. Hydrology in Malibu Creek has been altered by a combination of increased impervious area (which increases flow peaks), irrigation (which increases base flow levels), and impoundments (which decrease net flows and smooth out peaks). The IHA change analysis showed dramatic changes in both high and low flows, with large increases in both summer low flows and winter storm flow peaks (see Section 6.2). Median low flows increased in all months except February and March when comparing gaging for water years 1992-2009 to 1932-1965. The increased quantities of low flows likely creates unfavorable stream habitat for native benthic macroinvertebrates relative to the reference locations.

In general, the rates of flow rise and fall do not show statistically significant differences over time, and there is little difference in small floods. The more significant (< 10 percent) observations are the changes in high flow pulse peaks (e.g., above baseflow) and timing, and large flood peaks and timing. The high flow pulses are smaller and occur later in the year post impact, while the large flood peaks are greater and occur earlier in the year. Both of these factors likely have enough force to to modify the physical conditions and morphology of the streambed; the changes in large floods can also have important consequences for the physical habitat of the floodplain. Although large flood peaks increased from 5,370 to 7,360 cfs, these episodic flows would not dramatically affect the benthic community directly because the associated velocities of each flow event would not increase by the same percentage. However, the cumulative impact of these modified flows on the habitat structure and composition would directly affect the benthic community.

In addition, hydrology in the Malibu Lagoon has been altered due to changes in upstream flow, filling and constrictions of the Lagoon, and changes in the rate of opening to the ocean.

B2. **Channel Alteration**: Hydromodification to the stream channel has the potential to change the shape of the stream, redistribute sediments, change the sediment sizes, and erode channel sides. The major alterations to the channel of Malibu Creek and its tributaries have been the creation of several lakes or impoundments. Malibu Lagoon has been extensively modified over the years by sediment fill, surrounding development, construction of railroad/road crossings, and intentional breaching of the barrier beach to allow draw down of impounded water.

B3. **Fire Impacts**: Fire is a recurrent and important factor of the landscape in southern California that can cause important temporary changes in runoff and sediment loading. In the years after intense fires, the lack of viable vegetation results in increased peak runoff and elevated sediment loads, and massive turbidity flows; these actions can impact biology directly. Although fire is a natural phenomenon in chaparral landscapes, human intervention to suppress fire events and magnitudes can lead to less frequent, but more intense and damaging fires. Malibu Creek Watershed has experienced many significant fires over the past several decades.

B4. **Point Source Discharges**: Wastewater treatment plants and other permitted point source discharges can contribute to excess loads of nutrients, oxygen demanding waste, and other pollutants. Within the Malibu Creek Watershed, the only traditional permitted point source discharge is the Tapia Water Reclamation Facility (urban runoff in Los Angeles County is also covered by a NPDES MS4 point source discharge permit, but is addressed separately under the heading “urban runoff”). The Tapia WRF, built in 1965, discharged to Malibu Creek along Malibu Canyon Road. Discharges from Tapia were severely restricted by orders of the RWQCB in 1997-1999. Since then, discharges to Malibu Creek are prohibited from April 15 to November 15. Much of the reclaimed water is used for irrigation. Winter discharges occur, but are restricted to 8 mg/L total inorganic N and 3 mg/L total P in accordance with the 2003 nutrient TMDL and permit modifications. LVMWD (2011) reports that the median nitrate-N concentration upstream of the Tapia discharge is about 1.0 mg/L during the discharge season (winter) and 0.5 mg/L during the non-discharge season (summer), while the median concentration downstream is 2.88 mg/L during the discharge season (winter) and 0.2 mg/L during the non-discharge season (summer). Total N concentrations (including organic N) are higher, and the LACDPW mass emissions station reports a median total N concentration during the non-discharge season of 1.65 mg/L downstream of Tapia. LVMWD (2011) reports that the median

PO_4-P concentration upstream of Tapia during the non-discharge season (summer) is 0.10 mg/L, while the downstream concentration during the non-discharge season (summer) is 0.29 mg/L., perhaps reflecting the effects of past discharges.

B5. **Urban Runoff**: Urbanization accounts for an increase in impervious surface in the watershed from 5.26% in 1990 to 6.95% in 2008. While most of the watershed remains undeveloped, this impervious area percentage increase is concentrated in cities along the 101 corridor, leading to more expansive impervious grounds in one area. Urban impervious surfaces play an important role in altering the flow regime by reducing infiltration and increasing “flashiness” of stream flooding. Additionally, urban runoff is a potential source of a variety of pollutants, such as bacteria indicators, nutrients, copper derived from brake pads, pesticides, herbicides, and petroleum products. Active urban development (active construction) results in increased sedimentation from surface runoff. Urban runoff in Los Angeles and Ventura Counties is covered by two unified NPDES MS4 point source discharge permit.

B6. **Agricultural Runoff**: In many watersheds, agricultural runoff (including irrigation return flow) is a potential cause of impairment. Agricultural runoff can contribute to elevated levels of sediment, nutrients, pesticides, and herbicides. Satellite imagery data indicate that agricultural land use in the Malibu Creek watershed has decreased from 1.9% in 1990 to 1.3% in 2008 (Table 4-2). However, Goepel et al. (2012) report that many existing vineyards are small, situated adjacent to residential structures, and likely represent “hobby vineyards.” These small vineyards cannot be identified in the satellite imagery, and this made it challenging to evaluate its potential for loading. Currently, the amount of agricultural runoff within the watershed appears to be minimal, but improved geographical information and monitoring data will provide a better indication of this source.

B7. **Natural Geology**: In some watersheds, stressors are elevated due to natural conditions. The Malibu Creek Watershed occupies the unique geology of the Santa Monica Mountains. This is an area with rapid uplift rates, resulting in naturally high rates of erosion and sedimentation (see Section 4.4). The marine Modelo formation outcrops have elevated levels of sulfate, phosphate, and various metals (LVMWD, 2011), including selenium. These deposits may contribute to naturally elevated levels of not only selenium, but orthophosphate, sulfate, and total dissolved solids, as well. Such conditions may result in biological impairment from sedimentation and reduced habitat quality or toxicity.

9.3 ANALYZE EVIDENCE AND CHARACTERIZE CAUSES

The previous section, “List Candidate Causes” identifies sources and stressors that are present in the impaired watershed and that may be responsible—either singly or in combination—for the biological impairment. This section presents an analysis of the evidence for each of the five major sets of interacting and proximate stressors that are potential causes of biological impairment in Malibu Creek and Estuary and the seven groups of stressor sources that are also enumerated as potential causes of observed impairment for further evaluation. SC-IBI scores are evidently lower for impaired sites compared with reference sites: average SC-IBI scores range between approximately 20 and 25 for impaired sites, compared with scores between 55 and 65 for reference sites.

Multiple causal pathways are evaluated for Malibu Creek and Lagoon. As shown in the conceptual model, however, the causal pathways are not fully independent. Overlap between the pathways results in the following set:

1. Reduced habitat quality from excess sedimentation (A1) can be caused by altered hydrology (B1), channel alteration (B2), fire impacts (B3), urban runoff, including runoff from construction sites (B5), agricultural runoff (B6), or natural geology (B7)

2. Reduced habitat quality from excess algal growth (A2) can be caused by point source discharges (B4), urban runoff (B5), or agricultural runoff (B6)
3. Reduced DO (A3) can be caused by excess algal growth resulting from point source discharges (B4), urban runoff (B5), or agricultural runoff (B6), or by oxygen-demanding wastes resulting from point source discharges (B4)
4. Toxicity from metals or organic toxics (A4) can be caused by urban runoff (B5) or natural geology (B7)
5. Niche competition (A5) can be caused by invasive species (B8)

This section first explores the linkages between each stressor and observations of biological impairment. Then, linkages between sources and stressors are evaluated. The strength of evidence for each candidate cause is presented within this discussion, to maintain coherence between the presentation of the evidence and the conclusions drawn from it. Additionally, Section 9.4 summarizes the Characterization and present the results in tabular format.

A1. Reduced Habitat Quality from Excess Sedimentation: Sources of excess sedimentation include altered hydrology (B1), channel alteration (B2), fire impacts (B3), urban runoff (B4), construction site impacts (often resulting from urban development), agricultural runoff (B6), or natural geology (B7). Each of these sources are discussed below; construction site impacts are discussed with urban runoff (B4).

Malibu Creek

Sedimentation in the Malibu Creek watershed is high. Measures of sedimentation include TSS and turbidity. TSS monitoring data are limited for Malibu Creek. Elevated TSS or SSC concentrations are documented for the main stem (at two sites, by USEPA and LACDPW), but TSS data are not available for most other biological sampling sites and therefore do not provide sufficient information for a comparative analysis of evidence. On the other hand, turbidity data are routinely collected by Heal the Bay, predominantly, but not exclusively during dry weather. The three impacted sites all show increased turbidity relative to the reference sites, with averages at the impacted sites ranging from 1.31 to 2.62 NTU compared to 0.27 to 0.75 NTU at the reference sites. Excess sedimentation also has been demonstrated by sedimentation in the Lagoon and the filling of the pool behind Rindge Dam such that it was 85 percent filled by 1949 (Ambrose and Orme, 2000). Furthermore, Heal the Bay’s Stream Walk program reported that 21.29 miles of 68 surveyed stream miles were impaired by excess fine sediments. Only 0.29 miles of the impaired streams occurred upstream of developed areas. Biological impairment largely occurs downstream of impaired areas (see B7 below).

RBP Physical Habitat scores, which aggregate ten individual scores including embeddedness, sediment deposition, and bank stability (a measure of erosion potential), were similar between impaired and reference sites and generally fall within the optimal or sub-optimal categories. The 2005 Malibu Creek Bioassessment Monitoring Program (Aquatic Bioassay, 2005) Report concluded that, for the four sites rated optimal or sub-optimal (of eight total sites), “stressors other than habitat conditions may have impacted these sites.” However, the few sites showing poor physical habitat are all on tributaries, not on Malibu Creek proper, and were rated poor due to excessive sedimentation. The impact of sedimentation on the tributaries likely would impact the main stem…... Las Virgenes Municipal Water District also reports RBP Physical Habitat scores: sites with lower average RBP scores tend to have received poor or marginal ratings on the embeddedness, sediment deposition, and riffle frequency measures.

The following information on sedimentation is excerpted from USEPA’s CADDIS website (USEPA, 2012):

High suspended sediment concentrations can adversely affect aquatic biota by four main pathways: (1) impairment of filter feeding, by filter clogging or reduction of food quality; (2) reduction of light penetration and visibility in the stream, which may alter interactions between visually cued predators *and prey, as well as reduce photosynthesis and growth by submerged aquatic plants, phytoplankton, and periphyton; (3) physical abrasion by sediments, which may scour food sources (e.g., algae) or directly abrade exposed surfaces (e.g., gills) of fishes and invertebrates; and (4) increased heat absorption, leading to increased water temperatures. Deposited and bedded sediments may lead to biological impairment by three main pathways: (1) increased coverage by fine particles, which can alter benthic habitats (e.g., increasing fine substrate habitats favored by burrowing insects and tolerated by nest cleaning fishes, or reducing deeper pool habitats) and bury relatively sessile taxa and life stages (e.g., fish eggs); (2) clogging of interstitial spaces, leading to reduced interstitial flows and habitats; and (3) reduction of substrate size, leading to reduced substrate diversity and stability. Deposited sediments can have indirect effects by reducing oxygen levels either with restricted flow through streambed substrates or by oxygen consumption by bacterial respiration, especially when sediments contain a high concentration of organic matter.*

Many other examples from the literature support the adverse effects of sedimentation on aquatic biota. For example, Wood and Armitage (1997) indicate that sedimentation predominantly impacts primary productivity, faunal diversity, and abundance. Dudgeon (1994) and Armitage (1995) found that increases in fine sediment favor chironomids and oligochaetes. Ephemeroptera, Plecoptera, and Trichoptera are most commonly adversely affected (Harrison et al., 2007). EPT taxa counts at impacted sites in Malibu Creek were demonstrably lower than at reference sites. However, Luce (2003) found that while benthic macroinvertebrate metrics including EPT richness, EPT index, and sensitive EPT index were significantly negatively correlated with percent embeddedness, there was no significant relationship between benthic macroinvertebrates and percent fines. This finding may be due to the unique nature of the geology of the Malibu Creek watershed. Since it is highly erosive, percent fines may not be a critical factor defining the differences in the benthic communities.

Based on the information from the case, excess sedimentation co-occurs spatially with impairment, based on Heal the Bay's Stream Walk observations and the well documented fact that sedimentation has long been present in the watershed, providing evidence for temporality. However, the biological gradient evidence is weak, because the physical habitat scores are generally acceptable and do not appear to correlate with the SC-IBI scores. Evidence from the literature supports sedimentation as a plausible, but not specific stressor resulting in benthic macroinvertebrate community impairment. Other stressors elicit similar responses. No evidence is available to support predictive performance. Overall, the consistency of evidence for sedimentation causing biological impairment to Malibu Creek is most consistent.

Malibu Lagoon

Malibu Lagoon also is impacted by sedimentation. The Lagoon is naturally a highly dynamic system in which substantial aggradation occurs in cycle with major winter floods that open the barrier beach and scour out accumulated sediments. Reviewing detailed maps of the Lagoon shows that increased aggradation combined with proximate development that constricts the Lagoon footprint has resulted in a smaller and fresher Lagoon than was likely the case under natural conditions. However, increased flows during the natural dry season have overtopped the beach barrier and opened the Lagoon to ocean waters. While these increased flows may help scour out accumulated sediments, the timing of the events may conflict with Lagoon benthic macroinvertebrate phenology. No data are presented to support or refute this hypothesis. Due to low flushing, fine sediments accumulate in the tidal channels. These sediments are associated with greater nutrient loads that cause algal blooms, resulting in eutrophication (Shifting Baseline, 2011; Jones and Stokes, 2006; Moffatt and Nichol, 2005; 2NDNATURE, 2010). Measurements of sediment in 1987 suggested the average rate of sedimentation since 1983 was 10 cm/year. This level of sedimentation is estimated to be nearly ten times the rate that would have occurred during pre-European settlement periods (Topanga-Las Virgenes Resources Conservation District, 1989). During the flood of February 6, 1999, LACDPW data shows that 2,321 mg/L of suspended sediment was carried through Malibu Creek into the Lagoon.

A large body of data evaluating the benthic invertebrate community composition in Malibu Lagoon indicates that the Lagoon invertebrate community is impaired. Recent sampling performed by USEPA found that a site closest to the head of the estuary with consistent upstream freshwater flow had the greatest number of taxa collected. Sites located in back channels with limited flow, or closest to the Lagoon mouth in the central part of the Lagoon, showed the largest abundance of organisms, but the largest proportion of those organisms were highly tolerant species that can survive in highly impacted conditions. Results of this sampling effort strongly suggest poor benthic community diversity and abundance.

Based on information from the case, excess sedimentation co-occurs spatially with impairment, and increased sediment has long been present in the Lagoon. Sedimentation/scour cycles are part of the natural dynamics of the Lagoon, and limited information is available to evaluate how the changed timing of the cycle might affect benthic macroinvertebrate recruitment or breeding, leaving the evidence for the biological gradient weak. However, it should be noted that modification to the natural hydrology in the watershed, and thus flow into the Lagoon, has impacted the natural tidal flushing patterns expected from an non-impacted estuary. Evidence of this is well-documented for southern California estuaries. Therefore, evidence supporting the causal pathway is incomplete. Evidence from the literature is similar to the literature evidence for Malibu Creek, supporting sedimentation as a plausible, but not specific stressor. No evidence is available to support predictive performance. Overall, all of the evidence for sedimentation as a cause of biological impairment to Malibu Lagoon is consistent and inconsistencies can be explained by a credible mechanism.

A2. Reduced Habitat Quality from Excess Algal Growth: Sources of excess algal growth include excess nutrients resulting from point source discharges (B4), non-point sources attributable to urban runoff (B5), or agricultural runoff (B6). Evidence for linkages between these sources and excess nutrients/excess algal growth are discussed in each source’s section. The following discussion presents the evidence for linkage between excess nutrients, excess algal growth, and reduced habitat quality for benthic macroinvertebrates.

Malibu Creek

Nutrient concentrations in Malibu Creek are elevated in many locations, although only limited data on total nutrient concentrations are available. Notably, average concentrations of NO_x-N, ammonia-N, and PO_4-N, as reported by the Heal the Bay Stream Team are higher at impacted sites than reference sites, as shown in Table 9-1. Orthophosphate concentrations appear to be naturally elevated within the Modelo formation; however, both orthophosphate and nitrate concentrations increase dramatically as streams pass through the developed area in the 101 corridor. Available information on total N and total P concentrations suggest that the totals (which include organic forms) are much higher than the inorganic nutrient concentrations. Much of the mass in organic forms of N and P can be rapidly broken down by biological activity, becoming available to support plant growth. Further examination of the Stream Team data reveal that NO_x-N concentrations are clearly elevated at the downstream station, MC-1, downstream of the Tapia WRF, while concentrations upstream of Tapia at MC-12 are not much different from reference sites (Figure 7-12). Additionally, results reported by LVMWD (2011) suggest that median nitrate-N concentration is about 1.0 mg/L upstream of the Tapia discharge and 2.88 mg/L downstream during the discharge season (discharge season are generally winter months; values are below the 2003 nutrient TMDL targets), and 0.60 mg/L upstream and 0.20 mg/L downstream of Tapia during the non-discharge season (generally summer months).

Table 9-1. Ranges of Average Nutrient Concentrations (mg/L) in Impacted Versus Reference Sites

Nutrient Form	Range of average concentrations at Impacted Sites	Range of average concentrations at Reference Sites
NO_x-N	0.08 – 2.46	0.03 – 0.27
Total Ammonia as N	0.07 – 0.30	0.04 – 0.05
PO_4-P	0.27 – 1.82	0.08 – 0.13

Excess algal growth has been measured directly at the impacted Malibu Creek sites at concentrations much greater than at the reference sites. In addition, a nutrient TMDL was developed for Malibu Creek by USEPA (2003) with a target of achieving not more than 30 percent coverage for filamentous algae greater than 2 cm in length and not more than 60 percent cover for bottom algae greater than 0.3 cm thick. Although the nutrient limits proposed in the TMDL appear to have been achieved the algal density targets have not. Mean concentrations of mat algae coverage in the impacted sites range between approximately 65% to approximately 90%, compared to means between 5% and 10% at reference sites. Busse et al. (2006) measured periphyton chlorophyll *a* densities and nutrient, light, and water currents and concluded that nutrient concentrations were not limiting on algal growth in Malibu creek. Instead, periphytic algae varied positively with light and negatively with winter season scouring flows. Moreover, total nitrogen, total phosphorus, and total chlorophyll concentrations were all positively correlated with the proportion of upstream land covered by impervious surfaces. Luce (2003) reported somewhat more complex, but still positive, relationships between nutrient concentrations and algal cover. At least in Malibu Creek Watershed, it appears critical to evaluate the organic and inorganic forms of nitrogen, in addition to validating the chemical observations with the mat algae coverage in-stream. To effectively assess the condition, it is necessary to evaluate the two lines of evidence; this will provide better and a more informative assessment of the condition.

Sites exhibiting excess algal growth also exhibit SC-IBI scores lower than reference sites. Heal the Bay (Sikich et al., 2012) reported that benthic algal cover was lowest at reference sites and highest at outlet sites, and that the vast majority of impacted sites occurred downstream of development. Interestingly, despite lower NO_x-N concentrations upstream of Tapia, SC-IBI scores upstream of Tapia are not significantly different from scores downstream in three separate data collection efforts (Table 9-2). In fact, scores at the Heal the Bay downstream site MC-1 have been higher than those at the upstream MC-12 site since 2005. This is a critical reason why this TMDL evaluation included additional method of evaluating the benthic community (i.e., O/E scores).

Table 9-2. Comparison of Median SC-IBI Scores Upstream and Downstream of Tapia Discharge

Site	Upstream/Downstream Stations	Upstream SC-IBI	Downstream SC-IBI
Heal the Bay	MC-12/MC-15, MC-1	21	24, 25
LVMWD	R-1/R-2, R-13	19	15, 19
USEPA	EPA-2/EPA-1	31	27

LVMWD (2011) contends that pH and DO generally fall within regulatory limits, suggesting weak impacts of eutrophication. However, this argument is unconvincing because high gas exchange rates are expected in shallow streams, and dense benthic algal growth alone may cause impairment via habitat effects or boundary layer DO.

The following information on nutrients and algal growth is excerpted from USEPA's CADDIS website (USEPA, 2012):

> *Fish and invertebrates are usually not directly adversely affected by excess nutrient concentrations, but rather are affected by other proximate stressors resulting from nutrient enrichment. For example, increases in dissolved N and P can lead to increases in plant and microbial biomass or productivity, which may lead to greater microbial infection of invertebrates or fish, or altered benthic organic matter processing (e.g., faster processing rates). Increased respiration of microbes and plants often leads to decreases in DO concentrations, especially during times when photosynthesis is limited (e.g., at night). In addition, increased photosynthesis may lead to increased pH; this increase may be especially important when N is elevated, as unionized ammonia, a toxic form of N, is more prevalent at high pH. Blooms of certain algal taxa also may result in increased production and release of toxins that can affect fish or invertebrates.*
>
> *Increased plant or algal production may translate to increased food resources, which can benefit herbivorous organisms but may adversely impact other taxa by altering the food resources derived from detritus. Changes in plant assemblage structure also may occur with enrichment, and these changes can affect aquatic fauna by altering habitat structure or by altering the quantity or quality of food resources. Changes in community structure may occur even without overall increases in primary producers, due to alterations of nutrient availability ratios. Increases in suspended organic matter (i.e., phytoplankton or suspended benthic algae) also can negatively affect aquatic biota, for example by increasing turbidity.*

The excess algal growth in Malibu Creek does not appear to strongly affect DO concentrations in the creek (A3). However, excess growth of periphytic and attached algae can have a direct deleterious impact on habitat suitability. Excess algal growth can cover suitable habitat (Allan, 1995) and may depress overall invertebrate taxa richness (Yuan, 2010) or shift invertebrate community composition toward grazers and scrapers (Feminella and Hawkins, 1995; Quinn et al., 1997). Although Luce (2003) observed more periphyton cover at Malibu Creek area sites with higher nutrient concentrations, including high-nutrient reference sites included in the study, no dense populations of grazers were observed.

Median IBI scores greater than 30 only occur at sites with average nitrate-N concentrations less than 1 mg/L, suggesting that nutrient impacts may be depressing benthic biotic health in the watershed. Sites with the highest nitrate concentrations occur in the Modelo formation and have been hypothesized to be naturally-occurring as a result of the underlying geology. However, at CH-6, which drains portions of the Modelo formation, nitrate concentrations are near zero. It is noteworthy that this station (CH-6) is upstream of most high density development in the watershed, whereas other sites with high nitrate concentrations are downstream of high density development areas.

Based on the information from the case, excess nutrients and excess algal growth co-occurs spatially with impairment, and elevated nutrient concentrations appear to have worsened with development, beginning in the 1960s. Evidence for the biological gradient is strong. Both nutrient concentrations and mat algal coverage are much higher in Malibu Creek than at reference sites. However, the biological gradient with respect to the Tapia WRF discharge is less clear. Although the biological gradient and the Tapia discharge is tenuous, this does not include the evaluation of the long-term impact of Tapia's discharge in the Watershed. The long-term Tapia discharge since 1965 undoubtedly caused to nutrient increases in the system, which would directly impact the benthic community over time. The uncertainty is linked to the amount of nutrient load stored, available, and depleted in the stream system over time. Even though NO_x-N concentrations are lower upstream of the discharge compared to downstream, SC-IBI scores appear more closely related to urban development. Lastly, there is evidence for all steps in the complete exposure pathway. Evidence from the literature supports excess nutrients resulting in excess algal growth as a plausible, but not specific stressor resulting in benthic macroinvertebrate community impairment: other stressors elicit similar responses. Many analogous examples are present in the literature to support the causal pathway, although no evidence is available to support predictive performance. Overall, the evidence for reduced habitat quality from excess nutrients and excess algal growth causing biological impairment to Malibu Creek are all consistent and any inconsistencies can be explained by a credible mechanism.

Malibu Lagoon

Benthic aquatic life in Malibu Lagoon is "impaired by eutrophication resulting from excessive nitrogen loads" (Callaway et al., 2009). The City of Malibu does not provide regional sewage collection or treatment, and high water tables decrease the efficiency of onsite wastewater treatment. The Regional Control Board staff estimated that current loads from onsite wastewater disposal in the Civic Center area that constitute direct (non-point source) input of inorganic nitrogen into the Lagoon amount to 30-35 lb/day inorganic nitrogen. Additionally, Malibu Lagoon receives fine sediments associated with greater nutrient loads that can cause algal blooms (Shifting Baseline, 2011; Jones and Stokes, 2006; Moffatt and Nichol, 2005; 2NDNATURE, 2010). Malibu Lagoon currently shows elevated concentrations of NO_x nitrogen and ammonium (Moffatt and Nichol, 2005; 2NDNATURE, 2010) and excessive algal growth.

Based on the information from the case, the linkage between excess nutrients, excess algal growth, and biological impairment is complete for Malibu Lagoon. Excess nutrients and excess algal growth co-occurs spatially with impairment, and elevated nutrient concentrations appear to be associated with non-point source inputs of inorganic nitrogen from onsite wastewater disposal and from nutrient-bearing fine sediments transported from the Malibu Creek Watershed, beginning in the 1960s, coincident with development. Evidence for the biological gradient evidence is uncertain. Correlations between a gradient of nutrient concentrations and benthic invertebrate responses are not available. Evidence from the literature supports excess nutrients resulting in excess algal growth as a plausible, but not specific stressor resulting in benthic macroinvertebrate community impairment: other stressors elicit similar responses. Many analogous examples are present in the literature to support the causal pathway, although no evidence is available to support predictive performance. Overall, the evidence for reduced habitat quality from excess nutrients and excess algal growth causing biological impairment to Malibu Lagoon are all consistent and any inconsistencies can be explained by a credible mechanism.

A3. Reduced DO: Reduced DO from excess algal growth/excess nutrients can be caused by point source discharges (B4), urban runoff (B5), or agricultural runoff (B6), or by oxygen-demanding wastes resulting from point source discharges (B4). Evidence for linkages between these sources and excess nutrients/excess algal growth are discussed in each source's section. The following discussion presents the evidence for linkage between excess nutrients, excess algal growth, and reduced DO capable of impacting benthic macroinvertebrates.

Malibu Creek

Impaired sites in Malibu Creek show average dissolved oxygen concentrations that are similar to concentrations at reference sites, ranging between 9.09 and 10.90 mg/L for impaired sites for which sufficient data are available, and 9.30 and 9.93 mg/L for reference sites. The frequency of low DO observations (<5 mg/L) at impacted sites is higher than at reference sites, ranging from 4. 10% to 5.50% at impaired sites compared to 0% at reference sites. DO is strongly affected by water temperature, and water temperatures differ somewhat between impaired and reference sites. Impaired sites were 2.3 °C and 4 °C greater than reference sites during the summer season. Increased algal growth is evident at impaired sites compared to reference sites, as discussed above.

Sikich et al. (2012) reported continuous DO measurements for lower Malibu Creek (Lunch and Start Pools) between August 11, 2009 and September 1, 2009. The Start Pool site is situated approximately 250 m upstream of the Malibu Creek Outlet. Lunch Pool is located approximately 720 m upstream of Start

Pool. Lunch Pool experienced little diurnal DO variation, with measurements ranging from approximately 6 mg/L to approximately 9 mg/L over the course of the study. On the other hand, Start Pool experienced a wide range of DO measurements, with greater DO (up to approximately 12 mg/L) occurring in mid to late afternoon, and very low DO (less than 2 mg/L occurring from about 11 PM until about 11 AM.

No continuous monitoring data are available to compare the daily range of DO concentrations upstream and downstream of the Tapia discharge.

Decreased dissolved oxygen in Malibu Creek can result from increased water temperature or increased biological oxygen demand (due to excessive algal growth and increased plant and microbial respiration, A2, discussed above). The following information on enrichment/DO is excerpted from USEPA's CADDIS website (USEPA, 2012):

> *Low or extremely high DO levels can impair or kill fishes and invertebrates. In addition, large fluctuations in DO levels over relatively short periods of time (e.g., daily) can stress aquatic organisms. Human activities can significantly affect DO concentrations in streams, most notably by decreasing oxygenation and by increasing chemical or biochemical oxygen demand. Agricultural practices, forestry practices, and other activities may involve channel alteration (e.g., straightening or deepening of streams) or impoundments downstream of a location, which may decrease aeration and the diffusion of oxygen into water. Impoundments upstream of a location may discharge low oxygen water downstream, but releases also may increase turbulence and oxygenate water. These land use practices also may directly introduce nutrients (e.g., fertilizers, animal wastes), chemical contaminants (e.g., heavy metals), or organic matter (e.g., sewage, animal wastes) to streams, or indirectly increase the delivery of these substances to streams via land cover alteration. The resulting chemical reactions and increased respiration of microbes and plants can increase oxygen demand in streams, leading to decreases in DO.*

DO saturation occurs at lower concentrations in warm versus cold water, so factors contributing to increased water temperatures (e.g., loss of riparian cover, warm effluents) may contribute to decreased DO concentrations. Similar relationships are seen with increasing ionic strength and sediment. Although most impairments associated with DO result from insufficient oxygen levels, in rare cases DO concentrations may be too high (e.g., due to increased photosynthesis and subsequent oxygen production in nutrient-enriched streams). Even if elevated DO levels do not cause direct impairment, they may contribute to stressful DO fluctuations when followed by significant drops in DO at night.

Based on evidence from the case, low DO measurements co-occur spatially with some impaired sites in the very lower reaches of Malibu Creek (at the outlet). At sites upstream of the outlet, DO levels are similar to those at reference sites, except that the minima are lower at the impacted sites. There is no evidence relating oxygen-demanding wastes from Tapia with low DO. Evidence for temporality is consistent. Occasional DO problems are expected with increased algal growth, and low DO is evident at the outlet of Malibu Creek at times of increased plant and microbial respiration. Evidence for the biological gradient is weak. Reference sites do not fall as low as impaired sites, and, with the exception of the Malibu Creek outlet, it is unclear if the frequency of low DO is sufficient to cause impairment. Evidence for the complete exposure pathway is incomplete. Benthic macroinvertebrate impairment may occur as a result of loss of suitable habitat when that habitat is covered with mat algae, as opposed to the effect of low DO. Evidence from outside the case indicates that low DO resulting from excess algal growth is a plausible mechanism for impairment, but it is not specific. Many examples exist in the literature of benthic invertebrate impairment resulting from low DO in eutrophic waters. There is no evidence for predictive performance. Most lines of evidence are consistent with low DO as a causal factor, and any inconsistencies can be explained by a credible mechanism.

Malibu Lagoon

Malibu Lagoon also experiences low DO conditions, starting at the Malibu Creek outlet, as demonstrated by the DO results for the Start Pool presented above (Sikich et al., 2012). Sikich et al. (2012) also presented data for Malibu Lagoon, based on a study by Briscoe, stating that pre-dawn DO levels averaged 1.15 ± 0.12 mg/L SE in Malibu Lagoon. Ambrose et al. (1995) obtained diurnal DO levels between July 1993 and April 1994 at a westerly channel site in the Lagoon and at a mid-Lagoon site. The westerly channel site exhibited bottom water ranges between 2.6 and 10 mg/L DO, and the mid-Lagoon site had bottom water ranges between 5.5 and 12.2 mg/L.

Benthic aquatic life in Malibu Lagoon is "impaired by eutrophication resulting from excessive nitrogen loads" (Callaway et al., 2009). The City of Malibu does not provide regional sewage collection or treatment, and high water tables decrease the efficiency of onsite wastewater treatment. The Regional Control Board staff estimated that current loads from onsite wastewater disposal in the Civic Center area that constitute direct (non-point source) input of inorganic nitrogen into the Lagoon amount to 30-35 lb/day inorganic nitrogen. Additionally, Malibu Lagoon receives fine sediments associated with greater nutrient loads that can cause algal blooms (Shifting Baseline, 2011; Jones and Stokes, 2006; Moffatt and Nichol, 2005; 2NDNATURE, 2010). Malibu Lagoon currently shows elevated concentrations of NO_x nitrogen and ammonium (Moffatt and Nichol, 2005; 2NDNATURE, 2010) and excessive algal growth.

Evidence supports a linkage between low DO and benthic invertebrate impairment. Evidence for spatial co-occurrence is compatible. Evidence for temporality is consistent. Low DO levels precede biological impairment, but the evidence for the biological gradient is weak. It is unclear if the frequency of low DO is sufficient to cause the impairment. Therefore, evidence for the causal pathway is incomplete. Evidence for the complete exposure pathway is incomplete. Benthic macroinvertebrate impairment may occur as a result of loss of suitable habitat when that habitat is covered with mat algae, as opposed to the effect of low DO. Evidence from outside the case indicates that low DO resulting from excess algal growth is a plausible mechanism for impairment, but it is not specific. Many examples exist in the literature of benthic invertebrate impairment resulting from low DO in eutrophic waters. There is no evidence for predictive performance. Most lines of evidence are consistent with low DO as a causal factor, and any inconsistencies can be explained by a credible mechanism.

A4. Toxicity from Metals or Organic Toxics: Toxicity from metals or organic toxics (A4) can be caused by urban runoff (B5) or natural geology (B7). Evidence for linkages between these sources and toxicity are discussed in each source's section. The following discussion presents the evidence for linkage between toxicity and impaired benthic macroinvertebrates.

Malibu Creek

Occasional water column toxicity has been observed since 2005 in wet and dry weather surface water samples from Malibu Creek, using *Ceriodaphnia dubia* (water flea) survival and reproduction and *Strongylocentrotus purpuratus* (purple sea urchin) fertilization tests. LADPW reports indicated that the toxic effect apparently dissipated after holding the sample, and attributed the cause to volatile chemicals. In a separate study, Brown and Bay (2005) examined Malibu Creek water near the mouth under both wet and dry conditions. One out of eight dry weather samples showed acute toxicity (survival) and two of eight showed chronic toxicity (reproduction) to *C. dubia*. The authors attribute the results to sulfate and other dissolved salts.

Water quality data for both sulfate and selenium demonstrate frequent exceedances of water quality standards. Rowe et al. (2002) present case studies demonstrating biomagnification of selenium resulting in sub-lethal and possibly lethal concentrations in organisms at the highest trophic levels. However, low concentrations of selenium also are essential for animal health and are considered beneficial for plant health (Kapustka et al., 2004).

Although selenium and sulfate data haven't been routinely obtained for the Malibu Creek watershed, conductivity data are routinely available. Conductivity presents a readily obtainable and more commonly observed measure of ionic salt content in water, and can be used as a surrogate measure for toxic salts. Conductivity measurements appear higher in impaired sites than in reference sites, ranging from 1,877 – 2,287 µS/cm on average for impaired sites compared to 1,185 – 1,505 µS/cm for reference sites. Luce (2003) found that impacted sites had conductivities greater than 2,000 µS/cm. Reference sites had conductivities less than 1,500 µS/cm, except for two, where mean conductivity was about 3,500 µS/cm. Luce concludes that for these two reference sites, conductivity was not an indicator of stormwater runoff but instead may be related to elevated phosphate at these two sites that must have another source "such as the geology of the watershed or groundwater inputs to the creek."

The following information on ionic strength (conductivity) is excerpted from USEPA's CADDIS website (USEPA, 2012):

> *There is debate among scientists as to the exact mechanisms responsible for toxicity associated with ionic strength. Toxicity due to ionic strength could result from disruption of organisms' osmotic regulation processes, decreases in bioavailability of essential elements, increases in availability of heavy metal ions, increases in particularly harmful ions, changes in ionic composition, absence of chemical constituents that offset impacts of harmful ions, a combination of the above, or other as yet unknown mechanisms. In some instances (perhaps the majority), increased ionic strength causes shifts in community composition rather than mortality; thus, specific conductivity, salinity, and TDS levels may be associated with biological impairment and yet be below mortality thresholds.*

Based on evidence from the case, the linkage between toxicity and benthic macroinvertebrate impairment in Malibu Creek is incomplete. Only occasional water column toxicity has been observed, even though toxicity is frequently assessed at the mass emission station downstream of the Tapia WRF. However, toxicity data are not available from other sites in the watershed. Therefore, evidence for spatial co-occurrence is uncertain. Evidence for temporality is uncertain, because toxicity results are not consistent over time. Evidence for the biological gradient is weak, because two reference sites also exhibited high conductivity, but high SC-IBI scores. Evidence supporting the causal pathway is incomplete. Toxicity has the potential to impact benthic organisms, but it is unclear whether the frequency of toxicity is sufficient to explain the observed impairment. Elevated sulfate and selenium may impact benthic macroinvertebrates, but insufficient site-specific information exists. Conductivity can be used as a surrogate measure for toxic salts, but on its own doesn't provide conclusive evidence of toxicity. Therefore, based on the evidence from the case, the evidence supporting a complete exposure pathway is insufficient. Actual evidence exists in the literature for toxicity from selenium and sulfate, but the evidence does not support specificity. There is no evidence of predictive performance. Most of the evidence is consistent with toxicity as a causal factor of benthic macroinvertebrate impairment, and any inconsistencies can be explained by a credible mechanism.

Malibu Lagoon

Sediment toxicity tests using amphipods have shown no toxicity to Malibu Lagoon sediments (Bay et al., 2000; Bay et al., 2005). Anderson et al. (1998) alludes to mussel development tests that apparently showed some impact from exposure to subsurface water in Malibu Lagoon, but results are not available for review. Meyers et al. (2001) performed sea urchin pore water toxicity testing for eight sites in Malibu Lagoon. Of those eight sites, two exhibited toxicity. Both toxic sites were located upstream, but were not the farthest upstream sites tested in the Lagoon. Sites farthest upstream were expected to be the most toxic, since they are first to come into contact with water discharging from the watershed. Similarly, mouth sites were expected to be the least toxic, due to the effects of filtering as water passes through the Lagoon. However, these spatial patterns were not upheld in Malibu Lagoon.

Based on evidence from the case, the linkage between toxicity and benthic macroinvertebrate impairment is incomplete. Only limited toxicity has been observed, and evidence for spatial co-occurrence is uncertain, because spatial patterns of toxicity do not conform to expectations and because it is not clear how sites tested for toxicity relate to sites at which benthic macroinvertebrates were collected. No evidence for temporality exists. Toxicity has only rarely been observed in Malibu Lagoon, whereas biological impairment has been present consistently. No evidence exists to support a biological gradient. Evidence supporting the exposure pathway is incomplete. Actual evidence exists in the literature for toxicity from selenium and sulfate, but the evidence does not support specificity. There is no evidence of predictive performance. There are multiple inconsistencies with respect to toxicity as a causal factor of benthic macroinvertebrate impairment in Malibu Lagoon, and no explanations are currently available to explain the inconsistencies.

A5: Invasive Species: Invasive species can impair benthic macroinvertebrates communities through niche competition. This section evaluates the linkage between invasive species (specifically the New Zealand mudsnail) and biological impairment.

The presence of the invasive New Zealand mudsnail has been increasing in the Malibu Creek and surrounding watersheds. The mudsnail is very easily spread by fishermen and other stream visitors due to its very small size and resistance to desiccation (CAFG, 2012). The New Zealand mudsnail was first collected in samples collected by the City of Calabasas in 2005, and are now found in eight streams in the Santa Monica Mountains. Abramson et al. (2009) report that the New Zealand mudsnail "colonies disrupt the food web by displacing native aquatic invertebrates that fish and amphibians rely on for food" and have been found on more than 70 percent of substrate samples in Malibu Creek.

In general, invasive species impair native ecosystems by outcompeting native species for resources such as food or habitat and ultimately reducing species diversity (Strayer, 2010). Specifically, at high densities, the mudsnail may compete with other invertebrates for food and habitat, resulting in reduced densities and diversities of native benthic macroinvertebrates. Additionally, the Riparian Invasive Research Laboratory reports that the mudsnail may aid growth of filamentous algae (e.g., *Cladophora*) by grazing on epiphytic diatoms and removing competition for light (UCSB, 2012).

If the New Zealand mudsnail were causing impaired benthic biota in the Malibu Creek watershed, sites with a high density of the snails would be expected to have lowered IBI scores. However, in spring 2006, mudsnails constituted three percent of the biological sample at MC-1, which had an IBI score of 26. By spring 2009, the biological sample at the same site contained 81% mudsnails. The corresponding IBI score was 27. Anomalously low IBI scores in spring 2010 also had low densities of mudsnails (from less than 1 percent at MC-1 to 13 percent at MC-15). Additionally, mudsnails are present at one of the reference sites, but downstream of the macroinvertebrate sample location. This observation may be due to the limitations of the S-IBI's framework, which was not developed to account for the invasive species. Since the S-IBI metrics are based on the categorizing the richness and abundance of functional groups, this approach may not appropriately capture the impact of invasive species. Further evaluation is necessary to identify the impact of the New Zealand mudsnails on the benthic community in the Malibu Creek Watershed.

The evidence from the case is inconsistent with spatial co-occurrence of New Zealand mudsnails and benthic macroinvertebrate impairment in Malibu Creek. The evidence is inconsistent with temporality, since poor SC-IBI scores occurred prior to the introduction of the mudsnail. There is no evidence for the biological gradient at this time. Therefore, evidence for the exposure pathway is incomplete. However, evidence from the literature supports the plausibility but not the specificity of New Zealand mudsnails impairing the benthic macroinvertebrate community. Although only few studies exist, there are analogous situations showing clear indications impacts by New Zealand mudsnail. There is no evidence for predictive performance. The evidence is therefore ambiguous, but inconsistencies can be explained by a credible mechanism.

B1. Altered Hydrology: Changes in stream hydrology affect the flow regime, which is linked to both channel alteration (B2) and urban runoff (B5), can result in increased sedimentation (A1) and subsequent physical habitat alteration. This section evaluates the linkage between altered hydrology and increased sedimentation.

Stream flows have been altered in impaired reaches of the watershed, due to urbanization, water importation, reservoir construction, and wastewater discharges to Malibu Creek. Prior to development, the 11 major streams in the Malibu Creek watershed were intermittent to ephemeral, except for Las Virgenes Creek, lower Medea Creek, and Cold Creek, which were perennial to intermittent (NRCS, 1995). Now, as a result of irrigation with imported and reclaimed water, most of the larger tributaries and all of the main reaches from Westlake Lake to Malibu Lagoon generally have flows all year long (NRCS, 1995). Flows at reference sites likely are not impacted due to little change in impervious cover.

An evaluation of flow gauge data revealed that:

1. The magnitude and duration of annual extreme water conditions have changed significantly between the pre-impact and post-impact periods (i.e., before and after urbanization). Specifically, the 30-day median annual minimum flow increased 2,310 percent and the 30-day median annual maximum flow increased 410 percent. Although the number of zero-flow days increased 918 percent, the actual number of zero-flow days remains very low and therefore is not as important a change as the other measures. Increased magnitude and duration of annual extreme water conditions impact river channel morphology and physical habitat conditions. Alterations in channel morphology resulting from increased flows frequently increase channel erosion and resulting sedimentation.
2. The frequency and duration of high pulses have also changed significantly between pre- and post-impact. The number of high pulses within each water year (> 3 cfs) has decreased 14 percent. Decreased number of high pulses can decrease bedload transport, resulting in greater bed sedimentation, and can result in changes in channel sediment textures, affecting desirable habitat for benthic macroinvertebrate species and altering community composition in affected stream reaches.
3. The high flow pulses are smaller and occur later in the year post-impact, while the large flood peaks are greater and occur earlier in the year. Both of these factors are likely to be associated with shaping the physical conditions and morphology of the streambed, while the changes in large floods can also have important consequences for the physical habitat of the floodplain. In particular, high flows result in unstable stream banks exhibiting rapid erosion and channel scour.

Heal the Bay’s Stream Walk program documented unstable stream banks that had been scoured or eroded by stream flows, surface runoff from outflow pipes, and poorly drained roads and trails, amounting to 19.5 linear miles of 68 miles mapped in the watershed (Sikich et al., 2012). Unstable stream banks occurred in both developed and undeveloped areas. In developed areas, unstable banks typically occurred downstream of channel alteration comprised of bank hardening (see channel alteration, B2, below). In undeveloped areas, additional investigation into the causes of unstable stream banks revealed numerous unpaved roads and trails within 300 feet of eroded banks. Furthermore, 21.29 miles of all surveyed streams were observed to be impaired by excess fine sediments. Only 0.29 miles of the impaired streams occurred upstream of developed areas.

Based on evidence from the case, evidence for spatial co-occurrence between altered hydrology and increased sedimentation is consistent. Flows have been altered in reaches impacted with increased sedimentation; however, reference sites are likely not impacted by the sedimentation, where the riparian buffer is intact and there has been little change in impervious cover. Evidence for temporality is consistent. Flows have been altered since development of the watershed, and increased sedimentation has been observed over the same time frame. Evidence for the biological gradient is weak, since information on hydrology at reference sites is not typically available. Evidence supporting the linkage between altered hydrology and increased sedimentation is incomplete due to the lack of evidence for the biological gradient. Evidence from the literature indicates that a causal linkage between altered hydrology and increased sedimentation is plausible, but not specific. Many examples of similar causal relationships are found in the literature, but there is no evidence of predictive performance. Overall, the lines of evidence supporting the causal relationship are mostly consistent, and any inconsistencies can be explained by a credible mechanism.

The strength of the evidence supporting the causal pathway between altered hydrology and sedimentation is good, and the strength of the evidence supporting the causal pathway between increased sedimentation and reduced habitat quality leading to biological impairment is strong. Therefore, the complete causal pathway between altered hydrology and biological impairment is supported by the evidence.

Review of historical maps for Malibu Lagoon clearly reveals alterations to the Lagoon's morphology, resulting from increased sedimentation, altered flow regimes, and development constricting the size of the Lagoon. Development activities included construction of a railway across the Lagoon in 1908, which was transformed into the Pacific Coast Highway in 1929. A 1950 map shows constraint by roads and ongoing building projects, further reducing the Lagoon's footprint. By 2009 even greater constraints have encroached on the Lagoon, causing increased aggradation. Consequently, the Lagoon is much smaller and believed to be much fresher than it was under natural conditions. Moreover, Malibu Lagoon now receives year-round flow due to irrigation water and other urban-related runoff. Due to low flushing, though, fine sediments accumulate in the tidal channels (Shifting Baseline, 2011; Jones and Stokes, 2006; Moffatt and Nichol, 2005; 2NDNATURE, 2010). Measurements of sediment in 1987 suggested the average rate of sedimentation since 1983 was 10 cm/year. This level of sedimentation is estimated to be nearly ten times the rate that would have occurred during pre-European settlement periods (Topanga-Las Virgenes Resources Conservation District, 1989). During the flood of February 6, 1999, LACDPW data shows that 2,321 mg/L of suspended sediment was carried through Malibu Creek into the Lagoon.

Evidence from the case indicates that altered hydrology and increased sedimentation co-occur spatially. Additionally, the physical modification of the Lagoon pre-dated the increases in sedimentation, providing supporting evidence for temporality. Supporting evidence for the gradient between altered hydrology and increased sedimentation is strong. Therefore evidence for the full causal pathway between altered hydrology and increased sedimentation is complete. Evidence from outside the case supports altered hydrology as a plausible, but not specific, mechanism for increased sedimentation. Many examples exist in the literature to support linkages between altered hydrology and increased sedimentation. No evidence of predictive performance is available. Overall, the evidence supporting altered hydrology as a causal factor is both consistent and coherent.

The strength of the evidence supporting the causal pathway between altered hydrology and sedimentation in Malibu Lagoon is strong, and the strength of the evidence supporting the causal pathway between increased sedimentation and reduced habitat quality leading to biological impairment is good. Therefore, the complete causal pathway between altered hydrology and biological impairment is supported by the evidence.

B2. Channel Alteration: Channel alteration is closely linked to altered hydrology (B1) urban runoff (B5) and can result in increased sedimentation (A1) and subsequent physical habitat alteration.

Heal the Bay's Stream Walk program documented 987 streambank modifications, with a total of 20.9 linear miles engineered with hardened materials. Observed modifications included streambank reinforcement with concrete, boulders, fencing, planted vegetation, and other materials, intended to prevent or repair unstable stream banks (Sikich et al., 2012). Moreover, the Stream Walk program consistently documented increased erosion and sedimentation downstream of modified stream banks. According to Sikich et al. (2012), stream bank modifications are made in an effort to mitigate unstable stream bank erosion, protect adjacent private property, and to allow for access to the stream. These motivations support the suggestion that channel alteration largely resulted from development of the watershed.

Channel alteration can take many forms and is best summarized using the RBP Physical Habitat scores, which aggregate ten metrics and vary somewhat for low gradient and high gradient streams. The following information on physical habitat alteration is excerpted from USEPA's CADDIS website (USEPA, 2012):

> *Direct alteration of streams channels also can influence physical habitat, by changing discharge patterns, changing hydraulic conditions (water velocities and depths), creating barriers to movement, decreasing riparian habitat and altering the structure of stream geomorphological units (e.g., by increasing the prevalence of run habitats, decreasing riffle habitats, and increasing or decreasing pool habitats). Typically, physical habitat degradation results from reduced habitat availability (e.g., decreased snag habitat, decreased riffle habitat) or reduced habitat quality (e.g., increased fine sediment cover), which may contribute to decreased condition, altered behavior, increased mortality, or decreased reproductive success of aquatic organisms; ultimately, these effects may result in changes in population and community structure and ecosystem function.*

Malibu Creek

The evidence from the case clearly supports spatial co-occurrence of channel alteration and increased sedimentation in Malibu Creek. Evidence for temporality is uncertain. Stream bank modification may have occurred as a result of development, indicating support for temporality, but specific data are not available to support that conclusion at this time. Evidence for the biological gradient between channel alteration and increased sedimentation is weak. Evidence exists for increased sedimentation downstream of channel modifications. Given the highly erosive nature of the watershed, it is possible that stream bank erosion also occur as a natural condition. Evidence for the exposure pathway between channel alteration and increased sedimentation is therefore complete. Evidence from the literature supports the causal linkage between channel alteration and increased sedimentation as plausible, but not specific. Many analogous examples exist. There is no evidence for predictive performance. Most of the evidence is consistent with channel alteration as a causal factor for increased sedimentation. Additionally, any inconsistencies can be explained by a credible mechanism.

The strength of the evidence supporting the causal pathway between channel alteration and sedimentation is good, and the strength of the evidence supporting the causal pathway between increased sedimentation and reduced habitat quality leading to biological impairment is strong. Therefore, the complete causal pathway between altered hydrology and biological impairment is supported by the evidence.

Malibu Lagoon

Similarly in this case, our review of historical maps for Malibu Lagoon clearly reveals alterations to the Lagoon's morphology, largely resulting from increased development constricting the size of the Lagoon. Increased aggradation combined with proximate development that constricts the Lagoon footprint has resulted in a smaller and fresher Lagoon than was likely the case under natural conditions. However, increased flows during the natural dry season have overtopped the beach barrier and opened the Lagoon to ocean waters. While these increased flows may help scour out accumulated sediments, the timing of the events may conflict with lagoon benthic macroinvertebrate phenology.

The evidence from the case supports spatial co-occurrence of channel alteration and increased sedimentation in Malibu Lagoon. The evidence from the case also supports temporality: channel alterations, especially physical constraints resulting from increasing development, occurred prior to observations of increased sedimentation. Evidence for the biological gradient between channel alteration and increased sedimentation is weak. Aside from topographic maps and aerial photography, few data are available to indicate a lack of sedimentation in the absence of channel alterations. Nonetheless, evidence for the exposure pathway between channel alteration and increased sedimentation is therefore complete for Malibu Lagoon. Channel alterations have significantly altered the lagoon morphology coincident with increased sedimentation in the lagoon. Evidence from the literature supports the causal linkage between channel alteration and increased sedimentation as plausible, but not specific. Many analogous examples exist. There is no evidence for predictive performance. Most of the evidence is consistent with channel alteration as a causal factor for increased sedimentation. Additionally, any inconsistencies can be explained by a credible mechanism.

The strength of the evidence supporting the causal pathway between channel alteration and sedimentation is good, and the strength of the evidence supporting the causal pathway between increased sedimentation and reduced habitat quality leading to biological impairment is strong. Therefore, the complete causal pathway between altered hydrology and biological impairment is supported by the evidence.

B3. Fire Impacts: Fire impacts can affect benthic macroinvertebrates and physical habitat (especially woody debris) directly, can alter hydrology (B1), and cause increased nutrient concentrations (A2) and sedimentation (A1). This section evaluates the linkage between fire impacts and impaired benthic communities as well as between fire impacts and increased sedimentation.

The Malibu Creek watershed has experienced many significant fires over the past several decades. The fires that overlap in time with benthic macroinvertebrate data collection include fires in 2005 and 2007. The 2005 fire impacted the northern portion of the watershed. The LVMWD site R-7 was closest to the burned area. The SC-IBI score for this site in 2006, the first year for which an IBI is available, was 24.3 (poor). In subsequent years, this site received IBI scores in the “very poor” range. Site MC-1, near the mouth of Malibu Creek, had IBI scores of 26 for both winter 2005 and fall 2006, and 23 for fall 2003 (prior to the fire). A fire in 2007 directly impacted MC-1, burning an area around and immediately upstream of the site. In spring 2008, the first benthic sampling event following the fire, the site had an IBI score of 21, slightly lower than the fall 2006 score of 26. However, by spring 2009, the site’s IBI score had raised to 30. The same fire impacted SC-14, one of the potential reference sites, which has a median SC-IBI score (2000-2011) of 67. The IBI score at this site was 56 in Spring 2008, but had rebounded to 69 by Spring 2009.

RBP physical habitat scores are only available for MC-1, of the sites impacted by fire. The range of RBP scores for this site between 2000 and 2008 was between 123 and 151 (suboptimal). No direct data on sedimentation is available.

Studies of wildfire impacts reveal that flood flows following severe fire events can be the most damaging impact from wildfires, with floods as much as 100 times greater than pre-fire floods. Loss of terrestrial vegetation reduces water uptake and infiltration, resulting in increased baseflows, annual water yields, and peak flows (Neary et al., 2005). Increased peak flows may substantially increase sedimentation and channel modification. Moreover, peak flows frequently will occur more rapidly after precipitation onset resulting in flash flooding. Roby and Azuma (1995) observed lower benthic invertebrate diversity, density and taxa richness immediately following an intense wildfire affecting a northern California stream compared to an unaffected stream. Within three years, mean density was significantly higher in the burned reach, but ten years after the wildfire, taxa richness and species diversity remained lower. Other impacts resulting from wildfires include initial decreases in in-stream woody debris, followed by substantial increases, and increased nutrient concentrations (Gresswell, 1999).

Based on the limited information available for the Malibu Creek Watershed, the evidence for spatial co-occurrence and temporality between fire impacts and impaired biological condition are uncertain. While SC-IBI scores for sites directly impacted by fire decrease immediately following the fire, they quickly return to prior levels. No data are available to evaluate impacts farther downstream. The evidence for the biological gradient is weak, because sites appear to rebound quickly from the initial impacts. Evidence for the causal exposure pathway is missing or implausible. Evidence from the literature supports the linkage between fire impacts and impaired biological condition as plausible, but not specific. However, few analogous cases are available and results, when taken as a whole, are not clear. There is no evidence of predictive performance. The evidence contains multiple inconsistencies, and the inconsistencies cannot be explained.

Insufficient information is available to evaluate the linkage between fire impacts and increased sedimentation in Malibu Creek.

The effects of fire impacts in the upper reaches of the watershed would be expected to result in increased sediment load and increased nutrients into Malibu Lagoon. The October 2007 wildfires in the watershed were severe, leading to extensive damage that would be expected to influence nutrient loading and biogeochemical cycling in Malibu Lagoon. Neither sediment data (TSS or turbidity) nor benthic macroinvertebrate data are available for the Lagoon during the period following the fires.

Insufficient data are available to evaluate the linkage between fire impacts and increased sedimentation or adverse effects to the benthic macroinvertebrate community in Malibu Lagoon.

B4: Point Source Discharges: Point source discharges can cause excess nutrients/excess algal growth (A2) or increased amounts of oxygen-demanding wastes (A3) in stream water. This section evaluates the linkage between point source discharges and increased nutrients or oxygen-demanding wastes.

The Tapia Water Reclamation Facility (TWRF) is the only facility with a permitted wastewater discharge to Malibu Creek or its tributaries. Originally built in 1965, the facility has been expanded beyond its original design capacity to a current capacity of 16 mgd. Prior to 2003, the facility was prohibited from discharging between May 1st and November 1st each year. In 2003, discharge prohibitions were extended from April 15th to November 15th of each year and a TMDL established nutrient targets for two seasons. Summer targets (April 15 – November 15) for NO_x-N and total P are 1.0 and 0.1 mg/L, respectively. During the winter months (November 16 – April 14), the NO_x-N target is 8 mg/L and no total P target is applied. Consequently, median nitrate-N concentrations are 1.17 mg/L during the restriction period for all years (April 15 – November 15) and 2.60 mg/L during the discharge period for all years (November 16 – April 14). Water quality monitoring data from Malibu Creek shows that the TMDL nitrate nitrogen targets have generally been met in the Malibu Creek main stem. In contrast, concentrations of orthophosphate P are frequently above the TMDL target both upstream and downstream of the Tapia discharge.

Examination of Stream Team data (all years and all seasons) shows that concentrations of nitrate-N are clearly elevated at the downstream station, MC-1, while concentrations upstream of Tapia are not much different from the reference sites (Figure 7-10). Sample results from all agencies, as summarized by LVMWD (2011, p. 43) suggest that the median[2] nitrate-N concentration is about 1.0 mg/L upstream of Tapia and 1.90 mg/L downstream on an annual basis. The downstream concentration has a median of 2.88 mg/L nitrate-N during the wet season and 0.20 mg/L during the dry season, while the upstream concentration has a median of 1.0 during the wet season and 0.60 mg/L during the dry season. Time series data at MC-1 show a decrease in the frequency of high concentration events over time. Sikich et al. (2012) report that nitrogen loading occurs in the watershed in locations that are not affected by Tapia. Specifically, at Heal the Bay sites M13 and O5, nitrate levels during both wet and dry seasons "clearly indicate sources other than direct discharge from Tapia."

LVMWD (2011) suggest that nitrate concentrations in the watershed are naturally elevated due to the Modelo formation, noting the elevated concentration in Las Virgenes Creek (median of 2.88 mg/L). The highest concentrations of nitrate-N are indeed found at stations in the Modelo formation, but at LV-9 and CH-6, which drain portions of the Modelo formation, the nitrate (and ammonia) concentrations are near

[2] The median values are reported because these are the data presented in the reference studies an d reports. But, it is the case that for algal response in streams, the median is likely more relevant than the average as the median better reflects the typical exposure concentration over time. Averages can be highly skewed by the presence of a few high-concentration events.

zero. These two sites are upstream of most of the high-density development in the watershed, whereas other Modelo formation stations are downstream of high-density development.

Average concentrations of PO_4-P are greater than 1 mg/L in lower Malibu Creek and are significantly higher than concentrations at reference sites. In general, the total P TMDL targets have not been achieved. However, phosphate concentrations are high at many locations in the watershed. Sikich et al. (2012) theorize that sites not influenced by Tapia but with high phosphate concentrations are influenced by fertilizers, septic systems, or commercial discharges. In addition, the Modelo formation does appear to lead to elevated background concentrations of phosphorus.

For both nitrogen and phosphorus, however, elevated concentrations of nutrients and excess algal growth are observed at impaired sites throughout the watershed, not just below the Tapia discharge. Therefore, while discharges from Tapia likely have had adverse effects prior to upgrades and diversions in the 1990s, any such direct impact does not appear to have persisted upstream of the discharge (although past discharges may continue to contribute to current day elevated phosphate bioassessment scores); the discharge is unlikely to be a primary or only cause of the effect.

The evidence supports both spatial co-occurrence and temporality of point source discharge and increased nitrogen concentrations in Malibu Creek. The evidence for biological gradient is weak. Nitrate-N concentrations are elevated below the Tapia discharge during the winter months, but not during the summer months, when algal growth is of greatest concern. Moreover, nitrogen and algal growth are a concern upstream of the discharge, as well. Evidence supporting the exposure pathway is incomplete. A large body of evidence from the literature supports point source discharges as plausible, but not specific sources of nitrogen impairment. Most of the evidence is consistent in supporting the Tapia discharge as a source of nitrogen impairment, and the inconsistencies can be explained by a credible mechanism.

The evidence from the case supports both spatial co-occurrence and temporality of point source discharge and increased phosphorus concentrations in Malibu Creek. The evidence for biological gradient is weak. PO_4-P concentrations are significantly elevated below the Tapia discharge. However, phosphorus and algal growth are a concern upstream of the discharge, as well. Evidence supporting the exposure pathway is complete. A large body of evidence from the literature supports point source discharges as plausible, but not specific sources of nitrogen impairment. Most of the evidence is consistent in supporting the Tapia discharge as a source of nitrogen impairment, and the inconsistencies can be explained by a credible mechanism.

The strength of the evidence supporting the causal pathway between the point source discharge and increased nutrients in Malibu Creek is moderate, and the strength of the evidence supporting the causal pathway between increased nutrients, excess algal growth and reduced habitat quality leading to biological impairment is strong. Therefore, the complete causal pathway between the point source discharge and biological impairment is supported by the evidence.

Malibu Lagoon receives nutrient inputs that have been discharged from Tapia during the winter months, along with nutrient inputs from the entire watershed. Of greater concern, Regional Board staff estimated that current loads of inorganic nitrogen to Malibu Lagoon from onsite wastewater disposal in the Civic Center area amount to 30 – 35 lb/day. Therefore, while the evidence supports Tapia as a source of nitrogen and phosphorus to Malibu Lagoon, the non-point source discharges directly to the Lagoon appear to be of greater magnitude and concern.

B5: Urban Runoff: Urban runoff can cause increased sedimentation (A1), excess nutrients/excess algal growth/reduced habitat quality (A2), reduced DO (A3), toxicity from metals or organic toxics (A4). It also can alter hydrology (B1) and channel alteration (B2). This section evaluates the linkage between urban runoff and increased sediment, increased nutrients, and increased toxicity from metals or organic toxics.

Malibu Creek

Although still a largely undeveloped watershed, the Malibu Creek watershed has seen a history of urban growth. Areas of barren and undeveloped LU/LC had the largest decrease of all LU/LC types between 1990 and 2008, while both density classes of Single Family Residential increased the most. This increased urbanization of portions of the upper watershed increased the amount of impervious surfaces from 3,694 to 4,878 acres. As of the 2008 SCAG land use coverage, the Malibu Creek watershed was 6.95% impervious. Using the Simple method rule (Caraco et al., 1998) that the impervious land generates surface runoff relative to pervious land in a ratio of 0.95/0.05, impervious surfaces are estimated to yield about 59 percent of the surface runoff in the watershed.

Busse et al. (2006) found that total nitrogen, total phosphorus, and total chlorophyll concentrations were all positively correlated with the proportion of upstream land covered by impervious surfaces. LVMWD (2011) suggest that nutrient concentrations are naturally elevated in the watershed due to the Modelo formation. While the highest concentrations of inorganic nitrogen and inorganic phosphorus tend to be found at sites in the Modelo formation, sites LV-9 and CH-6, which drain the Modelo formation, have very low concentrations of inorganic nitrogen and CH-6 has lower inorganic phosphorus than any other sites in the Modelo formation. It is noteworthy that these two sites are upstream of most development, whereas the other Modelo formation sites (with significantly higher nitrogen and phosphorus concentrations) are downstream of high-density development areas.

Increased impervious surface has long been demonstrated to increase stream flashiness (e.g., Walsh et al. 2005; Allan, 1995). Altered flood hydrology increases stream bank erosion, resulting in excess sedimentation downstream and increased turbidity, particularly during storm events. Limited sampling shows high TSS/SSC concentrations during storm events. Turbidity has been demonstrated to be higher at impaired sites than at reference sites, but direct correlations with urban development or impervious surface are not available. Sikich et al. (2012) reported significant channel alteration and stream bank erosion leading to increased sedimentation in the watershed. Creeks adjacent to urban development had a larger proportion of stream banks altered by bank modifications than those surrounded by open space or less developed areas. It is also important to note that developing areas experience significant construction activity. California’s general construction permit does not currently contain a limit for turbidity. Consequently, construction activities could generate significant excess sedimentation. No data currently exist to quantify this potential impact, however.

Urban runoff can reduce DO as a result of increased nutrient loading, resulting in algal blooms that lead to eutrophication, and increased stream temperature resulting from runoff from warm or hot asphalt surfaces, as discussed under A2 and A3.

Surface water runoff from urban areas may contain toxic metals (commonly from brake pads, but also from metal-working, manufacturing facilities, and other metal waste-producing activities), pesticides, and other toxic organic chemicals (including PCBs, oil and grease, volatile organic chemicals, and PAHs). However, only occasional water column toxicity has been observed since 2005 in wet and dry weather surface water samples from Malibu Creek, using *Ceriodaphnia dubia* (water flea) survival and reproduction and *Strongylocentrotus purpuratus* (purple sea urchin) fertilization tests. LADPW reports indicated that the toxic effect apparently dissipated after holding the sample, and attributed the cause to volatile chemicals. In a separate study, Brown and Bay (2005) examined Malibu Creek water near the mouth under both wet and dry conditions. One out of eight dry weather samples showed acute toxicity (survival) and two of eight showed chronic toxicity (reproduction) to *C. dubia*. The authors attribute the results to sulfate and other dissolved salts.

Sikich et al. (2012) calculated percent effective impervious area (PEI) for sites in the Malibu Creek Watershed to explore the effect of impervious surface on the benthic macroinvertebrate community. They found that mean SC-IBI scores decreased dramatically as the PEI in the area above each site increased. Furthermore, they report that “[a]t 6.3% PEI and above, all mean IBI scores are 39 or below (39 is the threshold for impairment used by the State Water Resources Control Board). No sites with greater than 3% PEI have average IBI scores above 60, in the good range." Based on their data, PEI accounts for nearly 74% of the variation in IBI scores in the watershed. (Note that the method used by Sikich et al. results in higher estimates of imperviousness than the analysis conducted using the NLCD land use coverage and reported in Section 4.5)

In summary, less urbanized sites in the Malibu Creek watershed, especially reference sites, have consistently lower nutrient concentrations, lower benthic algal densities, lower turbidity, and higher SC-IBI scores. Impaired sites have higher nutrient concentrations, higher turbidity, and lower SC-IBI scores, and generally occur downstream of urban development. This pattern holds true even for sites in the Modelo formation (B7).

The scientific literature contains many examples of the numerous impacts caused by urban development. Increasing levels of urban development and imperviousness have been directly associated with effects on aquatic life, with biological effect levels perceived at or below 10 percent urban development and 5 percent impervious cover (Yoder et al. 1999; CWP 1999; Roy et al. 2003; Cuffney et al. 2010). Streams in urban areas exhibit multiple and complex stressor *symptoms* (termed *urban stream syndrome*; Walsh et al. 2005). Multiple primary stressors and stressor causes are correlated with urban development, including flashier hydrography (B1), altered channel morphology (B2), and elevated concentrations of nutrients (A2), metals (toxicity, A4), and sediments (Walsh et al. 2005; USEPA, 2012). Although exacerbated by urban development, it is these stressors and not the development itself that directly affect the aquatic biota.

Evidence for increased sedimentation in Malibu Creek co-occurring with urban development/runoff is compatible, and excess sedimentation has increased since development began in the watershed, based on the observations of morphological changes to the Lagoon (temporality is consistent). Evidence for the gradient between urban runoff and increased sedimentation is strong. In combination, evidence for the exposure pathway is complete. Many studies in the literature show that the relationship between urban development and sedimentation is plausible, but not specific. There is no evidence of predictive performance. The evidence supporting the relationship between urban runoff and increased sedimentation is consistent and any inconsistencies can be explained by a credible mechanism.

The strength of evidence supporting the causal pathway between urban runoff and increased sedimentation is moderate, and the strength of evidence supporting the causal pathway between increased sedimentation and biological impairment is strong. Therefore, the complete causal pathway between urban runoff and biological impairment—through increased sedimentation—is moderate.

Evidence for increased nutrients in Malibu Creek co-occurring with urban development/runoff is compatible, and nutrient concentrations have increased since development began in the watershed (temporality is consistent). Evidence for the gradient between urban runoff and increased nutrients is strong. Total nitrogen and total phosphorus were positively correlated with impervious surface upstream. In combination, the evidence for the exposure pathway is complete. Evidence from the literature indicates that the relationship between urban runoff and increased nutrients in surface water is plausible. Urban runoff is not a specific source of increased nutrients in surface water, and there is no evidence of predictive performance. The evidence supporting the relationship between urban runoff and increased nutrients is consistent and any inconsistencies can be explained by a credible mechanism.

The strength of evidence supporting the causal pathway between urban runoff and increased nutrients in Malibu Creek is strong, as is the strength of evidence supporting the causal pathway between increased nutrients and biological impairment. Therefore, the complete causal pathway between urban runoff and biological impairment—through increased nutrients—is strong.

Evidence for reduced DO in Malibu Creek co-occurring with urban development/runoff is incompatible, because low DO is not consistently observed in the watershed. Evidence for temporality is consistent, because of the area's history of urban growth. Evidence for the gradient between urban runoff and low DO is weak, because low DO does not consistently occur. In combination, the evidence for the exposure pathway is incomplete. Evidence from the literature supports the plausibility but not specificity of urban runoff decreasing DO, especially due to thermal effects. Many analogous cases can be found in the literature, especially with respect to development impacts on coldwater streams. There is no evidence for predictive performance. The evidence supporting the relationship between urban runoff and decreased DO is consistent, and any inconsistencies can be explained by a credible mechanism.

The strength of evidence supporting the causal pathway between urban runoff and decreased DO in Malibu Creek is weak, due to the limited frequency with which low DO is observed. The strength of evidence for low DO causing biological impact is moderate. Therefore, the complete causal pathway between urban runoff and biological impairment—through decreased DO—is weak.

Evidence for increased toxicity in Malibu Creek co-occurring with urban development/runoff is incompatible, because water column toxicity is not consistently observed in the watershed. Evidence for temporality is inconsistent, because of the limited observations of toxicity relative to the frequency of testing. Evidence for the gradient between urban runoff and increased toxicity is weak, because increased toxicity does not consistently occur. In combination, the evidence for the exposure pathway is incomplete. Evidence from the literature supports the plausibility but not specificity of urban runoff increasing toxicity. Analogous cases can be found in the literature, but there is no evidence for predictive performance. The evidence supporting the relationship between urban runoff and increased toxicity is consistent, and any inconsistencies can be explained by a credible mechanism.

The strength of evidence supporting the causal pathway between urban runoff and increased toxicity in Malibu Creek is weak, due to the limited frequency with which toxicity is observed. The strength of evidence for increased toxicity causing biological impact is strong to moderate, depending on the suspected toxin. The complete causal pathway between urban runoff and biological impairment—through increased toxicity—is weak, because toxicity is observed only inconsistently.

Evidence for altered hydrology and channel alteration (which are themselves interrelated) in Malibu Creek co-occurring with urban development/runoff is compatible, and evidence for temporality is consistent. Evidence for the gradient between urban runoff and altered hydrology/channel alteration is strong, based on the observation that creeks adjacent to urban development had a larger proportion of stream banks altered by bank modifications than those surrounded by open space or less developed areas. In combination, the evidence for the exposure pathway is complete. Evidence from the literature supports the plausibility but not specificity of urban runoff altering hydrology and channel morphology. Analogous cases can be found in the literature, but there is no evidence for predictive performance. The evidence supporting the relationship between urban runoff and altered hydrology and channel alteration is consistent, and any inconsistencies can be explained by a credible mechanism.

The strength of evidence supporting the causal pathway between urban runoff and altered hydrology and channel alteration in Malibu Creek is strong. The strength of evidence for altered hydrology and channel alteration causing biological impact is strong. The complete causal pathway between urban runoff and biological impairment—through altered hydrology and channel alteration—is strong.

Overall, based on the evidence from the case and the literature, the strength of evidence for urban runoff to cause biological impairment directly is weak, but the strength of evidence for indirect cause of impairment as a result of primary stressors (primarily sediment and nutrients) that are exacerbated by urban runoff is strong.

Malibu Lagoon

Little information is available related to impacts of urban runoff directly on Malibu Lagoon. Most obviously, urban development around the Lagoon has constrained the Lagoon and altered its hydrology and morphology. These changes have been well documented in maps and photos. Additionally, the

Regional Board staff estimated that current inorganic nitrogen loads directly to the Lagoon from onsite wastewater disposal in the Civic Center area amount to 30-35 lb/day. The Lagoon clearly experiences increased sedimentation, but it is not clear how much of the sedimentation results from adjacent urban development. Little toxicity has been observed in the Lagoon.

Evidence for increased nutrients in Malibu Lagoon co-occurring with urban development/runoff is compatible, and nutrient concentrations have increased since development began in the watershed (temporality is consistent). Evidence for the gradient between urban runoff and increased nutrients is strong. In combination, the evidence for the exposure pathway is complete. Evidence from the literature indicates that the relationship between urban runoff and increased nutrients in surface water is plausible, but not specific. There is no evidence of predictive performance. The evidence supporting the relationship between urban runoff and increased nutrients is consistent and any inconsistencies can be explained by a credible mechanism.

The strength of evidence supporting the causal pathway between urban runoff and increased nutrients in Malibu Lagoon is strong, as is the strength of evidence supporting the causal pathway between increased nutrients and biological impairment. Therefore, the complete causal pathway between urban runoff and biological impairment—through increased nutrients—is strong.

Evidence for altered hydrology and channel alteration (which are themselves interrelated) in Malibu Lagoon co-occurring with urban development/runoff is compatible, and evidence for temporality is consistent. Evidence for the gradient between urban runoff and altered hydrology/channel alteration is strong. In combination, the evidence for the exposure pathway is complete. Analogous cases can be found in the literature, but there is no evidence for predictive performance. The evidence supporting the relationship between urban runoff and altered hydrology and channel alteration is consistent, and any inconsistencies can be explained by a credible mechanism.

The strength of evidence supporting the causal pathway between urban runoff and altered hydrology and channel alteration in Malibu Creek is strong. The strength of evidence for altered hydrology and channel alteration causing biological impact is strong. The complete causal pathway between urban runoff and biological impairment—through altered hydrology and channel alteration—is strong.

Overall, based on the evidence from the case and the literature, the strength of evidence for urban runoff to cause biological impairment in Malibu Lagoon directly is weak, but the strength of evidence for indirect cause of impairment as a result of primary stressors (primarily nutrients) that are exacerbated by urban runoff is strong.

B6: Agricultural Runoff: Agricultural runoff can affect benthic macroinvertebrates by causing increased nutrient concentrations (A2) and sedimentation (A1). Depending on the type of agriculture, increased toxics (pesticides) can also occur. This section evaluates the linkage between agricultural runoff and increased sedimentation and nutrient concentrations.

Agricultural land use (as identified in the SCAG coverage) comprises only about 2 percent of the Malibu Creek watershed. Moreover, most of the agricultural land use lies along Hidden Valley Creek, in the upper reaches of the watershed. The nearest downstream site from the dominant agricultural portion of the watershed is HV, a MCWMP site, for which biological data are not available. The next closest site with biological data is TR-17, a Heal the Bay site. However, at more than 4 miles distance from the putative agricultural source, this site is too distant to use for evidence of co-occurrence. In general, the agricultural land use identified in the Malibu Creek watershed occurs upstream, in relatively less impaired areas of the watershed. Goepel et al. identified small vineyards that appear to exist as accessory uses to structures such as residences, and likely represent "hobby vineyards."

There is a broad body of literature available regarding agricultural impacts on streams. Agricultural land uses can alter stream channel morphology and water chemistry in a number of ways (Allan, 1995). Riparian vegetation frequently is diminished if not eliminated, decreasing infiltration. Crop production often results in increased peak runoff rates and increased nutrients, pesticides, and suspended solids in surface water runoff compared to undeveloped land (Skaggs et al., 1994). Grazing can result in increased nutrients and suspended sediments, as well as increased organic matter and bacteria. Moreover, if animals can access the stream directly, channel degradation and increased erosion can occur.

The evidence from the case is inconsistent with spatial co-occurrence of agricultural land use and benthic macroinvertebrate impairment. The evidence is also inconsistent with temporality, since agricultural land cover in the watershed has decreased over time. There is no evidence for the biological gradient. Evidence for the exposure pathway is implausible. A large body of evidence from the literature supports the plausibility but not the specificity of agricultural runoff impacting benthic macroinvertebrates. There is no evidence for predictive performance. The evidence therefore presents multiple inconsistencies, for which there is no known explanation.

B7: Natural Geology: Natural geology (especially marine sedimentary deposits associated with the Modelo formation) can affect benthic macroinvertebrates by causing increased sedimentation (A1) and increased toxicity (A4). This section evaluates the linkage between natural geology, increased sedimentation and toxicity, and biological impairment.

The Modelo Formation in the Malibu Creek watershed is believed to be the source of very high levels of sulfate, phosphate, metals, and total dissolved solids. Of these, selenium and sulfate are of greatest concern, due to their toxicity (A4). These naturally-occurring salts, metals, and solids are suggested as causes of biological impairment in the watershed. However, despite frequent water column toxicity tests at the mass balance station, only occasional (and inconsistent) toxicity has been observed. This toxicity has been attributed to volatile chemicals. Conductivity, a surrogate measure for toxic salts, appears higher in impaired sites than in reference sites, ranging from 1,877 – 2,287 µS/cm on average for impaired sites compared to 1,185 – 1,505 µS/cm for reference sites. Luce (2003) found that impacted sites had conductivities greater than 2,000 µS/cm. Reference sites had conductivities less than 1,500 µS/cm, except for two, where mean conductivity was about 3,500 µS/cm. Luce concludes that for these two reference sites, conductivity was not an indicator of stormwater runoff but instead may be related to elevated phosphate at these two sites that must have another source "such as the geology of the watershed or groundwater inputs to the creek."

Erosion on the south flank of the Santa Monica mountains, represented in normalized form as denudation rate, is on the order of 0.5 mm/yr (Meigs et al., 1999). Areas of the watershed with marine sediments (the Modelo formation) could be expected to generate sediment yields on the order of 5,000 tons per square kilometer per year, compared to 1,000 tons per square kilometer per year from other portions of the range.

Median IBI scores at sites downstream of the Modelo formation outcrops are lower than those in the undeveloped areas upstream of the Modelo formation, and lower than those that do not drain the Modelo formation at all. However, IBI scores are relatively high at CH-6, which lies within the Modelo formation but has little upstream development and can therefore be considered a reference site for sites influenced by the Modelo formation. CH6 exhibits higher conductivity and a higher average SC-IBI score than any of the impacted sites within the Modelo formation. However, all sites with median SC-IBI scores lower than 30 lie in areas with high-density development, regardless of location relative to the Modelo formation. In contrast, all sites with median SC-IBI scores greater than 35 lie in areas of lower density to no development. These correlations diminish the evidence for natural geology as a candidate cause while strengthening the evidence for urban development.

The evidence from the case is inconsistent with spatial co-occurrence of the Modelo formation and increased sediment in Malibu Creek. Increased sediment occurs at impacted sites that are not influenced by the Modelo formation, as well as sites within the Modelo formation. The evidence is consistent with temporality, since the Modelo formation existed prior to impairment. However, there is little evidence for the biological gradient. Evidence for the exposure pathway is incomplete. Evidence from the literature supports the plausibility but not the specificity of natural geology increasing sedimentation. There is no evidence for predictive performance. The evidence is therefore consistent, and inconsistencies can be explained by a credible mechanism.

The evidence from the case is inconsistent with spatial co-occurrence of the Modelo formation and increased toxicity. Limited toxicity has been observed in Malibu Creek, and high conductivity occurs both in and out of the Modelo formation. The evidence is consistent with temporality, since the Modelo formation existed prior to impairment. However, there is little evidence for the biological gradient. Evidence for the exposure pathway is incomplete. Evidence from the literature supports the plausibility but not the specificity of natural geology increasing sedimentation. There is no evidence for predictive performance. The evidence is therefore consistent, and inconsistencies can be explained by a credible mechanism.

The evidence from the case is inconsistent with spatial co-occurrence of the Modelo formation and benthic macroinvertebrate impairment in Malibu Creek. The evidence is consistent with temporality, since the Modelo formation existed prior to impairment. However, there is little evidence for the biological gradient. Sites upstream of high-density development, but within the Modelo formation, exhibit slightly lowered SC-IBI scores, but not as low as scores for sites impacted by urban development. Evidence for the exposure pathway is incomplete. Evidence from the literature supports the plausibility but not the specificity of natural geology impacting benthic macroinvertebrates. There is no evidence for predictive performance. The evidence is therefore consistent, and inconsistencies can be explained by a credible mechanism.

Overall, based on the evidence from the case and the literature, the strength of evidence for natural geology to cause biological impairment in Malibu Creek is moderate, but it is likely a contributing stressor, not the primary stressor.

9.4 Characterize Causes

9.4.1 Eliminate

Elimination of potential causes requires care as the dominance of one cause may mask other sufficient causes. Only causes where lack of evidence for causality is unambiguous should be eliminated. As a result, two of the 12 candidate causes listed above are eliminated as highly unlikely to be a significant and sufficient cause of the observed biological impairment (these causes may contribute in a minor way to the observed impairment). The eliminated causes are:

B3. Fire Regime: Periodic fires in the watershed do not appear to be temporally associated with depressed bioassessment scores. The last fire in the watershed occurred in 2007 and affected station MC-1 and reference station SC-14, but not the main stem station MC-12. Bioassessment scores at MC-1 and SC-14 in 2008 were only slightly lower than in 2006, while those in 2009 were greater than 2006. At MC-12, 2008 bioassessment scores were greater than 2006, but 2009 bioassessment scores were lower.

B6. Agricultural Runoff: Agricultural runoff does not seem to be a primary cause of impairment for the same reasons discussed for point source discharges. Station MC-12 has little evidence of agricultural land upstream (with the exception of the Ventura County portion of the watershed upstream of Lake Sherwood, which is separated from the lower portion of Malibu Creek by Lake Sherwood, Westlake, and Malibou Lake). Station MC-1, located downstream end of the watershed, drains limited amounts of agricultural land on Las Virgenes, Stokes, and Cold creeks.

Potential cause A3 (Reduced DO) was also considered, but could not be definitively eliminated. DO concentrations below the water quality standard are observed at MC-1 and MC-12, but less than 10 percent of the time – likely not at a sufficient frequency to cause impairment. Hypoxic concentrations less than 2 mg/L have not been observed at these stations. However, better DO conditions are clearly observed at the reference stations, with no observations below 6 mg/L. Therefore, cause A3 is not eliminated at this stage.

9.4.2 Diagnostic Analysis

For Malibu Creek and Lagoon, diagnostic protocols are potentially applicable to low DO and acute toxic effects of some chemicals. However, direct observations of organism lethality or condition due to a specific cause are not available. Therefore, the diagnostic analysis step is not applicable to Malibu Creek and Lagoon impairment analysis at this time.

9.4.3 Strength of Evidence

Strength of evidence analysis uses the information developed in the data analysis to determine if the candidate causes have a true effect on the benthic macroinvertebrates. The causal considerations for the strength of evidence analyses used three types of evidence: case-specific evidence, evidence from other situations or biological knowledge, and evidence based on multiple lines of evidence, as described in Section 9.1.

The results of the strength of evidence analysis, which are presented in narrative form in each analysis of the evidence, are summarized in Table 9-3. The bottom of each cell displays the visual scoring recommended in USEPA (2000b), ranging from strongly positive “+++”) to strongly negative (“---”)..The full range of symbols is not used for every line of evidence. For instance, co-occurrence has potential values of “+”, “0”, and “---” only.

Table 9-3. Strength of Evidence Analysis for Case-Specific Considerations

	Consideration	Results	Stream	Lagoon
A1. Reduced Habitat from Sedimentation				
Case-specific Evidence	Co-Occurrence	Compatible. Excess sedimentation results from the geology of the Santa Monica Mountains and is documented for the watershed by the filling of the pool behind Rindge Dam and sedimentation in the Lagoon. Limited sampling shows high TSS/SSC concentrations during storm events. Increased turbidity was observed at the impacted locations relative to the reference sites. Sikich et al. (2012) reported 21.29 of 68 surveyed stream miles were impaired by fine sediments.	+	+
	Temporality	Consistent: Excess sedimentation has long been present in the watershed as shown by the filling of the pool behind Rindge Dam and sedimentation in the Lagoon.	+	+
	Biological Gradient	Possible, but not strong. Luce (2003) showed that embeddedness (but not percent fines) was correlated to low BMI metrics in the upper watershed. RBP physical habitat scores are similar between impacted sites on the main stem and reference sites; however, IBI appears to decline with decreased PHab scores in the upper watershed.	+	+
	Complete Exposure Pathway	Incomplete evidence (for stream). Sedimentation may occur at excessive levels but linkage to impaired biology is not fully proven. Physical habitat scores for Malibu Creek main stem stations are generally acceptable (optimal or sub-optimal). Sedimentation appears to impact BMI, but BMI appear to be limited by additional factors in the Malibu Creek main stem. Complete evidence (for Lagoon). Excess sedimentation has reduced historical habitat areas.	+	++

	Consideration	Results	Stream	Lagoon
Information from Other Situations or Biological Knowledge	Plausibility	Plausible: Relationship of sedimentation to degraded habitat and impaired biology is well documented.	+	+
	Specificity	One of many possible causes of impairment.	0	0
	Analogy	Analogous cases: Many. Literature has documented instances of sedimentation (fines, sediment, embeddedness) adversely impacting benthic macroinvertebrates.	++	++
	Predictive Performance	No evidence for predictive performance.	NE	NE
Considerations Based on Multiple Lines of Evidence	Consistency of Evidence	Most lines of evidence are consistent (for stream). All lines of evidence are consistent (for Lagoon)	+	+++
	Coherence of Evidence	Inconsistencies can be explained by a credible mechanism.	+	+
A2. Reduced Habitat from Excess Algal Growth				
Case-specific Evidence	Co-Occurrence	Compatible: Elevated benthic algal coverage was observed at the impaired Malibu Creek sites and the estuarine sites are downstream.	+	+
	Temporality	Consistent: Elevated nutrients appear associated with development, beginning in the 1960s.	+	+
	Biological Gradient	Strong. Both nutrient concentrations and mat algae coverage are much higher in Malibu Creek than at reference sites. Malibu Lagoon currently shows elevated concentrations of nutrients and excessive algal growth.	+++	+++
	Complete Exposure Pathway	Complete evidence. TMDL identified nutrients/algae as a problem and levels have not significantly declined. Comparison to reference sites suggests association. LVMWD (2011) contends that pH and DO within regulatory limits suggests weak impacts of eutrophication. This argument is unconvincing because high gas exchange rates are expected in shallow streams, and dense benthic algal growth alone may cause impairment via habitat effects or boundary layer DO.	++	++
Information from Other Situations or Biological Knowledge	Plausibility	Plausible. Relationship between excessive algal growth and altered benthic communities is well-documented in the scientific literature.	+	+
	Specificity	One of many possible causes of impairment.	0	0
	Analogy	Analogous cases: Many. The literature has documented many cases of altered benthic communities or reduced biodiversity resulting from excessive algal growth.	++	++
	Predictive Performance	No evidence for predictive performance.	NE	NE
Considerations Based on Multiple Lines of Evidence	Consistency of Evidence	All lines of evidence are consistent.	+++	+++
	Coherence of Evidence	Inconsistencies can be explained by a credible mechanism.	+	+
A3. Reduced DO from Excess Algal Growth or Oxygen-Demanding Wastes				
Case-specific Evidence	Co-Occurrence	Uncertain (for stream). No evidence of DO impact. Background dissolved oxygen levels at the impacted sites are similar to the reference sites, except that minima at the impacted sites are lower. Compatible (for Lagoon). Low DO concentrations have been reported in the Lagoon, particularly in the westerly portions of the Lagoon.	0	+
	Temporality	Consistent: Occasional DO problems are expected to occur with increased algae and precede all biological measurements.	+	+

	Consideration	Results	Stream	Lagoon
	Biological Gradient	Weak. Reference sites do not fall as low as impaired sites, but it is unclear if frequency of low DO is sufficient to cause impairment; thus, full pathway is uncertain.	+	+
	Complete Exposure Pathway	Incomplete evidence (for stream). Impairment may result from reduced physical habitat, not low DO. Incomplete evidence (for Lagoon). Low DO has been documented in the Lagoon, but it is not clear how widespread or frequently anoxia occurs.	+	+
Information from Other Situations or Biological Knowledge	Plausibility	Plausible. Relationship between algal growth and low DO is well-documented in the scientific literature.	+	+
	Specificity	One of many possible causes of impairment.	0	0
	Analogy	Analogous cases: Many. The literature has documented many cases of excessive algal growth causing low DO concentrations and subsequent benthic invertebrate impairment.	++	++
	Predictive Performance	No evidence for predictive performance.	NE	NE
Considerations Based on Multiple Lines of Evidence	Consistency of Evidence	Most lines of evidence are consistent	+	+
	Coherence of Evidence	Inconsistencies can be explained by a credible mechanism.	+	+
A4. Toxicity from Metals or Organic Toxics				
Case-specific Evidence	Co-Occurrence	Uncertain. Toxicity has been occasionally observed at sampling locations in Malibu Creek and Lagoon. Some toxicity has been documented in both dry and wet weather stream samples, but it is not consistent in space and time. Two of eight Lagoon samples showed toxicity, but the location of the toxic samples was inconsistent with expectations.	0	0
	Temporality	Incompatible: Direct toxicity results not consistent in time.	---	---
	Biological Gradient	Weak. As discussed in Section 8.2, the proposition that low IBI scores are associated with toxicity from Modelo formation drainage with elevated sulfate appears weakly supported.	+	+
	Complete Exposure Pathway	Incomplete evidence. Toxicity that is present has potential to impact organisms, but it is not clear if the frequency of toxicity is sufficient to explain impacts. No tissue evidence or diagnostic symptoms have been reported for these stressors. Elevated sulfate and selenium may suppress benthic macroinvertebrates but site-specific evidence does not appear to be present.	+	+
Information from Other Situations or Biological Knowledge	Plausibility	Actual evidence.	++	++
	Specificity	One of many possible causes of impairment.	0	0
	Analogy	Analogous cases: Many. The scientific literature contains many cases of toxicity, especially of selenium. Case studies are available on effects of elevated sulfate, but their applicability to Malibu is unclear.	++	++
	Predictive Performance	No evidence for predictive performance.	NE	NE
Considerations Based on Multiple Lines of Evidence	Consistency of Evidence	Most lines of evidence are consistent	+	+
	Coherence of Evidence	Inconsistencies can be explained by a credible mechanism.	+	+

	Consideration	Results	Stream	Lagoon
A5. Niche Competition from Invasive Species				
Case-specific Evidence	Co-Occurrence	Compatible (for stream). Invasive species (New Zealand mudsnails) are present in the impaired reaches of Malibu Creek. Incompatible (for Lagoon). The New Zealand mudsnail is a freshwater species that is not currently observed in the Lagoon, but the majority of the invertebrate samples have been freshwater species.	+	---
	Temporality	Uncertain (for stream). It is not clear if mudsnails were present before biological impairment. IBI scores do not appear to be related to mudsnail density. Incompatible (for Lagoon). Currently, the mudsnail is not observed at the Lagoon.	0	---
	Biological Gradient	Weak (for stream). Mudsnails are present at one of the two reference sites (Solstice, but not Lachusa), but downstream of the macroinvertebrate sample location. None (for Lagoon).	+	-
	Complete Exposure Pathway	Incomplete evidence (for stream). Some steps missing or implausible (for Lagoon).	+	-
Information from Other Situations or Biological Knowledge	Plausibility	Plausible. Niche competition by native species is well-documented. Impacts of mudsnails on native biotic communities have also been documented.	+	+
	Specificity	One of many possible causes of impairment.	0	0
	Analogy	Analogous cases: Few analogous cases appear in the literature, but their findings are clear.	+	+
	Predictive Performance	No evidence for predictive performance.	NE	NE
Considerations Based on Multiple Lines of Evidence	Consistency of Evidence	Multiple inconsistencies in the lines of evidence. Mudsnails were not documented until 2005, whereas IBI scores have been low since at least 2000.	---	---
	Coherence of Evidence	Inconsistencies can be explained by a credible mechanism.	+	+
B1. Altered Hydrology				
Case-specific Evidence	Co-Occurrence	Compatible (for stream). Flows have been shown to be altered in the impaired reaches; likely not impacted at reference sites where there has been little change in impervious cover. Compatible (for Lagoon). Year-round discharge of water into the Lagoon and the practice of breaching the sand barrier in summer and fall has disrupted the natural hydrologic cycle.	+	+
	Temporality	Consistent: Flows have been altered by development in the watershed and physical modification of Lagoon.	+	+
	Biological Gradient	Weak (for stream). Information on hydrology at reference sites is not available. Strong (for Lagoon). Natural salinity and tidal cycles have been altered, directly stressing the biotic community.	+	+++
	Complete Exposure Pathway	Incomplete evidence (in stream).Mechanism is unclear other than sedimentation (A1). Evidence for all steps (for Lagoon). Impairment strongly associated with hydrologic alterations.	+	++
Information from Other Situations or Biological Knowledge	Plausibility	Plausible. The scientific literature contains many reports of altered hydrology impacting biotic communities.	+	+
	Specificity	One of many possible causes of impairment.	0	0

	Consideration	Results	Stream	Lagoon
	Analogy	Analogous cases: Many cases in the literature report impairments to benthic macroinvertebrate communities upon alteration of the natural hydrologic regime.	++	++
	Predictive Performance	No evidence for predictive performance.	NE	NE
Considerations Based on Multiple Lines of Evidence	Consistency of Evidence	All lines of evidence are consistent.	+++	+++
	Coherence of Evidence	Inconsistencies can be explained by a credible mechanism.	+	+
B2. Channel Alteration				
Case-specific Evidence	Co-Occurrence	Compatible (for stream). Sikich (2012) reported 987 streambank modifications, with 20.9 linear miles engineered with hardened materials. Compatible (for Lagoon). The Lagoon channel clearly has been altered as a result of adjacent development.	+	+
	Temporality	Consistent (for stream). Channel alteration has occurred as the watershed has been developed, apparently in an effort to protect private property from erosion. Consistent (for Lagoon). Development of the area, including building transportation routes has occurred since the 1950s.	+	+
	Biological Gradient	Weak (for stream). Little reference information available. Strong (for Lagoon). Channel alteration has affected the hydrology and sedimentation in the Lagoon.	+	+++
	Complete Exposure Pathway	Incomplete evidence (for stream). RBP physical habitat scores in the watershed typically fall into the optimal and suboptimal categories. Complete evidence (for Lagoon). Anthropogenic modifications have severely altered habitat.	+	++
Information from Other Situations or Biological Knowledge	Plausibility	Plausible. The scientific literature contains many reports of channel alteration impacting the hydrologic regime and physical habitat to the detriment of the biotic community.	+	+
	Specificity Analogy	One of many possible causes of impairment. Analogous cases: Many cases are documented in the scientific literature.	0 ++	0 ++
	Predictive Performance	No evidence for predictive performance.	NE	
Considerations Based on Multiple Lines of Evidence	Consistency of Evidence	Multiple inconsistencies in the lines of evidence (for stream). While Sikich (2012) reported significant alterations, especially in developed areas, RBP physical habitat scores remain in the optimal or suboptimal categories. All lines of evidence are consistent (for Lagoon).	---	+++
	Coherence of Evidence	Inconsistencies can be explained by a credible mechanism.	+	+
B4. Point Source Discharges				
Case-specific Evidence	Co-Occurrence	Compatible. Increased nutrient concentrations are found downstream of the discharge.	+	+
	Temporality	Consistent: History of discharge.	+	+
	Biological Gradient	Weak: N and P are elevated in the stream in non-discharge periods. Excess algal growth and elevated nutrient concentrations occur upstream of the discharge. Additional sources of of nutrient load from onsite wastewater disposal.	+	+

	Consideration	Results	Stream	Lagoon
	Complete Exposure Pathway	Incomplete for N: Nitrate-N concentrations are elevated below the Tapia discharge during the winter months, but not during the summer months, when algal growth is of greatest concern. Moreover, nitrogen and algal growth are a concern upstream of the discharge, as well. Complete for P: PO_4-P concentrations are significantly elevated below the Tapia discharge. P loads are likely to be stored in the lagoon sediment and subsequently released.	++	++
Information from Other Situations or Biological Knowledge	Plausibility	Plausible. The scientific literature includes many reports of biota impaired by point source discharges.	+	+
	Specificity	One of many possible causes of impairment.	0	0
	Analogy	Analogous cases: Many cases are reported in the scientific literature of point source discharges impacting benthic macroinvertebrates.	++	++
	Predictive Performance	No evidence for predictive performance.	NE	NE
Considerations Based on Multiple Lines of Evidence	Consistency of Evidence	Most lines of evidence are consistent.	+	+
	Coherence of Evidence	Inconsistencies can be explained by a credible mechanism.	+	+
B5. Urban Runoff				
Case-specific Evidence	Co-Occurrence	Compatible. Impaired sites are downstream of developed areas.	+	+
	Temporality	Consistent: History of urban growth.	+	+
	Biological Gradient	Strong. Less urbanized reference sites have consistently better IBIs. Strong. Impairment of the Lagoon biota is well-documented. Inorganic nitrogen from on-site wastewater disposal in the Civic Center area discharges to the Lagoon.	+++	+++
	Complete Exposure Pathway	Evidence for all steps (for stream). Urban runoff likely acts as a cause rather than a primary stressor. Plausible mechanisms are associated with A2, A4 and B1. Increased imperviousness correlates with increased nutrients/algal growth and impaired benthic invertebrate communities occur downstream of urban development but not upstream. Evidence for all steps (for Lagoon). Urban runoff, specifically nitrogen loading from onsite wastewater disposal impacts benthic macroinvertebrates in the Lagoon. However, urban runoff likely acts as a cause rather than a primary stressor. Plausible mechanisms are associated with A2 and A4.	++	++
Information from Other Situations or Biological Knowledge	Plausibility	Not known (other than for specific impacts under A1-A4).	0	0
	Specificity	One of many possible causes of impairment.	0	0
	Analogy	Analogous cases: Many cases are reported in the scientific literature of urban runoff impacting benthic macroinvertebrates.	++	++
	Predictive Performance	No evidence for predictive performance.	NE	NE
Considerations Based on Multiple Lines of Evidence	Consistency of Evidence	Most lines of evidence are consistent.	+	+
	Coherence of Evidence	Inconsistencies can be explained by a credible mechanism.	+	+

	Consideration	Results	Stream	Lagoon
B7. Natural Geology				
Case-specific Evidence	Co-Occurrence	Uncertain (for stream). Sites with poor IBI scores are mostly downstream of the Modelo Formation, but are also impacted by urban runoff. There are limited results for sites in the Modelo formation with no urban runoff and those outside Modelo formation suggest partial impacts (e.g., reduced EPT but not IBI). Uncertain (for Lagoon). The Lagoon is downstream of the Modelo Formation, but many other possible stressors lie upstream of the Lagoon and confound the relationship.	0	0
	Temporality	Consistent: Always present.	+	+
	Biological Gradient	Uncertain: Elevated conductivity shows runoff from marine sediments; however, apparent correlation to IBI results appears to be affected by confounding with presence of urban runoff.	0	0
	Complete Exposure Pathway	Incomplete evidence: Apparent correlation does not necessarily prove causation.	+	+
Information from Other Situations or Biological Knowledge	Plausibility	Plausible (see LVMWD, 2011)	+	+
	Specificity	One of many possible causes of impairment.	0	0
	Analogy	Analogous cases. Many case studies are available on the effects of elevated sulfate, but the applicability to Malibu is unclear.	++	++
	Predictive Performance	No evidence for predictive performance.	NE	NE
Considerations Based on Multiple Lines of Evidence	Consistency of Evidence	Multiple inconsistencies in the lines of evidence (for stream). IBI scores at CH-6 suggest limited impact. Multiple inconsistencies in the lines of evidence (for Lagoon). It is unclear that the Modelo Formation has any effect on the Lagoon, or if the effect is masked by other possible stressors.	NE	NE
	Coherence of Evidence	Inconsistencies can be explained by a credible mechanism.	+	+

9.5 CHARACTERIZE CAUSES: IDENTIFY PROBABLE CAUSE

The stressor identification process has identified a number of potential causes for the reduced quality of benthic macroinvertebrates in Malibu Creek and Lagoon; however, there is not a single primary cause. Instead, it appears that the impaired condition of macroinvertebrate biology in the stream and Lagoon is due to the impact of multiple stressors. For example, SC-IBI scores throughout the watershed appear to be reduced where physical habitat is sub-optimal or worse; however, Malibu Creek main stem stations also show poor IBI scores for samples with optimal physical habitat and are likely co-limited by other factors such as nutrients and algae.

All of the stressor sources presented in Table 9-3 are credibly related to the observed impairment. However, the evidence is stronger for some sources than for others. Further, the ultimate causes of the key stressors are closely linked to one another. Based on the preceding tables, the following two stressors emerge as primary stressors correlated with the impairment in both the stream and Lagoon:

A1. Sedimentation (linked to B1, B2, B5, B7)

A2. Nutrients/Algae (linked to A1, A3, B5, B7)

In addition, the following stressors are strongly associated with the impairment in the Lagoon, and possibly associated with impairment in the stream:

B1. Altered Hydrology (linked to B2, B5)

B2. Channel Alteration (linked to B1, B5)

B4. Point Sources Discharges (linked to A2)

Stressors A1 and A2 have previously been proposed as causes of impairment in the stream, while B1 has been discussed as a cause of impairment in the Lagoon. Four of the five primary stressors are associated with B5 – urban runoff, suggesting that implementation may need to address the multiple impacts of this source.

Point Source Discharges (B4 likely had adverse effects in the stream prior to upgrades and diversions at Tapia in the 1990s. But, it is not clear if significant impacts have persisted in the stream after curtailment of the growing season discharge (although past discharges may continue to contribute to current day elevated phosphate bioassessment scores). The discharge is unlikely a primary cause of the effect in the stream, but likely a contributing factor. Any remaining contributions of point source discharges to impairment in the stream will be captured under integrative causes A2 (algal growth). Winter discharges may contribute to impairment in the Lagoon as a result of loading of phosphorus that is stored in the sediment and subsequently released. Such impacts will also be addressed under integrative cause A2.

Natural conditions (B7) associated with runoff from the Modelo Formation, including elevated conductivity/TDS, clearly affect the biological potential of the main stem and various tributaries to Malibu Creek. Notably, these conditions appear to reduce EPT taxa. However, this stressor alone does not appear sufficient to result in poor IBI scores as unimpaired IBI scores are found at stations within the Modelo formation, while low IBI scores are found at stations that do not drain this formation (see Section 8.1.5). Instead, poor IBI scores appear to be more strongly associated with sites that are downstream of high density development areas. Therefore, natural conditions appear to be a contributing stressor, but not the primary stressor resulting in impaired biology.

Toxicity (A4) has been demonstrated occasionally in the stream, but not in the Lagoon, and direct toxicity data are limited. Toxicity may be associated with B5 (Urban Runoff) and B7 (Natural Conditions). Sulfate and selenium concentrations are present in excess of water quality criteria, apparently due to natural geologic background, but likely exacerbated by increased runoff from development. LVMWD (2011) has proposed that impaired biotic conditions in the watershed are in part due to high-sulfate discharge coming from the area where the marine Modelo formation is exposed. However, the existence of acceptable IBI scores at sites with high conductivity draining the Modelo formation, but not impacted by development, suggest that direct sulfate or selenium toxicity is not the primary cause of impairment.

Invasive species (B8) – specifically the New Zealand mudsnail – remains a potential contributor to impairment; however, the mudsnail was not confirmed to be present until 2005, whereas the low IBIs have been documented in the Malibu Creek main stem since 2000. If the mudsnail was not present before 2005 it cannot be a significant cause of impairment; however, absence is difficult to verify. There does not appear to be a temporal correlation between mudsnail density and IBI scores.

In sum, benthic macroinvertebrates in the Malibu Creek watershed and Malibu Lagoon are impacted by multiple stressors, all of which may contribute to the documented biological impairment. The sum of the evidence suggests that the dominant stressors are sedimentation and nutrients/algae as well as and altered hydrology, channel alteration, and point sources (in the Lagoon only). Resolving these stressors is likely to result in the support of non-impaired (although not necessarily optimal) benthic macroinvertebrate communities.

10. TMDLs and Allocations

Malibu Creek and Lagoon benthic community and Malibu Creek sedimentation are impaired by the interaction of a variety of stressors. The CWA states that the TMDL must achieve water quality standards and must be expressed in terms of the maximum daily load (or "other appropriate measure") of a pollutant that a water body can receive and still support its beneficial uses. Since USEPA's assessment of all available data and studies demonstrate that the impairment is a result of multiple interacting stressors, this TMDL identifies multiple numeric targets and allocations for the most significant pollutants.

A TMDL is a means for recommending controls needed to restore and maintain the quality of water resources (USEPA, 1991). TMDLs represent the total pollutant loading that a waterbody can receive without violating water quality standards. The TMDL process establishes allowable loadings for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. 40 CFR §130.2(i) states that a TMDL calculation is the sum of the individual wasteload allocations for point sources and the load allocations for nonpoint sources and natural background in a given watershed, and that TMDLs can be expressed in terms of either mass per time, concentration, toxicity, or other appropriate measure.

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. The sum of the wasteload and load allocations, the margin of safety (and any reserve capacity) must be equal to or less than the loading capacity.

A TMDL targets a level of pollutant loading by adding the pollutant sources, both point and nonpoint, and a margin of safety. A TMDL is typically expressed as:

$$\mathbf{TMDL = WLA + LA + MOS}$$

where:

> WLA = Waste Load Allocation – the portion of the loading to the water body assigned to each existing and future permitted point source of the pollutant
>
> LA = Load Allocation – the portion of the pollutant loading assigned to existing and future nonpoint sources of the pollutant
>
> MOS = Margin of Safety – an accounting of the uncertainty of the pollutant load and the quality of the water body

To effectively address the benthic macroinvertebrate community impairments in Malibu Creek and Lagoon and sedimentation impairment in Malibu Creek, this TMDL considered all stressors and causes to critically identify the pollutants of concern. The key stressors impacting the biota (both directly and indirectly) are sedimentation and nutrient loading, as summarized in Section 9. Excessive levels of sedimentation cause suboptimal habitat, and are also associated with the movement of sediment-associated nutrients and toxics. Excess nutrient loading causes overgrowth of algae including the development of macro-algal mats, which also directly impair the habitat available for benthic macroinvertebrates, while indirectly contributing to exceedances of DO and pH criteria.

Our initial assessment efforts to focus only on the main stem resulted in uncertainty and critical data gaps associated with our understanding of the stressors and causes of the observed results. USEPA determined that to properly capture the sources and stressors of the observed impaired condition in Malibu Creek, it was necessary to evaluate the benthic community and water quality conditions of the major tributaries feeding into Malibu Creek main stem. In many cases, the water quality and benthic community conditions showed worse water quality conditions. For instance, physical habitat condition reflected the excess sedimentation in the tributaries, which then directly affected the main stem (See Section 9.3).

Consequently, based on our comprehensive evaluation of the main stem and the major tributaries, this proposed TMDL concludes that Malibu Creek main stem and the major tributaries are impaired for sedimentation and nutrient related water quality impairments, which is directly linked to negative impacts to the benthic community condition. This is comparable to many TMDLs in other states addressing benthic community impacts (e.g., Benthic TMDL Development Report Turley Creek and Long Meadow Run Rockingham County, Virginia 2012; Cuyahoga River Watershed TMDLs, Ohio for nutrient, bacteria and benthic habitat 2003).

10.1 BIOLOGICAL RESPONSE TARGETS FOR THE WATERSHED

The TMDL for Malibu Creek and Lagoon identified multiple targets that in combination define the support of beneficial uses in the listed waterbodies. A series of responses are specified, and these are the specific measures directly associated with the biotic impairment that can be measured and assessed (e.g., SC-IBI). The response targets ensure that the TMDL achieves beneficial use protection and provide a valuable means of tracking progress.

Response targets are defined as measures of effect that provide direct evidence of whether aquatic life uses are supported. Specifically, these response targets are defined in terms of measures of benthic community health, including the SC-IBI, the SC-O/E, and the benthic algal coverage targets previously developed for the Malibu Creek nutrient TMDL.

SC-IBI: The SC-IBI scores at stations MC-1, MC-12, and MC-15 should obtain a median value of 40 or better, consistent with at least a “Fair” ranking (Ode et al., 2005). Scores less than 40 result in a determination of impairment, and a score of 40 also separates the impacted sites on the Malibu Creek main stem from the reference sites (see Section 8.1.2). The evaluation should be based on a median over a minimum of 4 years to account for significant year-to-year variability in individual measurements.

SC-O/E: The O/E scores provide a second line of evidence to complement the IBI. O/E should equal at least the 10th percentile of the model reference distribution. Similar to the SC-IBI, the evaluation should be based on a median over a minimum of four years to account for year-to-year variability.

Benthic Algal Coverage: Algal coverage targets were established in the USEPA (2003) nutrient TMDL based on Biggs (2000) recommendations of no more than 30 percent cover for filamentous (floating) algae greater than 2 cm in length and no more than 60 percent cover for bottom algae greater than 0.3 cm thick. Ongoing studies by SCCWRP suggest these targets should be protective of goals established in the draft CA NNE framework. The NNE framework suggests that, for support of the COLD beneficial use, maximum benthic chlorophyll *a* density should always be constrained to be less than 150 mg/m^2 and ideally less than 100 mg/m^2 (referred to as the BURC II/III and BURC I/II boundaries).[3]

The chlorophyll *a* target is to maintain a minimum of 150 mg/L for both streams and Lagoon.

10.2 SEDIMENTATION LOADING CAPACITY FOR THE WATERSHED

As described in Section 9.5, sedimentation – the excess movement and deposition of sediment – is a critical problem in Malibu Creek, its tributaries, and the Lagoon; it negatively impacts the benthic biotic communities and results in a less than healthy biological community. Sedimentation can be indicative of

[3] The ongoing work by SCWRRP suggests that maximum benthic chlorophyll *a* densities greater than 150 mg/m^2 are likely to occur when macroalgal cover exceeds 30 percent. Specifically, preliminary quantile regressions (based on four samples each at 17 sites sites) suggest that the 75th quantile of benthic chlorophyll *a* density of 150 mg/m^2 is associated with a 75th quantile estimate of 37 percent macroalgal coverage (preliminary draft of B. Fetscher, *Development of Multimetric Tools for Setting Numeric Nutrient Targets including a Periphyton Index of Biotic Integrity*; report not yet submitted). This result is comparable to Biggs (2000) recommendations. In addition, this TMDL does not modify the chlorophyll *a* numeric target established in 2003.

a variety of stressor sources that are associated with urban runoff and altered hydrology, as in the case in Malibu Creek Watershed.

While there is evidence of high sedimentation rates in the Malibu Creek Watershed, there is general recognition that this watershed is also expected to have naturally elevated sediment yield due to the presence of erodible soils and comparatively rapid geologic uplift of the Santa Monica Mountains; this is characterized by mean uplift and denudation rates of around 0.5 mm/yr (Meigs et al. 1999). Unfortunately, other appropriate reference sites in southern California with comparable geology and size, and lack of significant human influences, do not exist. In the absence of an appropriate reference site or watershed, a reasonable sedimentation rate to protect the health of the Malibu Creek watershed is determined by evaluating the natural capacity of flow to move sediment in the Malibu Creek Watershed.

First, USEPA concludes and acknowledges that upland sediment supply will be naturally high in the Santa Monica Mountains, based on the watershed’s natural geologic characteristics. Since the supply of detached sediment is not limiting, the important variable feature is the capacity of flow to move sediment into and through the channel network. In addition, we considered the history of extensive anthropogenic activities in this Watershed causing significant alterations to its flow regime, which increased sediment transport capacity.

The objective of this TMDL should demonstrate how best to reduce elevated sedimentation and stream sediment transport rates to those reflective of natural conditions.

10.2.1 Sediment Transport Capacity

To evaluate the change in sediment transport capacity as a result of development or related anthropogenic activities, the sediment transport capacity is estimated. Most of the sediment mass moving through Malibu Creek lead to the filling of natural pools and clogging of substrate, and then moves as bedload during major storm events. Bedload transport theory allows the examination of the sediment transport capacity of the stream as a function of critical shear stress (the force applied to the bed necessary to dislodge and erode sediment), which in turn depends on slope and flow depth. Specifically, the focus is on effective work, which is the integrated product of *excess* shear stress and velocity. This is the product of force and the distance through which work acts. This work combines both the detachment and the movement of sediment and thus represents the forces that lead to *downstream sedimentation*.

Meyer-Peter and Muller (1948), as revised by the analysis of Wong and Parker (2006), determined that bedload transport varied as a function of $8 \cdot (\tau^* - \tau_C)^{3/2}$, where τ^* is the boundary shear stress and τ_C is the critical shear stress for incipient motion, approximated in general of 0.0495 g/cm^2. When $\tau^* \leq \tau_C$, bedload transport is zero.

Effective work, W, is obtained by integrating the product of the excess shear stress formula for bedload transport and the stream velocity, V: $W = K \int (\tau^* - 0.0495)^{3/2}\, V\, dt$, where t is time, K is an appropriate units conversion factor, and both τ^* and V are functions of time. The boundary shear stress is given by $\tau^* = S \cdot \gamma \cdot H$, where S is the slope (dimensionless), γ is the density of water (1 gm/cm^3) and H is the hydraulic radius. The hydraulic radius can in turn be calculated as $(D \cdot W)/(2\,D + W)$, where D is the average depth of a cross section and W is the top width.

A complete analysis of effective work requires integration (or piece-by-piece summation) over the complete time series distribution of τ^* and V. Sufficient information is not currently available to complete such an analysis for Malibu Creek Watershed. But more importantly, the necessary component is an estimate of the *relative* change in effective work in Malibu Creek compared to natural conditions.

Most of the work on natural channels (that is, the movement of sediment) occurs at flows between 1-year and 10-years recurrence. Smaller storms are not able to mobilize large amounts of sediment. Storms larger than a 10-year recurrence can move more sediment, but occur so infrequently that they account for a smaller amount of the total load. The IHA analysis presented in Section 6-4 showed that both the 10-

year and 2-year storm magnitudes in lower Malibu Creek have increased significantly following development. For example, at the LACDPW F-130 gage, the estimated 10-yr peak increased from 5,370 to 7,360 cfs, while the estimated 2-yr peak increased from 1,180 to 1,697 cfs; this is likely due to increases of impervious areas in the watershed. These estimates are taken as representative of the whole watershed because the drainage area between this gage and the mouth of Malibu Creek is small.

Calculating shear stress requires establishing a relationship between depth, top width, and flow velocity. This information is available from field measurements collected by USGS in the process of calculating rating curves at gage 11105510, in the natural channel near the mouth of Malibu Creek. (Note that the LACDPW F-130 stream gage is located on a grouted weir, not a natural channel section, and does not require field calibration. Thus, similar information is not available for that gage.)

Analysis of the data at gage 11105510 shows the following relationships to flow in ft, fps, and cfs: $H = 0.3054\ Q^{0.4023}$ and, for flows greater than about 500 cfs, $V = 0.000803 \cdot (Q - 594) + 1$ (see Figure 10-1).

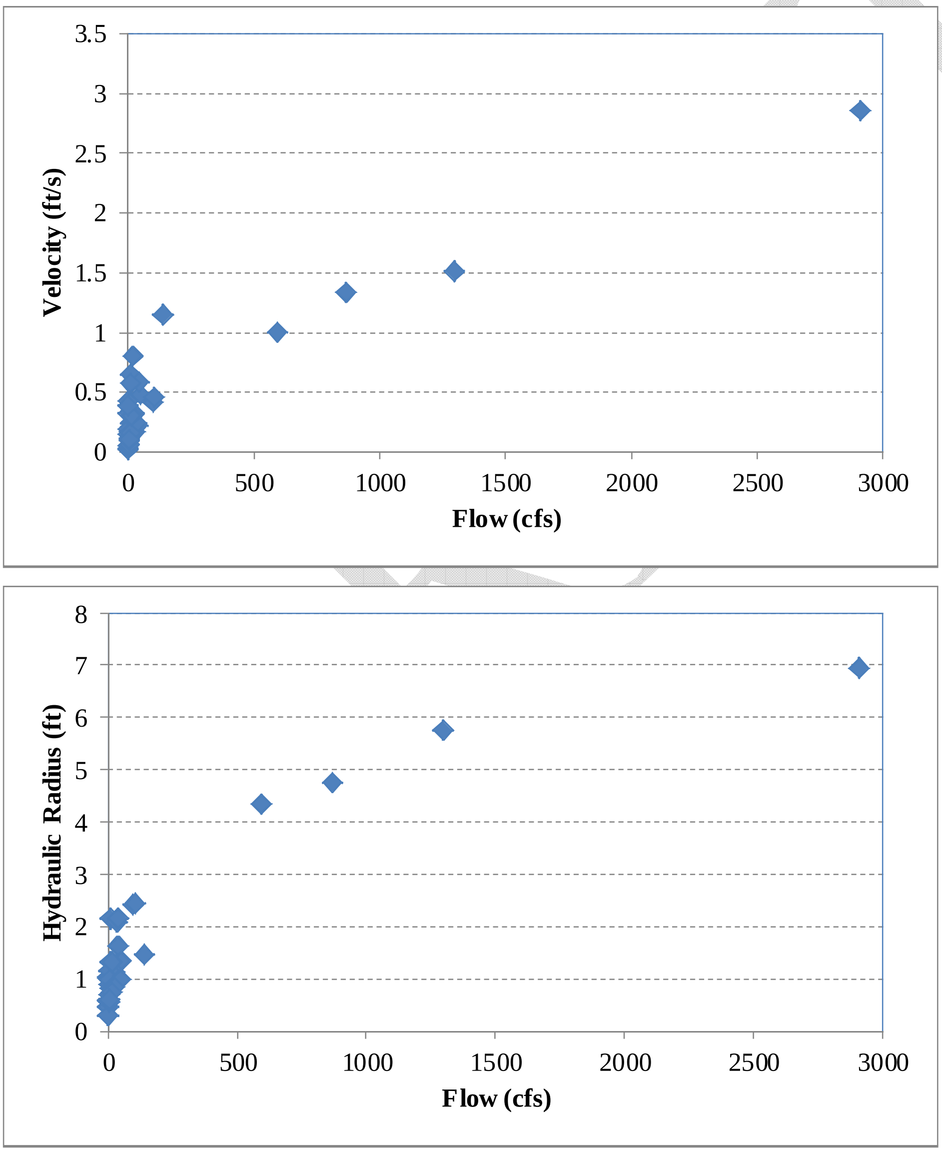

Figure 10-1. Velocity and Hydraulic Radius as a Function of Flow at USGS Gage 11105510

Boundary shear stress also depends on slope. Slope tends to increase with distance upstream in the Malibu Creek main stem. USGS gage 11105510 is near sampling station MC-1, where the estimated slope is 0.5%, increases to 3.5% at MC-15 (below Cold Creek), and is about 9.5% at MC-12 (above Las Virgenes Creek).

10.2.2 Excess Work and Change in Sedimentation Rate

The *change* in effective work can be approximated by estimating the change in instantaneous work at the 2-year and 10-year recurrence levels, spanning the major range over which the majority of total work on the channel is expected to occur (Table 10-1). The sensitivity of the result to slope was tested by running the analysis at both 0.5 and 10 percent slopes (which increases the effective shear). The results are consistent across both 2- and 10-year events and for 0.5 and 10 percent slopes and suggest that work being done on the channel is about 160 percent of that done in pre-development conditions (i.e., $W_{post}/W_{pre} \approx 1.6$). In other words, the predevelopment work on the channel was $1/1.6 \approx 62$ percent of that under current conditions, and a reduction of approximately $0.6/1.6 \approx 38$ percent from existing conditions would be needed to restore an approximately natural sedimentation regime.

Table 10-1. Analysis of Change in Effective Work in Malibu Creek

Slope	0.5%				10%			
Recurrence	10-year		2-year		10-year		2-year	
Condition	Post	Pre	Post	Pre	Post	Pre	Post	Pre
Flow (cfs)	7,360	5,370	1,697	1,180	7,360	5,370	1,697	1,180
V (m/s)	1.961	1.474	0.575	0.448	1.961	1.474	0.575	0.448
H (cm)	334.6	294.7	185.4	169.2	334.6	294.7	185.4	169.2
τ^* (g/cm^2)	1.673	1.474	0.927	0.801	33.460	29.475	18.543	16.021
W_{post}/W_{pre}	1.619		1.618		1.610		1.598	
Needed Reduction	38.2%		38.2%		37.9%		37.4%	

Note: "Condition" refers to the IHA analysis, where the "Pre" condition is based on flow records from water years 1932 – 1965 and the "Post" condition is based on water years 1993 – 2009. Flow records are from LACDPW gage F-130. V is stream velocity, H is hydraulic radius, τ^* is boundary shear stress, and W is instantaneous work, proportional to $(\tau^* - 0.0495)^{3/2}$ V. Needed reduction (to reduce work to pre-impact levels) is $(W_{post}-W_{pre})/W_{post}$. Available data allows calculation of the W_{post}/W_{pre} ratios, but not their individual values.

Because effective work is a measure of the power to transport sediment, the 38 percent reduction in work is equivalent to a 38 percent reduction in channel sediment transport. The reduction goal can be converted to a load basis by examining sediment transport at the LACDPW F-130 mass emissions station.

Estimates of long-term load require average flow and TSS concentrations in the stream. The best estimate of long-term load is provided by a stratified flow-weighted averaging estimator (Preston et al., 1989). A natural stratification of the results appears to occur at a flow of about 80 cfs. Flows less than this amount (as a daily average) have an average flow-weighted concentration of 125.9 cfs. Flows greater than or equal to 80 cfs have an average flow-weighted concentration of 301.8 mg/L.

Applying these estimators to the flow series observed from water years 1993 through 2010 yields an estimate of the current conditions average annual load passing station F-130 of 11,038 tons/yr. Estimated annual loads range from 1,360 tons in water year 2002 to 43,000 tons in water year 1993; this range is generally consistent with the partial load estimates calculated by USEPA based on turbidity and suspended solids monitoring in 2011-2012 (Section 7.4.3). The TMDL target is a 38 percent reduction in the average annual load, resulting in a load of 6,844 tons/yr – as a long term average. The conversion to daily load results in a requirement not to exceed 301.8 mg/L suspended solids (on average) for daily flows greater than 80 cfs.

Monitoring at the mass emissions station has generally not reported data from the high flow range, when sampling can be dangerous. In addition, sediment transport in a flashy system like Malibu Creek is more a function of instantaneous peak flow than daily average flow. Thus, there is not a strong relationship between the reported flow-weighted TSS concentration and daily average flow (Figure 10-2), although the minimum observed concentration does appear to increase with higher daily average flows. This is accounted for above by using a stratified flow-weighted averaging estimator. Any additional uncertainty related to this will be further considered in the margin of safety determination.

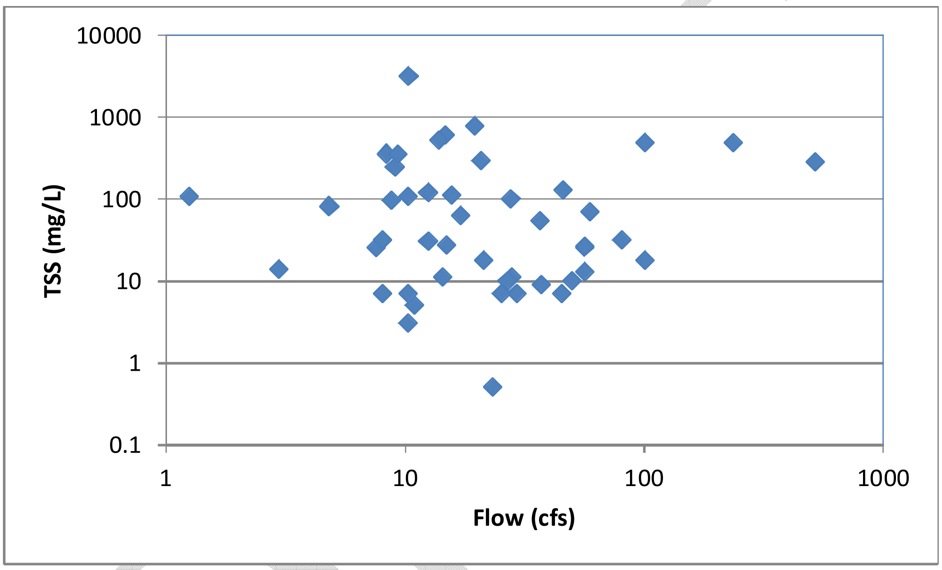

Figure 10-2. Relationship between Flow-weighted TSS Concentration and Daily Average Flow at the Malibu Creek Mass Emissions Station, 1998-2010

10.2.3 TMDL Allocations for Sedimentation in the Watershed

The goal of a TMDL is to ensure that the impaired water will attain water quality standards. The TMDL determines the amount of a given pollutant that can be loaded to the water body and still meet water quality standards (the loading capacity) and allocates that load among the various sources.

Identification of the pollutant's loading capacity for a water body is an important step in developing a TMDL. USEPA defines the loading capacity as "the greatest amount of loading that a water body can receive without violating water quality standards" (USEPA, 2000e). The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a water body into compliance with standards. The portion of the receiving water's loading capacity assigned to a particular point source is termed a wasteload allocation, while the portion of the receiving water's loading capacity assigned to one or more nonpoint sources is termed a load allocation. By definition, a TMDL is the sum of the allocations, which must not exceed the loading capacity.

10.2.3.1 Total Sedimentation Allowable Load for Point Sources

For sedimentation in Malibu Creek, the loading capacity is 6,844 tons/yr of sediment movement past the F-130 gage (see Section 10.2). The work that moves sediment in the channel is due to stormwater runoff; therefore the allocations are proportional to the fraction of stormwater generated by a given source.

Stormwater in the entire Malibu Creek Watershed is subject to one of three MS4 permits: the Los Angeles County Unified MS4 Permit, the Ventura County Unified MS4 Permit, and the Caltrans MS4 Permit. Each of these permittees receives a wasteload allocation. The Tapia discharge is not considered a significant contributor to high flows that cause bank and channel erosion; therefore, a zero wasteload allocation for sedimentation is assigned to this point source.

10.2.3.2 Sedimentation WLA

The allocatable load is divided up among the three MS4 permits on the basis of relative contributions to stormwater flow (note: The Tapia discharge is given a WLA of zero). The analysis of flow is based on Schueler's Simple method, as presented in Caraco et al. (1998). In this formulation, storm runoff depth is expressed as 0.9 x P x (0.05 + 0.09 Ia), where P is precipitation and Ia is the impervious area fraction. Alternatively, this implies that the total storm runoff volume is a function of (0.95 x Imp + 0.05 x Perv) times a units conversion. The sedimentation WLAs are assigned proportional to the flow from each jurisdiction. For any jurisdiction *i*, this is simply:

$$Allocation_i = \frac{0.95\, x\, \mathrm{Imp}_i + 0.05\, x\, \mathrm{Perv}_i}{0.95\, x \sum \mathrm{Imp}_i + 0.05\, x \sum \mathrm{Perv}_i}$$

Land use and imperviousness was determined from the 2008 SCAG coverage and tabulated by jurisdictional area, as shown in Table 5-1 above. The resulting allocations are shown in Table 10-2, which account for a 10 percent Margin of Safety from the loading capacity of 6,844 tons/yr, so the total allocatable load distributed below is 5,817 tons/yr.

Table 10-2. Wasteload Allocations for Sedimentation (based on SCAG 2008 land use)

Permittee	Impervious Area	Pervious Area	Allocation Fraction	Sedimentation Allocation (t/yr)
Los Angeles Co.	2,755	39,924	58.4%	3,397
Ventura Co.	1,922	25,180	39.1%	2,274
Caltrans	200	206	2.5%	145

An explicit MOS of 15 percent of the loading capacity (1,027 tons/yr) is assigned to account for uncertainty in the TMDL. The results of the TSS and turbidity relationship illustrated the significant amount of load that can be transported down the watershed along the main stem Malibu Creek during typical sized storm events. As a case in point, during the sampling period between 2011 to 2012, the largest storm event, with a measured flow of over 10,000 cfs, was not captured because the equipment was flooded and damaged. Since we do not have a comparable data set collected prior to a modified Malibu Creek Watershed (i.e., hydrology, imperviousness, etc.), we believe that an explicit MOS of 15% accounts for the uncertainty related to greater transport of sediment load during high flow events or year.

Sedimentation in Malibu Creek and Lagoon presents a long-term cumulative threat to the support of aquatic life. Therefore, allocations to individual seasons are not needed. However, seasonal variations are addressed in the TMDL because the allocations are proportional to flow, which varies seasonally.

10.2.3.3 Sedimentation Load for Non-Point Sources

Because the entire watershed is covered by MS4 permits, and because flows from properties that drain directly to the creeks without passing through an organized stormwater conveyance represent minimal amounts of impervious area and are considered to be an insignificant contributor to the overall sedimentation transport capacity in the creek, there is also no explicit nonpoint source load allocation assigned. The LA for the Malibu Creek Watershed non-point sources is zero for the identified non-point sources.

10.3 NUTRIENT ENDPOINTS

USEPA established a nutrient TMDL for Malibu Creek Watershed in 2003 (USEPA, 2003). This established nutrient targets for two seasons: During the summer (April 15 – November 15) nitrate-plus-nitrite-N and total P targets are 1.0 and 0.1 mg/L, respectively. During the winter months (November 16 – April 14) the Nitrate-plus-nitrite-N target is 8 mg/L and no total P target is applied. It is important to note that the summer nutrient targets are based on a reference approach reflecting concentrations observed in "relatively undisturbed stream segments" on Upper Malibu Creek and Middle Malibu Creek. However, the 2003 TMDL based the reference approach on two reference sites, while this TMDL, applying the same reference approach, considered nine reference sites and the geology of the Watershed (these data were not available prior to the establishment of the 2003 TMDL). The 2003 winter target simply represents a 20 percent margin of safety adjustment on the existing 10 mg/L numeric objective provided in the basin plan, which is based on human health limits in drinking water, not aquatic life use protection. The existing TMDL clearly states that the factors controlling algal growth in Malibu Creek were not fully understood at that time and contains language suggesting the potential need to reopen the TMDL if more stringent limits are necessary following additional study. In light of the additional data and specific studies on nutrients in Malibu Creek Watershed conducted in the last 11 years, USEPA re-evaluated the record and provided modifications where applicable.

The nutrient TMDL was based on achieving a threshold of 30 percent cover for filamentous (floating) algae greater than 2 cm in length and a threshold of 60 percent cover for bottom algae greater than 0.3 cm thick. Water quality monitoring data from Malibu Creek shows that the TMDL nitrate targets have generally been met in the Malibu Creek main stem (see Figure 7-13); however, this has not been sufficient to achieve the stated thresholds for filamentous and bottom algae coverage (see Section 8.3). The data and analyses since 2003 have demonstrated that additional reductions in nutrient loads and concentrations are needed to achieve the protection of beneficial uses. Similarly, the Nutrient Numeric Endpoint for Malibu Creek Watershed includes detailed analysis that the appropriate nutrient concentrations needed to achieve protection of beneficial uses will have to be lower than established in the 2003 Malibu Creek Watershed Nutrient TMDL (Appendix F).

10.3.1 Relevance of CA Nutrient Numeric Endpoint Tool

USEPA reviewed and applied the best available information and tools to evaluate the sources and causes of the impaired condition. This included the California Nutrient Numeric Endpoints (CA NNE) framework (Appendix F; Tetra Tech, 2006) applied to Malibu Creek. The NNE framework is a process for developing site-specific nutrient targets based on secondary indicators, such as benthic algal density. The NNE approach also incorporates risk cofactors that affect algal productivity, including light availability, temperature, flow characteristics, and biological factors. As part of the NNE development, Tetra Tech (2006) provided simplified scoping tools to estimate algal response to nutrient concentrations, including a benthic biomass predictor that can be used to estimate nutrient concentrations consistent with achieving a specified algal density target. Our evaluation of past and recent data confirmed that assessing the condition based on a single line of evidence (i.e., inorganic levels of nitrogen and phosphorus) was not sufficient and may provide a false conclusion of in-stream condition (i.e., low NO_3-N concentrations suggest impairment is addressed, but high TN and extensive mat algal coverage was observed indicating impairment still persisted). The results of our re-evaluation and the results of t the applied NNE framework in Malibu Creek supported the need for evaluating multiple lines of evidence.

The CA NNE recommended targets are currently under consideration by the State Water Resources Control Board, and have not yet been officially adopted. However, the basis of the scientific study specific to Malibu Creek is critical for this re-evaluation and provides greater depth of explanation for our observed data results in the Creek and main tributaries. The approach recommends setting response targets for benthic algal biomass in streams based on maximum density as mg/m^2 chlorophyll *a*. Targets for a site are defined in terms of beneficial uses and Beneficial Use Risk Categories (BURCs).[4] A TMDL should, at a minimum, reduce average concentrations below the BURC II/III threshold. In the case of Malibu Creek, there is evidence that nutrient levels are naturally elevated to some extent due to the presence of marine sedimentary rocks, further suggesting use of the BURC II/III threshold as a target.

10.3.2 CA NNE for Malibu Creek Watershed

The COLD and SPWN beneficial use designations, which have the most stringent BURC thresholds, are applicable to the Malibu Creek main stem. Under the current proposed CA NNE approach, these have a BURC II/III threshold of 150 mg/m^2 maximum benthic chlorophyll *a*.

The NNE analysis for Malibu Creek and tributaries was based on detailed surveys undertaken in 2001 and 2002 (Busse et al., 2003; Busse et al., 2006). These studies reported algal biomass (both benthic and floating), nutrient levels (nitrogen and phosphorus), and physical conditions in multiple stream reaches with different surrounding land uses and habitat conditions. Reported benthic algal densities measured as chlorophyll *a* were quite high (up to 717 mg/m^2 in the Malibu Creek main stem), but the ratio of chlorophyll *a* to ash free dry mass (AFDM) was also elevated, so that a moderate amount of algal biomass can lead to very high chlorophyll *a* densities. The benthic biomass predictor "Revised QUAL2K" steady state method appears to provide reasonable predictions of the maximum observed benthic chlorophyll *a* density at each site.

The benthic biomass predictor contains a variety of methods, of which the Revised QUAL2K method (with accrual adjustment) provides the best fit to observations in Malibu Creek. Three individual sites in the main stem were analyzed. To reduce uncertainty, the results were averaged, yielding an estimate that the appropriate numeric nutrient goals to achieve the 150 mg/m^2 maximum benthic chlorophyll *a* target are:

- 0.24 mg/L total N and/or 0.0033 mg/L total P for the summer period.
- 0.65 mg/L TN and 0.090 mg/L TP during the winter period (11/16 – 4/16), with lower light availability.

These target concentrations are most appropriately interpreted as seasonal median concentrations as they are based on a steady-state model.

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[4] BURCs establish ranges for the interpretation of nutrient criteria, similar to the approach that USEPA has promulgated for nutrient criteria for Florida lakes (75 FR 75762, Dec. 6, 2010). BURC I water bodies have nutrient concentrations sufficiently low that they are not expected to exhibit impairment due to nutrients. BURC III water bodies have nutrient concentrations sufficiently high and with a high likelihood of exhibiting impairment due to nutrients; these are assumed to require nutrient reductions. Finally, BURC II water bodies are in an intermediate range of concentrations that may require additional information and analysis to determine appropriate site-specific protective nutrient criteria. For a given beneficial use designation, the BURC I/II threshold represents a protective level below which there is general consensus that nutrients will not present a significant risk of impairment. (This threshold should also be set so that is not less than the expected natural background.) Conversely, the BURC II/III threshold represents a level that is sufficiently high with general consensus that risk of use impairment by nutrients is probable.

A second line of evidence is provided by the empirical analyses of Dodds et al. (2002, corrected 2006), which predict benthic chlorophyll *a* based on TN and TP concentrations, but do not include shading or temperature as independent variables. The Dodds equations suggest that an appropriate target for achieving the 150 mg/m^2 chlorophyll *a* goal would be a TN concentration of 0.585 and a TP concentration of 0.081 mg/L (selected from the continuous curve at a point where the mass-based Redfield ratio of 7.23 is achieved). These values fall between the summer and winter targets developed using the QUAL2Kw approach. The QUAL2K-based approach assumes that algal growth is controlled by the most limiting nutrient. Therefore, achieving *either* the TN goal *or* the TP goal, above, should be sufficient to attain the algal density target.

The NNE framework makes clear that appropriate nutrient targets cannot be less than natural background. The discussion of natural reference conditions in Section 7.5.4 suggests that the natural background concentration for total N in the watershed is below 0.67 mg/L outside the Modelo formation and approximately 1.3 mg/L within the Modelo formation, both greater than the NNE target. Section 7.5.4 also presented a natural background concentration of 0.14 mg/L total P outside the Modelo formation and 0.6 mg/L within the Modelo formation, both well in excess of the target yielded by the NNE analysis.

Although the NNE study specific to Malibu Creek is not yet final, the NNE analyses confirm that lower nutrient targets are needed for Malibu Creek. It is critical that this TMDL includes the most recent information and analyses available. The information on natural background concentrations suggests that attaining the NNE target of 150 mg/m^2 chlorophyll *a* is likely not feasible in this watershed. As such USEPA proposes to establish targets based on the reference data estimated using the reference approach. USEPA believes that these numeric targets are appropriate for Malibu Creek and the main tributaries.

In summary, the detailed NNE analysis for Malibu Creek Watershed and the data observed from the available reference conditions, strongly suggests that the nutrient load or concentrations in the streams must be reduced if the benthic community is to be protected. .

10.3.3 TMDL Allocations for Nutrients in the Watershed

The existing nutrient TMDL for Malibu Creek (USEPA, 2003) estimated the loading capacity for nutrients and assigns summer and winter allocations based on concentration targets. USEPA's evaluation of the additional data collected since 2003 and our analysis presented above in Section 10.3 suggest that the loading capacity for nutrients, and thus the allocations, need to be reduced.

Because the listed impairment was benthic community impacts, USEPA evaluated all variables potentially impacting the benthic invertebrate condition. USEPA's extensive assessment of the stressors and causes of impairments to the benthic community finds nutrient as a primary cause of impact. Strong evidence indicates that the nutrient targets established in the 2003 TMDL have been mostly met; however, Busse et al.'s (2003) study and the overwhelming data on the algae and macroalgal coverage in the streams and main stem since the 2003 TMDL suggest that the assimilative capacity was substantially overestimated. As a result, nutrient enrichment has not only continued, but in some cases increased in Malibu Creek. Furthermore, our evaluation of the benthic community condition in the main stem and at the major tributaries show severe impact with very poor scores compared to reference sites, even when the unique geological conditions of the Modelo formation was factored into our analysis.

USEPA concludes that concentration-based allocations are the best approach towards meeting the protection of the identified beneficial uses. In the 2003 TMDL, mass-based loads were assigned to the various sources; however, our assessment of the data since 2003 strongly suggests that in-stream concentration will be more effective in addressing the stressors causing the impact to the benthic community. In this TMDL, the following TN and TP concentrations (Table 10-3) are set as the concentration-based allocations for Malibu Creek and the major tributaries feeding into the main stem based on concentrations found in natural background (see Section 10.3.2). The data overwhelmingly show that the tributaries feeding into the main stem are impaired, if not more impaired. It would be difficult to separate out the impact of the impaired tributaries from the main stem. As such, the concentration-based allocations apply to those tributaries directly feeding the main stem.

The instream numeric target and concentration-based allocation for TN is set at 0.6 mg/L in summer and 1.0 mg/L in winter. For TP, the original criterion of 0.1 mg/L is maintained because the observed data still consistently show that the 2003 numeric target is not met. In addition, evidence strongly suggests that phosphorus is consistently loading into the Creek system throughout the year, irrespective of season. Consequently, this TMDL establishes a numeric target and instream concentration-based allocation of TP of 0.1 mg/L throughout the year. Furthermore, these allocations must be linked to the algal coverage criterion. In order for the allocation to be achieved, both the nutrient allocations and the algal coverage target must be met.

Table 10-3. Proposed instream concentration-Based Allocations for TN and TP in Malibu Creek, Main Tributaries and Lagoon

Time Period	TN* (mg/L)	TP (mg/L)	Benthic Algal Coverage (%)
Summer (April 15-November 15)	0.6	0.1	≤30% filamentous algae; ≤ 60% bottom algae
Winter (November 16-April14)	1.0	0.1	≤30% filamentous algae; ≤ 60% bottom algae

* TN concentration includes the sum of the organic and inorganic species.

Invitation to Comment on Alternative Option

However, based on some good indication that those areas draining the Modelo formation may lead to elevated phosphorus levels, USEPA is inviting comment on an alternative option of setting slightly elevated numeric targets for TP in those areas draining the Modelo formation. This instream target would be set at no greater than 0.4 mg/L; this is comparable to the evidence provided for reference sites located in the Modelo formation and absent of any development nearby (Table 10-4). This option would be contingent on (1) additional data and information provided to illustrate that TP concentrations at or below 0.4 mg/L are also correlated to limited algal coverage data, which must be below the benthic algal coverage numeric criteria; and (2) delineation of and verification that sub areas in the Watershed can be appropriately distinguished between those areas draining the Modelo Formation and those sub areas draining from Non-Modelo Formation.

Table 10-4. Possible Alternative Option for Nutrient Allocations

Possible Alternative Option			
Time Period	TN* (mg/L)	TP (mg/L)	Benthic Algal Coverage (%)
Summer (Apr 15-Nov 15)	0.6	≤0.4	≤30% filamentous algae ≤ 60% bottom algae
Winter (Nov 16-Apr14)	1.0	≤0.4	≤30% filamentous algae ≤ 60% bottom algae

These revised concentration-based allocations should directly address the needed reductions in the nutrient allocations defined in the 2003 Nutrient TMDL. Additional nutrient reductions are needed primarily to obtain the algal coverage targets established in the 2003 nutrient TMDL. Because nutrients and algal coverage have been identified as significant contributing factors in the biotic impairment of

Malibu Creek and Lagoon, assigning these instream concentration-based allocations will directly address the nutrient stressor affecting the biotic impairment.

In addition to the instream allocations, load allocations are provided for the discharge of onsite wastewater disposals. Load allocations were calculated by applying the 2003 nutrient TMDL percent reductions to the existing nitrogen (summer and winter) and phosphorous (summer only) concentrations (calculated from Table 21 in USEPA, 2003), resulting in the 2003 nutrient TMDL target concentration in OWDS discharge. These 2003 target concentrations were then scaled by a factor equal to the ratio between the 2003 and 2012 instream targets to obtain the OWDS discharge concentration targets for this TMDL. Overall, a total nitrogen discharge concentration of 2.49 mg/L applies in the summer and 6.75 mg/L applies in the winter. The total phosphorous discharge concentration of 0.99 mg/L applies year-round. These concentrations assume that the OWDS discharge rates remain consistent with levels used in the 2003 TMDL.

The load allocations for this source category are set at levels that will require large reductions in nutrient loading from septic tanks throughout the watershed (most of the OWDS occur in the lower and middle watershed [Tetra Tech, 2002]). Implementation of the load allocation will probably necessitate aggressive actions to identify and repair all septic systems that do not function properly. The highest priority for implementation is to ensure that discharges from commercial septic systems do not cause nutrient discharges to surface waters, particularly in the Malibu Lagoon area. We expect that actions taken to address septic systems will provide improvements in discharge quality throughout the year; therefore, the winter LAs should be met if the summer LAs are met.

The concentration-based allocations for the entities are shown in Table 10-5.

Table 10-5. Wasteload and Load Allocations for TN and TP in Malibu Creek, Main Tributaries and Lagoon

Allocation	TN (mg/L) Summer	TN mg/L Winter	TP (mg/L) Year-round
Wasteload Allocation (instream) • Tapia WWTP (ongoing discharge) • Los Angeles County MS4 Permittees • Ventura County MS4 Permittees • Caltrans MS4 Permittee Load Allocation (instream) • Agriculture • Tapia WWTP spray field	0.6	1.0	0.1
Load Allocation (discharge) • Onsite Waste Disposal	2.49	6.75	0.99

10.3.4 Allocations and Biological Targets for Malibu Lagoon

Based on the observed species richness both for Malibu Lagoon and for other southern California coastal estuaries, it is appropriate to expect greater number of taxa/functional categories (i.e., species richness) as the Lagoon's conditions improve; this improvement would reflect the restored diverse benthic community. Given the best available information to date and the most recent restoration efforts in Malibu Lagoon, we should expect to see increased taxa richness over time. Consequently, to ensure that the benthic community condition continues to improve, this TMDL establishes the same nutrient concentrationbased allocations in Table 10-5 above. In addition, this TMDL also sets a response variable target for the Lagoon.

Because sedimentation and excessive nutrient loading into the Lagoon continues to be a problem that directly impacts the benthic community condition, the established pollutant load reduction, as described above, for sedimentation and nutrients will also be applicable in Malibu Lagoon.

Furthermore, this TMDL establishes a specific numeric target for Malibu Lagoon. This numeric target reflects the overall conclusion that the benthic community is significantly impacted. In addition, a wealth of evidence from other southern California coastal estuaries shows much greater taxa richness compared with Malibu Lagoon. Based on our evaluation of the observed taxa richness observed in other southern California coastal estuaries, the total number of taxa that should be achieved in Malibu Lagoon is a minimum of 35. This is the doubling of the average taxa richness observed over a 15 period time period. Based on the historical accounts for Malibu Lagoon and the detailed benthic invertebrate community evaluations of other coastal estuaries in southern California, the minimum total number of taxa richness is set at 35 based on annual averages.

The biological response numeric targets for Malibu Creek and Lagoon are directly linked to the allocations and should be placed into the applicable regulatory mechanism (i.e., NPDES permit) in order to ensure that the benthic community condition achieves the water quality objectives.

10.4. Critical Conditions and Seasonality

TMDLs must include consideration of critical conditions and seasonal variation to ensure protection of the designated uses of the waterbody at all times. For Malibu Creek and Lagoon there are multiple stressors related to biotic impairment that operate on different time lines. Thus, there is no single critical condition for this TMDL.

For sedimentation, the critical period is the winter and spring storm events that provide the majority of sediment transport through the creek and into the estuary.

Critical conditions for nutrient-impaired streams occur during the warm summer months when water temperatures are elevated and algal growth rates are high. In Malibu Creek this means that nutrient concentrations need to be controlled during the summer growing season, although concentrations in the other seasons are also of concern because the temperature and light availability is sufficient to support algal growth year round. In contrast, Malibu Lagoon is most sensitive to nutrient loads delivered during winter storms and stored within the estuary.

In sum, the biotic impairments in Malibu Creek and Lagoon do not have a single critical period, whether defined on hydrology or season. Instead, it will be important to control ambient nutrient concentrations under lower flow conditions (throughout the year) and nutrient and sediment loading during winter-spring high flow events.

10.5. Margin of Safety

All TMDLs are required to include a Margin of Safety (MOS) to account for uncertainty in the understanding of the relationship between pollutant discharges and water quality impacts. The Margin of Safety may be provided explicitly through an unallocated reserve or implicitly through use of adequately conservative assumptions in the analysis.

For the Malibu TMDL an explicit MOS of 15 percent of loading capacity is assigned to the sedimentation target.

For this TMDL an implicit MOS is also used. The TMDL targets are believed to be conservative for several reasons. Most notably, the stressor identification process suggests that impaired benthic biota in both the stream and the estuary result from the combined effects of multiple stressors rather than from any single stressor. This TMDL sets targets for individual stressor sources (nutrients, sedimentation) independently, rather than attempting to account for their poorly understood cumulative impacts. Thus, achieving both the sedimentation and nutrient goals is likely to provide an implicit MOS.

In addition, the TMDL targets are conservative because the primary endpoint measure of healthy benthic biota – SC-IBI, which is the measure on which the impairment designation was made - is not adjusted for the geologic conditions associated with the marine sediments of the Modelo formation. There is uncertainty with the SC-IBI scores in minimally disturbed sites within the Modelo formation. This TMDL conservatively assumed that sites within the Modelo formation are similar in response to sites outside of the Modelo formation. Lastly, this TMDL established lowered concentration based allocations for TN and TP based on the more conservative option.

11. Recommendations

Several programs are currently underway that will contribute towards implementation of these TMDLs. Some of these programs are described below along with suggested monitoring.

11.1 Malibu Lagoon Restoration Plan

Historically utilized as a dumping site, the Malibu Lagoon suffers from much malaise. Poor tidal flow and circulation in the west has decrease dissolved oxygen levels to near zero, threatening fish and wildlife, while harmful bacteria has flourished. Uncontrolled run-off water into the Lagoon and proliferation of foreign species threaten the livelihood of the native environment and the entire ecosystem.

To improve the Lagoon's diseased state, the Malibu Lagoon Restoration plan was accepted and approved, despite much heated debate. The approved plan will improve the function of the Lagoon by re-contouring the Western 12-acre section to lower bank slope grades and alter channels for improved hydrologic function and habitat diversity. In addition, the East Lagoon will be enhanced with an altered channel to provide for a new avian island and additional mudflat habitat. It will remove accumulated sediment and replace non-native vegetation with appropriate native species. For erosion control, measures will be taken to prevent uncontrolled run-off and limit future sedimentation within the Lagoon. A new underpass will be constructed to improve riparian habitat access north of the Pacific Coast Highway. The new public access trail will provide public educational information about the Lagoon and its improvements as well as the long-term monitoring plan.

In June 2012, Phase 1 of the 4-month project got underway (it is scheduled for completion by January 31, 2013). Since then, crews have removed more than 3,000 cubic yards of trash and debris from the Lagoon (Caskey, 2012). The wetlands and other construction pieces were completed by October 31, with current efforts dedicated to vegetation planting and aesthetic improvements.

As a result, USEPA believes that this restoration effort of the Lagoon should significantly improve the Lagoon conditions for the benthic community by providing improved habitat conditions. The Lagoon zones with anoxic conditions or limited tidal flushing are being corrected, in addition to removing debris and excess sediment that provided physical barrier for benthic community development.

The critical piece is to ensure that the sediment and nutrient loading from upstream sources are also reduced and addressed to ensure that both the in-Lagoon source and the Watershed sources are removed. Only by addressing both loads will the natural benthic community be able to flourish. Consequently, USEPA strongly recommends that the Regional Water Quality Control Board work with local stakeholders to identify effective and reasonable best management practices to control the watershed source.

11.2 OWTS State Policy

Assembly Bill (AB) 885 required the SWRCB to develop septic system regulations that treat and dispose wastewater below ground. On June 19, 2012, the SWRCB adopted Resolution No. 2012-0032 (Water Quality Control Policy for Siting, Design, Operation, and Maintenance of Onsite Wastewater Treatment Systems). This policy will become effective upon adoption by the Office of Administrative Law and will require regulation and management of OWTS, based on a tiered approach (SWRCB, 2012).

11.3 NNE STATE POLICY

USEPA acknowledges that SWRCB is developing a statewide policy for NNE. When the State policy on NNE is complete and adopted, USEPA recommends that the appropriate nutrient endpoint measures be applied in Malibu Creek Watershed.

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