Final Technical Report | **2007**

Surface Water Ambient Monitoring Program (SWAMP) Report on the San Diego Hydrologic Unit

January 2008

www.waterboards.ca.gov/swamp

SURFACE WATER AMBIENT MONITORING PROGRAM (SWAMP) REPORT ON THE SAN DIEGO HYDROLOGIC UNIT

Raphael D. Mazor
Ken Schiff

Southern California Coastal Water Research Project
3535 Harbor Blvd., Suite 110
Costa Mesa, CA 92626
www.sccwrp.org

Prepared for the California Regional Water Quality Control Board, San Diego Region (Region 9).

This project was funded by the Surface Water Ambient Monitoring Program.

Technical Report 527_SanDiego

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. ABSTRACT

In order to assess the ecological health of the San Diego Hydrologic Unit (San Diego County, CA), water chemistry, water and sediment toxicity, invertebrate tissues, benthic macroinvertebrate communities, and physical habitat were assessed at multiple sites. Water chemistry, toxicity, and invertebrate tissues were assessed under SWAMP in 2005 and 2006. Bioassessment samples were collected under SWAMP and other programs between 1998 and 2005. Although impacts to human health were also assessed, the goal of this monitoring program was to examine impacts to aquatic life in the watershed. Most of these ecological indicators showed evidence of widespread impacts to the watershed. For example, all sites (n = 7) exceeded aquatic life thresholds for several water chemistry constituents (up to 9 at one site). Toxicity was evident at all sites, although frequency varied from 62% of samples (at San Vicente Creek) to 86% (at Chocolate Creek). The alga *Selenastrum capricornutum* and the crustacean *Hyallela azteca* were the most sensitive indicators of toxicity, showing a toxic response to more than 90% of samples. Invertebrate tissues collected at the mouth of the San Diego River showed evidence of accumulation of PCBs, even exceeding thresholds established by the Office of Environmental Health Hazard Assessment (OEHHA). Bioassessment samples collected at 10 of 13 sites were in poor or very poor condition, with mean annual IBIs as low as 5.5, indicating that benthic assemblages were typical of impacted communities. Samples in good biological condition were observed at only 3 sites, all above El Capitan Reservoir. Physical habitat varied throughout the watershed, with mean physical habitat scores ranging from 6.3 (at Chocolate Creek) to 16.1 (at Boulder Creek) out of 20; only one site had minimal evidence of physical habitat degradation. Embeddedness was a widespread and severe impact on physical habitat, receiving at average score of 5.6 out of 20. Multiple stressors, such as contaminated water and sediment, and alteration of physical habitat, were likely responsible for the poor health of the watershed. Despite limitations of this assessment (e.g., uncertain spatial and temporal variability, low levels of replication, non-probabilistic sampling, and lack of thresholds for several indicators), multiple lines of evidence support the conclusion that portions of the San Diego watershed are in poor ecological condition.

2. INTRODUCTION

The San Diego hydrologic unit (HU 907) is in San Diego County and is home to about 500,000 people. The watershed represents an important water resource in one of the most arid regions of the nation. Despite strong interest in the surface waters of the San Diego HU, a comprehensive assessment of the ecological health of the watershed has not been conducted. The purpose of this study was assess the health of the watershed using data collected between 2004 and 2006 under the Surface Waters Ambient Monitoring Program (SWAMP), and data collected by National Pollution Discharge Elimination System (NPDES) permittees, as well as the Padre Dam Municipal Water District. SWAMP monitoring efforts rotated among sets of watersheds, ensuring that each HU is monitored once every 5 years (Table 1). These programs collected data to describe water chemistry, water and sediment toxicity, physical habitat, fish or invertebrate tissue, and macroinvertebrate community structure. By examining data from multiple sources, this report provides a measure of the ecological integrity of the San Diego HU.

Table 1. Watersheds monitored under the SWAMP program.

Year (Fiscal year)	Sample collection	Hydrologic unit	HUC
1 (2000-2001)	2002	Carlsbad	904
	2002	Peñasquitos	906
2 (2001-2002)	2002-2003	San Juan	901
	2003	Otay	910
3 (2002-2003)	2003	Santa Margarita	902
	2004-2006	San Dieguito	905
4 (2003-2004)	2004-2006	San Diego	907
	2004-2006	San Luis Rey	903
5 (2004-2005)	2005-2006	Pueblo San Deigo	908
	2005-2006	Sweetwater	909
	2005-2006	Tijuana	911

There are two objectives for this assessment: 1) To evaluate the condition of SWAMP sites; and 2) To evaluate the overall condition of the watershed. Evaluations were based on multiple indicators of ecological integrity, including water chemistry, water and sediment toxicity, invertebrate tissue bioaccumulation, biological assessment of benthic macroinvertebrate communities, and physical habitat assessment.

This report is organized into four sections. The first section (Introduction) describes the geographic setting in terms of climate, hydrology, and land use within the watershed. The second section (Methods) describes the approach to data collection, assessment indicators, and data analysis. The third section (Results) contains the results of these analyses. The fourth section (Discussion) integrates evidence of impact from multiple indicators, describes the limitations of this assessment, and summarizes the overall health of the watershed.

2.1 Geographic Setting

The San Diego HU is a large watershed in southern San Diego county draining into the Pacific Ocean near Mission Bay (Figure 1). Located entirely within San Diego County, the watershed covers 440 mi^2 and ranges from the Cuyamaca Mountains in the interior to the Pacific Coast.

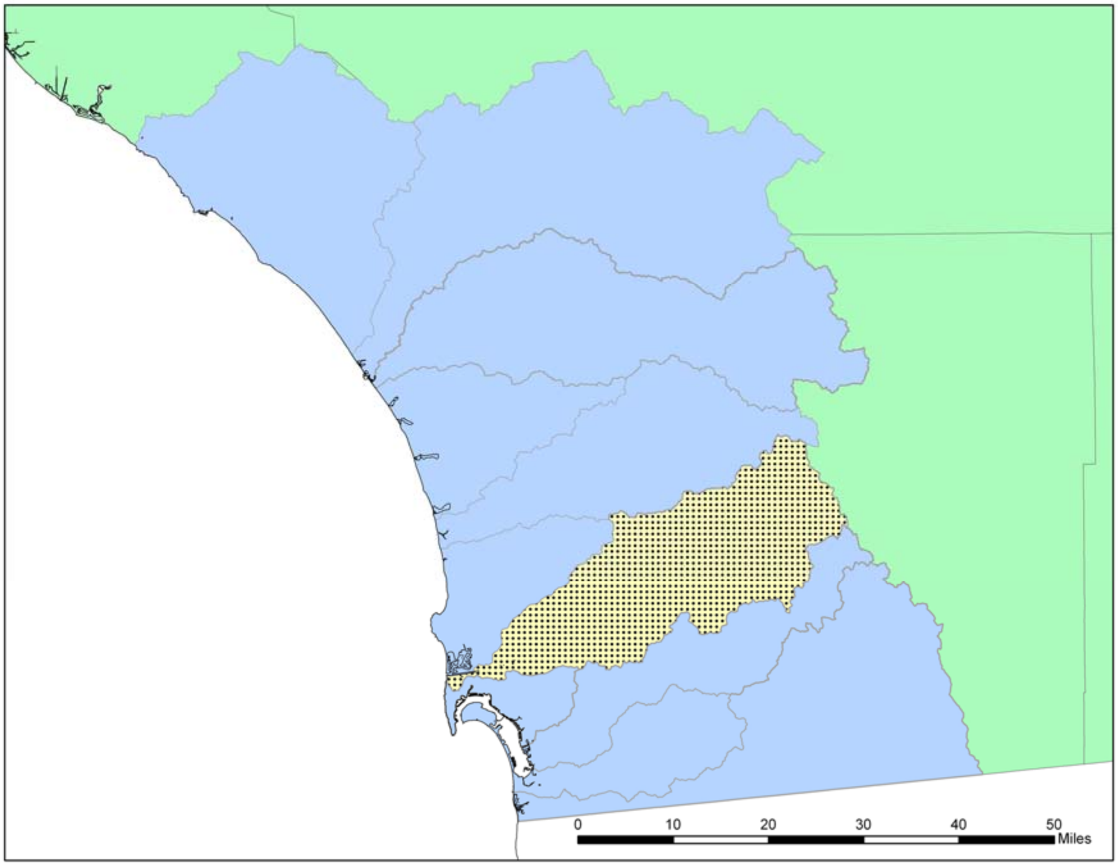

Figure 1. San Diego region (purple) includes portions of San Diego, Riverside, and Orange counties. The San Diego HU (tan, shaded) is located entirely within San Diego County.

2.1.1 Climate

The San Diego HU, like the entire San Diego region, is characterized by a mediterranean climate, with hot dry summers and cool wet winters. Average monthly rainfalls measured at the Lindberg Airport (SDG) in San Diego, California between 1905 and 2006 show that nearly all rain fell between the months of October and April, with hardly any falling between the months of May and September (California Department of Water Resources 2007). The wettest month was January, with an average rainfall of 2.05"). Average annual rainfall at this station was 10.37". Daily rainfall measured at Cuyamaca Rancho (near the inland end of the HU), Alpine (near the center of the HU) and at Seaworld (near the coast within the HU) shows considerable variability in rainfall throughout the HU (National Oceanic and Atmospheric Administration 2007) (Figure 2).

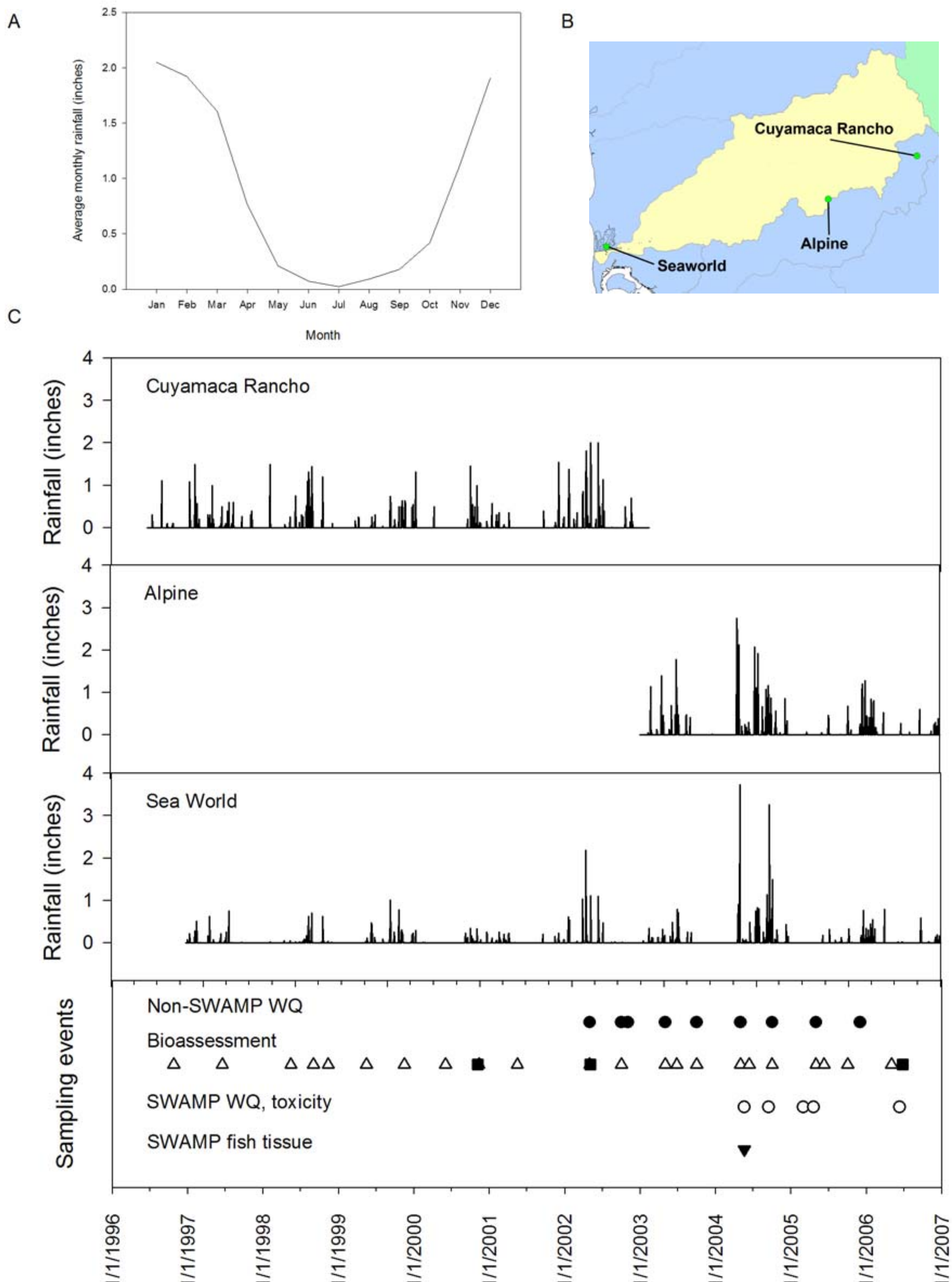

Figure 2. Rainfall and sampling events at stations in the San Diego region. A. Average precipitation for each month at the Lindberg Station (DWR station code SDG), based on data collected between January 1905 and November 2006. B. Location of the Seaworld, Alpine, and Cuyamaca Rancho gauges. C. Storm events and sampling events in the San Diego HU. The top three plots show daily precipitation between 1998 and 2007 at the three stations. The bottom plot shows the timing of

sampling events. Non-SWAMP water chemistry is shown as black circles. Non-SWAMP bioassessment is shown as white upward triangles. SWAMP bioassessment is shown as black squares. SWAMP water chemistry and toxicity is shown as white circles. SWAMP invertebrate tissue is shown as black downward triangles.

2.1.2 Hydrology

The San Diego HU consists of the San Diego River watershed (Figure 3). The river drains 440 mi^2 and enters the Pacific Ocean south of Mission Bay through the San Diego River estuary, although some water passes through the marshes of Famosa Slough. Major tributaries include Los Coches Creek, Chocolate Creek, San Vicente Creek, Boulder Creek, and Conejos Creek.

The San Diego River represents an important source of drinking water for the residents of San Diego County. Dams throughout the watershed have created several major reservoirs, supplying water to over 700,000 people in the City of San Diego. The largest of these reservoirs is El Capitan (on the mainstem), followed by San Vicente (on San Vicente Creek). Smaller reservoirs and groundwater storage represent additional water resources.

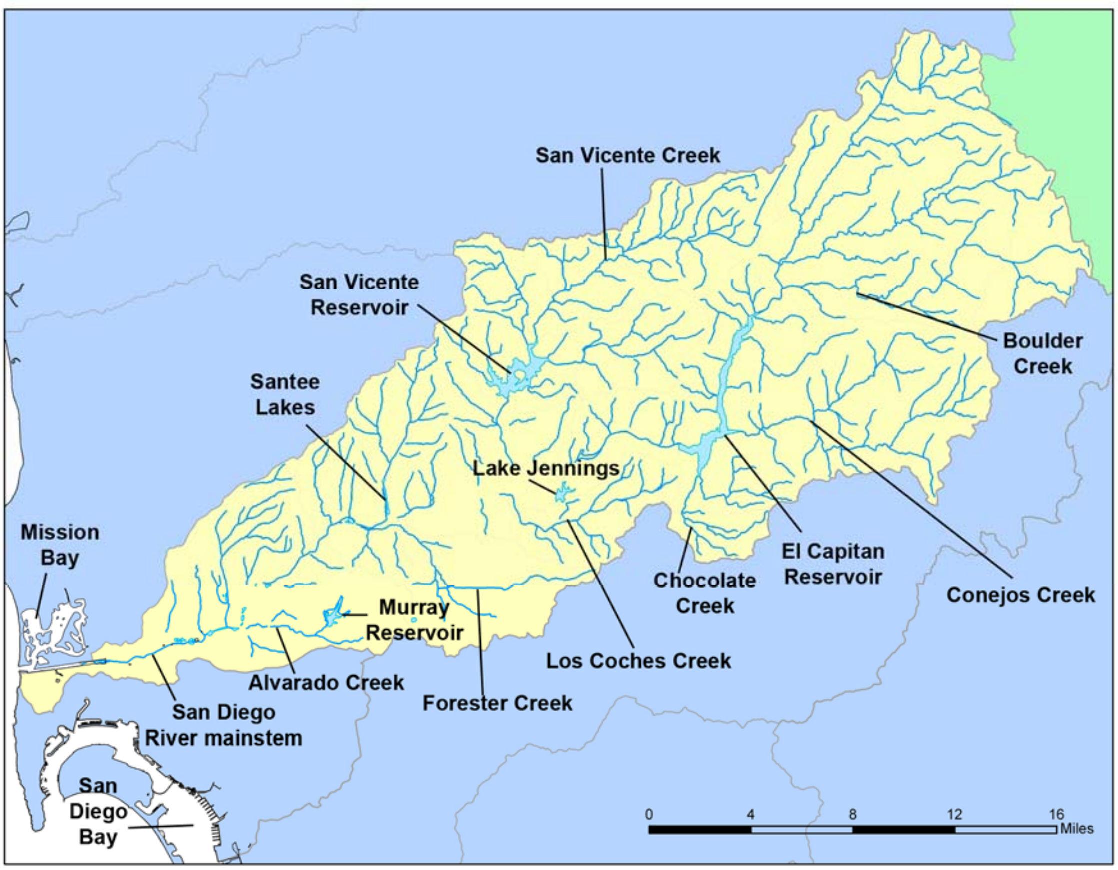

Figure 3. The San Diego watershed, including major waterways.

2.1.3 Land Use within the Watershed

Several municipalities have jurisdiction over portions of the watershed. The City of San Diego occupies the largest portion of the watershed (16.8%), followed by Santee (3.8%), El Cajon (3.3%) La Mesa (1.1%) and Poway (0.2%). However, the majority of the watershed (74.7%) is unincorporated and is under the jurisdiction of the County of San Diego. Most of the watershed (72%) is undeveloped open space. Developed urban land covers 26%. A small portion of the watershed (2%) is used for agriculture (Figure 4). Important protected areas include the Cleveland National Forest, Cuyamaca Rancho State Park, and Mission Trails Regional Park, operated by the City of San Diego. The headwaters are protected by the Santa Ysabel Open Space Preserve, operated by the County of San Diego. Caltrans is a major landowner within the HU, and it has jurisdiction of all major freeways and highways. Other major landowners include several Indian reservations, including the Capitan Grande, Barona, Inaja, and Cosmit Reservations, Large portions of the watershed were burned in the 2003 Cedar Fire. (SANDAG 1998).

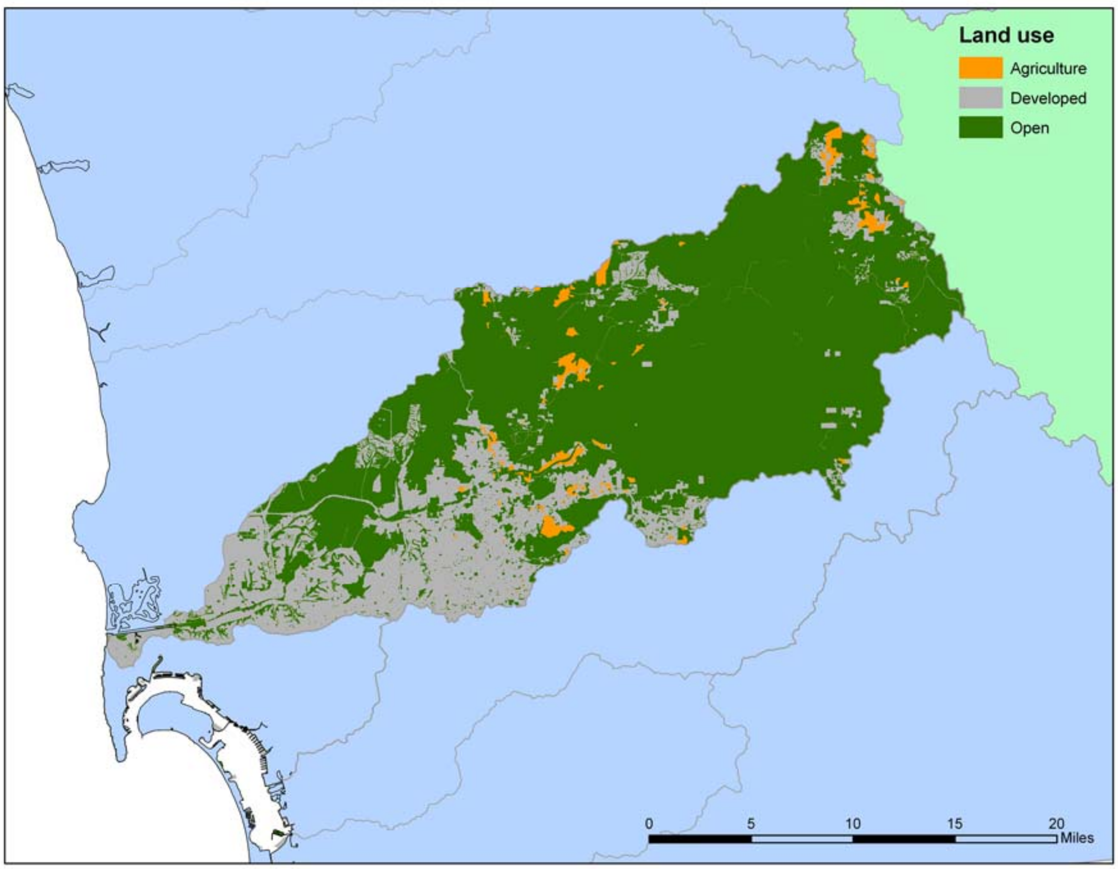

Figure 4. Land use within the San Diego HU. Undeveloped open space is shown as green. Agricultural areas are shown as orange. Urban and developed lands are shown as dark gray.

2.1.4 Beneficial Uses and Known Impairments in the Watershed

The San Diego HU is designated to support many beneficial uses. Beneficial uses in the watershed include municipal; agriculture; industry; recreation; warm and cold freshwater habitat; wildlife habitat; rare, threatened, or endangered species; and spawning habitat. Some streams in the San Diego HU have been exempted from municipal uses (Appendix I).

Several streams in the San Diego HU are listed as impaired on the 303(d) list of water quality limited segments, affecting a total of 20.4 stream miles. These streams include Forester Creek and the lower San Diego River. Known stressors include bacteria, low dissolved oxygen, pH, phosphorous, and total dissolved solids (Appendix I).

3. METHODS

This report combines data collected under SWAMP with data from California Department of Fish and Game (CDFG), NPDES monitoring, Padre Dam MWD, and the San Diego Water Board (Table 2). Ten sites of interest were sampled under SWAMP in the San Diego HU between 2004 and 2006 (Table 3; Figure 5). Water chemistry, water and sediment toxicity, and physical habitat were measured at each site. Invertebrate tissues were collected near one site on the mainstem (907SSDR15) to assess bioaccumulation. Bioassessment samples were collected at three sites under SWAMP (Alvarado Creek (907SDALV3), San Vicente Creek (907SDSVC3) and the mainstem (907SDSDR9). Additional bioassessment samples were collected by the CDFG Aquatic Bioassessment Laboratory (ABL), the San Diego Water Board (as part of special studies on repeat sampling and at Mission Trails Regional Park), Padre Dam Municipal Water District (MWD) and the County of San Diego as part of its NPDES permit. Monitoring under NPDES and MWD included conventional water chemistry (e.g., temperature, conductivity, dissolved oxygen) in addition to bioassessments. When two non-SWAMP sites were located within 500 meters of each other, they were treated as a single site. This distance was based on published measures of spatial correlation of benthic communities in streams (Gebler 2004). Non-SWAMP samples were collected between 1998 and 2005; in some cases, non-SWAMP sites were very close to SWAMP sites (Table 4; Figure 5).

Table 2. Sources of data used in this report.

Project	Indicators	Years
SWAMP	Water chemistry, toxicity, fish tissue, bioassessment, and physical habitat	2004-2006
Regional Board	Bioassessment	1996-2002
CA Department of Fish and Game	Bioassessment	1996-2006
San Diego County NPDES	Water chemistry, bioassessmer	2003-2005
Padre Dam MWD	Water chemistry, bioassessmer	2004-2006

Table 3: SWAMP sampling site locations. Indicators sampled at each site are indicated as follows: W = Water chemistry. T = Toxicity. F = Invertebrate tissue. B = Bioassessment (under SWAMP). N = Bioassessment (under non-SWAMP programs). P = Physical habitat.

Site		Description	Latitude (°N)	Longitude (°E)	W	T	F	B	N	P
1	907SDALV3	Alvarado Creek 3	32.7831	-117.0748	X	X		X	X	X
2	907SDBOC2	Boulder Creek 2	32.9635	-116.6641	X	X			X	X
3	907SDCHC3	Chocolate Creek 3	32.8472	-116.8069	X	X			X	X
4	907SDFRC2	Forrester Creek 2	32.8395	-117.0011	X	X				X
5	907SDLCO2	Los Coches Creek 2	32.8491	-116.8591	X	X				X
6	907SDSVC4	San Vicente Creek 3/4*	32.9934	-116.8498	X	X		X		X
7	907SSDR15	San Diego River 15	32.7619	-117.1927	X	X	X		X	X
8	907SSDR9	San Diego River 9	32.8389	-117.0454				X	X	

*Two sites on San Vicente Creek (SVC3 and SVC4) had identical coordinates and were treated as the same site.

Table 4. Non-SWAMP sampling site locations. W = sites where conventional water chemistry was sampled. B = sites where benthic macroinvertebrates were sampled.

Site	Description	SWAMP site	Sources (site name)	W	B	Lattitude (N)	Longitude (E)
1	Alvarado Creek	907SDALV3	Regional Board (907ALV204)		X	32.7819	-117.0751
2	Boulder Creek at Boulder Creek Road	907SDBOC	Regional Board (907BCBCRx)		X	32.9634	-116.6639
3	Cedar Creek at Cedar Creek Road	none	Regional Board (907CCCCRx)		X	33.0022	-116.7089
4	Chocolate Creek at Arnold Way	907SDCHC3	Regional Board (907CHC2xx)		X	32.8420	-116.8057
5	Conejos Creek at El Capitan Reservoir	none	Regional Board (907CONECR)		X	32.8903	-116.7631
6	San Diego River above Mission Dam	907SSDR9	CDFG (907SDRMDx)		X	32.8405	-117.0391
			Regional Board (907SDRMDx)		X		
			Padre Dam MWD (SDR-OMD)	X	X		
7	San Diego River below Mission Trails Park	none	CDFG (907SDRMTx)		X	32.8186	-117.0653
			Regional Board (907SDRMTx)		X		
			NPDES (SDR-MT)	X	X		
8	San Diego River at Sefton Park	907SSDR15	Regional Board (907SDR1x)		X	32.7650	-117.1914
			CDFG (907SDRS1a, 907SDR1x)		X		
			NPDES (SDR-1)	X	X		
9	San Diego River in Mission Trails Park	none	Regional Board (907SDRS2x, 907SDRS4x, 907SDRS6x, 907SDRS7x, 907SDRS8x)		X	32.7722	-117.1419
10	San Vicente Creek near Wildcat Canyon Ro	none	Regional Board (907SVWCRx)		X	32.9964	-116.8440
11	Cedar Creek (Reference)	none	NPDES (REF-CC)	X	X	33.0252	-116.6338
12	San Diego River at Carlton Hills Blvd	none	Padre Dam MWD (SDR-CHB)	X	X	32.8432	-116.9971

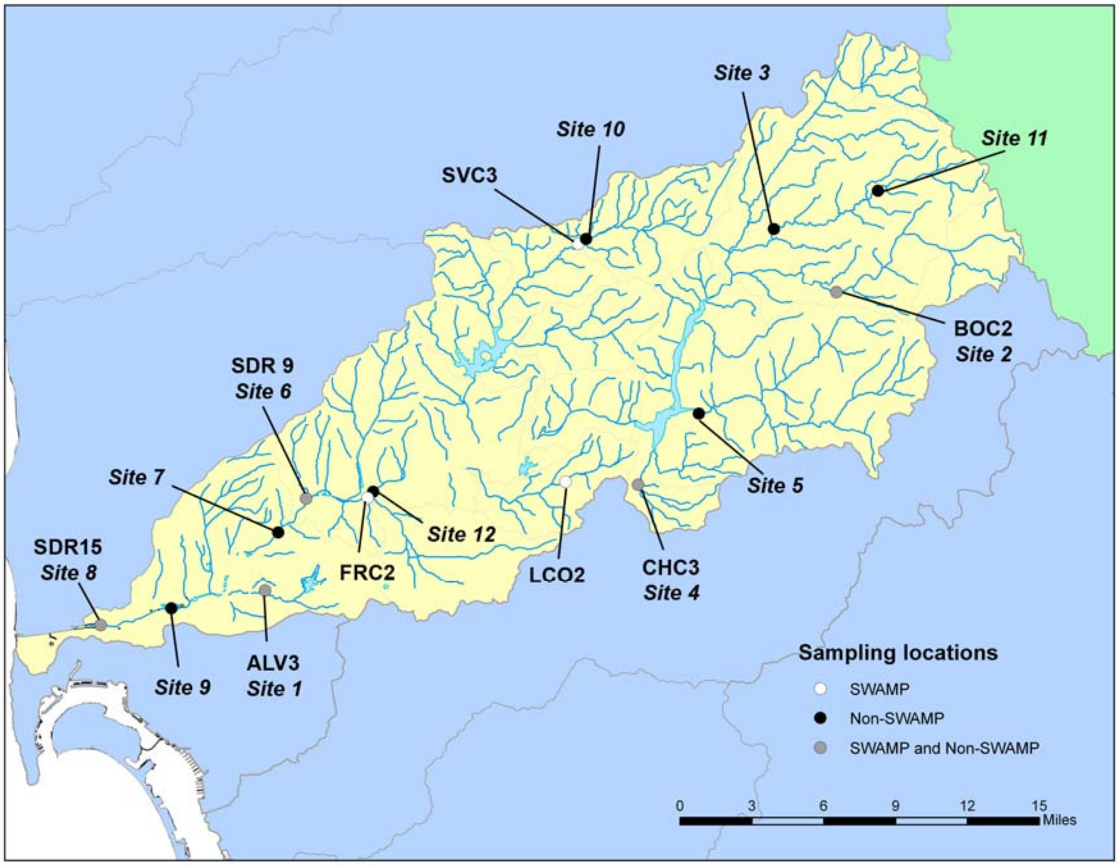

Figure 5. Sampling locations in the San Diego HU. White circles represent sites sampled under SWAMP. Black circles represent sites sampled under non-SWAMP programs. Gray circles represent sites sampled under both SWAMP and non-SWAMP programs. The SWAMP site prefix designating the hydrologic unit (i.e., 907SD-) has been dropped to improve clarity.

3.1 Indicators

Multiple indicators were used to assess the sites in the San Diego HU. Water chemistry, water and sediment toxicity, invertebrate tissues, benthic macroinvertebrate communities, and physical habitat.

3.1.1 Water chemistry

To assess water chemistry, samples were collected at each site. Water chemistry was measured as per the SWAMP Quality Assurance Management Plan (QAMP) (Puckett 2002). Measured indicators included conventional water chemistry (e.g., pH, temperature dissolved oxygen, etc.), inorganics, herbicides, pesticides, polycyclic aromatic hydrocarbons (PAHs), dissolved metals, pesticides, and polychlorinated biphenyls (PCBs). Appendix II contains a complete list of constituents that were measured.

Limited water chemistry was collected under non-SWAMP NPDES monitoring and by Padre Dam MWD as well. This monitoring was restricted to physical parameters, and followed procedures described in annual reports to California Regional Water Quality Control Board, San Diego Region (e.g., Weston Solutions Inc. 2007).

3.1.2 Toxicity

To evaluate water and sediment toxicity to aquatic life in the San Diego HU, toxicity assays were conducted on samples from each site as per the SWAMP QAMP (EPA 1993, Puckett 2002). Water toxicity was evaluated with 7-day exposures on the water flea, *Ceriodaphnia dubia*, and 96-hour exposures to the alga *Selenastrum capricornutum.* Both acute and chronic toxicity to *C. dubia* was measured as decreased survival and fecundity (i.e., eggs per female) relative to controls, respectively. Chronic toxicity to *S. capricornutum* was measured as changes in total cell count relative to controls. Sediment toxicity was evaluated with 10-day exposures on the amphipod *Hyallela azteca.* Both acute and chronic toxicity to *H. azteca* was measured as decreased survival and growth (mg per individual) relative to controls, respectively. Chronic toxicity endpoints (i.e., *C. dubia* fecundity, *H. azteca* growth, and *S. capricornutum* total cell count) were used to develop a summary index of toxicity at each site.

3.1.3 Tissue

To detect contamination in invertebrate tissues in the San Diego HU, tissues from two Asian clams (*Corbicula* sp.) were collected from the mouth of the San Diego River (907SSDR15). Samples were not combined so that variability among individual organisms could be estimated. Tissues were analyzed for metals and PCBs as per the SWAMP QAMP (Puckett 2002). Wet-weight concentrations of each constituent were recorded.

3.1.4 Bioassessment

To assess the ecological health of the streams in San Diego HU, benthic macroinvertebrate samples were collected at 21 sites. Samples were collected using SWAMP-comparable protocols, as per the SWAMP QAMP (Puckett 2002). Three replicate samples were collected from riffles at each site; 300 individuals were sorted and identified from each replicate, creating a total count of 900 individuals per site. Using a Monte Carlo simulation, all samples were reduced to 500 count for calculation of the Southern California Index of Biotic Integrity (IBI; Ode et al. 2005), a composite of seven metrics summed and scaled from 0 (poor condition) to 100 (good condition).

3.1.5 Physical Habitat

Physical habitat was assessed using semi-quantitative observations of 10 components relating to habitat quality, such as embeddedness, bank stability, and width of riparian zone. The assessment protocols are described in The California Stream Bioassessment Procedure (California Department of Fish and Game 2003). Each component was scored on a scale of 0 (highly degraded) to 20 (not degraded). Sites were assessed by the average component score.

3.2 Data Analysis

To evaluate the extent of human impacts to water chemistry in streams in the San Diego HU, two frequency-based approaches were employed to detecting impacts. First, established aquatic life and human health thresholds for individual constituents were evaluated for frequency of exceedances. Second, the frequency of detection for anthropogenic constituents (such as PCBs, pesticides, and PAHs) were also evaluated.

To evaluate the overall health of each site and of the watershed, three indicators were selected for analysis: number of constituents exceeding aquatic life water chemistry thresholds; frequency of chronic toxicity to *S. capricornutum, C. dubia,* and *H. azteca*; and mean IBI score. Tissue analysis was excluded because tissue samples were collected at only one site. Physical habitat assessment was excluded due to lack of agreed-upon thresholds for evaluation of physical habitat scores. These results were plotted on a map of the watershed, indicating the severity and distribution of human impacts.

Although non-SWAMP sources of water chemistry data were used, this report focuses on SWAMP data in order to maintain consistency of sampling methods and parameters measured at each site. Analyses of non-SWAMP water chemistry data is presented separately. In contrast, bioassessment data from multiple sources is analyzed together because of the high compatibility of sampling protocols used in different programs, and because of the limited availability of bioassessment data from a single source. Toxicity, invertebrate tissue, and physical habitat data were only available from SWAMP monitoring.

3.2.1 Thresholds

In order to use the data to assess the health of the watershed, thresholds were established for each indicator: water quality, toxicity, bioassessment, invertebrate tissue, and physical habitat. Exceedance of appropriate thresholds was considered evidence for impact on watershed health.

Water chemistry data from this study were compared to water quality objectives established by state and federal agencies to protect the most sensitive beneficial uses designated in the San Diego HU. Therefore, the most stringent water quality objectives (e.g., municipal drinking water, aquatic life, etc.) for the measured constituents were used as threshold points to evaluate the data.

The Water Quality Control Plan for the San Diego Basin (BP) was the primary source of water chemistry thresholds. Other sources for standards used in water chemistry thresholds included the California Toxics Rule (CTR), the Environmental Protection Agency National Aquatic Life Criteria (EPA), the National Academy of Sciences Health Advisory (NASHA), United States Environmental Protection Agency Integrated Risk Information System (IRIS), and the California Code of Regulations §64449 (CCR). The sources for thresholds used in this study are shown in Table 5.

Table 5. Threshold sources

Indicator	Source	Citation
Water chemistry	Water Quality Control Plan For the San Diego Basin (BP)	California Regional Water Quality Control Board, San Diego Region. 1994. Water quality control plan for the San Diego Region. San Diego, CA. http://www.waterboards.ca.gov/sandiego/programs/basinplan.html
	California Toxics Rule (CTR)	Environmental Protection Agency. 1997. Water quality standards: Establishment of numeric criteria for priority toxic pollutants for the state of California: Proposed Rule. *Federal Register* 62:42159-42208.
	EPA National Aquatic Life Criteria (EPA)	Environmental Protection Agency. 2002. National recommended water quality criteria. EPA-822-R-02-047. Office of Water. Washington, DC.
	National Academy of Sciences Health Advisory (NASHA)	National Academy of Sciences. 1977. Drinking Water and Health. Volume 1. Washington, DC.
	US Environmental Protection Agency Integrated Risk Information System (IRIS)	Environmental Protection Agency (EPA). 2007. Integrated Risk Information System. http://www.epa.gov/iris/index.html. Office of Research and Development. Washington, DC.
	California Code of Regulations §64449 (CCR)	California Code of Regulations. 2007. Secondary drinking water standards. Register 2007, No. 8. Title 22, division 4, article 16.
Invertebrate tissue	Office of Environmental Health Hazard Assessment (OEHHA)	Office of Environmental Health Hazard Assessment. 2006. Draft development of guidance tissue levels and screening values for common contaminants in California Sports Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene. Sacramento, CA.
Bioassessment	Ode et al. 2005	Ode, P.R., A.C. Rehn and J.T. May. 2005. A quantitative tool for assessing the integrity of southern California coastal streams. *Environmental Management* 35:493-504.

Although human health thresholds (e.g., drinking water standards) were applied to relevant water chemistry data, this report focuses on aquatic life, and does not address the risks to human health in the San Diego HU. When multiple thresholds were applicable to a single constituent, the most stringent threshold was used. Water chemistry thresholds for aquatic life and human health standards used in this study are presented in Table 6. Impacts were assessed as the total number of constituents exceeding thresholds, as opposed to the fraction of constituents. The fraction of constituents exceeding thresholds is not an ecologically meaningful statistic because the number of constituents below thresholds does not degrade or improve the ecological health of a site.

Table 6. Water chemistry thresholds for aquatic life and human health standards. San Diego Basin Plan (BP); California Toxics Rule (CTR); Environmental Protection Agency National Aquatic Life Standards (EPA); National Academy of Science Health Advisory (NASHA); Environmental Protection Agency Integrated Risk Information System (IRIS); California Code of Regulations §64449 (CCR).

			Aquatic life			Human health		
Category	Constituent	Applicability	Threshold	Unit	Source	Threshold	Unit	Source
Inorganics	Alkalinity as CaCO3	All sites	20000	mg/l	EPA	none	mg/l	none
Inorganics	Ammonia as N	All sites	0.025	mg/l	BP	none	mg/l	none
Inorganics	Nitrate + Nitrite as N	All sites	10	mg/l	BP	none	mg/l	none
Inorganics	Nitrate as NO3	MUN use	none	mg/l	none	45	mg/l	BP
Inorganics	Nitrite as N	All sites	none	mg/l	none	1	mg/l	EPA
Inorganics	Total N	All sites	10:1 (TN:TP) or 1	mg/l	BP	none	mg/l	none
Inorganics	Phosphorus as P,Total	All sites	0.1	mg/l	BP	none	mg/l	none
Inorganics	Selenium,Dissolved	All sites	5	µg/L	CTR	none	µg/L	none
Inorganics	Sulfate	HUC 907.1	500	mg/l	BP	none	mg/l	none
Inorganics	Sulfate	All other HUCs	65	mg/l	BP	none	mg/l	none
Inorganics	Chloride	HUC 907.1	400	mg/l	BP	230	mg/l	EPA
Inorganics	Chloride	All other HUCs	50	mg/l	BP	230	mg/l	EPA
Metals	Aluminum,Dissolved	All sites	1000	µg/L	BP	none	µg/L	none
Metals	Arsenic,Dissolved	All sites	50	µg/L	BP	150	µg/L	CTR
Metals	Cadmium,Dissolved	All sites	5	µg/L	BP	2.2	µg/L	CTR
Metals	Chromium,Dissolved	All sites	50	µg/L	BP	none	µg/L	none
Metals	Copper,Dissolved	All sites	9	µg/L	CTR	1300	µg/L	CTR
Metals	Lead,Dissolved	All sites	2.5	µg/L	CTR	none	µg/L	none
Metals	Manganese,Dissolved	HUC 907.11	1	mg/l	BP	none	mg/l	none
Metals	Manganese,Dissolved	All other	0.05	mg/l	BP	none	mg/l	none
Metals	Nickel,Dissolved	All sites	52	µg/L	CTR	610	µg/L	CTR
Metals	Silver,Dissolved	All sites	3.4	µg/L	CTR	none	µg/L	none
Metals	Zinc,Dissolved	All sites	120	µg/L	CTR	none	µg/L	none
PAHs	Acenaphthene	All sites	none	µg/L	none	1200	µg/L	CTR
PAHs	Anthracene	All sites	none	µg/L	none	9600	µg/L	CTR
PAHs	Benz(a)anthracene	All sites	none	µg/L	none	0.0044	µg/L	CTR
PAHs	Benzo(a)pyrene	All sites	0.0002	µg/L	BP	0.0044	µg/L	CTR
PAHs	Benzo(b)fluoranthene	All sites	none	µg/L	none	0.0044	µg/L	CTR
PAHs	Benzo(k)fluoranthene	All sites	none	µg/L	none	0.0044	µg/L	CTR
PAHs	Chrysene	All sites	none	µg/L	none	0.0044	µg/L	CTR
PAHs	Dibenz(a,h)anthracene	All sites	none	µg/L	none	0.0044	µg/L	CTR
PAHs	Fluoranthene	All sites	none	µg/L	none	300	µg/L	CTR
PAHs	Indeno(1,2,3-c,d)pyrene	All sites	none	µg/L	none	0.0044	µg/L	CTR
PAHs	Pyrene	All sites	none	µg/L	none	960	µg/L	CTR
PCBs	PCBs	All sites	0.014	µg/L	CTR	0.00017	µg/L	CTR
Pesticides	Aldrin	All sites	3	µg/L	CTR	1.3E-07	µg/L	CTR
Pesticides	Alpha-BHC	All sites	none	µg/L	none	0.0039	µg/L	CTR
Pesticides	Beta-BHC	All sites	none	µg/L	none	0.014	µg/L	CTR
Pesticides	Gamma-BHC (Lindane)	All sites	0.95	µg/L	CTR	0.019	µg/L	CTR
Pesticides	Ametryn	All sites	none	µg/L	none	60	µg/L	EPA
Pesticides	Atrazine	All sites	3	µg/L	BP	0.2	µg/L	OEHHA

Table 6, continued. Water chemistry thresholds for aquatic life and human health.

			Aquatic life			Human health		
Category	Constituent	Applicability	Threshold	Unit	Source	Threshold	Unit	Source
Pesticides	Azinphos ethyl	All sites	none	µg/L	none	87.5	µg/L	NASHA
Pesticides	Azinphos methyl	All sites	none	µg/L	none	87.5	µg/L	NASHA
Pesticides	Chlordanes	All sites	0.0043	µg/L	CTR	0.00057	µg/L	CTR
Pesticides	DDD(p,p')	All sites	none	µg/L	none	0.00083	µg/L	CTR
Pesticides	DDE(p,p')	All sites	none	µg/L	none	0.00059	µg/L	CTR
Pesticides	DDT(p,p')	All sites	none	µg/L	none	0.00059	µg/L	CTR
Pesticides	Dieldrin	All sites	none	µg/L	none	0.00014	µg/L	CTR
Pesticides	Dimethoate	All sites	none	µg/L	none	1.4	µg/L	IRIS
Pesticides	Endosulfan sulfate	All sites	none	µg/L	none	110	µg/L	CTR
Pesticides	Endrin	All sites	0.002	µg/L	BP	0.76	µg/L	CTR
Pesticides	Endrin Aldehyde	All sites	none	µg/L	none	0.76	µg/L	CTR
Pesticides	Endrin Ketone	All sites	none	µg/L	none	0.85	µg/L	CTR
Pesticides	Heptachlor	All sites	0.0038	µg/L	CTR	0.00021	µg/L	CTR
Pesticides	Heptachlor epoxide	All sites	0.0038	µg/L	CTR	0.0001	µg/L	CTR
Pesticides	Hexachlorobenzene	All sites	1	µg/L	BP	0.00075	µg/L	CTR
Pesticides	Methoxychlor	All sites	40	µg/L	BP	none	µg/L	none
Pesticides	Molinate	All sites	20	µg/L	BP	none	µg/L	none
Pesticides	Oxychlordane	All sites	none	µg/L	none	0.000023	µg/L	CTR
Pesticides	Simazine	All sites	4	µg/L	BP	none	µg/L	none
Pesticides	Toxaphene	All sites	0.0002	µg/L	CTR	0.0002	µg/L	CTR
Pesticides	Thiobencarb	All sites	70	µg/L	BP	none	µg/L	none
Physical	Oxygen, Dissolved	WARM use	5	mg/L	BP	none	mg/L	none
Physical	Oxygen, Dissolved	COLD use	6	mg/L	BP	none	mg/L	none
Physical	pH	All sites	>6 and <8	pH	BP	none	pH	none
Physical	Specific Conductivity	All sites	1600	µS/cm	CCR	none	mS/cm	none
Physical	Turbidity	All sites	20	NTU	BP	none	NTU	none

Several anthropogenic water chemistry constituents had no applicable threshold (e.g., malathion), and impacts from these constituents would not be detected using the threshold-based approach described above. To assess the impact from these constituents, the number of organic constituents (i.e., PAHs, PCBs, and pesticides) detected at each site were calculated. The total number of sites at which these compounds were detected was recorded.

Thresholds for toxicity assays were determined by comparing study samples to control samples (non-toxic reference samples). Samples meeting the following criteria were considered toxic: 1) treatment responses significantly different from controls, as determined by a statistical t-test; and 2) endpoints less than 80% of controls. To summarize the toxicity at a site using multiple endpoints, the frequency of toxic samples was calculated. To assign equal weight to all three indicators, a single endpoint of chronic toxicity per indicator was used (*C. dubia*: fecundity, *H. azteca*: growth, and *S. capricornutum*: total cell count).

Thresholds for tissue samples shown in Table 7 were derived from the Draft Development of Guidance Tissue Levels and Screening Values for Common Contaminant in California Sport Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene (OEHHA 2006). Several constituents had no applicable threshold.

Table 7. Threshold concentrations for invertebrate tissue contaminants established by OEHHA. All thresholds apply to wet-weight concentrations.

Constituent	Threshold	Unit
PCBs	20	ppm
Selenium	1.94	ppm

Thresholds for bioassessment samples were based on a benthic macroinvertebrate index of biological integrity (IBI) that was developed specifically for southern California (Ode et al. 2005). The results of the IBI produces a measure of impairment with scores scaled from 0 to 100, 0 representing the poorest health and 100 the best health. Based on the IBI, samples with scores equal to or below 40 are considered to be in “poor” condition, and samples below 20 are considered to be in “very poor” condition. Therefore, in this study samples with an IBI below 40 were considered impacted.

Thresholds for the evaluation of physical habitat have not been established. Therefore, measurements of physical habitat were excluded from the overall assessment of ecological health. However, because the protocol used to evaluate physical habitat qualitatively assigns scores lower than 10 (out of 20) to streams in poor condition, this number was used to determine sites with severely degraded habitat. Sites with scores below 15 were considered moderately degraded, and those with scores greater than 15 were considered unimpacted (California Department of Fish and Game 2003).

3.2.2 Quality Assurance and Quality Control (QA/QC)

The SWAMP QAMP guided QA/QC for all data collected under SWAMP (See SWAMP QAMP for detailed descriptions of QA/QC protocols, Puckett 2002). QA/QC officers flagged non-compliant physical habitat, water chemistry, toxicity, and tissue results. No chemistry, toxicity, or tissue data were excluded as a result of QA/QC violations. QA/QC procedures for NPDES and Padre Dam MWD water chemistry data were similar to those used in SWAMP (Weston Solutions Inc. 2007) Non-SWAMP bioassessment samples were screened for samples containing fewer than 450 individuals. No bioassessment sample was excluded from this analysis.

4. RESULTS

4.1 Water Chemistry

Analysis of water chemistry at SWAMP sites indicated widespread impact to water quality for multiple constituents. Across the entire watershed, 17 PAHs and 9 pesticides were detected (Table 8). Pesticides were detected at every site, and PAHs were detected at 2 sites. PCBs were not detected at any site. The mouth of the San Diego River (SDR15) had the highest numbers of detectable PAHs (17), and Forester Creek (FRC2) had the highest number of detectable pesticides (7). Means and standard deviations of all constituents are presented in Appendix II.

Table 8. Number of anthropogenic organic compounds detected at each site in San Diego HU.

	PAHs		PCBs		Pesticides	
	Tested	Detected	Tested	Detected	Tested	Detected
907SDALV3	48	0	50	0	90	4
907SDBOC2	48	0	50	0	90	1
907SDCHC3	48	0	50	0	90	3
907SDFRC2	48	4	50	0	90	7
907SDLCO2	48	0	50	0	90	2
907SDSVC3/4	52	0	57	0	92	1
907SSDR15	48	17	50	0	90	4
All sites	52	17	57	0	92	9

Several organic compounds were widespread throughout the watershed (Table 9). For example, the pesticide oxadiazon was found at all sites, except for Boulder Creek (BOC2) and San Vicente Creek (SVC3). The pesticides secbumeton and simazine were also found at a majority of sites. In contrast, all other anthropogenic constituents were detected at two or fewer sites.

Table 9. Frequency of detection of anthropogenic organic compounds in the San Diego HU. Constituent not detected at any site (--).

Category	Constituent	Sites tested	Sites detected	Frequency
PAHs	Acenaphthene	7	1	0.14
PAHs	Acenaphthylene	7	0	--
PAHs	Anthracene	7	0	--
PAHs	Benz(a)anthracene	7	1	0.14
PAHs	Benzo(a)pyrene	7	1	0.14
PAHs	Benzo(b)fluoranthene	7	1	0.14
PAHs	Benzo(e)pyrene	7	1	0.14
PAHs	Benzo(g,h,i)perylene	7	1	0.14
PAHs	Benzo(k)fluoranthene	7	0	--
PAHs	Biphenyl	7	0	--

Table 9, continued. Frequency of detection of anthropogenic organic compounds.

Category	Constituent	Sites tested	Sites detected	Frequency
PAHs	Chrysene	7	1	0.14
PAHs	Chrysenes, C1 -	7	0	--
PAHs	Chrysenes, C2 -	7	0	--
PAHs	Chrysenes, C3 -	7	0	--
PAHs	Dibenz(a,h)anthracene	7	0	--
PAHs	Dibenzothiophene	7	0	--
PAHs	Dibenzothiophenes, C1 -	7	0	--
PAHs	Dibenzothiophenes, C2 -	7	0	--
PAHs	Dibenzothiophenes, C3 -	7	0	--
PAHs	Dichlofenthion	7	0	--
PAHs	Dimethylnaphthalene, 2,6-	7	0	--
PAHs	Dimethylphenanthrene, 3,6-	7	0	--
PAHs	Fluoranthene	7	1	0.14
PAHs	Fluoranthene/Pyrenes, C1 -	7	1	0.14
PAHs	Fluorene	7	0	--
PAHs	Fluorenes, C1 -	7	0	--
PAHs	Fluorenes, C2 -	7	0	--
PAHs	Fluorenes, C3 -	7	0	--
PAHs	Indeno(1,2,3-c,d)pyrene	7	1	0.14
PAHs	Methyldibenzothiophene, 4-	7	0	--
PAHs	Methylfluoranthene, 2-	7	0	--
PAHs	Methylfluorene, 1-	7	0	--
PAHs	Methylnaphthalene, 1-	7	0	--
PAHs	Methylnaphthalene, 2-	7	0	--
PAHs	Methylphenanthrene, 1-	7	0	--
PAHs	Naphthalene	7	1	0.14
PAHs	Naphthalenes, C1 -	7	0	--
PAHs	Naphthalenes, C2 -	7	2	0.29
PAHs	Naphthalenes, C3 -	7	2	0.29
PAHs	Naphthalenes, C4 -	7	0	--
PAHs	Perylene	7	0	--
PAHs	Phenanthrene	7	1	0.14
PAHs	Phenanthrene/Anthracene, C1 -	7	2	0.29
PAHs	Phenanthrene/Anthracene, C2 -	7	2	0.29
PAHs	Phenanthrene/Anthracene, C3 -	7	0	--
PAHs	Phenanthrene/Anthracene, C4 -	7	0	--
PAHs	Pyrene	7	1	0.14
PAHs	Trimethylnaphthalene, 2,3,5-	7	0	--
PAHs	alpha-BHC	1	0	--
PAHs	beta-BHC	1	0	--
PAHs	delta-BHC	1	0	--
PAHs	gamma-BHC (Lindane)	1	0	--
PCBs	PCBs	7	0	--
Pesticide	Toxaphene	1	0	--
Pesticides	Aldrin	7	0	--
Pesticides	Ametryn	7	0	--
Pesticides	Aspon	7	0	--
Pesticides	Atraton	7	0	--
Pesticides	Atrazine	7	1	0.14

Table 9, continued. Frequency of detection of anthropogenic organic compounds.

Category	Constituent	Sites tested	Sites detected	Frequency
Pesticides	Azinphos ethyl	7	0	--
Pesticides	Azinphos methyl	7	0	--
Pesticides	Bolstar	7	0	--
Pesticides	Carbophenothion	7	0	--
Pesticides	Chlordane, cis-	7	0	--
Pesticides	Chlordane, trans-	7	0	--
Pesticides	Chlordene, alpha-	7	0	--
Pesticides	Chlordene, gamma-	7	0	--
Pesticides	Chlorfenvinphos	7	0	--
Pesticides	Chlorpyrifos	7	0	--
Pesticides	Chlorpyrifos methyl	7	0	--
Pesticides	Ciodrin	7	0	--
Pesticides	Coumaphos	7	0	--
Pesticides	Dacthal	7	0	--
Pesticides	DDD(o,p')	7	0	--
Pesticides	DDD(p,p')	7	0	--
Pesticides	DDE(o,p')	7	0	--
Pesticides	DDE(p,p')	7	0	--
Pesticides	DDMU(p,p')	7	0	--
Pesticides	DDT(o,p')	7	0	--
Pesticides	DDT(p,p')	7	0	--
Pesticides	Demeton-s	7	0	--
Pesticides	Diazinon	7	2	0.29
Pesticides	Dichlorvos	7	0	--
Pesticides	Dicrotophos	7	0	--
Pesticides	Dieldrin	7	0	--
Pesticides	Dimethoate	7	0	--
Pesticides	Dioxathion	7	0	--
Pesticides	Disulfoton	7	0	--
Pesticides	Endosulfan I	7	0	--
Pesticides	Endosulfan II	7	0	--
Pesticides	Endosulfan sulfate	7	0	--
Pesticides	Endrin	7	0	--
Pesticides	Endrin Aldehyde	7	0	--
Pesticides	Endrin Ketone	7	0	--
Pesticides	Ethion	7	0	--
Pesticides	Ethoprop	7	0	--
Pesticides	Famphur	7	0	--
Pesticides	Fenchlorphos	7	0	--
Pesticides	Fenitrothion	7	0	--
Pesticides	Fensulfothion	7	0	--
Pesticides	Fenthion	7	0	--
Pesticides	Fonofos	7	0	--
Pesticides	HCH, alpha	7	0	--
Pesticides	HCH, beta	7	0	--
Pesticides	HCH, delta	7	0	--
Pesticides	HCH, gamma	7	0	--
Pesticides	Heptachlor	7	0	--
Pesticides	Heptachlor epoxide	7	0	--

Table 9, continued. Frequency of detection of anthropogenic organic compounds.

Category	Constituent	Sites tested	Sites detected	Frequency
Pesticides	Hexachlorobenzene	7	0	--
Pesticides	Leptophos	7	0	--
Pesticides	Malathion	7	1	0.14
Pesticides	Merphos	7	0	--
Pesticides	Methidathion	7	0	--
Pesticides	Methoxychlor	7	0	--
Pesticides	Mevinphos	7	0	--
Pesticides	Mirex	7	0	--
Pesticides	Molinate	7	0	--
Pesticides	Naled	7	0	--
Pesticides	Nonachlor, cis-	7	0	--
Pesticides	Nonachlor, trans-	7	0	--
Pesticides	Oxadiazon	7	5	0.71
Pesticides	Oxychlordane	7	0	--
Pesticides	Parathion, Ethyl	7	0	--
Pesticides	Parathion, Methyl	7	0	--
Pesticides	Phorate	7	0	--
Pesticides	Phosmet	7	0	--
Pesticides	Phosphamidon	7	0	--
Pesticides	Prometon	7	0	--
Pesticides	Prometryn	7	0	--
Pesticides	Propazine	7	2	0.29
Pesticides	Secbumeton	7	4	0.57
Pesticides	Simazine	7	4	0.57
Pesticides	Simetryn	7	0	--
Pesticides	Sulfotep	7	0	--
Pesticides	Tedion	7	0	--
Pesticides	Terbufos	7	0	--
Pesticides	Terbuthylazine	7	2	0.29
Pesticides	Terbutryn	7	0	--
Pesticides	Tetrachlorvinphos	7	0	--
Pesticides	Thiobencarb	7	1	0.14
Pesticides	Thionazin	7	0	--
Pesticides	Tokuthion	7	0	--
Pesticides	Trichlorfon	7	0	--
Pesticides	Trichloronate	7	0	--
Pesticides	Chlordane (tech)	1	0	--

Comparison with applicable aquatic life and human health thresholds do not support the conclusion that water quality was impacted by these constituents, although a few PAHs exceeded human health thresholds at the mouth of the San Diego River (SDR15). Other constituents, such as nutrients, may impact aquatic life (Table 10). Most sites showed similar results, suggesting that impacts were not restricted to specific regions within the watershed (Figure 6, 7).

Some impacts were widespread, affecting every site in the watershed. For example, ammonia-N, total phosphorus, and total nitrogen, exceeded aquatic life thresholds at every site (Table 11). Selenium and specific conductivity exceeded thresholds at all sites except Boulder Creek. Impacts to pH were nearly as widespread, affecting all sites except Boulder Creek and the mouth of the San Diego River. Other constituents had more narrowly distributed impacts, affecting a minority of sites in the HU. For example, sulfate, dissolved oxygen, turbidity, and benzo(a)pyrene affected 3 or fewer sites.

Although impacts were observed at every site in the watershed, the number of impacts varied from site to site. For example, the highest number of exceedances of aquatic life thresholds were observed at San Vicente Creek, where 9 thresholds were exceeded, followed by the mouth of the San Diego River, Chocolate Creek, and Forester Creek, where 8 constituents exceeded aquatic life thresholds. The fewest were observed at Boulder Creek, where 4 thresholds were exceeded. Several constituents exceeded human health thresholds at the mouth of the San Diego River. However, these exceedances of human health thresholds were restricted to a single sampling date. No constituents exceeded human health thresholds at other sites (Table 12).

Results from non-SWAMP water chemistry monitoring at 5 sites were similar to results from SWAMP (Table 10C). For example, specific conductivity exceeded aquatic life thresholds at nearly every site, and at most sampling dates. Turbidity exceeded thresholds at the San Diego River site above Mission Dam (Site 6) and further upstream at Carlton Hills Boulevard (Site 12). Dissolved oxygen was frequently below thresholds at site 8 (San Diego River at Sefton Park), and on one occasion at site 7 (San Diego River at Mission Trails Park) and site 12 (Carlton Hills Boulevard). Only one exceedance was observed for pH (site 7).

Table 10. Frequency of water chemistry threshold exceedances. A) Frequency of aquatic life threshold exceedances at SWAMP sites. B) Frequency of human health threshold exceedances at SWAMP sites. C) Frequency of aquatic life threshold exceedances at non-SWAMP sites. No human health thresholds applied to constituents measured at non-SWAMP sites. Freq = Frequency of samples exceeding applicable thresholds at each site. AL = Aquatic life. HH = Human health. -- = Constituent never exceeded threshold. NT = constituent was not measured at the site.

A. Aquatic life thresholds at SWAMP sites.

		907SDALV3		907SDBOC2		907SDCHC3		907SDFRC2		907SDLCO2		907SDSVC4		907SSDR15	
Category	Constituent	Freq	n	Freq	n	Freq	n	Freq	n	Freq	n	Freq	n	Freq	n
Inorganics	Alkalinity as CaCO3	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Inorganics	Ammonia as N	0.75	4	0.33	3	0.67	3	1.00	4	0.50	4	0.40	5	1.00	4
Inorganics	Chloride	nt	0	nt	0	nt	0	nt	0	--	1	nt	--	nt	0
Inorganics	Phosphorus as P,Total	0.25	4	0.67	3	0.67	3	0.25	4	0.50	4	0.40	5	1.00	4
Inorganics	Selenium,Dissolved	1.00	4	--	3	0.33	3	1.00	4	0.75	4	0.25	4	0.75	4
Inorganics	Sulfate	--	4	--	3	1.00	3	0.75	4	--	4	1.00	5	--	4
Inorganics	Total N	1.00	4	0.33	3	1.00	3	1.00	4	1.00	4	1.00	5	0.25	4
Metals	Aluminum,Dissolved	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Metals	Arsenic,Dissolved	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Metals	Cadmium,Dissolved	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Metals	Chromium,Dissolved	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Metals	Copper,Dissolved	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Metals	Lead,Dissolved	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Metals	Manganese,Dissolved	0.25	4	--	3	0.33	3	0.25	4	--	4	0.20	5	--	4
Metals	Nickel,Dissolved	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Metals	Silver,Dissolved	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Metals	Zinc,Dissolved	--	4	--	3	--	3	--	4	--	4	--	5	--	4
PAHs	Benzo(a)pyrene	--	4	--	3	--	3	--	4	--	4	--	5	0.25	4
PCBs	PCBs	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Pesticide	Toxaphene	nt	0	nt	0	nt	0	nt	0	nt	0	--	1	nt	0
Pesticides	Chlordanes	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Pesticides	Endrin	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Pesticides	gamma-BHC (Lindane)	nt	0	nt	0	nt	0	nt	0	nt	0	--	1	nt	0
Pesticides	Heptachlor	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Pesticides	Heptachlor epoxide	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Pesticides	Hexachlorobenzene	--	4	--	3	--	3	--	4	--	4	--	4	--	4
Pesticides	Methoxychlor	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Pesticides	Molinate	--	4	--	3	--	3	--	4	--	4	--	4	--	4
Pesticides	Simazine	--	4	--	3	--	3	--	4	--	4	--	4	--	4
Pesticides	Thiobencarb	--	4	--	3	--	3	--	4	--	4	--	4	--	4
Physical	Oxygen, Dissolved	--	4	--	3	--	3	--	4	--	4	0.25	4	0.25	4
Physical	pH	1.00	4	--	3	0.67	3	0.75	4	0.25	4	0.75	4	--	4
Physical	Specific conductivity	1.00	4	--	3	0.33	3	1.00	4	0.75	4	0.50	4	0.75	4
Physical	Turbidity	--	4	0.33	3	--	3	--	4	--	4	--	4	0.25	4

Table 10, continued. Frequency of water chemistry threshold exceedances.

B. Human health thresholds at SWAMP sites

	907SDALV3		907SDBOC2		907SDCHC3		907SDFRC2		907SDLCO2		907SDSVC4		907SSDR15	
Constituent	Freq	n	Freq	n	Freq	n	Freq	n	Freq	n	Freq	n	Freq	n
Chloride	nt	0	nt	0	nt	0	nt	0	--	1	nt	0	nt	0
Nitrate + Nitrite as N	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Nitrate as NO3	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Nitrite as N	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Arsenic,Dissolved	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Cadmium,Dissolved	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Copper,Dissolved	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Nickel,Dissolved	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Acenaphthene	--	4	--	3	--	3	--	4	--	4	--	5	--	4
alpha-BHC	nt	0	nt	0	nt	0	nt	0	nt	0	--	1	nt	0
beta-BHC	nt	0	nt	0	nt	0	nt	0	nt	0	--	1	nt	0
gamma-BHC (Lindane)	nt	0	nt	0	nt	0	nt	0	nt	0	--	1	nt	0
Anthracene	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Benz(a)anthracene	--	4	--	3	--	3	--	4	--	4	--	5	0.25	4
Benzo(a)pyrene	--	4	--	3	--	3	--	4	--	4	--	5	0.25	4
Benzo(b)fluoranthene	--	4	--	3	--	3	--	4	--	4	--	5	0.25	4
Benzo(k)fluoranthene	--	4	--	3	--	3	--	4	--	4	--	4	--	4
Chrysene	--	4	--	3	--	3	--	4	--	4	--	5	0.25	4
Dibenz(a,h)anthracene	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Fluoranthene	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Indeno(1,2,3-c,d)pyrene	--	4	--	3	--	3	--	4	--	4	--	5	0.25	4
Pyrene	--	4	--	3	--	3	--	4	--	4	--	5	--	4
PCBs	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Toxaphene	nt	0	nt	0	nt	0	nt	0	nt	0	--	1	nt	0
Aldrin	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Ametryn	--	4	--	3	--	3	--	4	--	4	--	4	--	4
Atrazine	--	4	--	3	--	3	--	4	--	4	--	4	--	4
Azinphos ethyl	--	4	--	3	--	3	--	4	--	4	--	4	--	4
Azinphos methyl	--	4	--	3	--	3	--	4	--	4	--	4	--	4
Chlordanes	--	4	--	3	--	3	--	4	--	4	--	5	--	4
DDD(p,p')	--	4	--	3	--	3	--	4	--	4	--	5	--	4
DDE(p,p')	--	4	--	3	--	3	--	4	--	4	--	5	--	4
DDT(p,p')	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Dieldrin	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Dimethoate	--	4	--	3	--	3	--	4	--	4	--	4	--	4
Endosulfan sulfate	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Endrin	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Endrin Aldehyde	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Endrin Ketone	--	4	--	3	--	3	--	4	--	4	--	4	--	4
Heptachlor	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Heptachlor epoxide	--	4	--	3	--	3	--	4	--	4	--	5	--	4
Hexachlorobenzene	--	4	--	3	--	3	--	4	--	4	--	4	--	4
Oxychlordane	--	4	--	3	--	3	--	4	--	4	--	4	--	4

Table 10, continued. Frequency of water chemistry threshold exceedances.

C. Aquatic life thresholds at non-SWAMP sites

	Padre Dam MWD						San Diego County NPDES			
	Site 6 (SDR-OMD)		Site 7 (SDR-MT)		Site 12 (SDR-CHB)		Site 8 (SDR-1)		Site 11 (REF-CC)	
Constituent	Freq	n	Freq	n	Freq	n	Freq	n	Freq	n
Dissolved oxygen	--	2	0.29	7	0.50	2	0.57	7	--	1
pH	--	2	0.29	7	--	2	--	7	--	1
Specific conductivity	0.50	2	0.86	7	0.50	2	0.86	7	--	1
Turbidity	1.00	2	--	1	1.00	2	--	1	--	1

Table 11. Frequency of SWAMP sites with aquatic life and human health threshold exceedances for each constituent. Number of SWAMP sites included in evaluation (n). Constituent never exceeded threshold at any site (--). No applicable threshold for constituent (NA).

Category	Constituent	n	Aquatic Life	Human health
Inorganics	Alkalinity as CaCO3	7	--	NA
Inorganics	Ammonia as N	7	1.00	NA
Inorganics	Chloride	1	--	--
Inorganics	Nitrate + Nitrite as N	7	NA	--
Inorganics	Nitrate as NO3	7	NA	--
Inorganics	Nitrite as N	7	NA	--
Inorganics	Phosphorus as P,Total	7	1.00	NA
Inorganics	Selenium,Dissolved	7	0.86	NA
Inorganics	Sulfate	7	0.43	NA
Inorganics	Total N	7	1.00	NA
Metals	Aluminum,Dissolved	7	--	NA
Metals	Arsenic,Dissolved	7	--	--
Metals	Cadmium,Dissolved	7	--	--
Metals	Chromium,Dissolved	7	--	NA
Metals	Copper,Dissolved	7	--	--
Metals	Lead,Dissolved	7	--	NA
Metals	Manganese,Dissolved	7	0.57	NA
Metals	Nickel,Dissolved	7	--	--
Metals	Silver,Dissolved	7	--	NA
Metals	Zinc,Dissolved	7	--	NA
PAHs	Acenaphthene	7	NA	--
PAHs	Anthracene	7	NA	--
PAHs	Benz(a)anthracene	7	NA	0.14
PAHs	Benzo(a)pyrene	7	0.14	0.14
PAHs	Benzo(b)fluoranthene	7	NA	0.14
PAHs	Benzo(k)fluoranthene	7	NA	--
PAHs	Chrysene	7	NA	0.14
PAHs	Dibenz(a,h)anthracene	7	NA	--
PAHs	Fluoranthene	7	NA	--
PAHs	Indeno(1,2,3-c,d)pyrene	7	NA	0.14
PAHs	Pyrene	7	NA	--
PCBs	PCBs	7	--	--
Pesticide	Toxaphene	1	--	--
Pesticides	Aldrin	7	NA	--
Pesticides	alpha-BHC	1	NA	--
Pesticides	Ametryn	7	NA	--
Pesticides	Atrazine	7	NA	--
Pesticides	Azinphos ethyl	7	NA	--
Pesticides	Azinphos methyl	7	NA	--
Pesticides	beta-BHC	1	NA	--
Pesticides	Chlordanes	7	--	--
Pesticides	DDD(p,p')	7	NA	--
Pesticides	DDE(p,p')	7	NA	--
Pesticides	DDT(p,p')	7	NA	--
Pesticides	Dieldrin	7	NA	--
Pesticides	Dimethoate	7	NA	--
Pesticides	Endosulfan sulfate	7	NA	--

Table 11, continued Frequency of SWAMP sites with aquatic life and human health threshold exceedances for each constituent

Category	Constituent	n	Aquatic Life	Human health
Pesticides	Endrin	7	--	--
Pesticides	Endrin Aldehyde	7	NA	--
Pesticides	Endrin Ketone	7	NA	--
Pesticides	gamma-BHC (Lindane)	1	--	--
Pesticides	Heptachlor	7	--	--
Pesticides	Heptachlor epoxide	7	--	--
Pesticides	Hexachlorobenzene	7	--	--
Pesticides	Methoxychlor	7	--	NA
Pesticides	Molinate	7	--	NA
Pesticides	Oxychlordane	7	NA	--
Pesticides	Simazine	7	--	NA
Pesticides	Thiobencarb	7	--	NA
Physical	Oxygen, Dissolved	7	0.29	NA
Physical	pH	7	0.71	NA
Physical	Specific conductivity	7	0.86	NA
Physical	Turbidity	7	0.29	NA

Table 12. Number of constituents exceeding thresholds at each SWAMP site.

	Aquatic life		Human Health	
Site	# exceedances	# constituents tested	# exceedances	# constituents tested
907SDALV3	7	31	0	38
907SDBOC2	4	31	0	38
907SDCHC3	8	31	0	38
907SDFRC2	8	31	0	38
907SDLCO2	6	32	0	39
907SDSVC4	9	33	0	42
907SSDR15	8	31	5	38
All sites in watershed	11	34	5	43

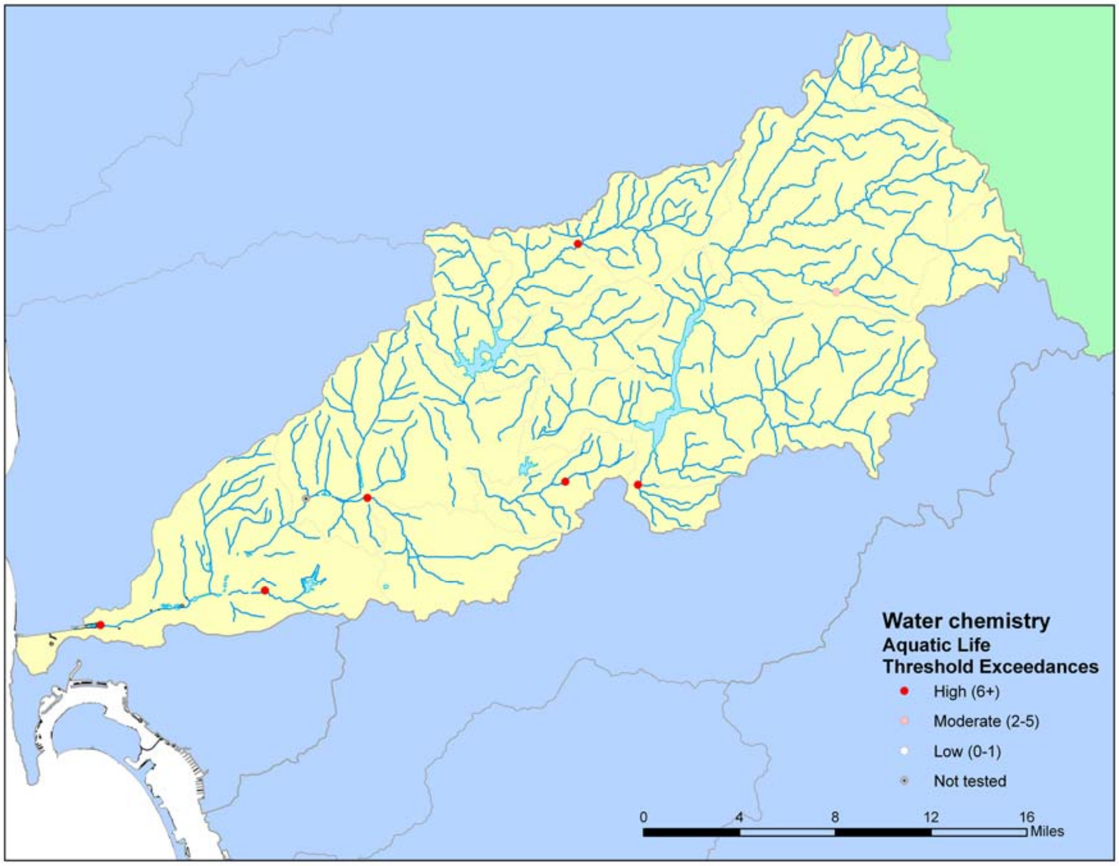

Figure 6. Map of aquatic life threshold exceedances for water chemistry at SWAMP sites. White circles indicate sites with one or fewer exceedances (this value did not occur in this watershed). Pink circles indicate sites with 2 to 5 exceedances. Red circles indicate sites with 6 to 9 exceedances. At Los Coches Creek (LCO2), 32 constituents were assessed. At San Vicente Creek (SVC4), 33 constituents were assessed. At all other sites, 31 constituents were assessed.

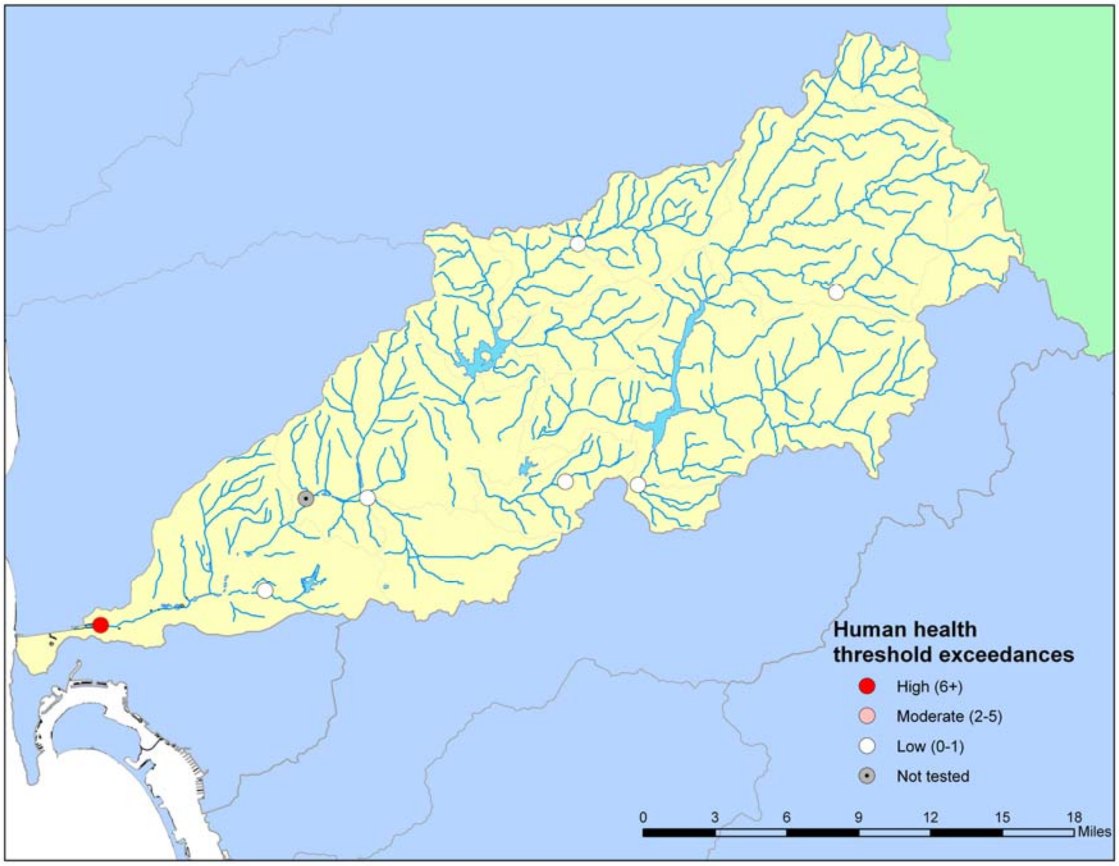

Figure 7. Map of human health exceedances for water chemistry at SWAMP sites. White circles indicate sites with one or fewer exceedances. Pink circles indicate sites with 2 to 5 exceedances. Red circles indicate sites with 6 to 9 exceedances (this value did not occur in this watershed). At Los Coches Creek, 39 constituents were assessed. At San Vicente Creek (SVC4), 42 constituents were assessed. At all other sites, 38 constituents were assessed.

4.2 Toxicity

Toxicity was evident at all sites within the watershed, and toxicity was generally severe (Table 13; Appendix III). More than half of the chronic assays indicated toxicity at every site, with frequencies ranging from 0.62 – 0.86. Chocolate Creek (CHC3) and Los Coches Creek (LCO2) had the greatest frequency of toxicity, with 80% and 86% of samples resulting in chronic toxicity to multiple indicators, respectively (Figure 8).

The alga *S. capricornutum* and the crustacean *H. azteca* were very sensitive indicators, as nearly every sample from every site resulted in toxicity (93% and 91% of all samples, respectively). Moreover, sediment samples from 2 sites (Forester Creek (FRC2) and the mouth of the San Diego River (SDR15) resulted in lethal toxicity to *H. azteca.* In contrast, acute toxicity to *C. dubia* was never observed, and chronic toxicity to this species was observed much less frequently (i.e., 42% of samples). No water samples from Forester Creek were toxic to *C. dubia*, despite the fact that sediment samples from this site were highly toxic to *H. azteca,* as noted above.

Table 13. Frequency of toxicity detected for each endpoint and at each site. A sample was considered toxic if the response was less than 80% of the control sample, and the difference was considered significant at 0.05. Number of samples where the endpoint was evaluated (n). Toxicity not detected in any sample (--). Indicator not tested (nt).

		C. dubia				*H. azteca*				*S. capricornutum*		Multiple	
	Sampling	Survival		Young / Female		Survival		Growth		Total cell count		indicators	
Site	events	Frequency	n	Frequency	n	Frequency	n	Frequency	n	Frequency	n	Frequency	n
907SDALV3	4	--	3	0.67	3	--	1	nt	0	0.75	4	0.71	7
907SDBOC2	3	--	3	0.33	3	--	1	1.00	1	1.00	3	0.71	7
907SDCHC3	3	--	3	0.67	3	--	1	1.00	1	1.00	3	0.86	7
907SDFRC2	4	--	2	--	2	0.67	3	1.00	2	1.00	4	0.75	8
907SDLCO2	4	--	4	0.50	4	--	2	1.00	2	1.00	4	0.80	10
907SDSVC4	5	--	5	0.40	5	--	3	0.67	3	0.80	5	0.62	13
907SSDR15	4	--	4	0.25	4	0.50	2	1.00	2	1.00	4	0.70	10
All sites in watershed	27	--	23	0.42	24	0.23	13	0.91	11	0.93	27	0.73	62

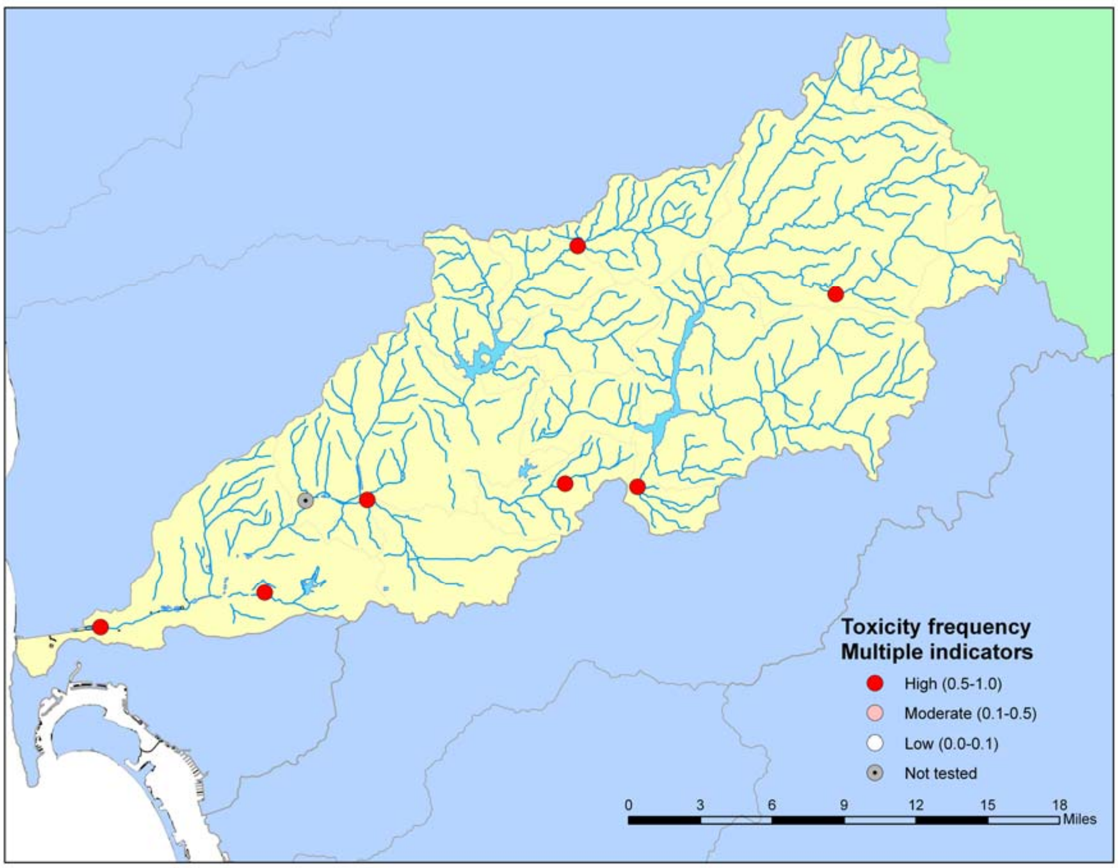

Figure 8. Frequency of toxicity (*C. dubia* fecundity, *H. azteca* growth, and *S. capricornutum* total cell count) at SWAMP sites. White circles indicate low frequency (0.0 to 0.1) of toxicity (this value did not occur in this watershed) . Pink circles indicate moderate frequency (0.1 to 0.5) of toxicity. Red circles indicate high (0.5 to 1.0) frequency of toxicity (this value did not occur in this watershed).

4.3 Tissue

Analysis of invertebrate tissues from the mouth of the San Diego River (SDR15) showed evidence of tissue contamination by PCBs, but not selenium. One replicate sample exceeded the OEHHA threshold of 20 ng/g PCBs, and the other replicate was slightly below the threshold. Selenium, which was evaluated in only one replicate, was well below the OEHHA threshold of 1.94 ppm (Table 14; Figure 9). Of the 48 PCBs analyzed, 28 were detected in one of the replicates, and 27 were detected in the other (Appendix IV).

Table 14. Concentrations of contaminants in invertebrate tissues, compared with OEHHA thresholds. A full list of analyzed constituents is presented in Appendix IV. Bold face indicates constituents exceeding threshold.

Category	Constituent	Unit	Threshold	Replicate 1	Replicate 2	Mean
Inorganics	Selenium	ppm	1.94	0.41		0.41
PCBs	PCBs	ng/g	20	**22.73**	19.75	**21.24**

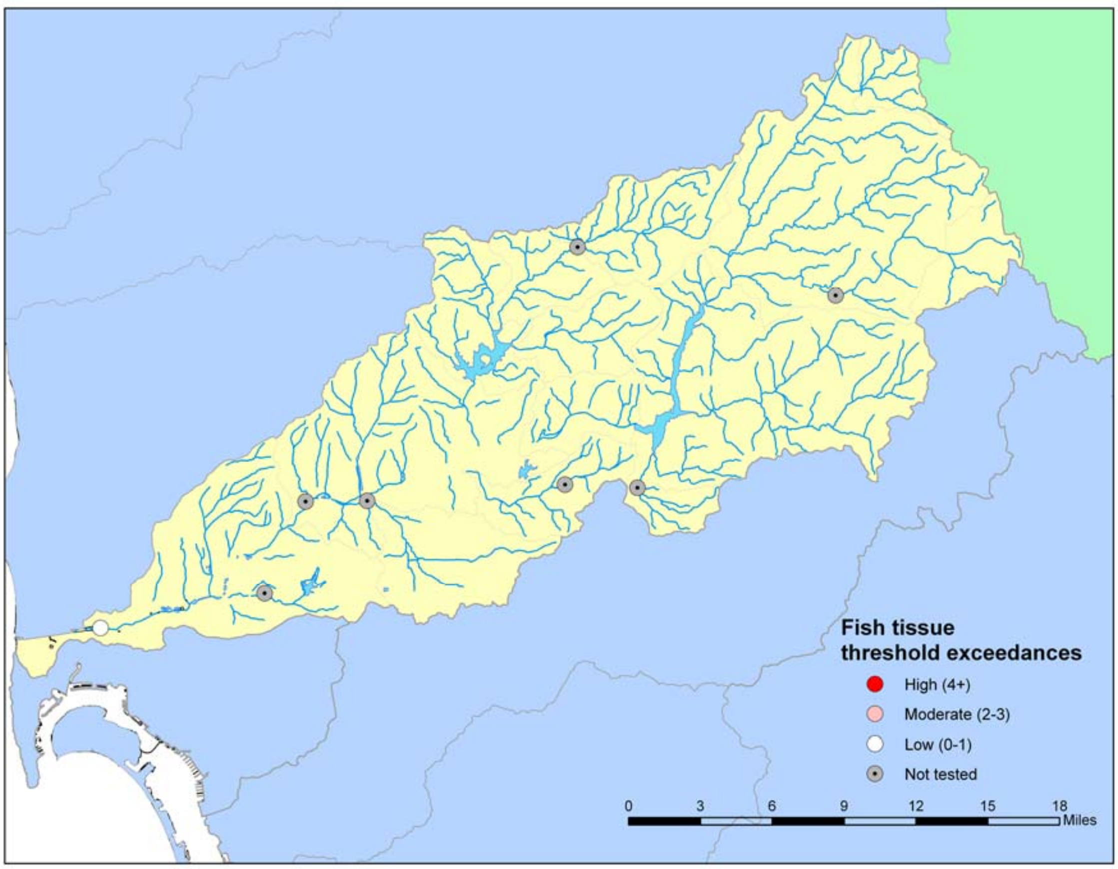

Figure 9. Invertebrate tissue exceedances at SWAMP sites. White circles indicate 1 or fewer exceedances. Pink circles indicate 2 to 3 exceedances (this value did not occur in this watershed). Red circles indicate 4 to 5 exceedances (this value did not occur in this watershed).

4.4 Bioassessment

Biological health was poor or very poor for nearly all sites and seasons in the San Diego HU, although a few sites were in fair or good condition. Mean IBI scores ranged from 5.5 at site 12 (San Diego River at Carlton Hills Boulevard) to 77.1 at site 3 (Cedar Creek at Cedar Creek Road). Both sites at Cedar Creek (sites 3 and 11) were never observed in poor condition. However, of the 15 sites sampled, 12 were always in poor or very poor condition, and one site (site 10, San Vicente Creek at Wildcat Canyon Road) was in very poor condition in 2 of 3 samples (Table 15; Figure 10).

Sites in poor or very poor condition were found throughout the watershed, except for Cedar Creek near the Cuyamaca Mountains (Figure 10). Many sites had IBI scores below 20, and 2 sites on the San Diego River mainstem (SDR15 and site 12) had scores below 10. There was no consistent effect of season in IBI scores, and the differences between seasons were slight for most sites (Table 15; Figure 11). Therefore, poor biological condition persisted during all seasons sampled.

Some metric components of the IBI were more sensitive than others. For example, the Coleoptera Taxa and the EPT Taxa metrics had low values or were entirely absent from sites in poor condition, but made large contributions to IBI scores of sites in good condition. In contrast, the % Collectors metric contributed to IBI scores of many sites in good and poor conditions (Append V, Figure 11).

Examination of IBI scores over time did not indicate improving or deteriorating biological condition (Figure 12). Variability among years was high, which may obscure trends in the data. Seasonal trends were not evident at any site.

Table 15. Mean and standard deviation of IBI scores at bioassessment sites within the San Diego HU. Number of samples collected within each season (n). Range from first to last year of sampling at each site (Years). Frequency of poor or very poor IBI scores (IBI <40) at each site and season (Frequency).

					IBI			
Site	Ecoregion	Season	n	Years	Mean	SD	Condition	Frequency
907SDALV3	Chaparral	Spring	2	2004-2006	13.6	3.0	Very poor	1.00
907SDBOC2	Chaparral	Spring	3	2001-2005	30.5	5.8	Poor	1.00
907SDCHC3	Chaparral	Spring	1	2004	14.3		Very poor	1.00
907SDSVC3	Chaparral	Average	2	2000-2002	19.3	13.1	Very poor	1.00
		Fall	1	2000	28.6		Poor	1.00
		Spring	1	2002	10.0		Very poor	1.00
907SSDR15	Chaparral	Average	12	1998-2005	6.5	1.7	Very poor	1.00
		Fall	5	1998-2004	7.7	5.7	Very poor	1.00
		Spring	7	1998-2005	5.3	3.1	Very poor	1.00
907SSDR9	Chaparral	Average	13	1996-2006	11.6	1.3	Very poor	1.00
		Fall	5	1996-2005	12.6	5.5	Very poor	1.00
		Spring	8	1997-2006	10.7	8.5	Very poor	1.00
Site 3	Chaparral	Spring	1	2001	77.1		Good	--
Site 5	Chaparral	Spring	3	2001-2005	30.5	1.6	Poor	1.00
Site 7	Chaparral	Average	16	1996-2005	22.3	3.3	Poor	1.00
		Fall	7	1996-2004	24.7	6.4	Poor	1.00
		Spring	9	1997-2005	20.0	9.2	Poor	1.00
Site 9	Chaparral	Average	10	1996-1997	17.1	8.1	Very poor	1.00
		Fall	5	1996	11.4	4.4	Very poor	1.00
		Spring	5	1997	22.9	5.2	Poor	1.00
Site 10	Chaparral	Average	3	2000-2005	29.3	15.2	Poor	0.67
		Fall	1	2000	40.0		Fair	--
		Spring	2	2004-2005	18.6	4.0	Very poor	1.00
Site 11	Mountains	Spring	1	2003	47.1		Fair	--
Site 12	Chaparral	Average	5	2004-2006	5.5	4.4	Very poor	1.00
		Fall	2	2004-2005	8.6	6.1	Very poor	1.00
		Spring	3	2004-2006	2.4	0.8	Very poor	1.00

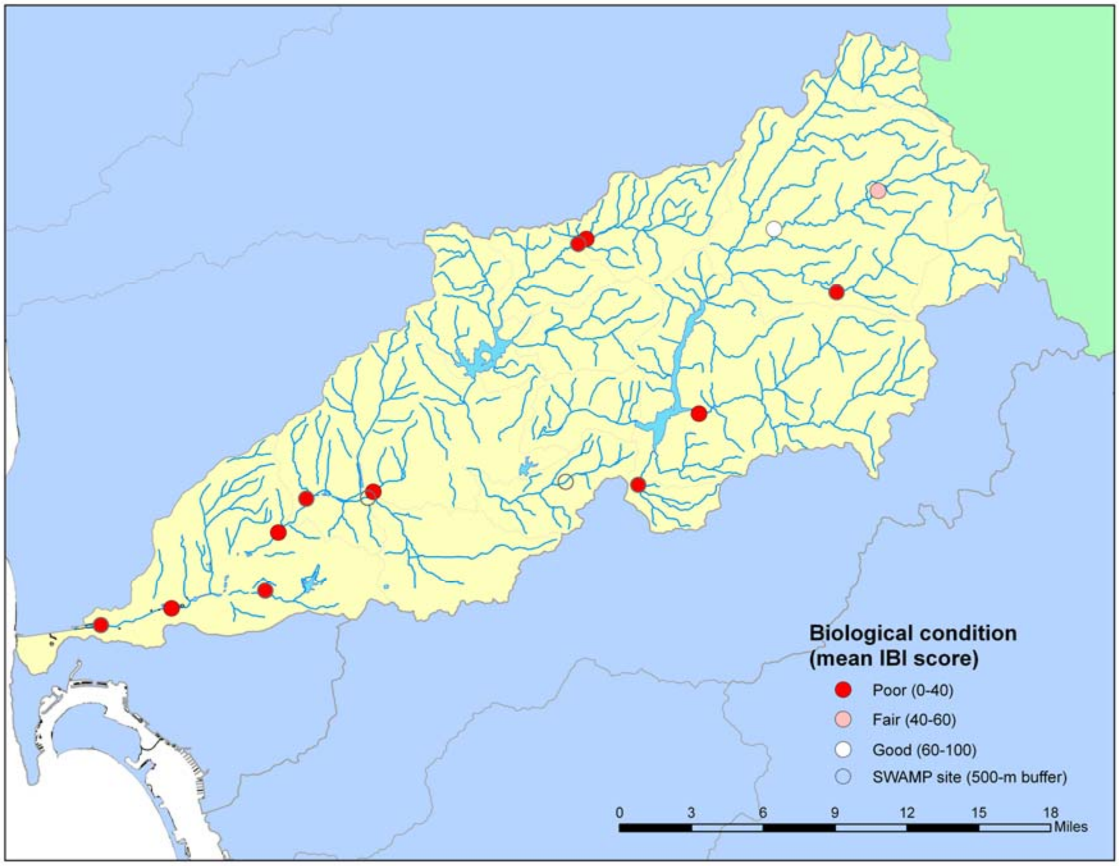

Figure 10. IBI scores at sites in the San Diego HU. White circles indicate good or very good (60 to 100) IBI scores (this value did not occur in this watershed). Pink circles indicate fair (40 to 60) IBI scores (this value did not occur in this watershed). Red circles indicate poor (0 to 40) IBI scores. Open circles represent 500-m buffers around SWAMP sites; six of these buffers included bioassessment sites, and three of these buffers did not.

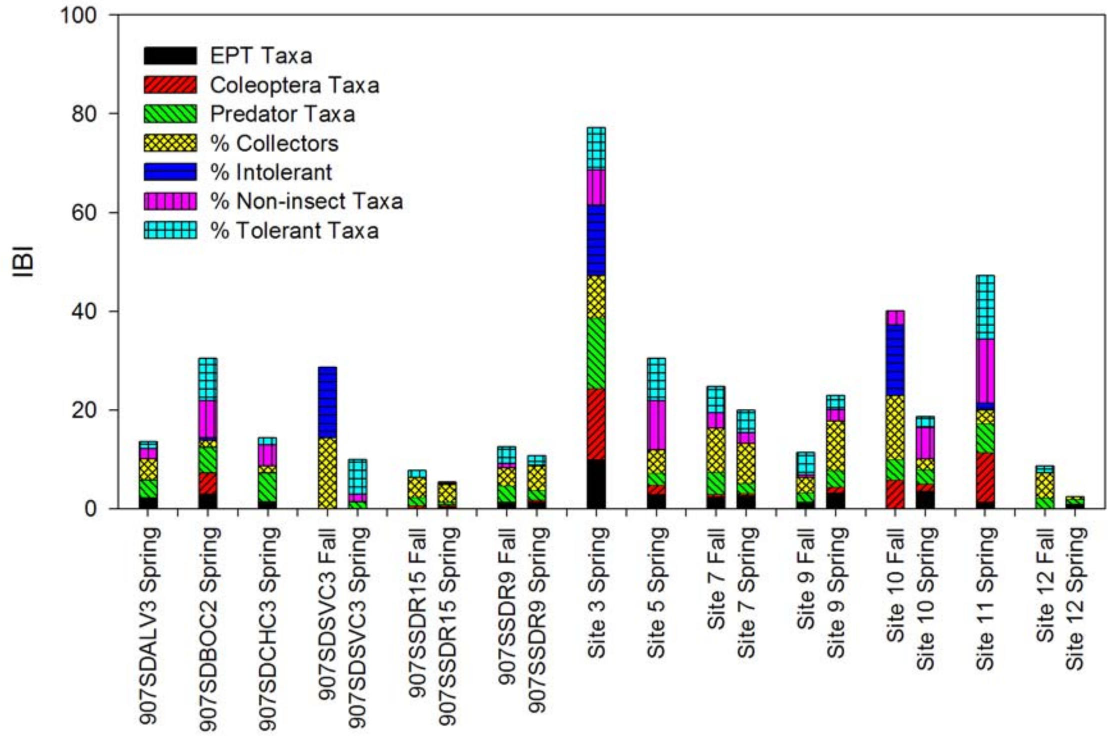

Figure 11. Mean IBI scores at each bioassessment site and each season. The height of the bar indicates the mean IBI score, and the size of each component of the bar represents the contribution of each metric to the IBI.

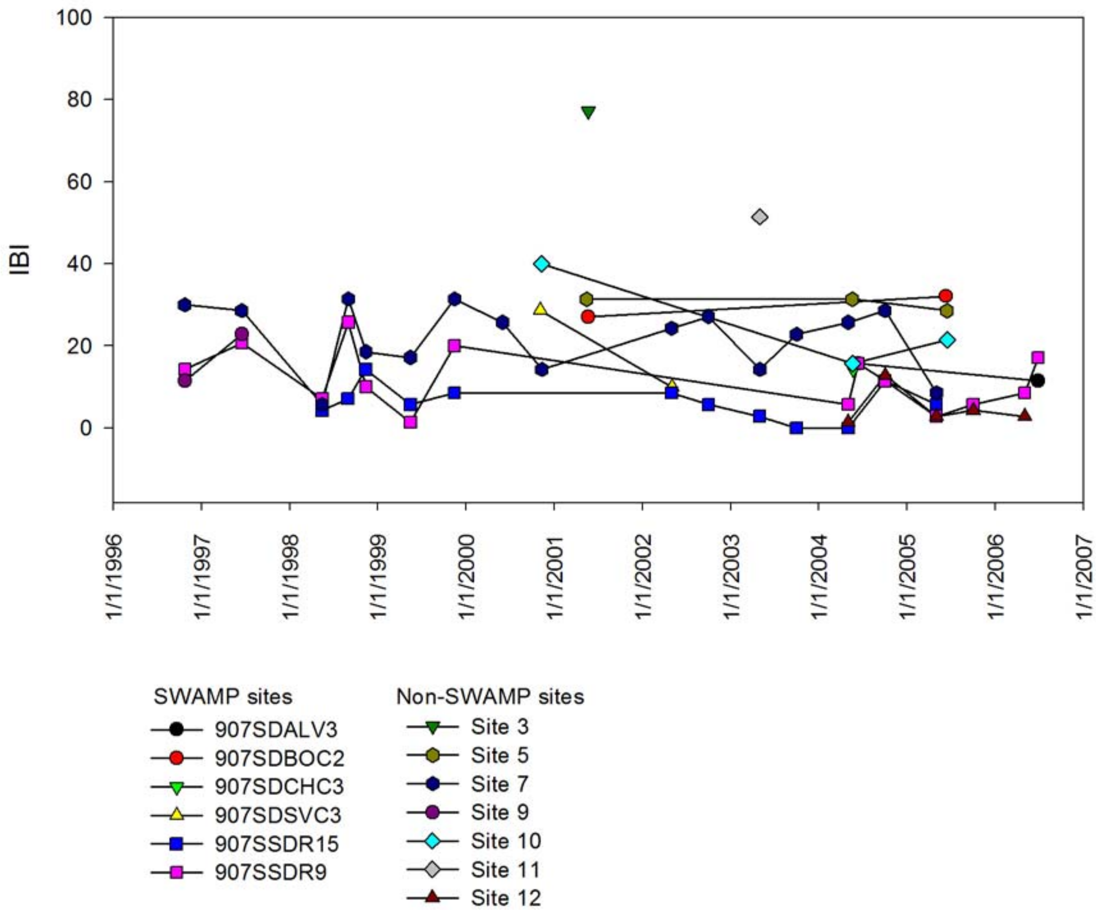

Figure 12. IBI values for each year and site. Each symbol represents a single sample.

4.5 Physical Habitat

Physical habitat varied among sites throughout the watershed, although human alteration was evident at every site visited. Good habitat (i.e., mean physical habitat score > 15) was only found at the Boulder Creek site (BOC2). Moderately altered habitat (i.e., mean physical habitat score > 10) was found at several sites throughout the watershed, including Alvarado Creek (ALV3), Forester Creek (FRC2), Los Coches Creek (LCO2), and San Vicente Creek (SVC4). Severely degraded habitat was observed at Chocolate Creek (CHC3) and the mouth of the San Diego River (SDR15) (Table 16; Figure 13). Chocolate Creek showed signs of severe degradation for all but two components of physical habitat.

Some components of physical habitat suggested very severe degradation in the watershed. For example embeddedness was severely impacted throughout the San Diego HU, receiving scores below 5 at all but two sites

(Boulder Creek and Alvarado Creek). The average embeddedness score in the San Diego HU was 5.5. Impacts to velocity-depth regime and riffle frequency were less widespread, having poor scores (<10) at all but 3 sites. In contrast, sediment deposition was minimal at all sites, and channel flow was in good condition at all sites but Chocolate Creek.

Table 16. Score and mean for each component of physical habitat. Component range: 0 (heavily impacted habitat) to 20 (unimpacted habitat).

Site	Date	Phab 1- Epifauna cover	Phab 2- Embeddedness	Phab 3- Velocity- depth regime	Phab 4- Sediment deposition	Phab 5- Channel flow	Phab 6- Channel alteration	Phab 7- Riffle frequency	Phab 8- Bank stability	Phab 9- Vegetation protection	Phab 10- Riparian zone	Mean Score
907SDALV3	2/20/2003	15	15	10	18	16	16	13	14	11	8	13.6
907SDBOC2	3/11/2003	17	16	13	18	16	15	18	17	14	17	16.1
907SDCHC3	2/21/2003	3	3	3	16	4	15	3	4	4	8	6.3
907SDFRC2	2/3/2003	9	0	7	16	14	16	3	12	14	11	10.2
907SDLCO2	2/3/2003	10	4	8	17	14	5	6	20		9	10.3
907SDSVC4	2/21/2003	11	1	10	19	18	17	10	13	9	9	11.7
907SSDR15	3/6/2003	5	0	3	16	19	5	1	17	14	15	9.5
907SSDR9	Not assessed											
All site in watershed		10.0	5.6	7.7	17.1	14.4	12.7	7.7	13.9	11.0	11.0	11.1

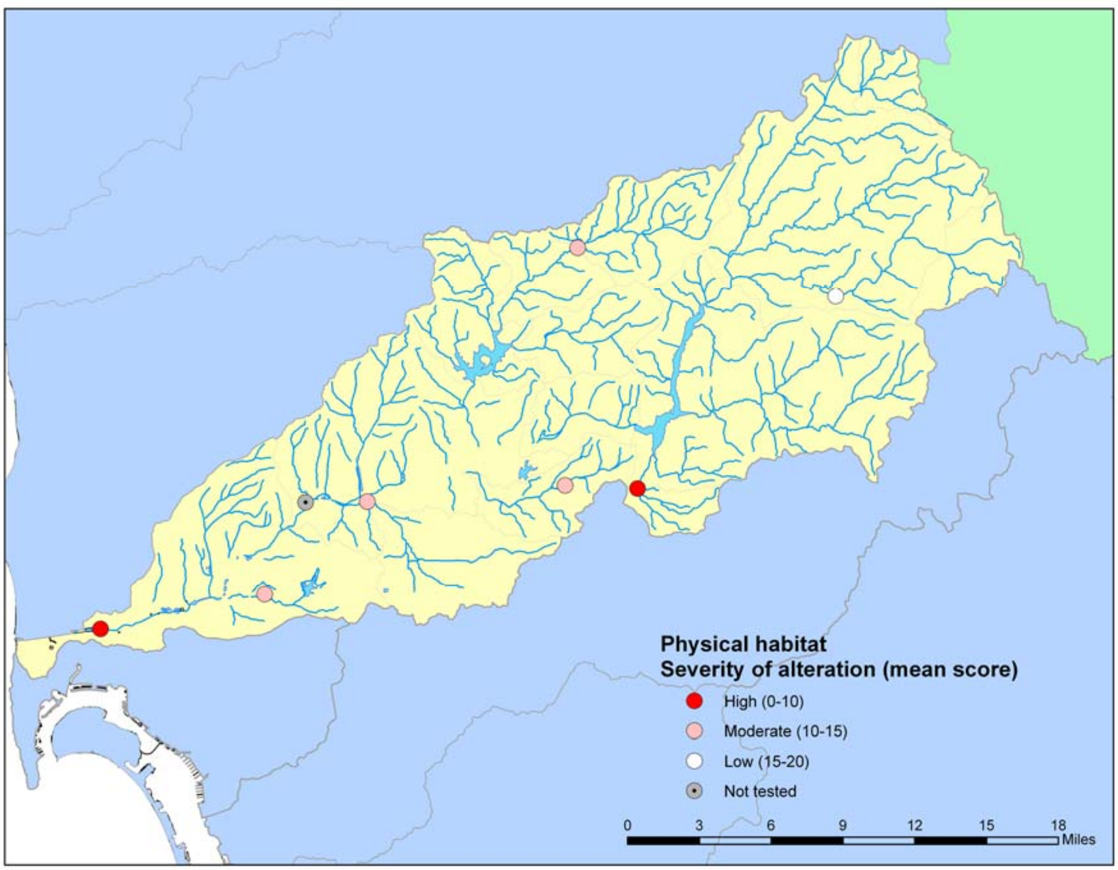

Figure 13. Assessment of physical habitat at SWAMP sites. White circles indicate sites with a mean physical habitat scores between 15 and 20. Pink circles indicate mean scores between 10 and 15. Red circles indicate mean scores between 0 and 10.

5. DISCUSSION

Data collected under SWAMP and other programs suggest that portions of the San Diego HU were in poor biological condition. Although the conditions observed at each site varied, every site sampled under SWAMP showed evidence of impact from multiple indicators (Table 17; Figure 14). Moreover, impacts for many of these indicators, such as water chemistry, toxicity, and biological integrity, were frequent. Physical habitat was moderately or severely degraded at all but one site assessed. Invertebrate tissues collected at the mouth of the San Diego River showed evidence of accumulation of PCBs, and one sample exceeded thresholds established by OEHHA.

Although poor ecological condition was observed throughout the watershed, some areas were in better condition than the others. In general, impacts were least severe in the interior of the watershed, above El Capitan Reservoir. For example, water chemistry at the site on Boulder Creek (BOC2) exceeded 5 aquatic life thresholds—fewer than any other site sampled in this watershed by SWAMP. Physical habitat was in good condition as well, with a mean score of 16.1 out of 20. However, toxicity was observed at this site, affecting all species tested. Furthermore, bioassessment samples collected by the Regional Board were in poor condition, with a mean IBI of 30.5.

Cedar Creek, another tributary upstream of the El Capitan Reservoir, was not sampled under SWAMP. However, two sites in this tributary were assessed by the County of San Diego's NPDES program and by the Regional Board (sites 11 and 3, respectively). Bioassessment samples from both of these sites were in good or fair condition, with mean IBIs ranging from 47.1 to 77.1. Furthermore, limited water quality assessments made under NPDES monitoring indicated no impairments to dissolved oxygen, pH, specific conductivity, or turbidity.

Table 17. Summary of the ecological health for five SWAMP sites in San Diego HU. Aquatic life (AL). Human health (HH). Toxicity frequency is frequency of toxicity for three chronic toxicity endpoints: *C. dubia* (fecundity), *H. azteca* (growth), and *S. capricornutum* (total cell count). Biology frequency is the frequency of IBIs below 40 (estimated from data collected at sites within 500 m). n.t. = Indicator not tested.

SWAMP site			Water chemistry: Aquatic life # constituents	Water chemistry: Human health # constituents	Tissue # constituents	Toxicity Frequency	Biology Frequency	Physical Habitat Mean score
1	907SDALV3	Alvarado Creek 3	7	0	n.t.	0.71	1.00	13.6
2	907SDBOC2	Boulder Creek 2	4	0	n.t.	0.71	1.00	16.1
3	907SDCHC3	Chocolate Creek 3	8	0	n.t.	0.86	1.00	6.3
4	907SDFRC2	Forrester Creek 2	8	0	n.t.	0.75	n.t.	10.2
5	907SDLCO2	Los Coches Creek 2	6	0	n.t.	0.80	n.t.	10.3
6	907SDSVC4	San Vicente Creek 3/4	9	0	n.t.	0.62	1.00	11.7
7	907SSDR15	San Diego River 15	8	5	1	0.70	1.00	9.5
8	907SSDR9	San Diego River 9	n.t.	n.t.	n.t.	n.t.	1.00	n.t.

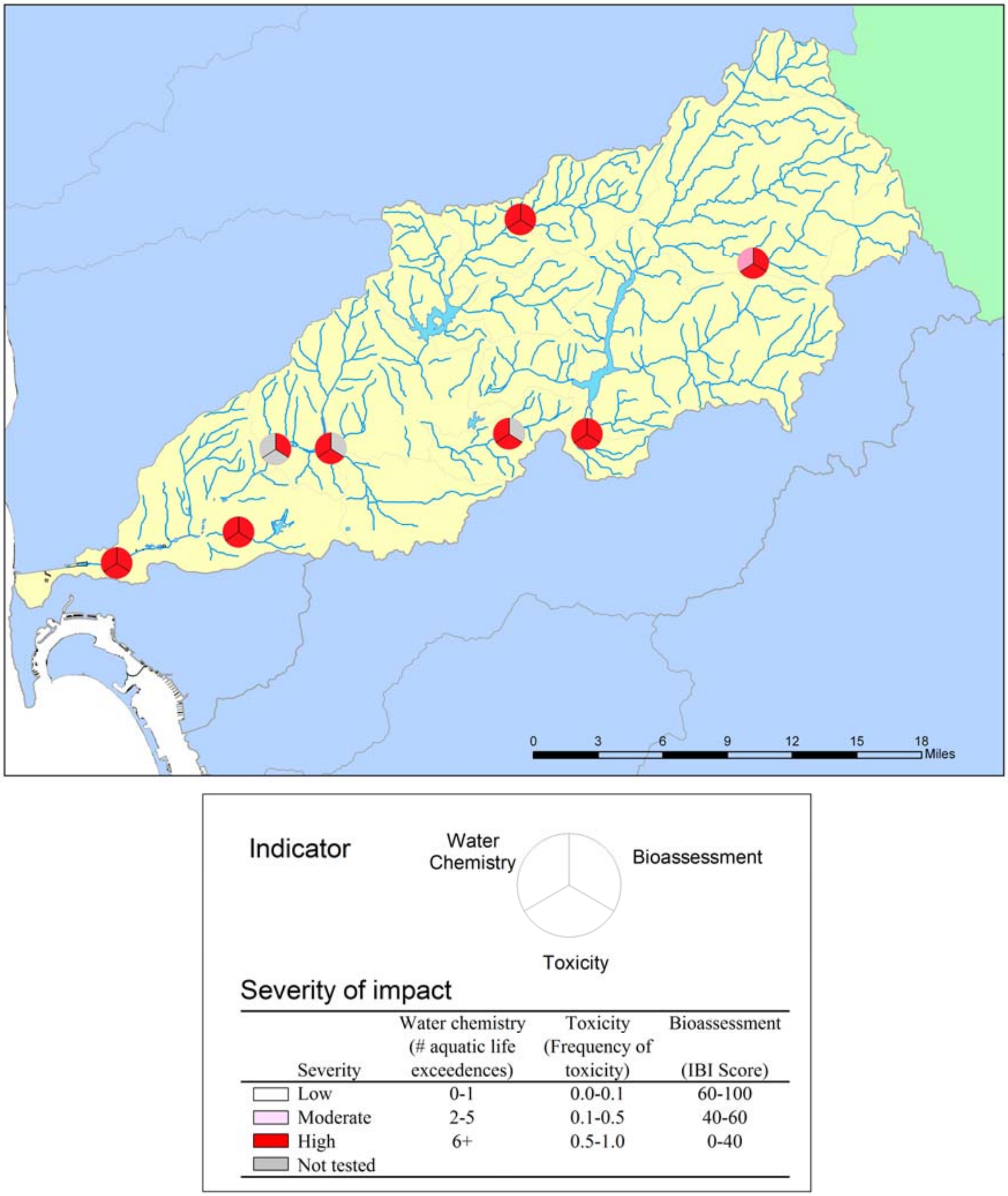

Figure 14. Summary of the ecological health of SWAMP sites in the San Diego HU, as determined by water chemistry, toxicity, and bioassessment indicators. Each pie slice corresponds to a specific indicator, as described in the inset, with darker colors corresponding to more degraded conditions (unmeasured indicators are shown in cross-hatched gray). The top-left slice corresponds to the number of water chemistry constituents exceeding aquatic life thresholds. The bottom slice corresponds to the frequency of toxicity among three endpoints: *C. dubia* (fecundity), *H. azteca* (growth), and *S. capricornutum* (total cell count). The top-right slice corresponds to the IBI of bioassessment samples.

Other tributaries sampled under SWAMP were generally in worse condition than Boulder and Cedar Creeks, including some tributaries of El Capitan Reservoir. For example, the site on Chocolate Creek (CHC2), a north-flowing tributary to the reservoir, was among the most impacted in the watershed. Water chemistry in Chocolate Creek's highly urbanized watershed exceeded thresholds for several nutrients, sulfate, selenium, manganese, pH, and conductivity. Furthermore, 3 pesticides were detected (i.e., malathion, oxadiazon, and thiobencarb). Water and sediment samples were toxic to all indicator species. A total of 86% of samples were toxic; a higher percentage than any other site in the HU. The bioassessment sample collected at Chocolate Creek was in very poor condition with an IBI score of 14.3. Only sites on the San Diego River mainstem had lower IBIs. Moreover, physical habitat scores were lower at Chocolate Creek than any other site in the HU, suggesting that impacts may have been caused by local as well as watershed-scale factors.

Conejos Creek, another tributary of El Capitan Reservoir, was also in poor condition. Bioassessment samples collected from Conejos Creek had a mean IBI of 30.5. This value is slightly higher than the IBI observed at Chocolate Creek, perhaps reflecting the fact that the Conejos Creek watershed was less developed. No other indicators were assessed at Conejos Creek.

San Vicente Creek, a tributary of San Vicente Reservoir, was also in poor ecological condition. Several nutrients exceeded aquatic life thresholds for water quality, as did manganese, sulfate, selenium, dissolved oxygen, pH, and conductivity. One pesticide (secbumeton) was detected in water samples from San Vicente Creek. Water and sediment samples were toxic to all indicator species, and all bioassessment samples were in poor or very poor condition. Although overall physical habitat was only moderately impacted (mean score of 11.7 out of 20), some individual components of physical habitat suggested severe degradation, (scores below 10) including embeddedness, minimal vegetation protection, and a limited riparian zone.

Los Coches Creek, a tributary in the central portion of the watershed, was also in poor condition. Seven water chemistry constituents exceeded aquatic life thresholds, including several nutrients, selenium, pH, and conductivity. Two pesticides were detected in water samples from Los Coches Creek (i.e., oxadiazon and simazine). Toxicity was observed in 80% of water and sediment samples—a higher frequency than all sites but Chocolate Creek. All indicator species indicated toxicity. Physical habitat was in moderate condition, with a mean physical habitat score of 10.3. Several components of physical habitat indicated severe degradation, including severe embeddedness, uniform velocity-depth regime, altered channels, and low riffle frequency. Bioassessment samples were not collected from Los Coches Creek.

Forester Creek, another mid-watershed tributary, was also in poor ecological condition. Eight water chemistry constituents exceeded aquatic life thresholds, including many nutrients, selenium, manganese, pH, and conductivity. Several of these constituents, like selenium and conductivity, exceeded thresholds in every sample, suggesting that impacts were more persistent at Forester Creek than at other sites in the watershed. Several anthropogenic compounds, including seven pesticides (atrazine, diazinon, oxadiazon, propazine, secbumeton, simazine, and terbuthylazine), were detected at Forester Creek. Toxicity was also frequently observed at Forester Creek affecting 75% of water and sediment samples. Furthermore, sediment samples were more toxic at Forester Creek than at most other sites in the HU. However, Forester Creek was unique in that water samples never resulted in toxicity to the crustacean *C. dubia,* suggesting that sediments were a more important source of toxicity to arthropods than the stream water. Assessments of physical habitat suggested moderate degradation overall, although some components indicated very severe impacts, such as lack of epifaunal cover, high embeddedness, uniform velocity-depth regimes, and low riffle frequency. Bioassessment samples were not collected, so the impacts of toxicity, water quality, and physical habitat on biological integrity could not be assessed.

Alvarado Creek, a small tributary in the western portion of the watershed, was also in poor ecological health. Seven water chemistry constituents exceeded aquatic life thresholds, including nutrients, selenium, manganese, pH, and conductivity. Furthermore, four pesticides were detected, including diazinon, oxadiazon, propazine, and simazine. Toxicity was evident in 71% of all samples collected at this site. However, acute toxicity to *H. azteca* was not observed, and chronic endpoints for this species were not assessed. Bioassessment samples in Alvarado Creek were in very poor condition with a mean IBI score of 13.6.

The conditions in the mainstem of the San Diego River were worse than in most of the tributaries. For example, more water chemistry constituents exceeded aquatic life thresholds at the mouth of the San Diego River than at any tributary, except for San Vicente Creek. These exceedances included several nutrients, selenium, manganese, benzo(a)pyrene, dissolved oxygen, conductivity, and turbidity. Furthermore, more organic constituents (17 PAHs and 4 pesticides) were detected at this site than any other in the HU. These constituents included naphthalenes, fluoranthenes, phenanthrenes, oxadiazon, secbumeton, and simazine. Several of these constituents exceeded human health thresholds on one sampling date. Although no PCBs were detected in water samples, accumulation of PCBs was evident in invertebrate tissues collected at the mouth of the San Diego River. One sample exceeded OEHHA thresholds, and another sample was slightly below the threshold. Toxicity to all indicators species was observed. The lowest IBI scores in the watershed were collected at the mouth (SDR 15) and upstream on the mainstem (site 12), where IBI scores were 6.5 and 5.5, respectively. Although condition improved between these two sites, IBI scores peaked at 22.3, at site 7, suggesting that the mainstem is in poor or very poor condition along much of its length. Physical habitat, assessed only at the mouth of the San Diego River, was severely degraded, with a mean physical habitat score of 9.5 out of 20. This score was caused by the lack of epifaunal cover, severe embeddedness, a uniform velocity-depth regime, major channel alteration, and the paucity of riffles.

Although this assessment indicated widespread impacts to ecological health in the San Diego River watershed, the study revealed a few positive signs. For example, water chemistry was limited to a few constituents, such as nutrients, manganese, and conductivity. Furthermore, no water chemistry constituent exceeded human health thresholds at any site in the HU, apart from five PAHs at the mouth of the San Diego River. Sites with healthy biological communities could be found in parts of the watershed, upstream of the El Capitan Reservoir. Habitat degradation was moderate or absent at most of the sites where physical habitat was assessed.

Despite the strength of the evidence, limitations of this study affect the assessment. These limitations include difficulties integrating data from SWAMP and non-SWAMP sources, the non-randomization of sample sites, small sample size, and the lack of applicable thresholds for several indicators. Although these limitations require that results be interpreted with caution, it is unlikely that they would alter the fundamental finding that the San Diego watershed is in poor health, as explained at the end of this section.

The geographical approach to integrating SWAMP and non-SWAMP data relies on assumptions about the spatial and temporal variability of the variables measured by these programs. For example, bioassessment data may have been collected up to 500 meters away and up to 8 years before water chemistry, toxicity, and tissue data were collected. This study assumes that anthropogenic impacts do not change across these distances or over these spans of time. There is little published research on either of these assumptions, although there may be greater support for the assumptions about spatial variability (e.g., Gebler 2004) than for temporal variability (e.g., Sandin and Johnson 2000, Bêche et al. 2006). In this study, bioassessment data were observed to be highly variable, and the use of data collected many years before water chemistry data is questionable.

The targeted selection of sites monitored under the SWAMP program facilitated integration of pre-existing data from non-SWAMP sources, but this non-probabilistic approach severely limits the extrapolation of data from these sites to the rest of the watershed. Non-random sampling violates assumptions underlying most statistical analyses, and the sites selected in this study cannot be assumed to represent the entire watershed (Olsen et al. 1999, Stevens Jr. and Olsen 2004).

The small number of sites monitored under SWAMP also limits the certainty of this study's assessment. For example, tissue samples were collected at only two sites; therefore, tissue contamination may have gone undetected in unsampled regions of the watershed. Although SWAMP has produced a wealth of data about the San Diego watershed using limited resources, some indicators (especially those with high variability) may require more extensive sampling to produce more precise and accurate assessments.

Thresholds are an essential tool for assessing water quality and ecological health. However, their use is limited to indicators that have been well studied, and they cannot provide a holistic view watershed health. This limitation is exacerbated by the fact that many constituents and indicators lack applicable thresholds. For example, of the 177 water chemistry constituents, 110 (62%) had no applicable water quality objectives that could be used as thresholds for water quality. No thresholds exist for physical habitat scores. Furthermore, thresholds applied to IBI scores and toxicity were based on statistical distributions and professional judgment (respectively), rather than on risks to ecological health. For example, the 80% threshold used to identify toxic samples is based on the assumption that this level is ecologically meaningful, although this assumption has not been verified in the field. The development of biocriteria to establish meaningful thresholds for bioassessment is subject of active interest in California (Bernstein and Schiff 2002).

Despite these limitations, the data gathered under SWAMP and other programs strongly supported the conclusion that portions of the San Diego HU were in poor ecological health. Some of these limitations (such as the lack of applicable thresholds and the small sample size) may in fact have caused this assessment to underestimate the severity of degradation in the watershed. All indicators showed signs of human impacts. Multiple stressors, including degraded water quality, sediment, and physical habitat were the likely causes of the impact. Future research (see final report on the SWAMP monitoring program for further study recommendations) is necessary to determine which stressors were responsible for the impacts seen in the watershed.

6. LITERATURE CITED

Bêche, L.A., E.P. McElravy and V.H. Resh. 2005. Long-term seasonal variation in the biological traits of benthic-macroinvertebrates in two Mediterranean climate streams in California, USA. *Freshwater Biology* 51:56-75.

Bernstien, B. and Schiff, K. 2002. Stormwater research needs in Southern California. Technical Report 358. Southern California Coastal Water Research Project. Westminster, CA.

California Code of Regulations. 2007. Barclay's Official California Code of Regulations. Title 22. Social Security Division 4. Environmental Health Chapter 15. Domestic Water Quality and Monitoring Regulations Article 16. Secondary Drinking Water Standards. §64449.

California Department of Fish and Game. 2003. California Stream Bioassessment Procedure: Protocol for Biological and Physical/Habitat Assessment in Wadeable Streams. Available from www.dfg.ca.gov/cabw/cabwhome.html.

California Department of Water Resources. 2007. http://www.water.ca.gov/.
Environmental Protection Agency (EPA). 1993. Methods for measuring acute toxicity of effluents and receiving waters to freshwater and marine organisms, Fourth Edition. EPA 600/4-90/027. US Environmental Protection Agency, Environmental Research Laboratory. Duluth, MN.

Environmental Protection Agency (EPA). 1997. Water quality standards: Establishment of numeric criteria for priority toxic pollutants for the state of California: Proposed Rule. *Federal Register* 62:42159-42208.

Environmental Protection Agency (EPA). 2002. National recommended water quality criteria. EPA-822-R-02-047. Environmental Protection Agency Office of Water. Washington, DC.

Environmental Protection Agency (EPA). 2007. Integrated Risk Information System. http://www.epa.gov/iris/index.html. Office of Research and Development. Washington, DC.

Gebler, J.B. 2004. Mesoscale spatial variability of selected aquatic invertebrate community metrics from a minimally impaired stream segment. *Journal of the North American Benthological Society* 23:616-633.

National Academy of Sciences. 1977. Drinking Water and Health. Volume 1. Washington, DC.

National Oceanic and Atmospheric Administration. 2007. National Weather Service data. Available from http://www.wrh.noaa.gov/sgx/obs/rtp/rtpmap.php?wfo=sgx

Ode, P.R., A.C. Rehn and J.T. May. 2005. A quantitative tool for assessing the integrity of southern California coastal streams. *Environmental Management* 35:493-504.

Office of Environmental Health Hazard Assessment (OEHHA). 2006. Draft development of guidance tissue levels and screening values for common contaminants in California Sports Fish: Chlordane, DDTs, Dieldrin, Methylmercury, PCBs, Selenium, and Toxaphene. OEHHA. Sacramento, CA.

Olsen, A.R., J. Sedransk, D. Edwards, C.A. Gotway, W. Liggett, S. Rathburn, K.H. Reckhow and L.J. Young. 1999. Statistical issues for monitoring ecological and natural resources in the United States. *Environmental Management and Assessment* 54:1-45.

Puckett, M. 2002. Quality Assurance Management Plan for the State of California's Surface Water Ambient Monitoring Program: Version 2. California Department of Fish and Game, Monterey, CA. Prepared for the State Water Resources Control Board. Sacramento, CA.

California Regional Water Quality Control Board, San Diego Region. 1994. Water quality control plan for the San Diego Region. San Diego, CA. http://www.waterboards.ca.gov/sandiego/programs/basinplan.html

SANDAG. 1998. Watersheds of the San Diego Region. SANDAG INFO.

Sandin, L. and R.K. Johnson. 2000. The statistical power of selected indicator metrics using macroinvertebrates for assessing acidification and eutrophication of running waters. *Hydrobiologia* 422/423:233-243.

Stevans, Jr., D.L. and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association: Theory and Methods* 99:262-278.

Weston Solutions, Inc. 2007. San Diego County Municipal Copermittees 2005-2006 Urban Runoff Monitoring. Final Report. County of San Diego. San Diego, CA. Available at http://www.projectcleanwater.org/html/wg_monitoring_05-06report.html.

7. APPENDICES

APPENDIX I

A. Beneficial uses of streams in the San Diego HU (California Regional Water Quality Control Board, San Diego Region 1994). B. Streams on the 303(d) list of impaired water bodies in the San Diego HUC. HUC = Hydrologic Unit Code. MUN = Municipal and domestic supply. AGR = Agricultural supply. IND = Industrial service supply. POW = Hydropower generation. REC1 = Contact recreation. REC2 = Non-contact recreation. WARM = Warm freshwater habitat. COLD = Cold freshwater habitat. WILD = Wildlife habitat. RARE = Rare, threatened, or endangered species. X = Exempted from municipal supply. E = Existing beneficial use. P = Potential beneficial use.

A. Beneficial uses of streams in the San Diego HU.

San Diego River	HUC	MUN	AGR	IND	PROC	REC1	REC2	WARM	COLD	WILD	RARE	SPWN
San Diego River	907.41	E	E	E	E	E	E	E	E	E		
Coleman Creek	907.42	E	E	E	E	E	E	E	E	E		
Eastwood Creek	907.42	E	E	E	E	E	E	E	E	E		
Jim Green Creek	907.42	E	E	E	E	E	E	E	E	E		
Mariette Creek	907.42	E	E	E	E	E	E	E	E	E		
Boring Creek	907.42	E	E	E	E	E	E	E	E	E		
Bailey Creek	907.42	E	E	E	E	E	E	E	E	E		
Coleman Creek	907.41	E	E	E	E	E	E	E	E	E		
Selenec Creek	907.42	E	E	E	E	E	E	E	E	E		
Selenec Creek	907.41	E	E	E	E	E	E	E	E	E		
Temescal Creek	907.41	E	E	E	E	E	E	E	E	E		
Paine Bottom	907.41	E	E	E	E	E	E	E	E	E		
Orinoco Creek	907.41	E	E	E	E	E	E	E	E	E		
Iron Springs Canyon	907.41	E	E	E	E	E	E	E	E	E		
Dye Canyon	907.41	E	E	E	E	E	E	E	E	E		
Richie Creek	907.41	E	E	E	E	E	E	E	E	E		
Cedar Creek	907.41	E	E	E	E	E	E	E	E	E		E
Sandy Creek	907.41	E	E	E	E	E	E	E	E	E		
Dehr Creek	907.41	E	E	E	E	E	E	E	E	E		E
Kelly Creek	907.41	E	E	E	E	E	E	E	E	E		
Little Stonewall Creek	907.43	E	E	E	E	E	E	E	E	E		E
Boulder Creek	907.41	E	E	E	E	E	E	E	E	E		E
Azalea Creek	907.41	E	E	E	E	E	E	E	E	E		
Johnson Creek	907.41	E	E	E	E	E	E	E	E	E		
Sheep Camp Creek	907.41	E	E	E	E	E	E	E	E	E		
San Diego River	907.31	E	E	E	E	E	E	E	E	E		
Isham Creek	907.31	E	E	E	E	E	E	E	E	E		
Sand Creek	907.31	E	E	E	E	E	E	E	E	E		
Conejos Creek	907.31	E	E	E	E	E	E	E	E	E		E
King Creek	907.31	E	E	E	E	E	E	E	E	E		
West Fork King Creek	907.31	E	E	E	E	E	E	E	E	E		
Echo Valley	907.31	E	E	E	E	E	E	E	E	E		
Peutz Valley	907.31	E	E	E	E	E	E	E	E	E		
Chocolate Canyon	907.32	E	E	E	E	E	E	E	E	E		
Alpine Creek	907.33	E	E	E	E	E	E	E	E	E		
Chocolate Canyon	907.31	E	E	E	E	E	E	E	E	E		
San Diego River	907.15	P		E		E	E	E		E	E	

A. Beneficial uses of streams in the San Diego HU, continued.

San Diego River	HUC	MUN	AGR	IND	PROC	REC1	REC2	WARM	COLD	WILD	RARE	SPWN
San Diego River	907.12	P		E		E	E	E		E	E	
Quail Canyon	907.12	P		E		E	E	E		E		
Wildcat Canyon	907.12	P		E		E	E	E		E		
San Vicente Creek	907.23	E	E	E	E	E	E	E		E		
Swartz Canyon	907.23	E	E	E	E	E	E	E		E		
Klondike	907.23	E	E	E	E	E	E	E		E		
San Vicente Creek	907.22	E	E	E	E	E	E	E		E		
Damey Canyon	907.22	E	E	E	E	E	E	E		E		
Longs Gulch	907.22	E	E	E	E	E	E	E		E		
West Branch San Vicente Creek	907.21	E	E	E	E	E	E	E		E		
Padre Barona Creek	907.24	E	E	E	E	E	E	E		E		
Wright Canyon	907.24	E	E	E	E	E	E	E		E		
Featherstone Canyon	907.24	E	E	E	E	E	E	E		E		
Padre Barona Creek	907.12	P		E		E	E	E		E		
Foster Canyon	907.21	E	E	E	E	E	E	E		E		
San Vicente Creek	907.12	P		E		E	E	E		E		
Slaughterhouse Canyon	907.12	P		E		E	E	E		E		
Las Coches Creek	907.14	P		E		E	E	E		E		
Rios Canyon	907.14	P		E		E	E	E		E		
Los Coches Creek	907.12	P		E		E	E	E		E		
Forrester Creek	907.13	P		E		E	E	E		E		
Forrester Creek	907.12	P		E		E	E	E		E		
Sycamore Canyon	907.12	X	E	E		E	E	E		E	E	
Unnamed tributary	907.12	X	E	E		E	E	E		E	E	
Clark Canyon	907.12	X	E	E		E	E	E		E	E	
West Sycamore Canyon	907.12	X	E	E		E	E	E		E		
Quail Canyon	907.12	X	E	E		E	E	E		E		
Little Sycamore Canyon	907.12	X	E	E		E	E	E		E		
Spring Canyon	907.12	X	E	E		E	E	E		E	E	
Oak Canyon	907.12	X	E	E		E	E	E		E		
San Diego River	907.11	X	E	E		E	E	E		E	E	
Unnamed tributary	907.11	X	E	E		E	E	E		E	E	
Alvarado Canyon	907.11	X	E	E		E	E	E		E		
Murphy Canyon	907.11	X	E	E		E	E	E		E	E	
Shepherd Canyon	907.11	X	E	E		E	E	E		E		
Murray Canyon	907.11	X	E	E		E	E	E		E		

Appendix I, continued.
B. 303(d)-listed streams in the San Diego HU.

Name	HUC	Stressor	Potential source	Affected length
Forester Creek	907.12	Fecal coliform	Urban runoff / storm sewers	1 mile
			Spills	
			Unknown nonpoint source	
			Unknown point source	
		Dissolved oxygen	Source unknown	6.4 miles
		pH	Industrial point source	3 miles
			Habitat modification	
			Spills	
			Unknown nonpoint source	
			Unknown point source	
		Phosphorous	Source unknown	6.4 miles
Lower San Diego River	907.11	Fecal coliform	Urban runoff / storm sewers	6 miles
			Wastewater	
			Nonpoint/point source	
		Dissolved oxygen	Urban runoff / storm sewers	16 miles
			Unknown nonpoint source	
			Unknown point source	
		Phosphorous	Urban runoff / storm sewers	16 miles
			Unknown nonpoint source	
			Unknown point source	
		Total dissolved solids	Urban runoff / storm sewers	16 miles
			Unknown nonpoint source	
			Unknown point source	

APPENDIX II

Means, standard deviations (SD), and number of samples (n) of water chemistry constituents in (A) SWAMP sites and (B) Non-SWAMP (NPDES) sites. The watershed average was calculated as the mean of the site averages. Blank cells indicate that the constituent was not analyzed at that site. -- = Constituent not detected at that site. SWAMP sites were monitored in 2002. Non-SWAMP sites were monitored in Spring and Fall between 2002 and 2005.

A. SWAMP sites.

			907SDALV3			907SDBOC2			907SDCHC3			907SDFRC2			907SDLCO2			907SDSVC3			907SSDR15		
Category	Constituent	Unit	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Bacteria	Enterococcus	MPN/100mL			0			0			0			0			0	520		1			0
Bacteria	Fecal Coliform	MPN/100mL			0			0			0			0			0	900		1			0
Bacteria	Total Coliform	MPN/100mL			0			0			0			0			0	1600		1			0
Inorganics	Alkalinity as CaCO3	mg/L	214	24	4	124	55	3	315	67	3	262	65	4	271	139	4	228	35	5	273	88	4
Inorganics	Ammonia as	mg/L	0.03	0.02	4	0.02	0.03	3	0.03	0.03	3	0.12	0.06	4	0.03	0.03	4	0.02	0.03	5	0.07	0.01	4
Inorganics	Chloride	mg/L			0			0			0			0	330		1			0			0
Inorganics	Nitrate as NO3	mg/L	1.10	1.17	4	0.57	0.80	3	5.19	2.29	3	5.04	5.03	4	13.43	5.58	4	604.84	3.71	5	0.48	0.85	4
Inorganics	Nitrite as N	mg/L	0.01	0.00	4	0.00	0.00	3	0.02	0.00	3	0.08	0.07	4	0.04	0.03	4	0.03	0.02	5	0.01	0.01	4
Inorganics	Nitrogen, Total Kjeldahl	mg/L	0.78	0.19	4	0.54	0.35	3	0.68	0.10	3	1.18	0.32	4	0.39	0.46	3	0.89	0.32	5	0.86	0.31	4
Inorganics	o-phosphate as P	mg/L			0			0			0			0			0	0.1		1			0
Inorganics	Phosphorus as P,Total	mg/L	0.1	0.0	4	0.2	0.2	3	0.1	0.0	3	0.1	0.1	4	0.1	0.0	4	0.1	0.1	5	0.2	0.1	4
Inorganics	Selenium,Dissolved	µg/L	12.8	9.5	4	1.2	0.5	3	6.2	5.4	3	10.1	7.6	4	8.9	6.2	4	4.3	3.8	4	10.8	7.2	4
Inorganics	Sulfate	mg/L	332	53	4	28	14	3	265	49	3	454	178	4	211	104	4	330	208	5	285	108	4
Metals	Aluminum,Dissolved	µg/L	3.0	1.4	4	27.2	14.5	3	2.6	1.2	3	5.2	3.5	4	9.6	3.0	4	8.8	7.0	5	2.3	1.7	4
Metals	Arsenic,Dissolved	µg/L	5.7	1.6	4	0.7	0.4	3	2.3	0.7	3	4.1	2.7	4	2.1	1.1	4	1.4	0.4	5	5.5	2.3	4
Metals	Cadmium,Dissolved	µg/L	0.0	0.0	4	0.0	0.0	3	0.0	0.0	3	0.0	0.0	4	0.1	0.0	4	0.0	0.0	5	0.0	0.0	4
Metals	Chromium,Dissolved	µg/L	0.8	0.6	4	0.1	0.1	3	1.2	1.6	3	0.6	0.3	4	0.4	0.2	4	0.4	0.2	5	1.1	1.2	4
Metals	Copper,Dissolved	µg/L	5.4	1.5	4	1.4	0.8	3	4.2	0.7	3	6.6	2.1	4	3.8	1.2	4	3.4	1.9	5	3.8	1.6	4
Metals	Lead,Dissolved	µg/L	0.1	0.0	4	0.2	0.2	3	0.1	0.0	3	0.1	0.1	4	0.1	0.1	4	0.1	0.1	5	0.1	0.1	4
Metals	Manganese,Dissolved	µg/L	36.3	26.6	4	19.5	17.6	3	34.7	29.0	3	39.0	15.5	4	15.6	10.9	4	28.7	24.0	5	238.8	252.8	4
Metals	Nickel,Dissolved	µg/L	1.1	1.7	4	0.3	0.3	3	--	0.0	3	1.0	1.8	4	0.8	1.4	4	2.4	2.5	5	1.7	3.1	4
Metals	Silver,Dissolved	µg/L	--	0	4	--	0	3	--	0	3	0.005	0.01	4	--	0	4	--	0	5	--	0	4
Metals	Zinc,Dissolved	µg/L	5.8	3.0	4	0.9	0.8	3	3.8	1.2	3	5.9	2.3	4	4.5	1.7	4	3.0	1.7	5	3.2	1.0	4
PAHs	Acenaphthene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	0.004	0.009	4
PAHs	Acenaphthylene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
PAHs	alpha-BHC	µg/L			0			0			0			0			0	--		1			0
PAHs	Anthracene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
PAHs	Benz(a)anthracene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	0.002	0.004	4
PAHs	Benzo(a)pyrene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	0.004	0.008	4
PAHs	Benzo(b)fluoranthene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	0.005	0.010	4
PAHs	Benzo(e)pyrene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	0.003	0.006	4
PAHs	Benzo(g,h,i)perylene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	0.006	0.011	4
PAHs	Benzo(k)fluoranthene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	beta-BHC	µg/L			0			0			0			0			0	--		1			0
PAHs	Biphenyl	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Chrysene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	0.0019	0.0038	4
PAHs	Chrysenes, C1 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Chrysenes, C2 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Chrysenes, C3 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	delta-BHC	µg/L			0			0			0			0			0	--		1			0
PAHs	Dibenz(a,h)anthracene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
PAHs	Dibenzothiophene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Dibenzothiophenes, C1 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Dibenzothiophenes, C2 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Dibenzothiophenes, C3 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Dichlofenthion	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Dimethylnaphthalene, 2,6-	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Dimethylphenanthrene, 3,6-	µg/L	--	0	3	--	0	2	--	0	2	--	0	3	--	0	3	--	0	3	--	0	3
PAHs	Fluoranthene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	0.005	0.009	4
PAHs	Fluoranthene/Pyrenes, C1 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	0.004	0.008	4
PAHs	Fluorene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
PAHs	Fluorenes, C1 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Fluorenes, C2 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Fluorenes, C3 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	gamma-BHC (Lindane)	µg/L			0			0			0			0			0	--		1			0
PAHs	Indeno(1,2,3-c,d)pyrene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	0.006	0.011	4
PAHs	Methyldibenzothiophene, 4-	µg/L	--	0	3	--	0	2	--	0	2	--	0	3	--	0	3	--	0	3	--	0	3
PAHs	Methylfluoranthene, 2-	µg/L	--	0	3	--	0	2	--	0	2	--	0	3	--	0	3	--	0	3	--	0	3
PAHs	Methylfluorene, 1-	µg/L	--	0	3	--	0	2	--	0	2	--	0	3	--	0	3	--	0	3	--	0	3
PAHs	Methylnaphthalene, 1-	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Methylnaphthalene, 2-	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Methylphenanthrene, 1-	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Naphthalene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	0.001	0.003	4
PAHs	Naphthalenes, C1 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Naphthalenes, C2 -	µg/L	--	0	4	--	0	3	--	0	3	0.002	0.004	4	--	0	4	--	0	4	0.002	0.003	4
PAHs	Naphthalenes, C3 -	µg/L	--	0	4	--	0	3	--	0	3	0.006	0.006	4	--	0	4	--	0	4	0.002	0.004	4
PAHs	Naphthalenes, C4 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4

Appendix IIa, continued. Means and standard deviations of water chemistry constituents.

			907SDALV3			907SDBOC2			907SDCHC3			907SDFRC2			907SDLCO2			907SDSVC3			907SSDR15		
Category	Constituent	Unit	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
PAHs	Perylene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Phenanthrene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	0.002	0.003	4
PAHs	Phenanthrene/Anthracene, C1 -	µg/L	--	0	4	--	0	3	--	0	3	0.002	0.005	4	--	0	4	--	0	4	0.003	0.005	4
PAHs	Phenanthrene/Anthracene, C2 -	µg/L	--	0	4	--	0	3	--	0	3	0.002	0.004	4	--	0	4	--	0	4	0.002	0.004	4
PAHs	Phenanthrene/Anthracene, C3 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Phenanthrene/Anthracene, C4 -	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PAHs	Pyrene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	0.005	0.010	4
PAHs	Trimethylnaphthalene, 2,3,5-	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 005	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 008	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 015	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 018	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 027	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 028	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 029	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 031	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 033	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 044	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 049	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 052	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 056	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 060	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 066	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 070	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 074	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 087	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 095	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 097	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 099	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 101	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 105	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 110	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 114	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 118	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 128	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 137	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 138	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 141	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 149	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 151	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 153	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 156	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 157	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 158	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 170	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 174	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 177	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 180	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 183	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 187	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 189	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 194	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 195	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 200	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 201	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 203	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 206	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB 209	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
PCBs	PCB-1016	µg/L			0			0			0			0			0	--		1			0
PCBs	PCB-1221	µg/L			0			0			0			0			0	--		1			0
PCBs	PCB-1232	µg/L			0			0			0			0			0	--		1			0
PCBs	PCB-1242	µg/L			0			0			0			0			0	--		1			0
PCBs	PCB-1248	µg/L			0			0			0			0			0	--		1			0
PCBs	PCB-1254	µg/L			0			0			0			0			0	--		1			0
PCBs	PCB-1260	µg/L			0			0			0			0			0	--		1			0
Pesticide	Toxaphene	µg/L			0			0			0			0			0	--		1			0
Pesticides	Aldrin	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
Pesticides	Ametryn	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Aspon	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Atraton	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Atrazine	µg/L	--	0	4	--	0	3	--	0	3	0.021	0.043	4	--	0	4	--	0	4	--	0	4
Pesticides	Azinphos ethyl	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4

Appendix IIa, continued. Means and standard deviations of water chemistry constituents.

			907SDALV3			907SDBOC2			907SDCHC3			907SDFRC2			907SDLCO2			907SDSVC3			907SSDR15		
Category	Constituent	Unit	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Pesticides	Azinphos methyl	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Bolstar	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Carbophenothion	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Chlordane (tech)	µg/L			0			0			0			0			0	--	0	1			0
Pesticides	Chlordane, cis-	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Chlordane, trans-	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Chlordene, alpha-	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Chlordene, gamma-	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Chlorfenvinphos	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Chlorpyrifos	µg/L	--	4	0	--	3	0	--	3	0	--	4	0	--	0	4	--	0	4	--	0	4
Pesticides	Chlorpyrifos methyl	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Ciodrin	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Coumaphos	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Dacthal	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	DDD(o,p')	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	DDD(p,p')	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
Pesticides	DDE(o,p')	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	DDE(p,p')	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
Pesticides	DDMU(p,p')	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	DDT(o,p')	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	DDT(p,p')	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
Pesticides	Demeton-s	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Diazinon	µg/L	0.0100	0.0117	4	--	0	3	--	0	3	0.0013	0.0025	4	--	0	4	--	0	4	--	0	4
Pesticides	Dichlorvos	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Dicrotophos	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Dieldrin	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
Pesticides	Dimethoate	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Dioxathion	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Disulfoton	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Endosulfan I	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
Pesticides	Endosulfan II	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
Pesticides	Endosulfan sulfate	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
Pesticides	Endrin Aldehyde	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
Pesticides	Endrin Ketone	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Endrin	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
Pesticides	Ethion	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Ethoprop	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Famphur	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Fenchlorphos	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Fenitrothion	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Fensulfothion	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Fenthion	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Fonofos	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	HCH, alpha	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	HCH, beta	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	HCH, delta	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	HCH, gamma	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Heptachlor epoxide	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
Pesticides	Heptachlor	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
Pesticides	Hexachlorobenzene	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Leptophos	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Malathion	µg/L	--	0	4	--	0	3	0.011	0.019	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Merphos	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Methidathion	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Methoxychlor	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	5	--	0	4
Pesticides	Mevinphos	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Mirex	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Molinate	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Naled	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Nonachlor, cis-	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Nonachlor, trans-	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Oxadiazon	µg/L	0.020	0.007	4	--	0.000	3	0.002	0.003	3	0.006	0.007	4	0.000	0.001	4	--	0.000	4	0.019	0.004	4
Pesticides	Oxychlordane	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Parathion, Ethyl	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Parathion, Methyl	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Phorate	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Phosmet	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Phosphamidon	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Prometon	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Prometryn	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Propazine	µg/L	0.014	0.017	4	--	0	3	--	0	3	0.040	0.063	4	--	0	4	--	0	4	--	0	4
Pesticides	Secbumeton	µg/L	--	0	4	0.007	0.012	3	--	0	3	0.006	0.012	4	--	0	4	0.012	0.024	4	0.0608	0.1215	4

Appendix IIa, continued. Means and standard deviations of water chemistry constituents.

			907SDALV3			907SDBOC2			907SDCHC3			907SDFRC2			907SDLCO2			907SDSVC3			907SSDR15		
Category	Constituent	Unit	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Pesticides	Simazine	µg/L	0.0133	0.0153	4	--	0	3	--	0	3	0.025	0.05	4	0.010	0.020	4	--	0.000	4	0.02	0.04	4
Pesticides	Simetryn	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Sulfotep	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Tedion	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Terbufos	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Terbuthylazine	µg/L	--	0	4	--	0	3	--	0	3	0.028	0.057	4	--	0	4	--	0	4	0.079	0.157	4
Pesticides	Terbutryn	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Tetrachlorvinphos	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Thiobencarb	µg/L	--	0	4	--	0	3	0.039	0.067	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Thionazin	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Tokuthion	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Trichlorfon	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Pesticides	Trichloronate	µg/L	--	0	4	--	0	3	--	0	3	--	0	4	--	0	4	--	0	4	--	0	4
Physical	Oxygen, Dissolved	mg/L	11.9	2.9	4	9.7	1.2	3	9.5	3.3	3	10.4	1.6	4	9.2	2.9	4	8.9	4.4	4	6.6	2.6	4
Physical	Oxygen, Saturation	%	132	30	4	97	5	3	94	34	3	116	13	4	99	29	4	100	49	4	73	22	4
Physical	pH	pH units	8.2	0.2	4	7.9	0.1	3	7.8	0.5	3	8.1	0.2	4	8.0	0.2	4	8.3	0.2	4	7.5	0.1	4
Physical	Salinity	ppt	1.3	0.1	4	0.1	0.0	3	0.9	0.1	3	1.3	0.2	4	0.9	0.2	4	0.9	0.4	4	1.3	0.5	4
Physical	Specific conductivity	µS/cm	2461	165	4	269	58	3	1704	378	3	2349	329	4	1674	370	4	1783	747	4	2420	989	4
Physical	Suspended Solids,Total	mg/L	5.4	10.9	4	199.9	299.3	3	5.3	9.2	3	10.2	8.2	4	11.9	9.6	4	21.6	45.6	5	18.5	13.6	4
Physical	Temperature	ºC	20.3	3.8	4	16.0	3.7	3	14.8	0.3	3	20.6	4.9	4	18.0	2.8	4	22.5	3.5	4	21.1	4.4	4
Physical	Turbidity	NTU	1.7	0.9	4	17.8	13.7	3	2.2	2.0	3	7.2	6.9	4	5.5	6.1	4	7.1	7.8	4	10.1	13.8	4
Physical	Velocity	ft/sec	0.51	0.20	3			0	1.20	1.13	3	1.32	1.22	3	0.37	0.53	2	0.94	0.82	3	1.65	1.26	2

Appendix II, continued. Means and standard deviations of water chemistry constituents.
B. Non-SWAMP sites.

	Site 11 (REF-CC)			Site 8 (SDR-1)			Site 12 (SDR-CHB)			Site 7 (SDR-MT)			Site 5 (SDR-OMD)		
Constituent	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Dissolved oxygen (mg/L)	7.5		1	4.8	2.4	7	5.4	1.2	2	7.7	2.8	7	8.4	1.7	2
pH	7.7		1	7.6	0.2	7	7.5	0.4	2	7.9	0.2	7	7.5	0.6	2
Specific conductivity (mS/cm)	0.6		1	2.8	0.8	7	1.6	0.6	2	3.0	1.5	7	1.9	0.6	2
Turbidity (NTU)	6.6		1	8.2		1	61.4	17.1	2	8.2		1	88.0	49.2	2
Water tempurature (ºC)	15		1	21.4	1.4	7	18.0	4.9	2	19.4	0.9	7	18.4	4.9	2

APPENDIX III

Results from toxicity assays for each endpoint at each site in the watershed. Mean = mean percent control. SD = standard deviation.

	C. dubia						*H. azteca*						*S. capricornutum*		
	Survival			Young / Female			Survival			Growth			Total cell count		
Site	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
907SDALV3	3	99	8	3	77	20	1	98		0			4	60	32
907SDBOC2	3	102	3	3	88	41	1	109		1	121		3	94	30
907SDCHC3	3	99	8	3	51	41	1	94		1	68		3	80	53
907SDFRC2	2	98	4	2	94	14	3	63	54	2	39	37	4	64	40
907SDLCO2	4	102	3	4	77	26	2	109	0	2	106	23	4	73	30
907SDSVC4	5	103	5	5	87	26	3	106	7	3	123	24	5	117	71
907SSDR15	4	100	0	4	92	31	2	89	19	2	95	45	4	72	42
All sites in watershed	24	100	4	24	79	28	13	92	30	11	92	40	27	75	34

APPENDIX IV

Concentrations of metals, PCBs, and pesticides in each replicate clams collected from two sites in the San Diego HU. -- = Constituent not detected. Bold type indicates constituents exceeding OEHHA standards.

Category	Constituent	Unit	Threshold	Replicate 1	Replicate 2	Mean
Metals	Aluminum	ppm		23.10		23.10
Metals	Arsenic	ppm		0.74		0.74
Metals	Cadmium	ppm		0.03		0.03
Metals	Chromium	ppm		0.33		0.33
Metals	Copper	ppm		5.06		5.06
Metals	Lead	ppm		0.08		0.08
Metals	Manganese	ppm		32.9		32.9
Metals	Nickel	ppm		0.192		0.192
Metals	Silver	ppm		0.02		0.02
Metals	Zinc	ppm		27.6		27.6
Inorganics	Selenium	ppm	1.94	0.41		0.41
Other	Lipid	%		1.7	1.6	1.7
PCBs	PCB 008	ng/g		--	--	--
PCBs	PCB 018	ng/g		0.270	0.250	0.260
PCBs	PCB 027	ng/g		--	--	--
PCBs	PCB 028	ng/g		--	--	--
PCBs	PCB 029	ng/g		--	--	--
PCBs	PCB 031	ng/g		0.150	--	0.075
PCBs	PCB 033	ng/g		--	--	--
PCBs	PCB 044	ng/g		0.970	0.850	0.910
PCBs	PCB 049	ng/g		0.360	0.310	0.335
PCBs	PCB 052	ng/g		0.980	0.670	0.825
PCBs	PCB 056	ng/g		0.250	0.140	0.195
PCBs	PCB 060	ng/g		--	--	--
PCBs	PCB 066	ng/g		0.550	0.440	0.495
PCBs	PCB 070	ng/g		0.410	0.280	0.345
PCBs	PCB 074	ng/g		0.230	0.100	0.165
PCBs	PCB 087	ng/g		0.590	0.550	0.570
PCBs	PCB 095	ng/g		1.360	1.190	1.275
PCBs	PCB 097	ng/g		0.970	0.820	0.895
PCBs	PCB 099	ng/g		0.670	0.710	0.690
PCBs	PCB 101	ng/g		1.860	1.560	1.710
PCBs	PCB 105	ng/g		0.630	0.430	0.530
PCBs	PCB 110	ng/g		2.160	1.820	1.990
PCBs	PCB 114	ng/g		--	--	--
PCBs	PCB 118	ng/g		1.880	1.870	1.875
PCBs	PCB 128	ng/g		0.310	0.220	0.265
PCBs	PCB 137	ng/g		--	--	--
PCBs	PCB 138	ng/g		2.520	2.350	2.435
PCBs	PCB 141	ng/g		--	--	--

Appendix IV. Concentrations of metals, PCBs, and pesticides in invertebrate tissues.

Category	Constituent	Unit	Threshold	Replicate 1	Replicate 2	Mean
PCBs	PCB 149	ng/g		1.280	1.250	1.265
PCBs	PCB 151	ng/g		0.500	0.380	0.440
PCBs	PCB 153	ng/g		2.440	2.260	2.350
PCBs	PCB 156	ng/g		0.120	0.110	0.115
PCBs	PCB 157	ng/g		--	--	--
PCBs	PCB 158	ng/g		0.250	0.230	0.240
PCBs	PCB 170	ng/g		--	--	--
PCBs	PCB 174	ng/g		--	--	--
PCBs	PCB 177	ng/g		0.110	0.100	0.105
PCBs	PCB 180	ng/g		0.360	0.350	0.355
PCBs	PCB 183	ng/g		0.130	0.130	0.130
PCBs	PCB 187	ng/g		0.420	0.380	0.400
PCBs	PCB 189	ng/g		--	--	--
PCBs	PCB 194	ng/g		--	--	--
PCBs	PCB 195	ng/g		--	--	--
PCBs	PCB 200	ng/g		--	--	--
PCBs	PCB 201	ng/g		--	--	--
PCBs	PCB 203	ng/g		--	--	--
PCBs	PCB 206	ng/g		--	--	--
PCBs	PCB 209	ng/g		--	--	--
PCBs	PCBs	ng/g	20	**22.73**	19.75	**21.24**

APPENDIX V

Mean IBI and metric scores for bioassessment sites in the San Diego HU. Note that the number listed under IBI is the mean IBI for each site, and not the IBI calculated from the mean metric values.

				IBI		EPT Taxa		Coleoptera Taxa		Predator Taxa		% Collectors		% Intolerant		% Non-insect Taxa		% Tolerant Taxa	
Site	Season	n	Years	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
907SDALV3	Spring	2	2004-2006	13.6	3.0	1.5	0.7	0.0	0.0	2.5	0.7	3.0	1.4	0.0	0.0	1.5	0.7	1.0	1.4
907SDBOC2	Spring	3	2001-2005	30.5	5.8	2.0	1.0	3.0	2.6	3.7	4.0	1.0	1.0	0.3	0.6	5.3	2.5	6.0	3.6
907SDCHC3	Spring	1	2004	14.3		1.0		0.0		4.0		1.0		0.0		3.0		1.0	
907SDSVC3	Average	2	2000-2002	19.3	13.1	0.0	0.0	0.0	0.0	0.5	0.7	5.0	7.1	5.0	7.1	0.5	0.7	2.5	3.5
	Fall	1	2000	28.6		0.0		0.0		0.0		10.0		10.0		0.0		0.0	
	Spring	1	2002	10.0		0.0		0.0		1.0		0.0		0.0		1.0		5.0	
907SSDR15	Average	12	1998-2005	6.5	1.7	0.1	0.2	0.3	0.1	0.8	0.5	2.6	0.3	0.0	0.0	0.0	0.0	0.6	0.5
	Fall	5	1998-2004	7.7	5.7	0.0	0.0	0.4	0.9	1.2	1.3	2.8	2.9	0.0	0.0	0.0	0.0	1.0	1.4
	Spring	7	1998-2005	5.3	3.1	0.3	0.5	0.3	0.8	0.4	0.8	2.4	2.5	0.0	0.0	0.0	0.0	0.3	0.8
907SSDR9	Average	13	1996-2006	11.6	1.3	1.0	0.0	0.1	0.2	1.8	0.6	3.0	0.5	0.0	0.0	0.4	0.3	1.9	0.7
	Fall	5	1996-2005	12.6	5.5	1.0	0.0	0.0	0.0	2.2	1.8	2.6	3.0	0.0	0.0	0.6	0.9	2.4	2.1
	Spring	1	2006	17.1		1.0		0.0		3.0		6.0		0.0		0.0		2.0	
907SSDR9	Spring	8	1997-2006	10.7	8.5	1.0	0.5	0.3	0.7	1.4	2.4	3.4	4.0	0.0	0.0	0.1	0.4	1.4	0.9
Site 3	Spring	1	2001	77.1		7.0		10.0		10.0		6.0		10.0		5.0		6.0	
Site 5	Spring	3	2001-2005	30.5	1.6	2.0	2.0	1.3	2.3	1.7	2.1	3.3	2.5	0.0	0.0	7.0	1.0	6.0	1.7
Site 7	Average	16	1996-2005	22.3	3.3	1.8	0.1	0.3	0.0	2.3	1.2	6.0	0.4	0.0	0.0	1.8	0.4	3.5	0.3
	Fall	7	1996-2004	24.7	6.4	1.7	0.8	0.3	0.8	3.1	1.7	6.3	3.6	0.0	0.0	2.1	1.7	3.7	2.6
	Spring	9	1997-2005	20.0	9.2	1.9	0.8	0.2	0.7	1.4	1.2	5.7	4.6	0.0	0.0	1.6	1.2	3.2	1.1
Site 9	Average	10	1996-1997	17.1	8.1	1.6	0.8	0.4	0.6	1.8	0.8	4.6	3.4	0.0	0.0	1.0	0.8	2.6	0.8
	Fall	5	1996	11.4	4.4	1.0	0.7	0.0	0.0	1.2	1.3	2.2	0.8	0.0	0.0	0.4	0.5	3.2	1.5
	Spring	5	1997	22.9	5.2	2.2	0.8	0.8	1.1	2.4	1.7	7.0	3.2	0.0	0.0	1.6	2.2	2.0	1.9
Site 10	Average	3	2000-2005	29.3	15.2	1.3	1.8	2.5	2.1	2.5	0.7	5.3	5.3	5.0	7.1	3.3	1.8	0.8	1.1
	Fall	1	2000	40.0		0.0		4.0		3.0		9.0		10.0		2.0		0.0	
	Spring	2	2004-2005	18.6	4.0	2.5	0.7	1.0	1.4	2.0	1.4	1.5	2.1	0.0	0.0	4.5	3.5	1.5	2.1
Site 11	Spring	1	2003	47.1		1.0		7.0		4.0		2.0		1.0		9.0		9.0	
Site 12	Average	5	2004-2006	5.5	4.4	0.3	0.5	0.0	0.0	1.1	0.6	1.9	2.2	0.0	0.0	0.0	0.0	0.5	0.7
	Fall	2	2004-2005	8.6	6.1	0.0	0.0	0.0	0.0	1.5	0.7	3.5	2.1	0.0	0.0	0.0	0.0	1.0	1.4
	Spring	3	2004-2006	2.4	0.8	0.7	0.6	0.0	0.0	0.7	0.6	0.3	0.6	0.0	0.0	0.0	0.0	0.0	0.0