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

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

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1. ABSTRACT

In order to assess the ecological health of the Tijuana Hydrologic Unit (San Diego County, CA), water chemistry, water and sediment toxicity, benthic macroinvertebrate communities, and physical habitat were assessed at multiple sites. Water chemistry and toxicity were assessed under SWAMP between 2005 and 2006. Bioassessment samples were collected under SWAMP and other programs between 1999 and 2006. Physical habitat was assessed under SWAMP in 2007. 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, although severity was greater at sites receiving drainage from Mexico (i.e., Tijuana River mainstem and Tecate Creek). For example, all sites (n = 4) exceeded aquatic life thresholds for several water chemistry constituents, but the number and persistence of exceedances was lower at sites within the United States. Nutrients and physical constituents of water quality (e.g., pH, conductivity) were impacted at sites throughout the watershed, and anthropogenic organic constituents affected sites on streams entering from Mexico. Toxicity was evident at all sites, although severity was greater at the Tijuana River and Tecate Creek sites, where sediment samples increased mortality to *Hyalella azteca.* Sub-lethal toxicity to *Hyalella* was evident in all samples from all sites. Bioassessment samples collected at 15 sites (72 samples) ranged from very poor condition to good, with mean annual IBIs ranging from 8.6 to 70.0. Sites with high IBIs had benthic macroinvertebrate communities similar to those found in reference condition, and were clustered in the northern interior portions of the watershed, such as the upper parts of Cottonwood Creek. Physical habitat at La Posta Creek showed signs of moderate degradation, with a mean physical habitat score of 13 out of 20. Embeddedness, velocity-depth regime, and sediment deposition were the most degraded components of physical habitat. Multiple stressors, such as contaminated water and sediment, industrial and urban discharges, and alteration of physical habitat, were likely responsible for the poor health of the southern portions 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 Tijuana watershed receiving drainage from Mexico are in poor ecological condition, and that the northern interior of the watershed is in moderate to good ecological condition.

2. INTRODUCTION

The Tijuana hydrologic unit (HU 911) is in San Diego County. Home to over 1,000,000 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 Tijuana HU, a comprehensive assessment of the ecological health of these waters has not been conducted. The purpose of this study was to assess the health of the watershed using data collected in 2005 and 2006 under the Surface Waters Ambient Monitoring Program (SWAMP), and data collected by National Pollution Discharge Elimination System (NPDES) permittees. 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, and macroinvertebrate community structure. By examining data from multiple sources, this report provides a measure of the ecological integrity of the Tijuana 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
	2003	San Dieguito	905
4 (2003-2004)	2004-2005	San Diego	907
	2004-2005	San Luis Rey	903
5 (2004-2005)	2005-2006	Pueblo San Diego	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, 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.

Although the Tijuana River watershed includes extensive portions of Mexico (1253 mi^2, or 73% of the watershed), this report focuses on the waters with the Tijuana HU, defined as the streams of the watershed within California.

2.1 Geographic Setting

The Tijuana HU is the northern portion of the Tijuana River watershed. The watershed extends from the peninsular mountain ranges, such as the Cuyamacas, to the Pacific Ocean, just south of San Diego Bay (Figure 1). The highest peak within the watershed is Cuyapaipe Peak, at 1,944 m elevation (Institute for Regional Studies of the Californias 2005)

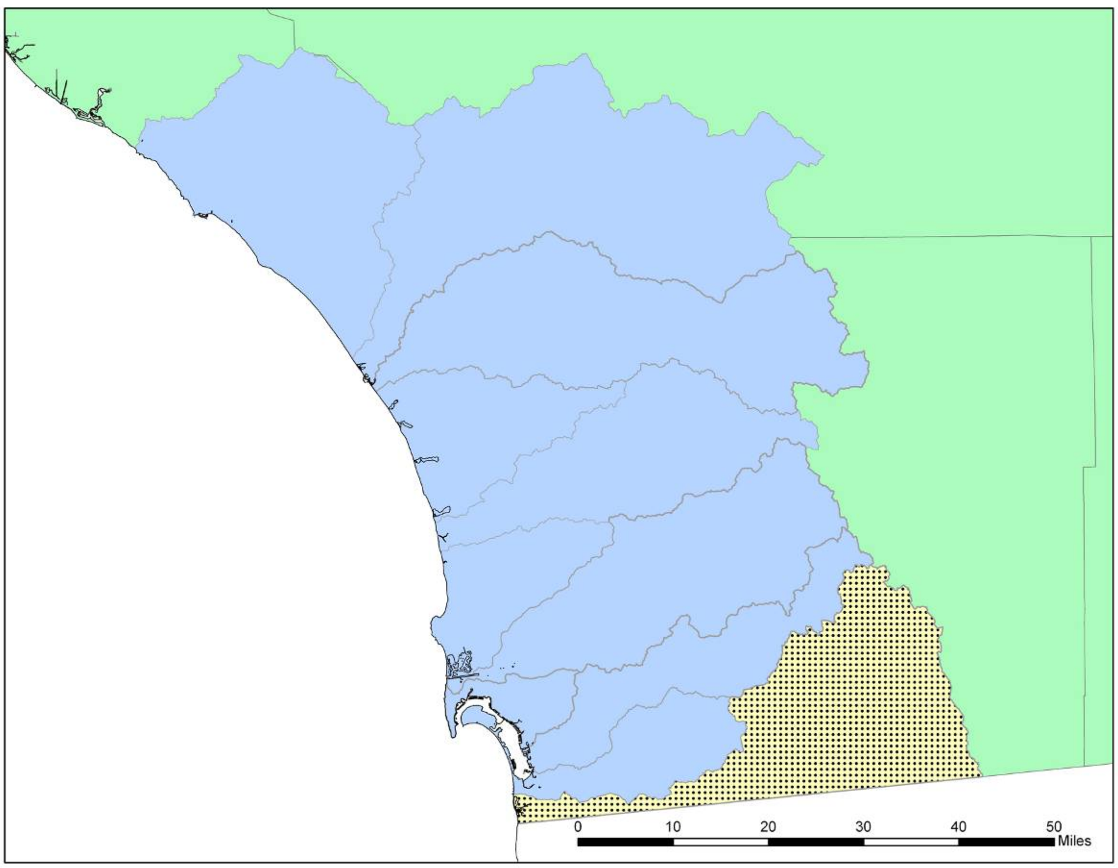


Figure 1. San Diego region (purple) includes portions of San Diego, Riverside, and Orange counties. The Tijuana HU (tan, shaded) is located entirely within San Diego County, although most of the Tijuana River watershed is in Mexico.

2.1.1 Climate

The Tijuana 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 Mount Laguna (near the inland end of the HU), Campo (in the central part of the HU) and at Sea World (near the coast outside the HU) shows considerable variability in rainfall throughout the HU (National Oceanic and Atmospheric Administration 2007) (Figure 2).

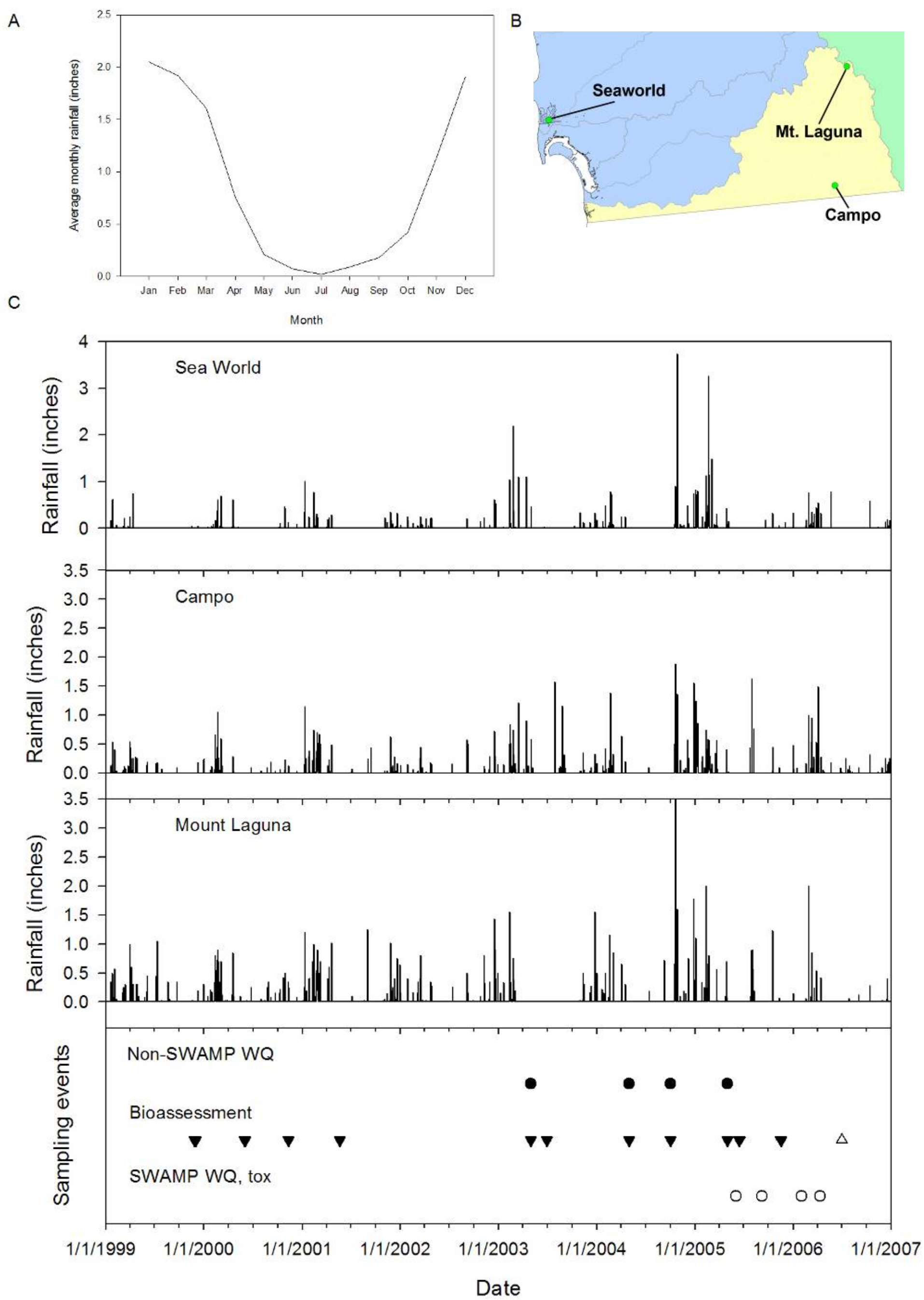


Figure 2. Rainfall and sampling events at stations in the San Diego region. A. Average precipitation for each month at the Lindberg Station (DWR station code SDG), based on data collected between January 1905 and November 2006. B. Location of the Sea World, Camp, and Mount Laguna gauges. C. Storm events and sampling events in the Tijuana 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 black downward triangles. SWAMP bioassessment is shown as upward white triangles. Swamp water chemistry and toxicity is shown as white circles.

2.1.2 Hydrology

The Tijuana HU consists of the northern portion of the Tijuana River Watershed. Major tributaries within the United States include Pine Valley Creek, Cottonwood Creek, Wilson Creek, and La Posta Creek. Campo Creek begins in the United States but meets with Tecate Creek in Mexico. Tecate Creek is mostly within Mexico, but enters the mainstem in the United States less than a mile from the border. The mainstem crosses from the United States into Mexico, and returns north before entering the Tijuana Estuary, one of the most extensive salt marshes remaining in southern California (Institute for Regional Studies of the Californias 2005). Major waterbodies within the HU include Morena Reservoir and Barrett Lake.

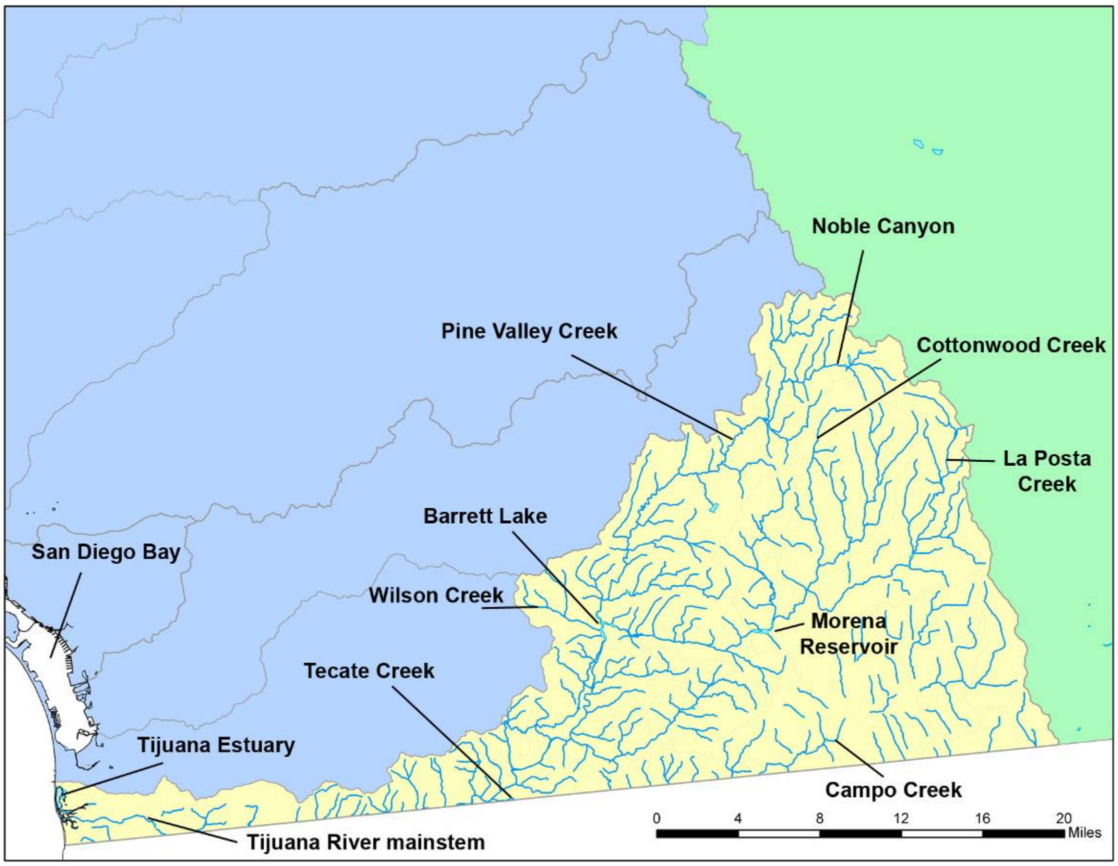


Figure 3. The Tijuana watershed, including major waterways.

2.1.3 Land Use within the Watershed

The majority (73%) of the Tijuana watershed is under Mexican jurisdiction, with the cities of Tijuana and Tecate being the largest population centers. Within California, most of the HU (95%) is unincorporated portions of San Diego County.

The cities of San Diego and Imperial Beach have jurisdiction over 4.7% and 0.7% of the HU, respectively. Caltrans is a major landowner within the HU, and has jurisdiction over all major freeways and highways. Indian reservations, including the La Posta, Campo, Cuyapaipe, and Manzanita Reservations, are found within the watershed (SANDAG 1998, Institute for Regional Studies of the Californias 2005).

Within the Tijuana HU, much of the watershed (90%) is undeveloped open space. Developed urban land accounts for 6% of the HU, and agriculture occupies 4% of the HU (SANDAG 1998). In the Mexican portion of the watershed, developed land comprises only 3%, and agriculture comprises 14% of the total area (Figure 4) (Center for Earth Systems Analysis Research 2000, Institute for Regional Studies of the Californias 2005). Within California, major protected areas include the Cleveland National Forest and Lake Morena County Park. Protected around the lower portions of the watershed include the Tijuana River National Estuarine Research Reserve, Border Field State Park, and the Tijuana River Valley Regional Park (SANDAG 1998, Institute for Regional Studies of the Californias 2005).

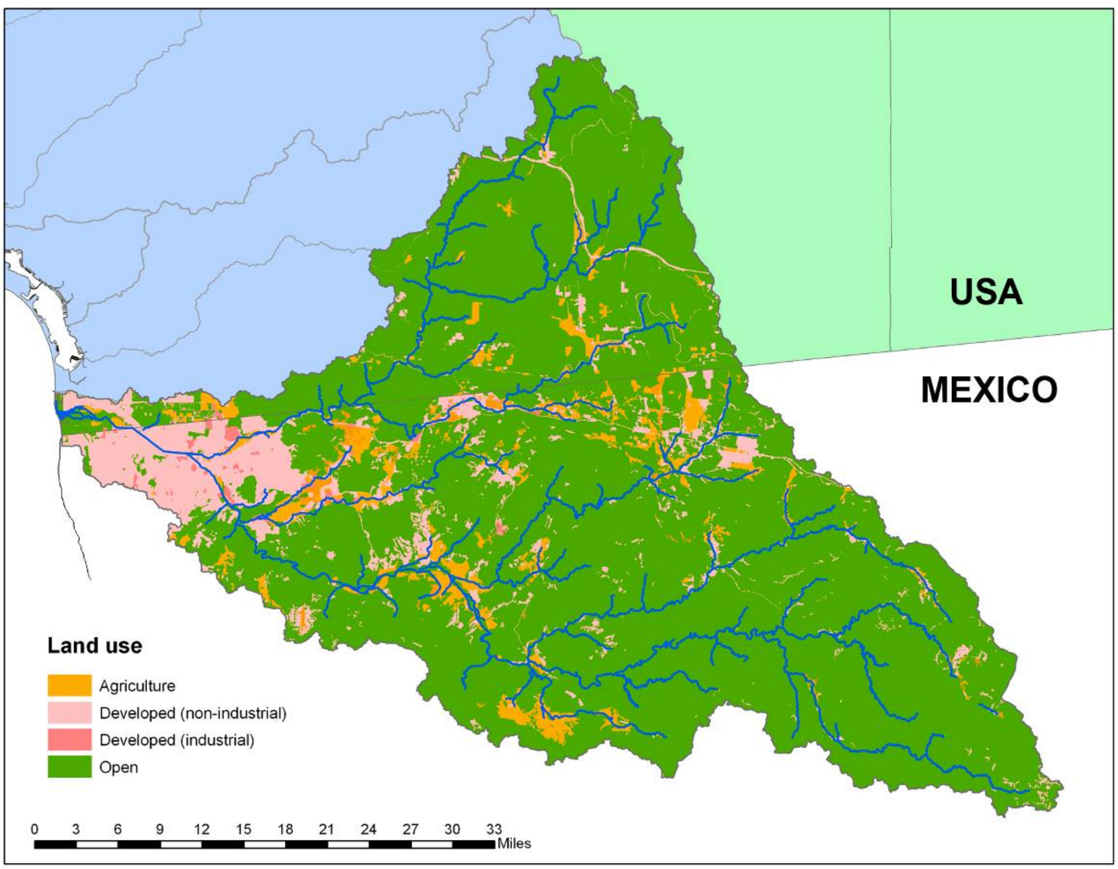


Figure 4. Land use within the Tijuana HU. Undeveloped open space is shown as green. Agricultural areas are shown as orange. Urban and developed lands are shown as pink, with industrial areas indicated by a darker shade.

2.1.4 Beneficial Uses and Known Impairments in the Watershed

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

Two streams in the Tijuana HU are listed as impaired on the 303(d) list of water quality limited segments, affecting a total of 8.9 stream miles. These streams include Pine Valley Creek and the Tijuana River mainstem. Known stressors include bacteria, phosphorus, turbidity, eutrophication, low dissolved oxygen, pesticides, solids, synthetic organics, trace elements, and trash (Appendix I).

3. METHODS

This report combines data collected under SWAMP with data from California Department of Fish and Game (CDFG) and NPDES monitoring (Table 2). Six sites of interest were sampled under SWAMP in the Tijuana HU in 2002 (Table 3; Figure 5). Water chemistry and toxicity were measured at 4 sites. Physical habitat was assessed at one site (La Posta Creek). Bioassessment samples were collected under SWAMP at 2 additional sites. In addition, bioassessment samples were collected by the CDFG Aquatic Bioassessment Laboratory (ABL) and the County of San Diego as part of its NPDES permit (between 2002 and 2005) at 14 sites, including 3 of the sites monitored under SWAMP. In addition to bioassessment, conventional water chemistry (e.g., temperature, conductivity, dissolved oxygen) was also measured at sites sampled by San Diego County NPDES. 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 1999 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.

Program	Indicators	Years
SWAMP	Water chemistry, bioassessment, toxicity, physical habitat	2005-2006
CA Department of Fish and Game	Bioassessment	1999-2005
San Diego County NPDES	Bioassessment, water chemistry	2002-2005

Table 3: SWAMP sampling site locations. W = Water chemistry. T = Toxicity. B = Bioassessment (under SWAMP). N = Bioassessment (under non-SWAMP programs). P = Physical habitat.

	Site	Description	Latitude (°N)	Longitude (°E)	W	T	B	N	P
1	911TCWD10	Cottonwood Creek 10	32.5730	-116.7575	X	X			
2	911TLAP04	La Posta Creek 4	32.7000	-116.4796	X	X		X	X
3	911TTET02	Tecate Creek 2	32.5654	-116.7585	X	X			
4	911TTJR05	Tijuana River 5	32.5492	-117.0651	X	X		X	
5	911TJLCC2	Long Canyon Creek 2	32.7784	-116.4429			X	X	
6	911TJPVC1	Pine Valley Creek 1	32.8357	-116.5432			X		

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 within 500 m	Sources	W	B	Lattitude (N)	Longitude (E)
1	Cottonwood Creek at Old Hwy 80	none	Regional Board (911CCH80x)		X	32.7880	-116.4976
2	Campo Creek at Hwy 94 Gauging Station	none	Regional Board (911CCH94x)		X	32.5893	-116.5180
			NPDES (CC-H94)	X	X		
3	Kitchen Creek at Cibbets Flat Campground	none	Regional Board (911KCBCFx)		X	32.7606	-116.4516
4	Kitchen Creek at Kitchen Creek Road	none	Regional Board (911KCKCRx)		X	32.7875	-116.4561
5	Long Canyon Creek at Cibbets Flat Campground	911TJLCC2	Regional Board (911LCCCFC)		X	32.7783	-116.4450
6	La Posta Creek Narrows	911TLAP04	Regional Board (911LPCCTT)		X	32.6999	-116.4791
7	Middle Cottonwood Creek below Morena Lake	none	Regional Board (911MCCBML)		X	32.6758	-116.5831
8	North Pine Creek above Noble Creek	none	Regional Board (911NPCNCx, 911NPCRx)		X	32.8652	-116.5183
9	Pine Creek upstream of Old Highway 80	none	Regional Board (911PCH80x)		X	32.8372	-116.5364
10	Troy Canyon Creek at Kitchen Creek Road	none	Regional Board (911TCCTCx)		X	32.8078	-116.4400
11	Wilson Creek above Barrett Lake	none	Regional Board (911WLCABL)		X	32.6936	-116.6953
12	Campo Creek in Campo	none	NPDES (CC-C)	X	X	32.6092	-116.4408
13	Wilson Creek at Lyons Valley Road (reference)	none	NPDES (REF-WC)	X	X	32.7075	-116.7372
14	Tijuana River at Dairy Mart Road	911TTJR05	NPDES (TJ-DM)	X	X	32.5469	-117.0624

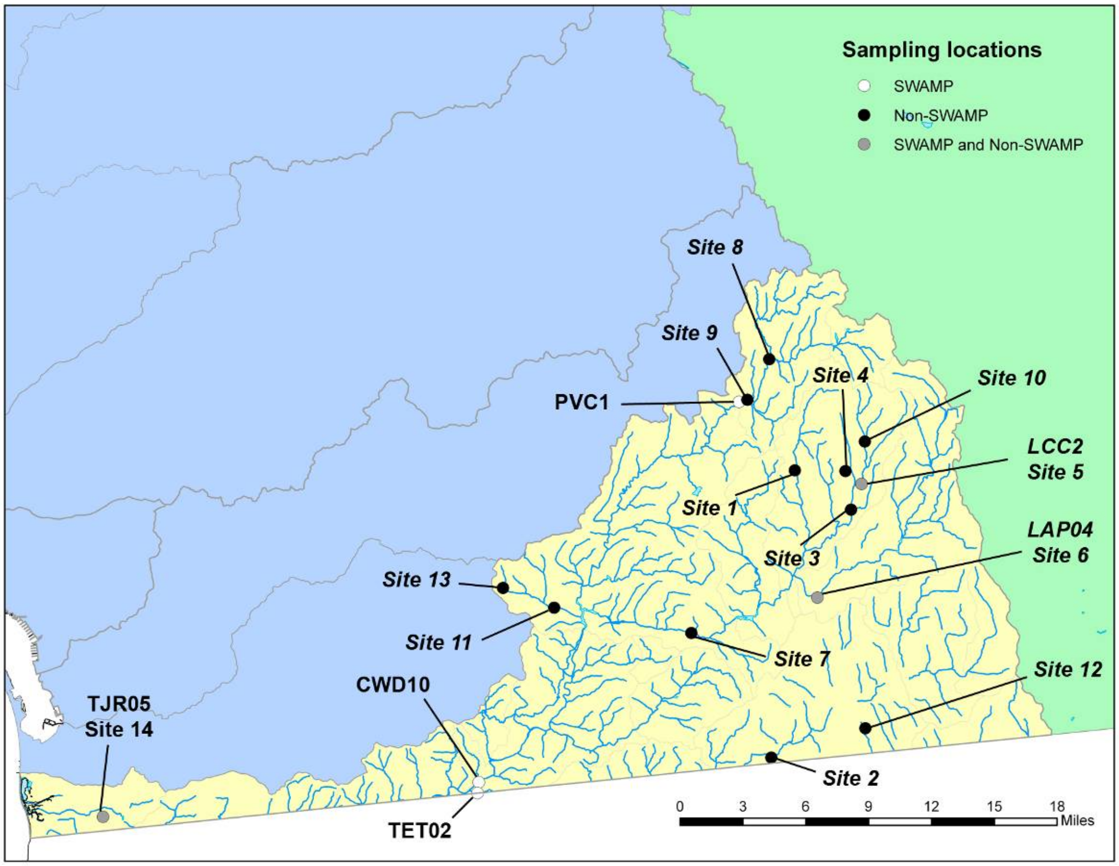


Figure 5. Sampling locations in the Tijuana HU. White circles represent sites sampled under SWAMP. Black circles represent sites sampled under non-SWAMP programs. Gray circles represent sites sampled under both SWAMP and non-SWAMP programs. The SWAMP site prefix designating the hydrologic unit (i.e., 911TJ-) has been dropped to improve clarity.

3.1 Indicators

Multiple indicators were used to assess the sites in the Tijuana HU. Water chemistry, water and sediment toxicity, 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 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 Tijuana 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

Fish tissues were not assessed in the Tijuana HU.

3.1.4 Bioassessment

To assess the ecological health of the streams in Tijuana HU, benthic macroinvertebrate samples were collected at 14 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 at La Posta Creek (LAP04) on April 16, 2007, 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 Tijuana 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. 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 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, 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 Tijuana HU. Therefore, the most stringent water quality objectives (e.g., municipal drinking water, aquatic life, etc.) for the measured constituents were used as thresholds 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.
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 Tijuana 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	Designated MUN only	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	All but HUC 911.1	250	mg/l	BP	none	mg/l	none
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	All but HUC 911.1	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	0.00000013	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
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 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

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	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	Thiobencarb	All sites	70	µg/L	BP	none	µg/L	none
Pesticides	Toxaphene	All sites	0.0002	µg/L	CTR	0.0002	µg/L	CTR
Physical	Oxygen, Dissolved	Designated WARM only	5	mg/L	BP	none	mg/L	none
Physical	Oxygen, Dissolved	Designated COLD only	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 but HUC 911.1	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 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, and toxicity. No chemistry or toxicity data were excluded as a result of QA/QC violations. QA/QC procedures for NPDES 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 and severe impacts throughout the watershed, although impacts were more severe in streams flowing from Mexico (Tecate Creek—TET02, and the Tijuana River mainstem—TJR05) than for watersheds entirely within the United States (Cottonwood Creek—CWD10, and La Posta Creek—LAP04). Across the entire watershed, 45 PAHs were detected, but none in watersheds entirely within the United States. All 45 were detected in the Tijuana River, and slightly more than half (i.e., 26) were detected in Tecate Creek. Of the 48 PAHs analyzed, all but 3 (i.e., dichlofenthion, C2-fluorenes, and c3-fluorenes) were detected at the Tijuana River. Analysis of pesticides shows a similar (but less severe) pattern of impact: 5 pesticides were detected in Tecate Creek, and 3 were detected in the Tijuana River, but only one (i.e., diazinon) was detected in watersheds entirely within the United States. This pesticide was found at every site in the HU. No PCBs were detected at any site. Means and standard deviations of all constituents are presented in Appendix II.

Table 7. Number of anthropogenic organic compounds detected at each site in Tijuana HU.

	PAHs		PCBs		Pesticides	
Site	Tested	Detected	Tested	Detected	Tested	Detected
911TCWD10	48	0	50	0	79	1
911TLAP04	48	0	50	0	79	1
911TTET02	48	26	50	0	79	5
911TTJR05	48	45	50	0	79	3
All sites	48	45	50	0	79	5

Apart from diazinon, all anthropogenic organic constituents were restricted to streams draining Mexico. All PAHs detected in Tecate Creek were also detected in the Tijuana River, and all pesticides detected in the Tijuana River were also found in Tecate Creek (Table 8). This distribution may reflect the strength of industrial sources of PAHs at the Tijuana River site and agricultural sources of pesticides at the Tecate Creek site.

Table 8. Frequency of detection of anthropogenic organic compounds in the Tijuana HU. Constituent not detected at any site (--).

Category	Constituent	Sites tested	Sites detected	Frequency
PAHs	Acenaphthene	4	1	0.25
PAHs	Acenaphthylene	4	1	0.25
PAHs	Anthracene	4	1	0.25
PAHs	Benz(a)anthracene	4	1	0.25

Table 8, continued. Frequency of detection of anthropogenic organic compounds.

Category	Constituent	Sites tested	Sites detected	Frequency
PAHs	Benzo(b)fluoranthene	4	1	0.25
PAHs	Benzo(e)pyrene	4	1	0.25
PAHs	Benzo(g,h,i)perylene	4	1	0.25
PAHs	Benzo(k)fluoranthene	4	1	0.25
PAHs	Biphenyl	4	2	0.50
PAHs	Chrysene	4	1	0.25
PAHs	Chrysenes, C1 -	4	1	0.25
PAHs	Chrysenes, C2 -	4	2	0.50
PAHs	Chrysenes, C3 -	4	1	0.25
PAHs	Dibenz(a,h)anthracene	4	1	0.25
PAHs	Dibenzothiophene	4	2	0.50
PAHs	Dibenzothiophenes, C1 -	4	2	0.50
PAHs	Dibenzothiophenes, C2 -	4	2	0.50
PAHs	Dibenzothiophenes, C3 -	4	2	0.50
PAHs	Dichlofenthion	4	0	--
PAHs	Dimethylnaphthalene, 2,6-	4	2	0.50
PAHs	Dimethylphenanthrene, 3,6-	4	2	0.50
PAHs	Fluoranthene	4	2	0.50
PAHs	Fluoranthene/Pyrenes, C1 -	4	2	0.50
PAHs	Fluorene	4	2	0.50
PAHs	Fluorenes, C1 -	4	2	0.50
PAHs	Fluorenes, C2 -	4	0	--
PAHs	Fluorenes, C3 -	4	0	--
PAHs	Indeno(1,2,3-c,d)pyrene	4	1	0.25
PAHs	Methyldibenzothiophene, 4-	4	2	0.50
PAHs	Methylfluoranthene, 2-	4	1	0.25
PAHs	Methylfluorene, 1-	4	2	0.50
PAHs	Methylnaphthalene, 1-	4	1	0.25
PAHs	Methylnaphthalene, 2-	4	1	0.25
PAHs	Methylphenanthrene, 1-	4	2	0.50
PAHs	Naphthalene	4	1	0.25
PAHs	Naphthalenes, C1 -	4	2	0.50
PAHs	Naphthalenes, C2 -	4	2	0.50
PAHs	Naphthalenes, C3 -	4	2	0.50
PAHs	Naphthalenes, C4 -	4	2	0.50
PAHs	Perylene	4	1	0.25
PAHs	Phenanthrene	4	2	0.50
PAHs	Phenanthrene/Anthracene, C1 -	4	2	0.50
PAHs	Phenanthrene/Anthracene, C2 -	4	2	0.50
PAHs	Phenanthrene/Anthracene, C3 -	4	2	0.50
PAHs	Phenanthrene/Anthracene, C4 -	4	2	0.50
PAHs	Pyrene	4	2	0.50
PAHs	Trimethylnaphthalene, 2,3,5-	4	2	0.50
PCBs	PCB 005	4	0	--
PCBs	PCB 008	4	0	--
PCBs	PCB 015	4	0	--
PCBs	PCB 018	4	0	--
PCBs	PCB 027	4	0	--
PCBs	PCB 028	4	0	--

Table 8, continued. Frequency of detection of anthropogenic organic compounds.

Category	Constituent	Sites tested	Sites detected	Frequency
PCBs	PCB 029	4	0	--
PCBs	PCB 031	4	0	--
PCBs	PCB 033	4	0	--
PCBs	PCB 044	4	0	--
PCBs	PCB 049	4	0	--
PCBs	PCB 052	4	0	--
PCBs	PCB 056	4	0	--
PCBs	PCB 060	4	0	--
PCBs	PCB 066	4	0	--
PCBs	PCB 070	4	0	--
PCBs	PCB 074	4	0	--
PCBs	PCB 087	4	0	--
PCBs	PCB 095	4	0	--
PCBs	PCB 097	4	0	--
PCBs	PCB 099	4	0	--
PCBs	PCB 101	4	0	--
PCBs	PCB 105	4	0	--
PCBs	PCB 110	4	0	--
PCBs	PCB 114	4	0	--
PCBs	PCB 118	4	0	--
PCBs	PCB 128	4	0	--
PCBs	PCB 137	4	0	--
PCBs	PCB 138	4	0	--
PCBs	PCB 141	4	0	--
PCBs	PCB 149	4	0	--
PCBs	PCB 151	4	0	--
PCBs	PCB 153	4	0	--
PCBs	PCB 156	4	0	--
PCBs	PCB 157	4	0	--
PCBs	PCB 158	4	0	--
PCBs	PCB 170	4	0	--
PCBs	PCB 174	4	0	--
PCBs	PCB 177	4	0	--
PCBs	PCB 180	4	0	--
PCBs	PCB 183	4	0	--
PCBs	PCB 187	4	0	--
PCBs	PCB 189	4	0	--
PCBs	PCB 194	4	0	--
PCBs	PCB 195	4	0	--
PCBs	PCB 200	4	0	--
PCBs	PCB 201	4	0	--
PCBs	PCB 203	4	0	--
PCBs	PCB 206	4	0	--
PCBs	PCB 209	4	0	--
Pesticides	Aldrin	4	0	--
Pesticides	Aspon	4	0	--
Pesticides	Azinphos ethyl	4	0	--
Pesticides	Azinphos methyl	4	0	--
Pesticides	Bolstar	4	0	--

Table 8, continued. Frequency of detection of anthropogenic organic compounds.

Category	Constituent	Sites tested	Sites detected	Frequency
Pesticides	Carbophenothion	4	0	--
Pesticides	Chlordane, cis-	4	0	--
Pesticides	Chlordane, trans-	4	0	--
Pesticides	Chlordene, alpha-	4	0	--
Pesticides	Chlordene, gamma-	4	0	--
Pesticides	Chlorfenvinphos	4	0	--
Pesticides	Chlorpyrifos	4	1	0.25
Pesticides	Chlorpyrifos methyl	4	0	--
Pesticides	Ciodrin	4	0	--
Pesticides	Coumaphos	4	0	--
Pesticides	Dacthal	4	0	--
Pesticides	DDD(o,p')	4	0	--
Pesticides	DDD(p,p')	4	0	--
Pesticides	DDE(o,p')	4	0	--
Pesticides	DDE(p,p')	4	0	--
Pesticides	DDMU(p,p')	4	0	--
Pesticides	DDT(o,p')	4	0	--
Pesticides	DDT(p,p')	4	0	--
Pesticides	Demeton-s	4	0	--
Pesticides	Diazinon	4	4	1.00
Pesticides	Dichlorvos	4	0	--
Pesticides	Dicrotophos	4	0	--
Pesticides	Dieldrin	4	0	--
Pesticides	Dimethoate	4	0	--
Pesticides	Dioxathion	4	2	0.50
Pesticides	Disulfoton	4	2	0.50
Pesticides	Endosulfan I	4	0	--
Pesticides	Endosulfan II	4	0	--
Pesticides	Endosulfan sulfate	4	0	--
Pesticides	Endrin	4	0	--
Pesticides	Endrin Aldehyde	4	0	--
Pesticides	Endrin Ketone	4	0	--
Pesticides	Ethion	4	0	--
Pesticides	Ethoprop	4	0	--
Pesticides	Famphur	4	0	--
Pesticides	Fenchlorphos	4	0	--
Pesticides	Fenitrothion	4	0	--
Pesticides	Fensulfothion	4	0	--
Pesticides	Fenthion	4	0	--
Pesticides	Fonofos	4	1	0.25
Pesticides	HCH, alpha	4	0	--
Pesticides	HCH, beta	4	0	--
Pesticides	HCH, delta	4	0	--
Pesticides	HCH, gamma	4	0	--
Pesticides	Heptachlor	4	0	--
Pesticides	Heptachlor epoxide	4	0	--
Pesticides	Hexachlorobenzene	4	0	--
Pesticides	Leptophos	4	0	--
Pesticides	Malathion	4	0	--

Table 8, continued. Frequency of detection of anthropogenic organic compounds.

Category	Constituent	Sites tested	Sites detected	Frequency
Pesticides	Merphos	4	0	--
Pesticides	Methidathion	4	0	--
Pesticides	Methoxychlor	4	0	--
Pesticides	Mevinphos	4	0	--
Pesticides	Mirex	4	0	--
Pesticides	Molinate	4	0	--
Pesticides	Naled	4	0	--
Pesticides	Nonachlor, cis-	4	0	--
Pesticides	Nonachlor, trans-	4	0	--
Pesticides	Oxadiazon	4	0	--
Pesticides	Oxychlordane	4	0	--
Pesticides	Parathion, Ethyl	4	0	--
Pesticides	Parathion, Methyl	4	0	--
Pesticides	Phorate	4	0	--
Pesticides	Phosmet	4	0	--
Pesticides	Phosphamidon	4	0	--
Pesticides	Sulfotep	4	0	--
Pesticides	Tedion	4	0	--
Pesticides	Terbufos	4	0	--
Pesticides	Tetrachlorvinphos	4	0	--
Pesticides	Thiobencarb	4	0	--
Pesticides	Thionazin	4	0	--
Pesticides	Tokuthion	4	0	--
Pesticides	Trichlorfon	4	0	--
Pesticides	Trichloronate	4	0	--

Comparison with applicable aquatic life and human health thresholds support the conclusion that water quality is impacted by a number of water chemistry constituents (Table 9, Figures 6, 7). Although differences between streams entering from Mexico and streams within the United States were evident, these differences were moderate. For example, streams receiving water from Mexico exceeded only a few more aquatic life thresholds than streams entirely within the United States, in contrast to the large differences observed in Table 8.

The identity of constituents exceeding thresholds varied from site to site, although a few constituents were impacted at multiple sites. For example, nutrients (particularly ammonia-N), selenium, and magnesium exceeded thresholds at a majority of sites, and half the sites did not meet standards for pH and dissolved oxygen (Table 10). Exceedances ranged from a low of 3 at La Posta Creek to a high of 8 at the Tijuana River mainstem (Table 11). Furthermore, all human health threshold exceedances were restricted to this site, where 7 constituents (all PAHs) exceeded thresholds (Table 11).

Water chemistry was minimally impacted at La Posta Creek, where only three constituents exceeded aquatic life thresholds: ammonia-N, total nitrogen, and dissolved oxygen. Furthermore, these exceedances were observed on a single sampling date, suggesting that these impacts were transient and that water chemistry was in good condition most of the time. In contrast, several constituents exceeded thresholds on all sampling dates at the other sites (Table 9).

Results from NPDES water chemistry monitoring at 4 sites suggested low levels of impact, although very few constituents were assessed at these sites (Table 9C). Dissolved oxygen, specific conductivity, and pH exceeded aquatic life thresholds at these sites, but never more than once at an individual site. Turbidity did not exceed applicable thresholds at site 2 (Campo Creek).

Table 9. 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. NA = No applicable thresholds at that site. Empty cells indicate that the constituent was not measured at the site.

A. Aquatic life thresholds at SWAMP sites.

		911TCWD10		911TLAP04		911TTET02		911TTJR05	
Category	Constituent	Freq	n	Freq	n	Freq	n	Freq	n
Inorganics	Alkalinity as CaCO3	--	2	--	4	--	4	--	2
Inorganics	Ammonia as N	1.00	2	0.25	4	1.00	4	1.00	2
Inorganics	Phosphorus as P,Total	0.50	2	--	4	1.00	4	1.00	2
Inorganics	Selenium,Dissolved	1.00	2	--	4	1.00	4	1.00	2
Inorganics	Sulfate	--	2	--	4	--	4	NA	0
Inorganics	Total N	--	2	0.25	4	--	4	--	2
Metals	Aluminum,Dissolved	--	2	--	4	--	4	--	2
Metals	Arsenic,Dissolved	--	2	--	4	--	4	--	2
Metals	Cadmium,Dissolved	--	2	--	4	--	4	--	2
Metals	Chromium,Dissolved	--	2	--	4	--	4	--	2
Metals	Copper,Dissolved	--	2	--	4	--	4	0.50	2
Metals	Lead,Dissolved	--	2	--	4	--	4	--	2
Metals	Manganese,Dissolved	0.50	2	--	4	1.00	4	NA	2
Metals	Nickel,Dissolved	--	2	--	4	--	4	--	2
Metals	Silver,Dissolved	--	2	--	4	--	4	--	2
Metals	Zinc,Dissolved	--	2	--	4	--	4	--	2
PAHs	Benzo(a)pyrene	--	2	--	4	--	4	0.50	2
PCBs	PCBs	--	2	--	4	--	4	--	2
Pesticides	Chlordanes	--	2	--	4	--	4	--	2
Pesticides	Endrin	--	2	--	4	--	4	--	2
Pesticides	Heptachlor	--	2	--	4	--	4	--	2
Pesticides	Heptachlor epoxide	--	2	--	4	--	4	--	2
Pesticides	Hexachlorobenzene	--	2	--	4	--	4	--	2
Pesticides	Methoxychlor	--	2	--	4	--	4	--	2
Pesticides	Molinate	--	2	--	4	--	4	--	2
Pesticides	Thiobencarb	--	2	--	4	--	4	--	2
Physical	Oxygen, Dissolved	--	2	0.25	4	0.50	4	--	2
Physical	pH	0.50	2	--	4	--	4	1.00	2
Physical	Specific conductivity	--	2	--	4	1.00	4	0.50	2
Physical	Turbidity	--	2	--	4	0.75	4	NA	0

Table 9, continued. Frequency of water chemistry threshold exceedances.

B. Human health thresholds at SWAMP sites

		911TCWD10		911TLAP04		911TTET02		911TTJR05	
Category	Constituent	Freq	n	Freq	n	Freq	n	Freq	n
Inorganics	Nitrate + Nitrite as N	--	2	--	4	--	4	--	2
Inorganics	Nitrate as NO3	--	2	--	4	--	4	NA	2
Inorganics	Nitrite as N	--	2	--	4	--	4	--	2
Metals	Arsenic,Dissolved	--	2	--	4	--	4	--	2
Metals	Cadmium,Dissolved	--	2	--	4	--	4	--	2
Metals	Copper,Dissolved	--	2	--	4	--	4	--	2
Metals	Nickel,Dissolved	--	2	--	4	--	4	--	2
PAHs	Acenaphthene	--	2	--	4	--	4	--	2
PAHs	Anthracene	--	2	--	4	--	4	--	2
PAHs	Benz(a)anthracene	--	2	--	4	--	4	0.5	2
PAHs	Benzo(a)pyrene	--	2	--	4	--	4	0.5	2
PAHs	Benzo(b)fluoranthene	--	2	--	4	--	4	0.5	2
PAHs	Benzo(k)fluoranthene	--	2	--	4	--	4	0.5	2
PAHs	Chrysene	--	2	--	4	--	4	0.5	2
PAHs	Dibenz(a,h)anthracene	--	2	--	4	--	4	0.5	2
PAHs	Fluoranthene	--	2	--	4	--	4	--	2
PAHs	Indeno(1,2,3-c,d)pyrene	--	2	--	4	--	4	0.5	2
PAHs	Pyrene	--	2	--	4	--	4	--	2
PCBs	PCBs	--	2	--	4	--	4	--	2
Pesticides	Aldrin	--	2	--	4	--	4	--	2
Pesticides	Azinphos ethyl	--	2	--	4	--	4	--	2
Pesticides	Azinphos methyl	--	2	--	4	--	4	--	2
Pesticides	Chlordanes	--	2	--	4	--	4	--	2
Pesticides	DDD(p,p')	--	2	--	4	--	4	--	2
Pesticides	DDE(p,p')	--	2	--	4	--	4	--	2
Pesticides	DDT(p,p')	--	2	--	4	--	4	--	2
Pesticides	Dieldrin	--	2	--	4	--	4	--	2
Pesticides	Dimethoate	--	2	--	4	--	4	--	2
Pesticides	Endosulfan sulfate	--	2	--	4	--	4	--	2
Pesticides	Endrin	--	2	--	4	--	4	--	2
Pesticides	Endrin Aldehyde	--	2	--	4	--	4	--	2
Pesticides	Endrin Ketone	--	2	--	4	--	4	--	2
Pesticides	Heptachlor	--	2	--	4	--	4	--	2
Pesticides	Heptachlor epoxide	--	2	--	4	--	4	--	2
Pesticides	Hexachlorobenzene	--	2	--	4	--	4	--	2
Pesticides	Oxychlordane	--	2	--	4	--	4	--	2

Table 9, continued. Frequency of water chemistry threshold exceedances.

C. Aquatic life thresholds at non-SWAMP sites.

	Site 2 (CC-H94)		Site 11 (REF-WC)		Site 12 (CC-C)		Site 14 (TJ-DM)	
Constituent	Frequency	n	Frequency	n	Frequency	n	Frequency	n
Dissolved oxygen	1.00	1	--	1	0.33	3	0.50	2
pH	--	1	1.00	1	--	3	--	2
Specific conductivity	1.00	1	--	1	--	3	0.50	2
Turbidity	--	1	n.t.	0	n.t.	0	NA	1

Table 10. 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	Aquatic life	Human health	n
Inorganics	Alkalinity as CaCO3	--	NA	4
Inorganics	Ammonia as N	1.00	NA	4
Inorganics	Nitrate + Nitrite as N	NA	--	4
Inorganics	Nitrate as NO3	NA	--	4
Inorganics	Nitrite as N	NA	--	4
Inorganics	Phosphorus as P,Total	0.75	NA	4
Inorganics	Selenium,Dissolved	0.75	NA	4
Inorganics	Sulfate	--	NA	3
Inorganics	Total N	0.25	NA	4
Metals	Aluminum,Dissolved	--	NA	4
Metals	Arsenic,Dissolved	--	--	4
Metals	Cadmium,Dissolved	--	--	4
Metals	Chromium,Dissolved	--	NA	4
Metals	Copper,Dissolved	0.25	--	4
Metals	Lead,Dissolved	--	NA	4
Metals	Manganese,Dissolved	0.67	NA	3
Metals	Nickel,Dissolved	--	--	4
Metals	Silver,Dissolved	--	NA	4
Metals	Zinc,Dissolved	--	NA	4
PAHs	Acenaphthene	NA	--	4
PAHs	Anthracene	NA	--	4
PAHs	Benz(a)anthracene	NA	--	4
PAHs	Benzo(a)pyrene	0.25	--	4
PAHs	Benzo(b)fluoranthene	NA	--	4
PAHs	Benzo(k)fluoranthene	NA	--	4
PAHs	Chrysene	NA	--	4
PAHs	Dibenz(a,h)anthracene	NA	--	4
PAHs	Fluoranthene	NA	--	4
PAHs	Indeno(1,2,3-c,d)pyrene	NA	--	4
PAHs	Pyrene	NA	--	4
PCBs	PCBs	--	--	4
Pesticides	Aldrin	NA	--	4
Pesticides	Azinphos ethyl	NA	--	4
Pesticides	Azinphos methyl	NA	--	4
Pesticides	Chlordanes	--	--	4

Table 10, continued. Frequency of SWAMP sites with aquatic life and human health threshold exceedances.

Category	Constituent	Aquatic life	Human health	n
Pesticides	DDD(p,p')	NA	--	4
Pesticides	DDE(p,p')	NA	--	4
Pesticides	DDT(p,p')	NA	--	4
Pesticides	Dieldrin	NA	--	4
Pesticides	Dimethoate	NA	--	4
Pesticides	Endosulfan sulfate	NA	--	4
Pesticides	Endrin	--	--	4
Pesticides	Endrin Aldehyde	NA	--	4
Pesticides	Endrin Ketone	NA	--	4
Pesticides	Heptachlor	--	--	4
Pesticides	Heptachlor epoxide	--	--	4
Pesticides	Hexachlorobenzene	--	--	4
Pesticides	Methoxychlor	--	NA	4
Pesticides	Molinate	--	NA	4
Pesticides	Oxychlordane	NA	--	4
Pesticides	Thiobencarb	--	NA	4
Physical	Oxygen, Dissolved	0.50	NA	4
Physical	pH	0.50	NA	4
Physical	Specific conductivity	0.50	NA	4
Physical	Turbidity	0.33	NA	3

Table 11. Number of constituents exceeding thresholds at each SWAMP site.

	Aquatic life		Human health	
	# exceedances	# tests	# exceedances	# tests
911TCWD10	5	30	0	36
911TLAP04	3	30	0	36
911TTET02	7	30	0	36
911TTJR05	7	27	7	36
All sites in watershed	11	30	7	36

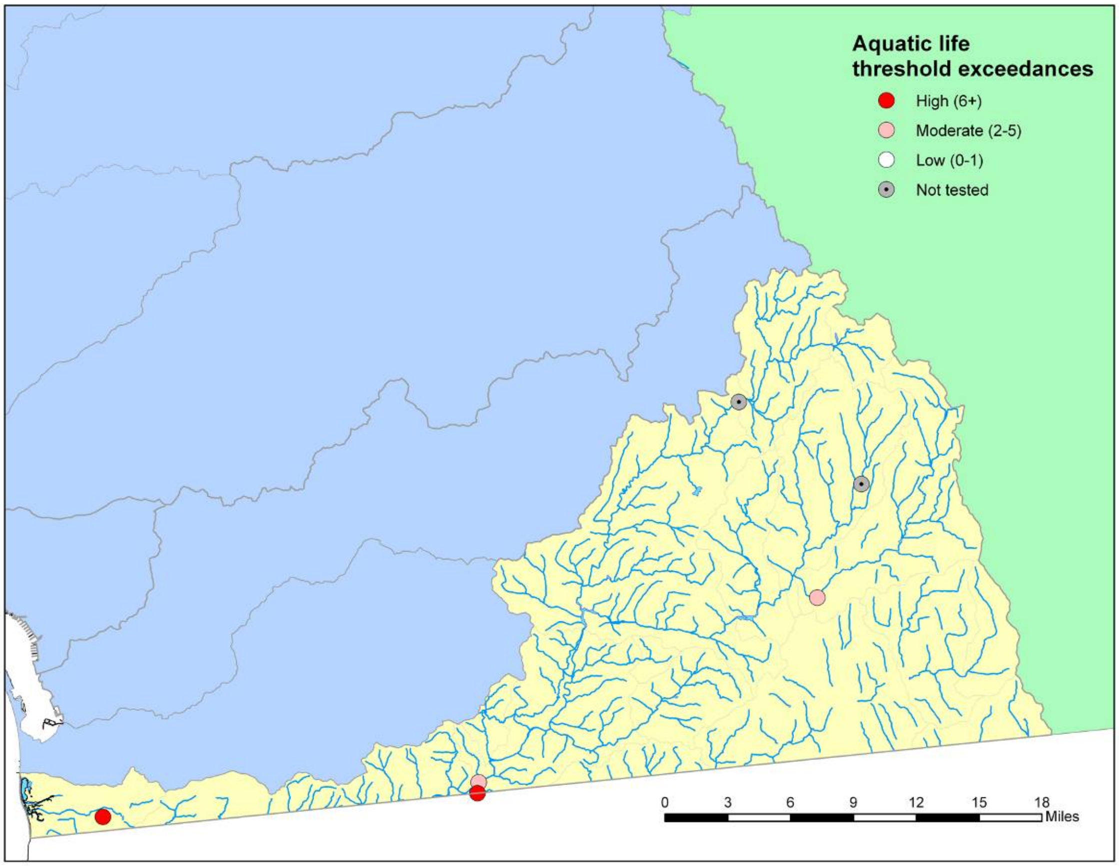


Figure 6. Map of aquatic life threshold exceedances for water chemistry at SWAMP sites. White circles indicate sites with one or fewer exceedances (this value did not occur in this watershed). Pink circles indicate sites with 2 to 5 exceedances. Red circles indicate sites with 6 to 9 exceedances. At the Tijuana River mainstem (TJR05), 27 constituents were assessed; at all other sites, 30 constituents were assessed.

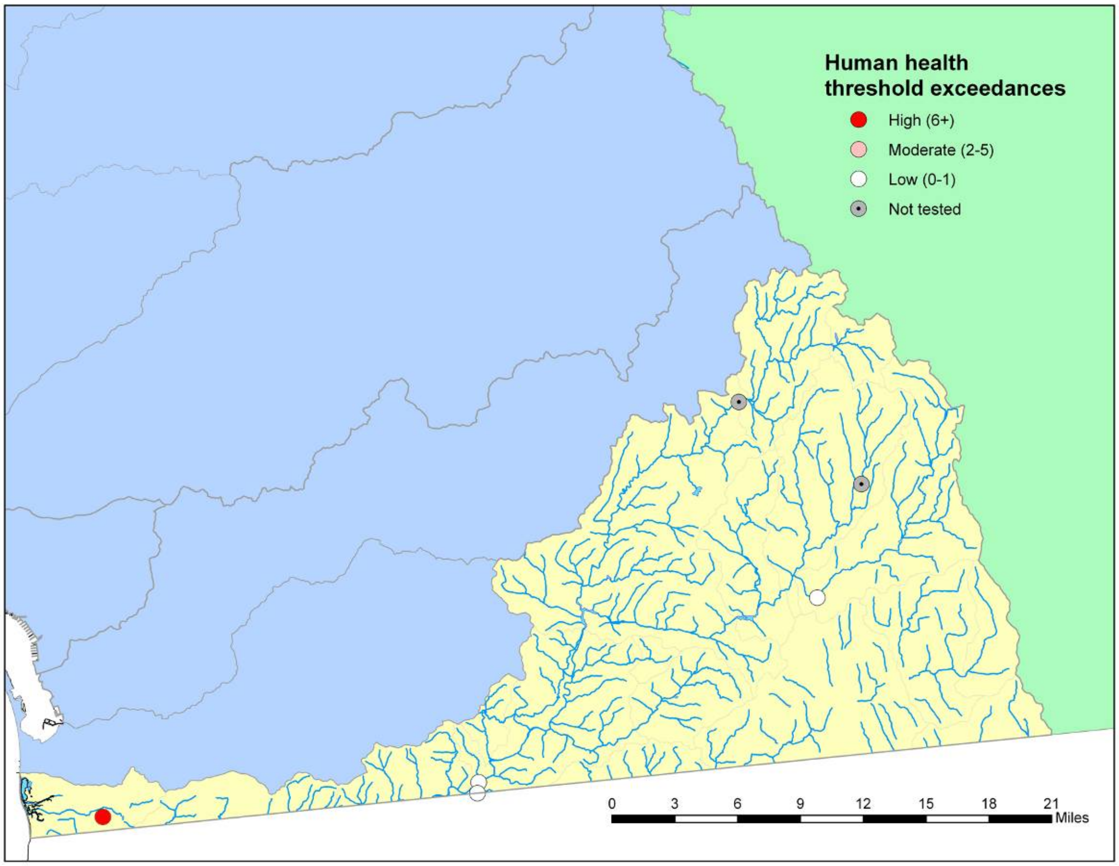


Figure 7. Map of human health exceedances for water chemistry at SWAMP sites. White circles indicate sites with one or fewer exceedances. Pink circles indicate sites with 2 to 5 exceedances. Red circles indicate sites with 6 to 9 exceedances (this value did not occur in this watershed). At all sites, 36 constituents were assessed.

4.2 Toxicity

Toxicity was evident at all sites within the watershed, although results varied among sites and indicators (Table 12; Appendix III). Furthermore, uneven effort among sites hamper meaningful comparisons of results across the HU. Toxicity was most severe at Tecate Creek and the mainstem Tijuana River, where every sample caused toxicity to the crustacean *H. azteca* (for both lethal and sub-lethal endpoints) and to the alga *S. capricornutum* (assessed only at Tecate Creek). In contrast, toxicity was less severe at Cottonwood and La Posta Creeks, where lethal toxicity was never observed. Furthermore, one sample from La Posta Creek did not cause toxicity to the crustacean *C. dubia* (Figure 8).

The crustacean *H. azteca* was a very sensitive indicator of toxicity in the Tijuana HU. However, too few assays using other species (i.e. one assay using *C. dubia* and two assays using *S. capricornutum*) were conducted to evaluate the relative sensitivity of these indicators.

Table 12. 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 P<0.05. Number of samples where the endpoint was evaluated (n). Toxicity not detected in any sample (--). Endpoint 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
911TCWD10	1	nt	0	nt	0	--	1	1.00	1	nt	0	1.00	1
911TLAP04	4	--	1	--	1	--	3	1.00	3	1.00	1	0.80	5
911TTET02	2	nt	0	nt	0	1.00	2	1.00	1	1.00	1	1.00	2
911TTJR05	2	nt	0	nt	0	1.00	2	1.00	2	nt	0	1.00	2
All sites in watershed	9	--	1	--	1	0.50	8	1.00	7	1.00	2	0.90	10

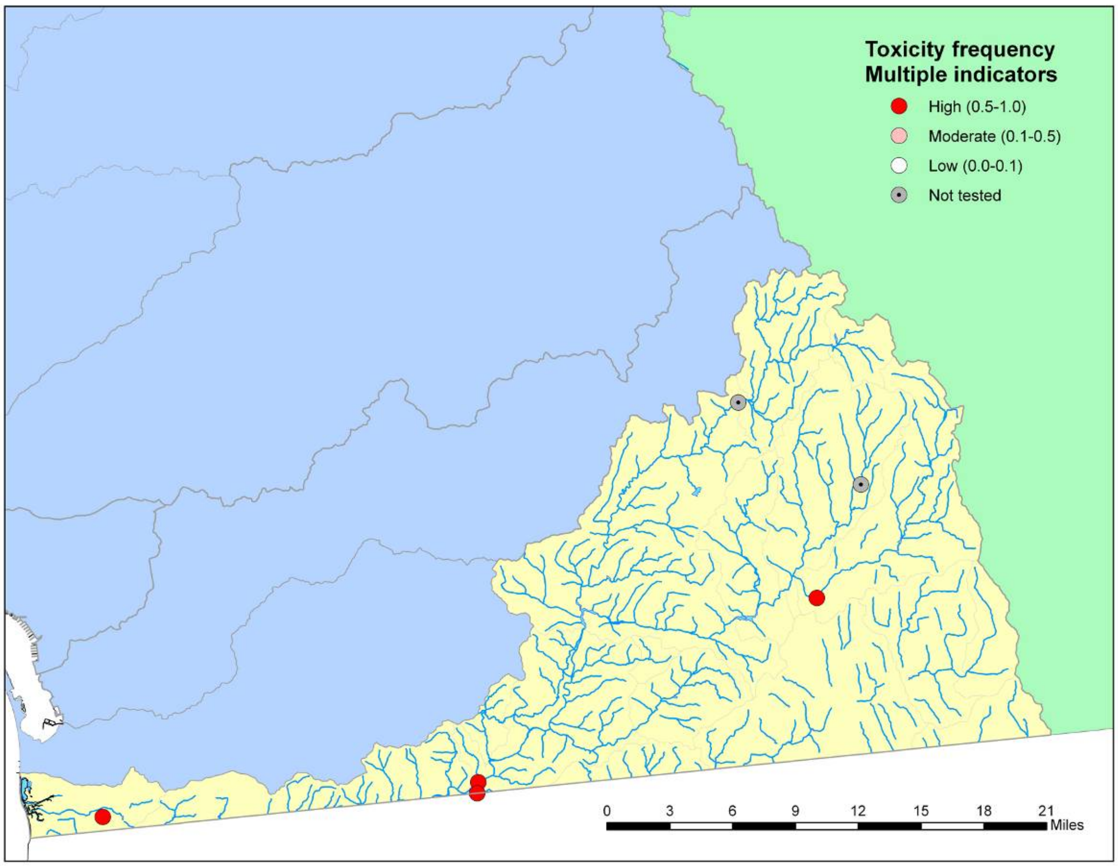


Figure 8. Frequency of toxicity (*C. dubia* fecundity, *H. azteca* growth, and *S. capricornutum* total cell count) at SWAMP sites. White circles indicate low frequency (0.0 to 0.1) of toxicity (this value did not occur in this watershed) . Pink circles indicate moderate frequency (0.1 to 0.5) of toxicity.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

4.3 Tissue

Fish tissues were not analyzed in the Tijuana HU.

4.4 Bioassessment

Biological health ranged from good to very poor at sites in the Tijuana HU. Mean IBI scores ranged from 8.6 at the mainstem of the Tijuana River to a high of 70.0 at Pine Valley Creek (Table 13; Figure 9). Sites in fair or good condition were concentrated in the upper Cottonwood Creek watershed above Morena Reservoir, where all 5 sites assessed had mean IBIs between 40 and 60 (Figure 9). Of the 15 sites where bioassessment samples were collected, samples in poor condition were observed at 8. Samples from 7 sites (i.e., Los Coches Creek (LCC2), Pine Valley Creek (PVC1), and sites 1, 3, 4, 9, and 13) were never in poor or very poor condition.

Although most sites in the northern part of the watershed were in better biological condition, a few sites contrasted with this pattern. For example, site 8 (north Pine Valley Creek) was in poor condition, although samples collected further downstream were in fair condition. In addition, samples from Cottonwood Creek below Morena Lake (site 7), Wilson Creek above Barrett Lake (site 11), and La Posta Creek (LAP04) were also in poor condition, with mean IBIs below 40. However, at two of these sites (i.e., site 7 and La Posta Creek), samples in fair biological condition were sometimes observed.

Some of the metrics that make up the IBI were very sensitive to degradation. For example, some metrics (e.g., % Collectors, EPT Taxa, and % Intolerant) made large contributions to IBI scores at sites in good condition, but small contributions at sites in poor condition. In contrast, other metrics (e.g., Predator Taxa) had a weaker relationship with the overall IBI score (Appendix IV; Figure 10).

Examination of IBI scores over time did not indicate a trend towards improving or deteriorating biological condition (Figure 11). Variability among years was high, which may obscure trends in the data. Seasonal trends were not apparent (Figures 11, 12).

Table 13. Mean and standard deviation of IBI scores at bioassessment sites within the Tijuana 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	Season	n	Years	Mean	SD	Condition	Frequency
911TLAP04	Average	5	2000-2005	30.0	4.0	Poor	0.60
	Fall	2	2000-2005	32.9	10.1	Poor	0.50
	Spring	3	2001-2005	27.1	15.1	Poor	0.67
911TTJR05	Spring	1	2003	8.6		Very poor	1.00
911TJLCC2	Spring	2	2001-2006	58.6	20.2	Fair	--
911TJPVC1	Spring	1	2006	70.0		Good	--
Site 1	Average	6	2000-2005	53.3	2.6	Fair	--
	Fall	1	2000	51.4		Fair	--
	Spring	5	2000-2005	55.1	8.5	Fair	--
Site 2	Average	3	2000-2003	37.1	14.1	Poor	0.67
	Fall	1	2000	47.1		Fair	--
	Spring	2	2001-2003	27.1	14.1	Poor	1.00
Site 3	Spring	1	2001	60.0		Good	--
Site 4	Spring	1	2001	60.0		Good	--
Site 7	Average	2	1999-2001	35.0	23.2	Poor	0.50
	Fall	1	1999	51.4		Fair	--
	Spring	1	2001	18.6		Very poor	1.00
Site 8	Spring	6	2001-2005	38.3	13.3	Poor	0.50
Site 9	Average	5	1999-2005	55.2	5.4	Fair	--
	Fall	3	1999-2005	59.0	12.1	Fair	--
	Spring	2	2000-2001	51.4	16.2	Fair	--
Site 10	Average	5	2000-2005	47.3	16.4	Fair	0.20
	Fall	1	2000	35.7		Poor	1.00
	Spring	4	2000-2005	58.9	8.6	Fair	--
Site 11	Spring	1	2001	32.9		Poor	1.00
Site 12	Average	3	2004-2005	11.1	3.5	Very poor	1.00
	Fall	1	2004	8.6		Very poor	1.00
	Spring	2	2004-2005	13.6	11.1	Very poor	1.00
Site 13	Spring	1	2005	51.4		Fair	--

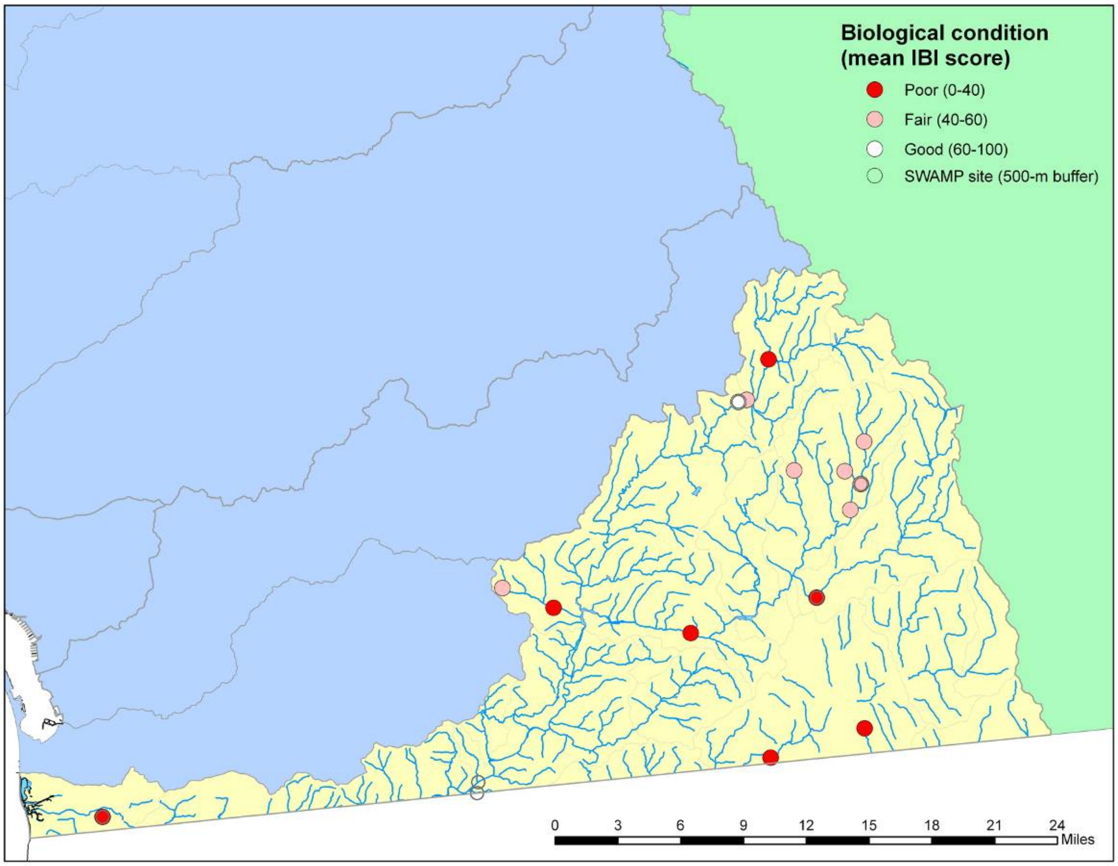


Figure 9. IBI scores at sites in the Tijuana HU. White circles indicate good or very good (60 to 100) IBI scores (this value did not occur in this watershed). Pink circles indicate fair (40 to 60) IBI scores (this value did not occur in this watershed). Red circles indicate poor (0 to 40) IBI scores. Open circles represent 500-m buffers around SWAMP sites; six of these buffers included bioassessment sites, and three of these buffers did not.

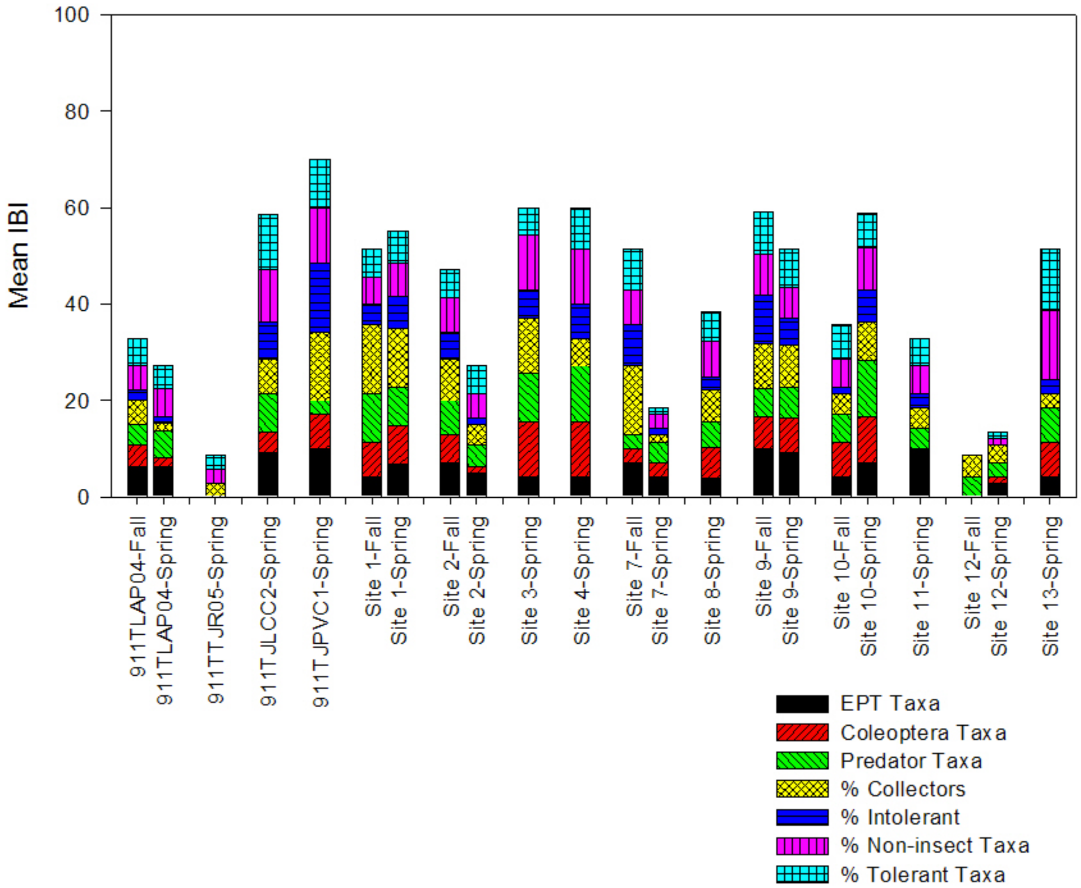


Figure 10. Mean IBI scores at each bioassessment site and each season. The height of the bar indicates the mean IBI score, and the size of each component of the bar represents the contribution of each metric to the IBI.

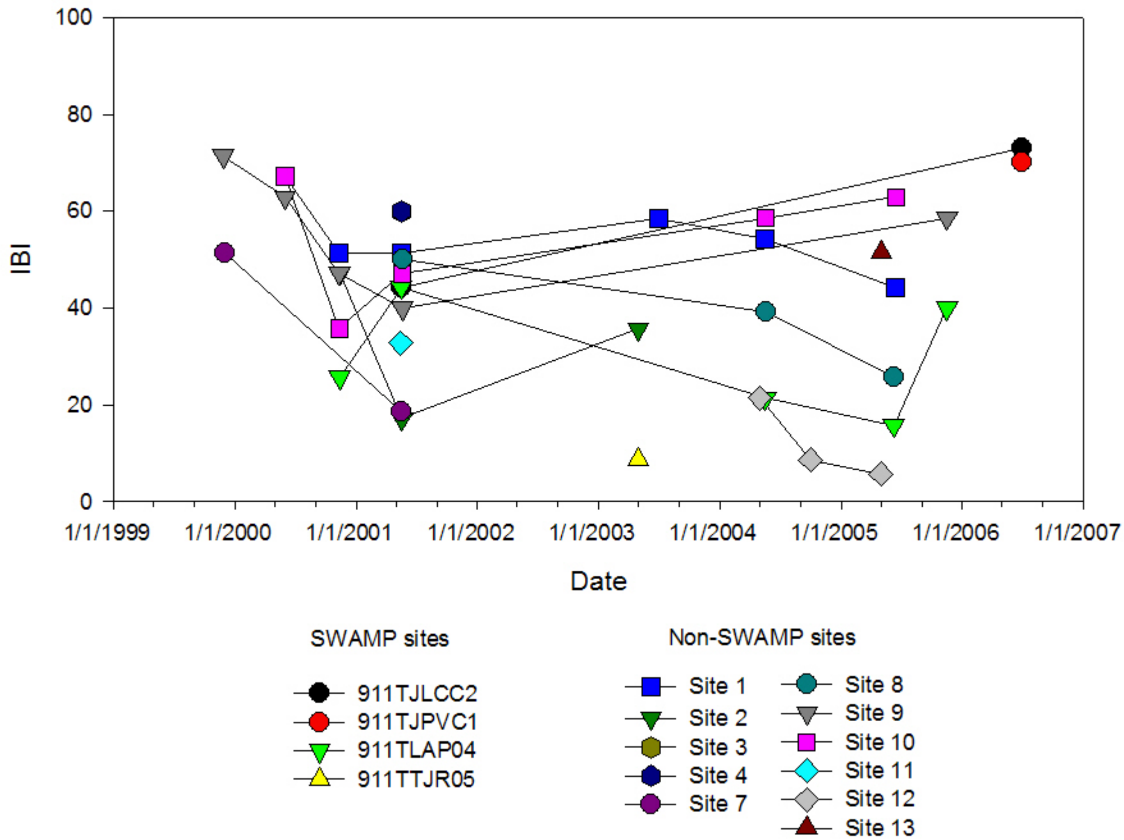


Figure 11. IBI values for each year and site. Each symbol represents a single sample.

4.5 Physical Habitat

Physical habitat was moderately degraded at La Posta Creek, which had a mean physical habitat score of 13.0. However, most components of physical habitat showed minimal signs of degradation (score ≥ 15). Instream cover was sparse, and received a score of 10, indicating moderate degradation. Three components of physical habitat (i.e., embeddedness, velocity-depth regime, and sediment deposition) were severely degraded, with scores below 10, (Table 14; Figure 12).

Table 14. Score and mean for each component of physical habitat at La Posta Creek (LAP04) measured on April 16, 2007. Component range: 0 (heavily impacted habitat) to 20 (unimpacted habitat).

Physical habitat component	Score
1 Epifaunal cover	10
2 Embeddedness	3
3 Velocity-depth regime	9
4 Sediment deposition	5
5 Channel flow	18
6 Channel alteration	19
7 Riffle frequency	16
8 Bank stability	16
9 Vegetation protection	15
10 Riparian zone	19
Mean physical habitat score	13.0

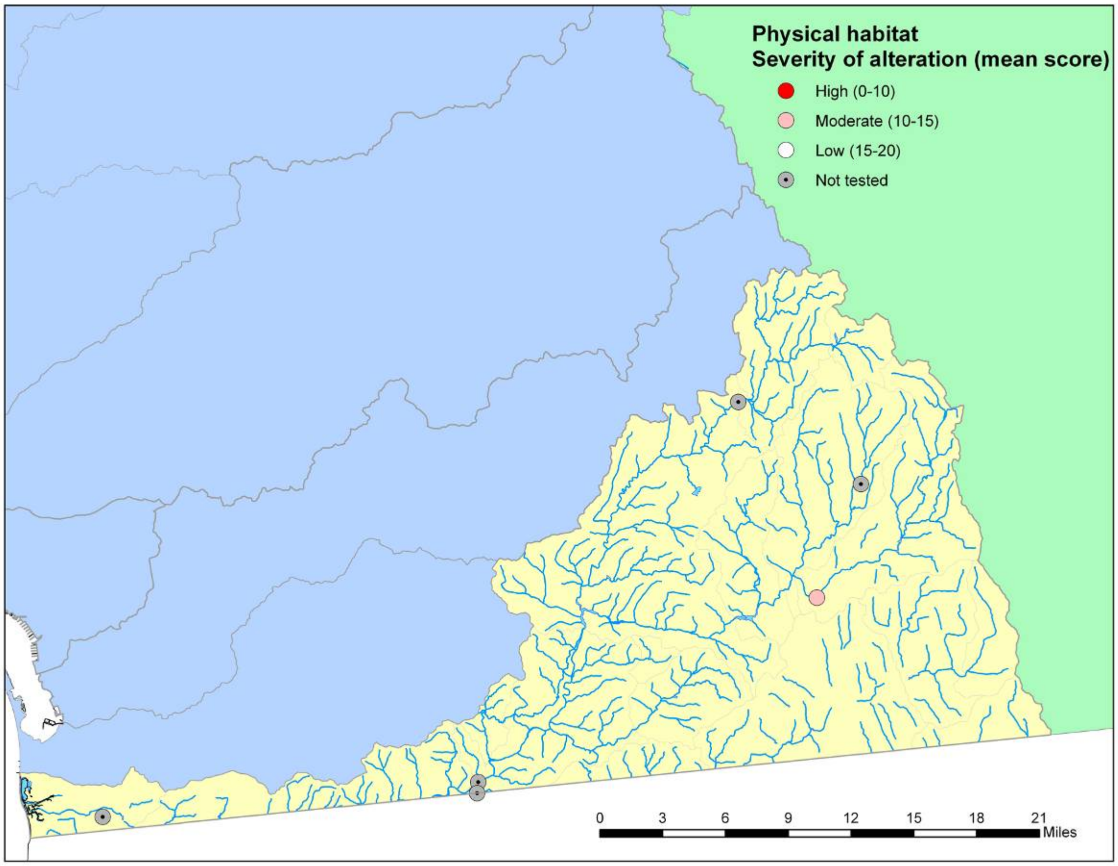


Figure 12. Assessment of physical habitat at SWAMP sites. White circles indicate sites with a mean physical habitat scores between 15 and 20. Pink circles indicate mean scores between 10 and 15. Red circles indicate mean scores between 0 and 10.

5. DISCUSSION

Every site sampled in the Tijuana HU showed evidence of impact from multiple indicators, although impacts at individual sites ranged from moderate to severe (Table 15; Figure 13). Most indicators suggest that sites downstream of the Mexican border (i.e., the Tijuana River mainstem and Tecate Creek) were more severely degraded than streams entirely within the United States. Sites in the northern interior parts of the watershed (such as Cottonwood, Pine Valley, and La Posta Creeks), were much less impacted.

Almost every indicator suggested that the mainstem site on the Tijuana River (TJR05) was the most severely degraded site in the HU. Water quality was heavily impacted at TJR05. Many anthropogenic organic constituents were detected in water samples from this site, including nearly every PAH. Seven constituents exceeded aquatic life standards, and seven exceeded human health standards. Aquatic life exceedances were observed for several nutrients, selenium, copper, benzo(a)pyrene, pH, and specific conductivity. Human health exceedances were observed for a number of PAHs. However, the number of potentially problematic constituents may be underestimated because many of the constituents detected at this site had no applicable thresholds. Toxicity was severe, as all samples caused lethal or sub-lethal responses from multiple indicators. Bioassessment samples collected near TJR05 were in very poor ecological condition and had the lowest mean IBI score (i.e., 8.6) in the entire HU. Although multiple sources may account for the severe degradation observed at the lower mainstem of the Tijuana River, the high number of PAHs, as well as elevated specific conductivity, are consistent with pollution caused by industrial discharges and urban runoff (Institute for Regional Studies of the Californias 2005). However, other sources of impacts, such as physical habitat alteration, were not assessed.

Tecate Creek was also severely degraded. Like the mainstem of the Tijuana River, Tecate Creek's watershed is mostly within Mexico. Similarly, the same suite of water chemistry constituents exceeded aquatic life thresholds in Tecate Creek, and a high number of PAHs and pesticides were detected. However, no human health thresholds were exceeded. Nutrients, selenium, manganese, dissolved oxygen, conductivity, and turbidity accounted for the exceedances of aquatic life thresholds. Toxicity at Tecate Creek was severe, and all samples caused lethal or sub-lethal toxicity to multiple indicators. Unlike the Tijuana River mainstem, agricultural activities are common in the Tecate Creek watershed, and industrial activities are less intense. This difference in land use may account for the higher number of pesticides (5 vs. 3) and lower number of PAHs (26 vs. 45) detected in Tecate Creek water samples.

The remaining sites included in the study occurred on sites draining watersheds exclusively within the United States, and impacts at these sites were less severe than Tijuana River or Tecate Creek. For example, the water samples from site at the bottom of the Cottonwood Creek watershed (CWD10) exceeded fewer aquatic life thresholds, and no human health thresholds. Nutrients, selenium, manganese, and pH accounted for the exceedances of aquatic life thresholds. Toxicity was less severe than at Tecate Creek or the Tijuana River mainstem, as sediment samples did not increase mortality in *H. azteca*. Although no bioassessment samples were collected near the SWAMP site on Cottonwood Creek, samples collected several kilometers up in the watershed above Morena Lake were frequently in fair or good condition.

The site on La Posta Creek (LAP04), a tributary of Cottonwood Creek, was in better ecological health than the other sites sampled under SWAMP. Only three water chemistry constituents (i.e., ammonia-N, total N, and dissolved oxygen) exceeded aquatic life thresholds, and these exceedances were observed on only one sampling date. Although all water and sediment samples were toxic to two indicator species (i.e., *H. azteca* and *S. capricornutum*), water samples did not affect a third species (*C. dubia*). However, bioassessment samples were frequently in poor condition (mean IBI 30.0), and an assessment of physical habitat suggested impacts to a few components of physical habitat (e.g., embeddedness and sediment deposition). Reconnaissance by San Diego Water Board staff observed intense grazing activity at this site (Lillian Busse, personal communication), which may account for the observed poor biological health and degradations to physical habitat (Braccia and Voshell 2007).

Other sites sampled under SWAMP were also located in the northern interior of the HU. Although only one indicator of ecological health was assessed (i.e., biological integrity), samples collected from these sites (Los Coches Creek 2 and Pine Valley Creek 1) were both in fair or good condition. Most bioassessment samples collected at other sites in this portion of the HU were also in fair or better condition. The healthy biological communities observed at Pine Valley Creek are not consistent with the inclusion of this stream on the 303(d) list of impaired waterbodies. However, listed stressors at Pine Valley Creek (i.e., *Enterococcus* bacteria, phosphorus, and turbidity) were not assessed in this study.

This study's assessment of the Tijuana HU suggests that portions of the watershed are in poor ecological health, but the northern interior is in fair or good health. Multiple lines of evidence support this conclusion. For water chemistry, toxicity, and macroinvertebrate communities were in poor or very poor condition at the bottom of watersheds draining lands from Mexico, while all indicators were in better condition at sites in the northern interior of the HU.

Although these impacts affected all sites, this study showed that, at least for water chemistry indicators, impacts were limited to certain constituents, such as nutrients and physical parameters. In contrast, metals (except manganese and copper) were below applicable thresholds at every site, as were nearly all pesticides. Human health impacts were restricted to the mainstem site of the Tijuana River, and these impacts were observed on a single sampling date.

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, unequal assessment effort at all sites, 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 Tijuana HU is in poor condition near the Mexican border, and in better condition in the northern parts of the watershed, 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 6 years before water chemistry and toxicity 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. Although SWAMP has produced a wealth of data about the Tijuana watershed using limited resources, some indicators (especially those with high variability) may require more extensive sampling to produce more precise and accurate assessments.

Although coverage was extensive in some regions, such as the upper Cottonwood Creek watershed, sites were more sparse in other regions, such as Campo Creek, Pine Valley Creek, and the upper portions of the Río Seco (in the southeastern portion of the HU). The lack of data from Mexican portions of the watershed make it difficult to assess causes of impacts to sites receiving water across the national border, such as Tecate Creek and the lower mainstem of the Tijuana River.

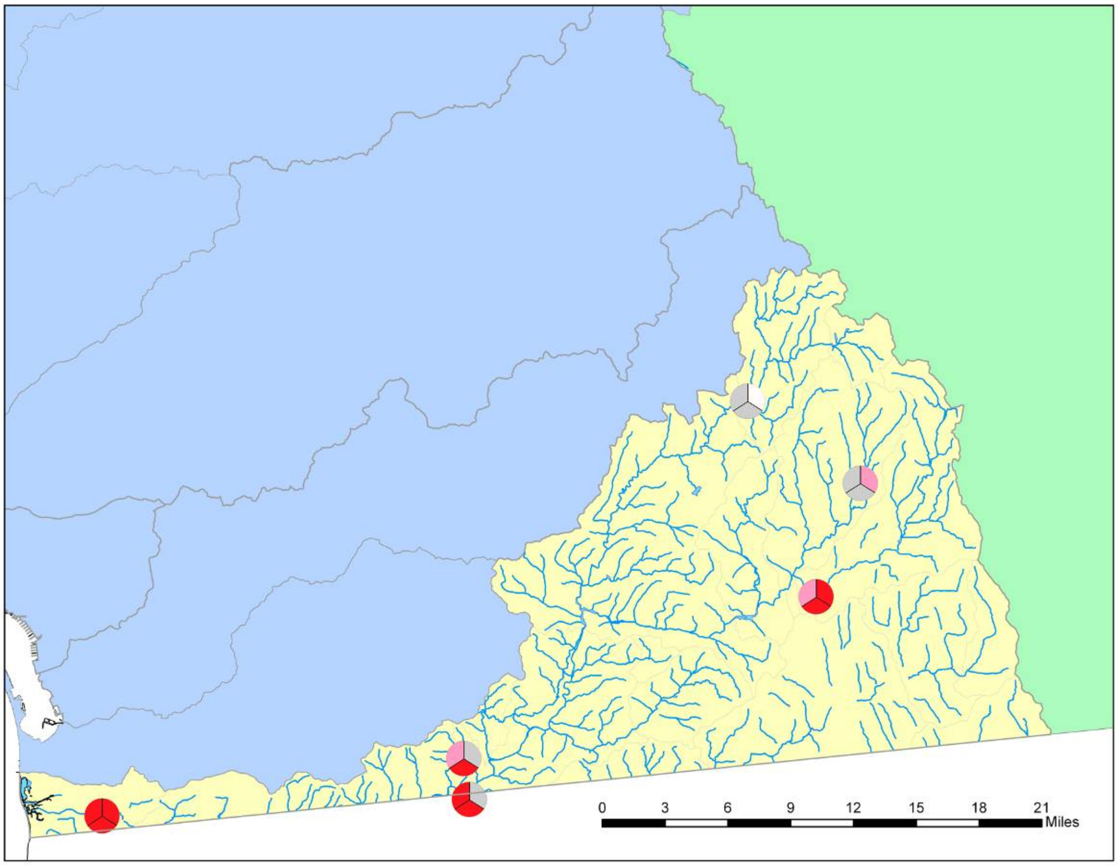
Thresholds are an essential tool for assessing water quality and ecological health. However, their use is limited to indicators that have been well studied, and they cannot provide a holistic view of watershed health. This limitation is exacerbated by the many constituents and indicators that lack applicable thresholds. For example, of the 155 water chemistry constituents, 93 (60%) 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).

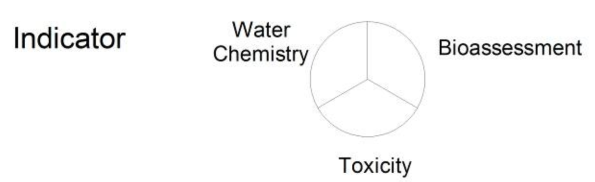
Despite these limitations, the data gathered under SWAMP and other programs strongly support the conclusion that portions of the Tijuana HU are in poor ecological health, and others are in good health. Some of these limitations (such as the lack of applicable thresholds and the small sample size) may 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 are the likely cause of the impact. Future research (see final report on the SWAMP monitoring program for further study recommendations) is necessary to determine which stressors are responsible for the impacts seen in the watershed.

Table 15. Summary of the ecological health for five SWAMP sites in Tijuana HU. 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. nt = Indicator not tested.

	Water chemistry		Toxicity	Biology*	Physical habitat
	Aquatic life	Human health			
Site	# exceedances	# exceedances	Frequency	Frequency	Mean score
911TCWD10	5	0	1.00	nt	nt
911TLAP04	3	0	0.80	0.60	13
911TTET02	7	0	1.00	nt	nt
911TTJR05	7	7	1.00	1.00	nt
911TJLCC2	nt	nt	nt	--	nt
911TJPVC1	nt	nt	nt	--	nt

* = Estimated from data collected at nearby (within 500 meters) non-SWAMP sites





Severity of impact

Severity	Water chemistry (# aquatic life exceedences)	Toxicity (Frequency of toxicity)	Bioassessment (IBI Score)
Low	0-1	0.0-0.1	60-100
Moderate	2-5	0.1-0.5	40-60
High	6+	0.5-1.0	0-40
Not tested			

Figure 13. Summary of the ecological health of SWAMP sites in the Tijuana 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.

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7. APPENDICES

APPENDIX I

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

A. Beneficial uses of streams in the Tijuana HU.

Tijuana River	HUC	MUN	AGR	IND	PROC	FRSH	REC1	REC2	BIOL	WARM	COLD	WILD	RARE	SPWN
Tijuana River	911.11	X					P	E		E		E	E	
Moody Canyon	911.11	X					P	E		E		E		
Smugglers Gulch	911.11	X					P	E		E		E		
Goat Canyon	911.11	X	E	P			P	E		E		E		
Spring Canyon	911.12	X	E	P			P	E		E		E		
Dillon Canyon	911.12	X	E	P			P	E		E		E		
Finger Canyon	911.12	X	E	P			P	E		E		E		
Wruck Canyon	911.12	X	E	P			P	E		E		E		
Unnamed intermittent streams	911.12	X	E	P			P	E		E		E		
Unnamed intermittent streams	911.21	X					E	E		E		E		
Tijuana River	911.21	X					E	E		E		E		
Tecate Creek	911.23	X					E	E		E		E		
Cottonwood Creek	911.60	E	E	E	E	E	P	E		E	E	E	E	
Kitchen Creek	911.60	E	E	E	E	E	P	E		E	E	E		E
Long Canyon	911.60	E	E	E	E	E	P	E		E	E	E		E
Troy Canyon	911.60	E	E	E	E	E	P	E		E	E	E		E
Fred Canyon	911.60	E	E	E	E	E	P	E		E	E	E		
Horse Canyon	911.60	E	E	E	E	E	P	E		E	E	E		
La Posta Creek	911.70	E	E	E	E	E	E	E		E	E	E		
Simmons Canyon	911.70	E	E	E	E	E	E	E		E	E	E		
La Posta Creek	911.60	E	E	E	E	E	P	E		E	E	E		
Morena Creek	911.50	E	E	E	E	E	E	E		E	E	E		E
Long Valley	911.50	E	E	E	E	E	E	E		E	E	E		
Bear Valley	911.50	E	E	E	E	E	E	E		E		E		
Cottonwood Creek	911.30	E	E	E	E	E	E	E		E	E	E	E	E
Hauser Creek	911.30	E	E	E	E	E	E	E		E	E	E		E
Salazar Creek	911.30	E	E	E	E	E	E	E		E	E	E		
Boneyard Canyon	911.30	E	E	E	E	E	E	E		E	E	E		
Skye Valley	911.30	E	E	E	E	E	E	E		E	E	E		
Pine Valley Creek	911.41	E	E	E	E	E	E	E		E	E	E		E
Indian Creek	911.41	E	E	E	E	E	E	E		E	E	E		
Lucas Creek	911.41	E	E	E	E	E	E	E		E	E	E		
Noble Canyon	911.41	E	E	E	E	E	E	E		E	E	E		E
Los Rasalies Ravine	911.42	E	E	E	E	E	E	E		E	E	E		
Paloma Ravine	911.42	E	E	E	E	E	E	E		E	E	E		
Bonita Ravine	911.42	E	E	E	E	E	E	E		E	E	E		
Chico Ravine	911.42	E	E	E	E	E	E	E		E	E	E		
Madero Ravine	911.42	E	E	E	E	E	E	E		E	E	E		
Los Gatos Ravine	911.42	E	E	E	E	E	E	E		E	E	E		
Boiling Spring Ravine	911.42	E	E	E	E	E	E	E		E	E	E		
Agua Dulce Creek	911.42	E	E	E	E	E	E	E		E	E	E		
Escondido Ravine	911.42	E	E	E	E	E	E	E		E	E	E		
Scove Canyon	911.41	E	E	E	E	E	E	E		E	E	E		
Pine Valley Creek	911.30	E	E	E	E	E	E	E		E	E	E		E
Oak Valley	911.30	E	E	E	E	E	E	E		E	E	E		E
Nelson Canyon	911.30	E	E	E	E	E	E	E		E	E	E		
Secret Canyon	911.30	E	E	E	E	E	E	E		E	E	E		
Horsethief Canyon	911.30	E	E	E	E	E	E	E		E	E	E		
Espinosa Creek	911.30	E	E	E	E	E	E	E		E	E	E		

Appendix I, continued.

A. Beneficial uses in the Tijuana HU.

Tijuana River	HUC	MUN	AGR	IND	PROC	FRSH	REC1	REC2	BIOL	WARM	COLD	WILD	RARE	SPWN
Wilson Creek	911.30	E	E	E	E	E	E	E		E	E	E		
Pats Canyon	911.30	E	E	E	E	E	E	E		E	E	E		E
Cottonwood Creek	911.23	X					E	E		E		E		
Dry Valley	911.23	X					E	E		E		E		
BobOwens Canyon	911.23	X					E	E		E		E		
McAlmond Canyon	911.24	X					E	E		E		E		
McAlmond Canyon	911.23	X					E	E		E		E		
Rattlesnake Canyon	911.23	X					E	E		E		E		
Potrero Creek	911.25	X					E	E		E		E		
Little Potrero Creek	911.25	X					E	E		E		E		
Potrero Creek	911.23	X					E	E		E		E		
Grapevine Creek	911.23	X					E	E		E		E		
Bee Canyon	911.22	X					E	E		E		E		
Bee Creek	911.23	X					E	E		E		E		
Mine Canyon	911.21	X					E	E		E		E		
Unnamed intermittent streams	911.81	X					E	E		E		E		

B. 303(d)-listed streams in the Tijuana HU.

Name	HUC	Stressor	Source	Area affected
Pine Valley Creek (upper)	911.41	Enterococcus	Grazing-related sources	2.9 miles
			Concentrated animal feeding operations	
			Transient encampments	
		Phosphorus	Source unknown	2.9 miles
		Turbidity	Source unknown	2.9 miles
Tijuana River	911.11	Eutrophic	Nonpoint/point source	6 miles
		Indicator bacteria	Nonpoint/point source	6 miles
		Low dissolved oxygen	Nonpoint/point source	6 miles
		Pesticides	Nonpoint/point source	6 miles
		Solids	Nonpoint/point source	6 miles
		Synthetic organics	Nonpoint/point source	6 miles
		Trace elements	Nonpoint/point source	6 miles
		Trash	Nonpoint/point source	6 miles

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.

			911TCWD10			911TLAP04			911TTET02			911TTJR05		
Type	Constituent	Unit	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Inorganics	Alkalinity as CaCO3	mg/L	203	6	2	295	24	4	605	20	4	397	64	2
Inorganics	Ammonia as	mg/L	0.05	0.00	2	0.01	0.03	4	27.4	18.5	4	13.2	14.5	2
Inorganics	Nitrate as NO3	mg/L	0.40	0.57	2	0.34	0.39	4	0.01	0.01	4	0.01	0.01	2
Inorganics	Nitrite as N	mg/L	0.010	0.014	2	0.002	0.004	4	0.153	0.151	4	0.006	0.003	2
Inorganics	Nitrogen, Total Kjeldahl	mg/L	0.8	0.1	2	0.3	0.1	4	25.3	7.0	4	26.0	24.9	2
Inorganics	Phosphorus as P,Total	mg/L	0.14	0.12	2	0.08	0.01	4	6.66	0.83	4	6.26	4.94	2
Inorganics	Selenium,Dissolved	µg/L	6.9	0.9	2	2.2	1.5	4	10.5	3.9	4	11.0	1.6	2
Inorganics	Sulfate	mg/L	113	41	2	64	11	4	329	19	4	309	106	2
Metals	Aluminum,Dissolved	µg/L	0.3	0.5	2	2.5	3.1	4	9.8	3.9	4	9.4	4.2	2
Metals	Arsenic,Dissolved	µg/L	1.0	0.3	2	1.7	0.5	4	5.6	0.9	4	6.8	1.8	2
Metals	Cadmium,Dissolved	µg/L	0.03	0.01	2	0.07	0.02	4	0.07	0.05	4	0.06	0.04	2
Metals	Chromium,Dissolved	µg/L	1.0	0.4	2	1.3	1.8	4	5.3	3.8	4	1.8	0.6	2
Metals	Copper,Dissolved	µg/L	3.0	2.4	2	1.2	0.5	4	5.5	2.1	4	14.6	12.6	2
Metals	Lead,Dissolved	µg/L	0.2	0.3	2	0.1	0.2	4	0.2	0.1	4	0.7	0.3	2
Metals	Manganese,Dissolved	µg/L	51	50	2	30	11	4	499	80	4	318	157	2
Metals	Nickel,Dissolved	µg/L	0.045	0.064	2	--	0.000	4	23.075	5.305	4	8.765	1.110	2
Metals	Silver,Dissolved	µg/L	--	0.00	2	--	0.00	4	0.03	0.02	4	0.08	0.08	2
Metals	Zinc,Dissolved	µg/L	1.0	0.2	2	0.5	0.1	4	5.7	1.8	4	13.9	14.2	2
PAHs	Acenaphthene	µg/L	--	0	2	--	0	4	--	0	4	0.0065	0.0091	2
PAHs	Acenaphthylene	µg/L	--	0	2	--	0	4	--	0	4	0.0078	0.0110	2
PAHs	Anthracene	µg/L	--	0	2	--	0	4	--	0	4	0.0088	0.0002	2
PAHs	Benz(a)anthracene	µg/L	--	0	2	--	0	4	--	0	4	0.0204	0.0288	2
PAHs	Benzo(a)pyrene	µg/L	--	0	2	--	0	4	--	0	4	0.0399	0.0564	2
PAHs	Benzo(b)fluoranthene	µg/L	--	0	2	--	0	4	--	0	4	0.0525	0.0742	2
PAHs	Benzo(e)pyrene	µg/L	--	0	2	--	0	4	--	0	4	0.0730	0.1032	2
PAHs	Benzo(g,h,i)perylene	µg/L	--	0	2	--	0	4	--	0	4	0.0825	0.1167	2
PAHs	Benzo(k)fluoranthene	µg/L	--	0	2	--	0	4	--	0	4	0.0167	0.0235	2
PAHs	Biphenyl	µg/L	--	0	2	--	0	4	0.0074	0.0058	4	0.0286	0.0404	2
PAHs	Chrysene	µg/L	--	0	2	--	0	4	--	0	4	0.0580	0.0820	2
PAHs	Chrysenes, C1 -	µg/L	--	0	2	--	0	4	--	0	4	0.1135	0.1605	2
PAHs	Chrysenes, C2 -	µg/L	--	0	2	--	0	4	0.0048	0.0095	4	0.1365	0.1930	2
PAHs	Chrysenes, C3 -	µg/L	--	0	2	--	0	4	--	0	4	0.1400	0.1980	2
PAHs	Dibenz(a,h)anthracene	µg/L	--	0	2	--	0	4	--	0	4	0.0102	0.0144	2
PAHs	Dibenzothiophene	µg/L	--	0	2	--	0	4	0.0020	0.0040	4	0.0169	0.0238	2
PAHs	Dibenzothiophenes, C1 -	µg/L	--	0	2	--	0	4	0.0280	0.0106	4	0.1547	0.1970	2
PAHs	Dibenzothiophenes, C2 -	µg/L	--	0	2	--	0	4	0.0462	0.0173	4	0.4808	0.6679	2
PAHs	Dibenzothiophenes, C3 -	µg/L	--	0	2	--	0	4	0.0354	0.0173	4	0.4630	0.6548	2
PAHs	Dichlofenthion	µg/L	--	0	2	--	0	4	--	0	4	--	0.0000	2
PAHs	Dimethylnaphthalene, 2,6-	µg/L	--	0	2	--	0	4	0.0110	0.0150	4	0.1622	0.1681	2
PAHs	Dimethylphenanthrene, 3,6-	µg/L	--	0	2	--	0	4	0.0043	0.0086	4	0.0755	0.1068	2
PAHs	Fluoranthene	µg/L	--	0	2	--	0	4	0.0180	0.0048	4	0.1260	0.1782	2
PAHs	Fluoranthene/Pyrenes, C1 -	µg/L	--	0	2	--	0	4	0.0207	0.0178	4	0.3110	0.4398	2
PAHs	Fluorene	µg/L	--	0	2	--	0	4	0.0029	0.0058	4	0.0386	0.0546	2
PAHs	Fluorenes, C1 -	µg/L	--	0	2	--	0	4	0.0249	0.0189	4	0.2125	0.3005	2
PAHs	Fluorenes, C2 -	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PAHs	Fluorenes, C3 -	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PAHs	Indeno(1,2,3-c,d)pyrene	µg/L	--	0	2	--	0	4	--	0	4	0.0272	0.0385	2
PAHs	Methyldibenzothiophene, 4-	µg/L	--	0	2	--	0	4	0.0097	0.0041	4	0.0560	0.0792	2
PAHs	Methylfluoranthene, 2-	µg/L	--	0	2	--	0	4	--	0	4	0.0354	0.0500	2
PAHs	Methylfluorene, 1-	µg/L	--	0	2	--	0	4	0.0110	0.0070	4	0.0775	0.1096	2
PAHs	Methylnaphthalene, 1-	µg/L	--	0	2	--	0	4	--	0	4	0.0589	0.0736	2
PAHs	Methylnaphthalene, 2-	µg/L	--	0	2	--	0	4	--	0	4	0.0885	0.1252	2
PAHs	Methylphenanthrene, 1-	µg/L	--	0	2	--	0	4	0.0087	0.0037	4	0.0505	0.0714	2
PAHs	Naphthalene	µg/L	--	0	2	--	0	4	--	0	4	0.0590	0.0834	2
PAHs	Naphthalenes, C1 -	µg/L	--	0	2	--	0	4	0.0025	0.0051	4	0.1542	0.1978	2
PAHs	Naphthalenes, C2 -	µg/L	--	0	2	--	0	4	0.0211	0.0212	4	0.4582	0.5428	2
PAHs	Naphthalenes, C3 -	µg/L	--	0	2	--	0	4	0.0840	0.0867	4	0.7626	1.0428	2
PAHs	Naphthalenes, C4 -	µg/L	--	0	2	--	0	4	0.0325	0.0497	4	0.2274	0.2709	2

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

			911TCWD10			911TLAP04			911TTET02			911TTJR05		
Type	Constituent	Unit	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
PAHs	Perylene	µg/L	--	0	2	--	0	4	--	0	4	0.0155	0.0219	2
PAHs	Phenanthrene	µg/L	--	0	2	--	0	4	0.0272	0.0114	4	0.1005	0.1421	2
PAHs	Phenanthrene/Anthracene, C1 -	µg/L	--	0	2	--	0	4	0.0694	0.0359	4	0.2765	0.3910	2
PAHs	Phenanthrene/Anthracene, C2 -	µg/L	--	0	2	--	0	4	0.0866	0.0601	4	0.7700	1.0889	2
PAHs	Phenanthrene/Anthracene, C3 -	µg/L	--	0	2	--	0	4	0.0250	0.0180	4	0.6050	0.8556	2
PAHs	Phenanthrene/Anthracene, C4 -	µg/L	--	0	2	--	0	4	0.0044	0.0088	4	0.1580	0.2234	2
PAHs	Pyrene	µg/L	--	0	2	--	0	4	0.0162	0.0067	4	0.1250	0.1768	2
PAHs	Trimethylnaphthalene, 2,3,5-	µg/L	--	0	2	--	0	4	0.0233	0.0163	4	0.0700	0.0990	2
PCBs	PCB 005	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 008	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 015	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 018	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 027	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 028	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 029	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 031	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 033	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 044	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 049	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 052	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 056	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 060	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 066	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 070	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 074	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 087	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 095	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 097	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 099	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 101	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 105	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 110	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 114	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 118	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 128	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 137	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 138	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 141	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 149	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 151	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 153	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 156	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 157	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 158	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 170	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 174	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 177	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 180	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 183	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 187	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 189	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 194	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 195	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 200	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 201	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 203	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 206	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
PCBs	PCB 209	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Aldrin	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Aspon	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Azinphos ethyl	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Azinphos methyl	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Bolstar	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Carbophenothion	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Chlordane, cis-	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Chlordane, trans-	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Chlordene, alpha-	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Chlordene, gamma-	µg/L	--	0	2	--	0	4	--	0	4	--	0	2

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

			911TCWD10			911TLAP04			911TTET02			911TTJR05		
Type	Constituent	Unit	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Pesticides	Chlorfenvinphos	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Chlorpyrifos	µg/L	--	0	2	--	0	4	--	0.006	4	--	0	2
Pesticides	Chlorpyrifos methyl	µg/L	--	0	2	--	0	4	--	0.012	4	--	0	2
Pesticides	Ciodrin	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Coumaphos	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Dacthal	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	DDD(o,p')	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	DDD(p,p')	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	DDE(o,p')	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	DDE(p,p')	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	DDMU(p,p')	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	DDT(o,p')	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	DDT(p,p')	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Demeton-s	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Diazinon	µg/L	0.0050	0.0071	2	0.0078	0.0100	4	0.0245	0.0193	4	0.0320	0.0453	2
Pesticides	Dichlorvos	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Dicrotophos	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Dieldrin	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Dimethoate	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Dioxathion	µg/L	--	0	2	--	0	4	0.2290	0.3787	4	0.1220	0.1725	2
Pesticides	Disulfoton	µg/L	--	0	2	--	0	4	0.0153	0.0305	4	0.0665	0.0940	2
Pesticides	Endosulfan I	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Endosulfan II	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Endosulfan sulfate	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Endrin Aldehyde	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Endrin Ketone	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Endrin	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Ethion	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Ethoprop	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Famphur	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Fenchlorphos	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Fenitrothion	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Fensulfothion	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Fenthion	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Fonofos	µg/L	--	0	2	--	0	4	0.0135	0.0270	4	--	0	2
Pesticides	HCH, alpha	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	HCH, beta	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	HCH, delta	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	HCH, gamma	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Heptachlor epoxide	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Heptachlor	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Hexachlorobenzene	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Leptophos	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Malathion	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Merphos	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Methidathion	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Methoxychlor	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Mevinphos	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Mirex	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Molinate	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Naled	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Nonachlor, cis-	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Nonachlor, trans-	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Oxadiazon	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Oxychlordane	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Parathion, Ethyl	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Parathion, Methyl	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Phorate	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Phosmet	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Phosphamidon	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Sulfotep	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Tedion	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Terbufos	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Tetrachlorvinphos	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Thiobencarb	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Thionazin	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Tokuthion	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Pesticides	Trichlorfon	µg/L	--	0	2	--	0	4	--	0	4	--	0	2

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

			911TCWD10			911TLAP04			911TTET02			911TTJR05		
Type	Constituent	Unit	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Pesticides	Trichloronate	µg/L	--	0	2	--	0	4	--	0	4	--	0	2
Physical	Oxygen, Dissolved	mg/L	11.2	8.7	2	8.0	2.3	4	5.0	2.2	4	12.5	1.7	2
Physical	Oxygen, Saturation	%	125	98	2	74	16	4	58	22	4	150	48	2
Physical	pH	pH units	7.9	0.7	2	7.4	0.5	4	7.7	0.3	4	9.1	0.5	2
Physical	Salinity	ppt	0.7	0.1	2	0.4	0.0	4	1.3	0.1	4	0.5	0.7	2
Physical	Specific conductivity	µS/cm	1307	187	2	782	58	4	2465	178	4	1090	1520	2
Physical	Suspended Solids,Total	mg/L	5.4	7.7	2	0.4	0.8	4	52.1	22.8	4	105.6	96.3	2
Physical	Temperature	ºC	20.5	0.7	2	12.4	4.1	4	23.5	5.1	4	23.8	9.9	2
Physical	Turbidity	NTU	3.1	2.6	2	0.6	0.6	4	19.1	9.8	4	31.4	4.7	2
Physical	Velocity	ft/sec			0	1.5	1.8	2	2.4	0	3			0

B. Non-SWAMP sites.

	Dissolved oxygen (mg/L)			pH			Specific conductivity (mS/cm)			Turbidity (NTU)			Temperature (ºC)		
Station	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n
Site 2 (CC-H94)	1.5		1	7.3		1	2.28		1	7.6		1	17.4		1
Site 11 (REF-WC)	19.1		1	8.1		1	0.36		1			0	17.9		1
Site 12 (CC-C)	9.1	7.7	3	7.4	0.2	3	1.02	0.15	3			0	14.6	1.8	3
Site 14 (TJ-DM)	6.5	3.0	2	7.5	0.7	2	2.39	1.14	2	56.2		1	18.7	1.2	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*		
	Sampling	Survival			Young / Female			Survival			Growth			Total cell count		
Site	events	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD
911TCWD10	1	0			0			1	122		1	95		0		
911TLAP04	4	1	105		1	103		3	104	12	3	139	19	1	120	
911TTET02	2	0			0			2	17	21	1	108		1	9	
911TTJR05	2	0			0			2	15	13	2	102	12	0		
All sites in watershed	9	1	105		1	103		8	62	51	7	118	24	2	64	79

APPENDIX IV

Mean IBI and metric scores for bioassessment sites in the Tijuana 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
911TLAP04	Average	5	2000-2005	30.0	4.0	4.4	0.1	2.2	1.2	3.5	0.7	2.3	1.8	1.3	0.4	3.8	0.4	3.7	0.5
	Fall	2	2000-2005	32.9	10.1	4.5	0.7	3.0	1.4	3.0	0.0	3.5	2.1	1.5	0.7	3.5	0.7	4.0	1.4
	Spring	3	2001-2005	27.1	15.1	4.3	1.5	1.3	2.3	4.0	3.6	1.0	1.0	1.0	0.0	4.0	1.0	3.3	2.3
911TTJR05	Spring	1	2003	8.6		0.0		0.0		0.0		2.0		0.0		2.0		2.0	
911TJLCC2	Spring	2	2001-2006	58.6	20.2	6.5	3.5	3.0	1.4	5.5	4.9	5.0	4.2	5.5	2.1	7.5	0.7	8.0	1.4
911TJPVC1	Spring	1	2006	70.0		7.0		5.0		2.0		10.0		10.0		8.0		7.0	
Site 1	Average	6	2000-2005	53.3	2.6	3.9	1.3	5.3	0.4	6.3	1.0	9.2	1.1	3.9	1.3	4.4	0.6	4.3	0.4
	Fall	1	2000	51.4		3.0		5.0		7.0		10.0		3.0		4.0		4.0	
	Spring	5	2000-2005	55.1	8.5	4.8	0.8	5.6	3.8	5.6	3.2	8.4	2.2	4.8	4.8	4.8	0.8	4.6	1.5
Site 2	Average	3	2000-2003	37.1	14.1	4.3	1.1	2.5	2.1	4.0	1.4	4.5	2.1	2.5	2.1	4.3	1.1	4.0	0.0
	Fall	1	2000	47.1		5.0		4.0		5.0		6.0		4.0		5.0		4.0	
	Spring	2	2001-2003	27.1	14.1	3.5	0.7	1.0	1.4	3.0	1.4	3.0	1.4	1.0	0.0	3.5	3.5	4.0	2.8
Site 3	Spring	1	2001	60.0		3.0		8.0		7.0		8.0		4.0		8.0		4.0	
Site 4	Spring	1	2001	60.0		3.0		8.0		8.0		4.0		5.0		8.0		6.0	
Site 7	Average	2	1999-2001	35.0	23.2	4.0	1.4	2.0	0.0	2.5	0.7	5.5	6.4	3.5	3.5	3.5	2.1	3.5	3.5
	Fall	1	1999	51.4		5.0		2.0		2.0		10.0		6.0		5.0		6.0	
	Spring	1	2001	18.6		3.0		2.0		3.0		1.0		1.0		2.0		1.0	
Site 8	Spring	6	2001-2005	38.3	13.3	2.8	1.6	4.3	2.9	3.7	2.4	4.7	3.5	2.0	3.0	5.2	1.3	4.2	1.6
Site 9	Average	5	1999-2005	55.2	5.4	6.8	0.4	4.8	0.2	4.3	0.4	6.3	0.5	5.5	2.1	5.3	1.1	5.8	0.4
	Fall	3	1999-2005	59.0	12.1	7.0	2.0	4.7	0.6	4.0	3.5	6.7	3.5	7.0	4.4	6.0	1.7	6.0	1.7
	Spring	2	2000-2001	51.4	16.2	6.5	0.7	5.0	0.0	4.5	2.1	6.0	5.7	4.0	2.8	4.5	0.7	5.5	0.7
Site 10	Average	5	2000-2005	47.3	16.4	4.0	1.4	5.9	1.2	6.0	2.8	4.4	1.9	2.8	2.5	5.1	1.6	5.0	0.0
	Fall	1	2000	35.7		3.0		5.0		4.0		3.0		1.0		4.0		5.0	
	Spring	4	2000-2005	58.9	8.6	5.0	2.9	6.8	2.4	8.0	2.7	5.8	3.1	4.5	4.0	6.3	1.9	5.0	1.4
Site 11	Spring	1	2001	32.9		7.0		0.0		3.0		3.0		2.0		4.0		4.0	
Site 12	Average	3	2004-2005	11.1	3.5	1.0	1.4	0.5	0.7	2.5	0.7	2.8	0.4	0.0	0.0	0.5	0.7	0.5	0.7
	Fall	1	2004	8.6		0.0		0.0		3.0		3.0		0.0		0.0		0.0	
	Spring	2	2004-2005	13.6	11.1	2.0	1.4	1.0	1.4	2.0	2.8	2.5	2.1	0.0	0.0	1.0	1.4	1.0	1.4
Site 13	Spring	1	2005	51.4		3.0		5.0		5.0		2.0		2.0		10.0		9.0	