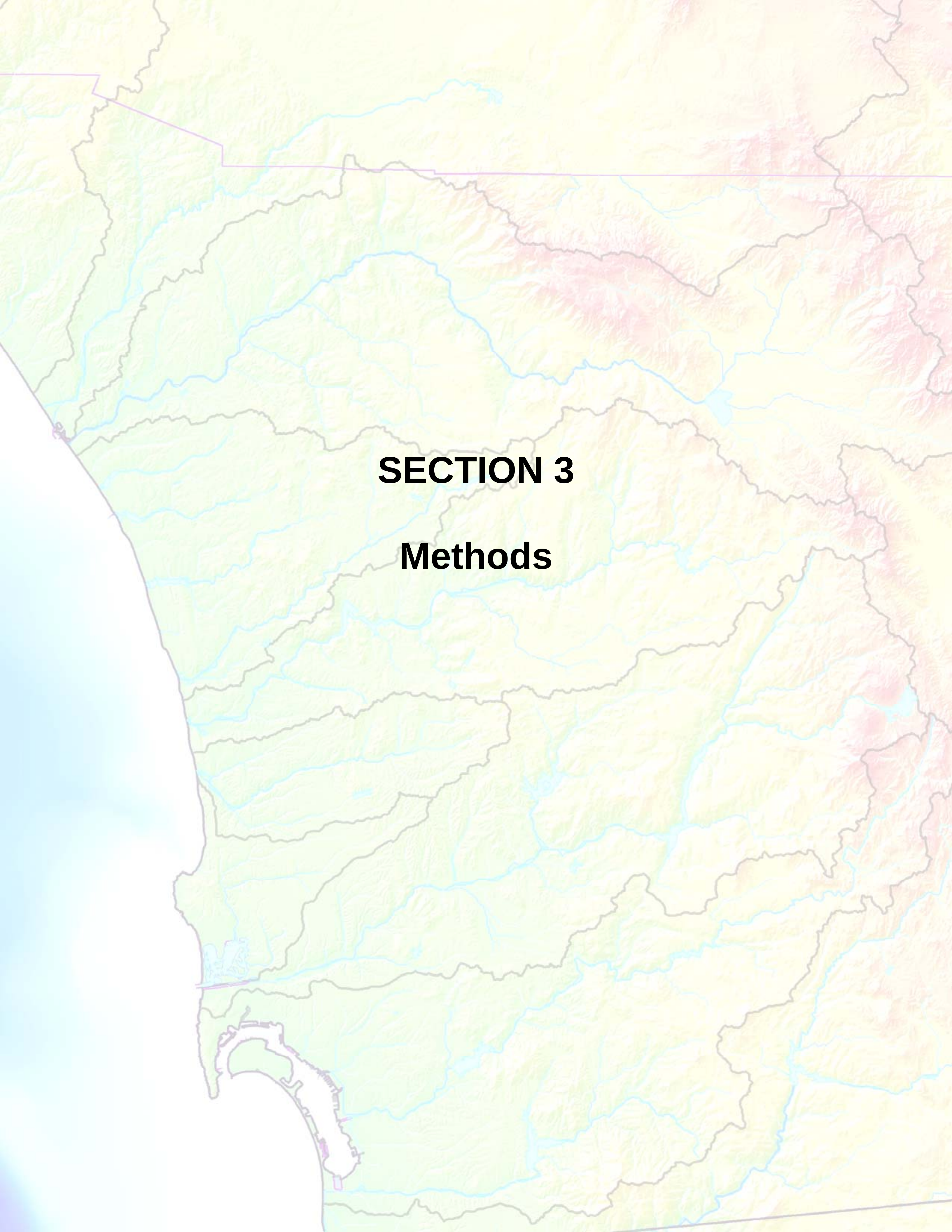

SECTION 3

Methods

Program Monitoring and Data Analysis Methods

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3.0 PROGRAM MONITORING AND DATA ANALYSIS METHODS

The core monitoring program includes collection and analysis of storm water runoff at mass loading stations. Storm water samples are collected during three storm events at each mass loading station and analyzed for chemical constituents, indicator bacteria, and toxicity to bioassay test organisms. This monitoring program also uses a triad approach to assessing watersheds which includes a Rapid Stream Bioassessment Program (RSB). The water quality monitoring, RSB, data analysis, and watershed assessment methods are described in this section.

3.1 Water Quality Monitoring Methods

3.1.1 Mass Loading Station (MLS) Site Selection

The 2006-2007 storm water monitoring program included monitoring at ten mass loading stations (MLS). The data collected at the MLS is representative of large drainage areas with mixed land use characteristics. Their locations are shown in Figure 2-5. In 2000, the mass loading monitoring site locations were selected by Weston Solutions, Inc. (Weston) (formerly MEC Analytical, Inc.), working with the San Diego Copermittees' Monitoring Workgroup, and approved by the San Diego RWQCB. The primary site selection factors included:

- Suitability of the site drainage area to monitor area-wide contributions of storm water pollutant loading
- Suitability of the site's hydrological characteristics to enable practical measurement of flow and collection of representative storm water samples
- Maintenance of long-term data collection at appropriate existing monitoring stations (Agua Hedionda Creek, Tecolote Creek, and Chollas Creek)
- Safety from traffic and other hazards
- Suitable siting for sampling equipment
- Accessibility to phone lines (convenient, though not necessary for modem communications) and
- Crew access for retrieving samples and maintaining equipment during storm conditions

The MLS sites were selected to directly measure pollutant loads being discharged into San Diego's receiving waters by the major watersheds within the San Diego region. Monitoring sites were installed where flow from the catchment area passes a single hydrologically ratable point, and is suitable for water quality sampling. In some instances, sites were located upstream of the drainage area discharge point for accessibility and/or to avoid tidal influences.

3.1.2 Monitoring Equipment

Flow was monitored at all stations using American Sigma flow meters. A variety of flow measurement technologies were utilized to accurately measure flow rates including ultrasonic sensors, bubblers, and submerged pressure transducers. The sensors provided a continuous measurement of river or stream stage (height) and relayed that information to the flow meter. The flow meter continually calculated flow rates by inserting the stage information into the preprogrammed discharge equation. Two stations are co-located with U.S. Geological Survey (USGS) stream gauging stations. At these sites the USGS rating curves were used.

Field crews measured the flow rate of streams using USGS stream profiling guidelines prior to the beginning of, and periodically throughout, the storm season. This was accomplished by manual rating techniques using a hand held flow meter. The resulting discharge rates were used to calculate a discharge equation, which was utilized by the flow monitoring equipment at some stations. At other stations where a discharge equation could not be developed, velocity/stage measurements were utilized to calculate discharge rates using the area velocity method.

3.1.3 Sampling Procedures

3.1.3.1 Grab Samples

Grab samples were collected for those constituents that are not amenable to composite sampling. The grab samples were analyzed for the following parameters:

- Temperature
- pH
- Specific Conductance
- Biochemical Oxygen Demand
- Oil and grease
- Total coliform
- Fecal coliform
- Enterococcus

Samples were collected from the horizontal and vertical center of the channel if possible and kept clear from uncharacteristic floating debris. Because oil and grease and other petroleum hydrocarbons tend to float, oil and grease grab samples were collected at the air/water interface. Bacteria samples were collected in a sterile sample bottle and then placed in a clean Ziploc bag and put on ice for transport to the laboratory for analysis within 6 hours.

3.1.3.2 Composite Samples

Storm water samples were collected as flow-weighted composites of the storm event. Where practical, the entire event was sampled. At some monitoring stations this was not practical due to the runoff characteristics of the watershed. For example, San Luis Rey and San Diego Rivers are large water bodies that continue to rise following the initial flow of runoff during storm events and it is not uncommon to see a double peak in the hydrographs. The first peak (usually smaller than the second) is the immediate response from runoff. The second peak is the result of groundwater flowing from the unsaturated zone that appears as a much larger peak, usually hours or days after rainfall has stopped. Sampling this flow would dilute the constituents of concern in the composite sample and may skew results when compared with other watersheds that see only immediate runoff response. For large watersheds, the sampling strategy was determined by using best professional judgment to monitor rainfall and runoff and determine the appropriate time to terminate sampling.

In general, a larger concentration of constituents from urban runoff enters the storm drainage system during the initial stages of flow and during peak flow and/or peak rainfall intensity for small rainfall events, which are typical in our region (Tiefenthaler et al., 2001; City of Austin, 1990). Therefore, a successful event was determined by capturing (at a minimum) the initial peak of runoff from the storm event.

Storm teams evaluated telemetry data from the monitoring sites during storms to ensure all of these conditions were met before terminating sampling. Storm hydrographs for each of the monitored events are presented in Appendix C and in each WMA section.

3.1.4 Stream Rating Methods

During storms, the flow rate at each of the monitoring sites was determined by stream stage (water level) sensors that are typically secured to the bottom of the channel. To quantify flow rates based on stream stage, a relationship between flow and stage was derived using standardized stream rating protocols developed by the USGS (Rantz, 1982; Oberg et al., 2005). Instantaneous flow measurements were measured at various stages at each of the MLS sites. The measurements were combined to produce a rating curve for each MLS site.

Methodology has been improved for the measurement and accuracy of flow estimates at MLS sites. Due to safety issues, past estimates for high flows based on stage were made based on extrapolation of the rating curve at low flow. This extrapolation was derived using a best-fit curve approach. To accurately measure flow in streams there are three critical elements needed to develop rating curves:

- An accurate survey of the stream channel cross section and longitudinal slope.
- Accurate level measurements based on a fixed point
- Measurements of velocity and flows at several points throughout the rating curve including low flow, mid flow, and peak flow conditions.

To measure instantaneous flows during low flow and base flow conditions, two velocity measurement instruments were used: (1) a Marsh-McBirney Model 2000 Portable Flow Meter connected via a cable to an electromagnetic open channel velocity sensor, and (2) the SonTek (YSI) FlowTracker Acoustic Doppler Velocimeter. The FlowTracker is a high-precision, shallow-water velocity/flow meter that measures velocity in 3 dimensions and features an automatic discharge computation.

The velocity sensors are attached to a stainless steel top-setting wading rod. To make an instantaneous flow measurement, a tape measure was stretched across the stream, perpendicular to flow and secured on both banks of the stream. The tape was positioned so that it was suspended approximately one foot above the surface of the water. The distance on the tape directly above the waterline (where the water met the bank) was then recorded as the initial point. The first measurement was then made at the first point where there was adequate depth (at least 0.2 feet) and measurable velocity. At this point three measurements were made: water depth, velocity, and distance from the bank (the initial point). Subsequent depth, velocity, and distance measurements were then made incrementally across the entire width of the channel so that a minimum of ten points were measured per site. Water depth was determined from calibrations on the wading rod in tenths of feet. Velocity measurements were made at each point along the transect by positioning the velocity sensor perpendicular to flow at 60% of the water depth (from the surface) to attain an average velocity. The top setting wading rod is designed so that the sensor can be conveniently positioned at the appropriate depth. Water velocity was measured in feet per second.

Data from the field measurements were entered into a computer model that calculates the stream's cross-sectional profile from the depth and distance from bank measurements. Total flow across the channel was determined by integrating the velocity measurements over the cross-sectional surface area of the stream channel. The result is an instantaneous flow measurement in cubic feet per second.

This past season, new equipment was procured that allows measurement of flows at high stream stages that are observed during storm events. The measurement of peak flow conditions in Southern California streams can be a significant hazard and can pose significant challenges due to debris in the discharge stream, heavy vegetation, and shifting channel bottoms. A StreamPro Acoustic Doppler Current Profiler (ADCP) was used to measures high stage and flow conditions. The StreamPro ADCP is the USGS instrument of choice for measuring flows nation-wide (Oberg et al., 2005). The instrument is pulled across the stream either by walking across a bridge or attaching the unit to a tagline. Data are collected in real-time and transmitted via a wireless data link to a palm PC. Data can be viewed in real time and is typically post-processed following the field event in the office.

Rating curves were extended to high stream stages not measured using site-specific survey information and the Chézy-Manning formula (Linsley et al., 1982). The Chézy-Manning formula is an empirical formula for open channel flow, or flow driven by gravity:

$$Q = (1.486/n)AR^{2/3}S^{1/2}$$

where,

Q = Flow
n = Manning Roughness coefficient
A= Cross sectional area
R = Hydraulic radius
S= Hydraulic slope

The hydraulic radius is derived as:

$$R = A/P$$

Where;

A = cross sectional area of flow (ft^2)
P = wetted perimeter (ft)

The Chézy-Manning formula was developed for conditions of uniform flow in which the water surface profile and energy gradient are parallel to the streambed and the area, hydraulic radius, and depth remain constant throughout the reach. Field surveys of the channel geometry of each MLS Site were conducted in order to compute the channel characteristics for each site.

Channel cross section surveys were conducted at each site in order to derive stream discharge using the Manning equation. The cross-section surveys involve placing endpoints and a benchmark on the nearest overhead bridge structure or stretched line such that the endpoints are placed at the highest point of the channel on each bank. A tape is then stretched between the endpoints such that the zero end of the tape is attached to the endpoint on the left bank of the channel (looking downstream). Using a weighted tape measure, at least twenty vertical distance measurements from a standard level on the bridge or stretched line to the channel bottom are then recorded at equal horizontal distances across the creek. A DeWalt transit level was used to survey the channel thalweg. A minimum of three elevations at increasing horizontal distances from the transit level were recorded in the channel bed. A minimum of five elevations were measured at sites with irregularly sloped or curved channel surfaces. The average channel slope was calculated from the survey data.

Channel survey data were used with the Chézy-Manning formula to produce a rating curve for each sampling site. Each rating curve was calibrated using instantaneous flow measurements by adjusting the formula roughness coefficient.

For long-term flow monitoring, instream flow measurement devices (such as the Sigma 950 flow meter) with pressure/level sensors, area velocity sensors, or ultrasonic level sensors are used. These data are downloaded weekly from each site and are verified by a Senior Hydrologist to ensure accuracy and identify maintenance and calibration needs. Flow data are then entered into the data management system. All flow data are backed up and archived on a weekly basis.

3.1.5 Sample Handling and Processing

In accordance with USEPA sampling protocols and the Weston Quality Assurance Program, all samples collected were stored in the appropriate container type for the analytical method to be performed. Additionally, all samples were stored chilled in ice-chests for transfer to the laboratory and between laboratories. The sample containers used were certified as clean and sterile by the laboratory performing the analyses. Chain-of-custody forms were completed for each sample and accompanied the samples to the laboratories and between laboratories at all times.

Sample preservatives and holding time requirements for each analytical measurement (Table 3-1, Table 3-2, and Table 3-3) were based on the recommendations by the Standard Methods for the Examination of Water and Wastewater and the USEPA methods. All storm water samples were transported from the field to the laboratory under Weston chain-of-custody procedures. Samples moved between laboratories were transported under the laboratories' chain-of-custody procedures. Samples not processed at Weston's laboratories were submitted by Weston to EnviroMatrix Analytical, Inc. in San Diego, CA and CRG Marine Laboratories in Torrance, CA.

3.1.6 Laboratory Analysis

3.1.6.1 Chemical Constituents

General physical and chemical constituents were analyzed by EnviroMatrix Analytical, Inc. with the exception of field measured constituents (pH, conductivity, and temperature), organophosphate pesticides, and synthetic pyrethroids. Field measurements were conducted by Weston field technicians and scientists during field sampling activities.

EPA 625 was utilized to test for Diazinon and Chlorpyrifos during the 2006-2007 monitoring season. Additionally, the organophosphate pesticide Malathion was added during the 2004-2005 monitoring season. EPA 625 was initially utilized during the 2004-2005 monitoring season to provide a method that would consistently meet the low reporting limit for these constituents. During the 2003-2004 monitoring season the chemistry laboratory was not able to consistently meet the low reporting limit requirements using EPA 8141. Therefore, an enzyme linked immunosorbant assay (ELISA) method was utilized for organophosphate pesticides. The ELISA method was discontinued following the 2003-2004 monitoring season. CRG Marine Laboratories provided laboratory services for the analysis of Diazinon, Chlorpyrifos, and Malathion, using the EPA 625 Method. Synthetic pyrethroids were also analyzed on a subset of the MLS samples that included Agua Hedionda Creek, Chollas Creek, and Tecolote Creek. Synthetic pyrethroids were analyzed by CRG Marine Laboratories using EPA 625 in negative chemical ionization mode (NCI).

Additionally, Dissolved Organic Carbon (DOC) and Total Organic Carbon (TOC) were analyzed by Delmar Analytical Laboratories of Irvine, California during one storm sampling event due to temporary failure of the analytical instrument utilized to analyze these constituents at EnviroMatrix Analytical.

The chemical constituents measured in this monitoring program are presented in Table 3-1, Table 3-2, and Table 3-3.

Table 3-1. Analytical Requirements for Mass Loading Stations 2006-2007.

Constituent	Volume Required	Method	Reporting Limit	Units	Holding Time
General Physical and Inorganic Non-Metals					
Total Dissolved Solids (TDS)	100 mL	SM 2540 C	20	mg/L	7D
Total Suspended Solids (TSS)	100 mL	SM 2540 D	40	mg/L	7D
Turbidity	100 mL	SM 2130 A-B	0.1	NTU	48H
Total Hardness	150 mL	EPA 200.7	10	mg $CaCO_3$/L	6M
pH	In field	EPA 150.1	0.1	S.U.	I
Specific Conductance	In field	SM 2510 B	1.0	umhos/cm	28D
Temperature	In field				I
Dissolved Phosphorus	250 mL	SM 4500 B,E	0.05	mg/L	48H
Total Phosphorus	250 mL	SM 4500 B,E	0.10	mg/L	28D
Nitrite as N	200 mL	SM 4500 NO2 B	0.05	mg/L	48H
Nitrate as N	200 mL	SM 4500 NO3 E	0.1	mg/L	48H
Total Kjeldahl Nitrogen (TKN)	500 mL	SM 4500N C	0.5	mg/L	28D
Ammonia as N	250 mL	SM 4500 NH3B,C	0.1	mg/L	28D
Biochemical Oxygen Demand, 5-day (BOD)	1000 mL	SM 5210 B	2	mg/L	48H
Chemical Oxygen Demand (COD)	25 mL	EPA 410.4	25	mg/L	28D
Dissolved Organic Carbon (DOC)	200 mL	EPA 415.1	1.0	mg/L	
Total Organic Carbon (TOC)	200 mL	EPA 415.1	1.0	mg/L	
Surfactants (MBAS)	250 mL	SM 5540 C	0.5	mg/L	48H
Organics					
Oil and Grease (O&G)	500 mL	EPA 1664	1.0	mg/L	14D
Diazinon	1 L	EPA 625	0.05	µg/L	7/40D
Chlorpyrifos			0.05	µg/L	
Metals, Dissolved					
Antimony (Sb)	75 mL	EPA 200.8	0.006	mg/L	6M
Arsenic (As)			0.001	mg/L	6M
Cadmium (Cd)			0.001	mg/L	6M
Chromium (Cr)			0.005	mg/L	6M
Copper (Cu)			0.002	mg/L	6M
Lead (Pb)			0.002	mg/L	6M
Nickel (Ni)			0.002	mg/L	6M
Selenium (Se)			0.005	mg/L	6M
Zinc (Zn)			0.02	mg/L	6M
Metals, Total					
Antimony (Sb)	75 mL	EPA 200.8	0.006	mg/L	6M
Arsenic (As)			0.001	mg/L	6M
Cadmium (Cd)			0.001	mg/L	6M
Chromium (Cr)			0.005	mg/L	6M
Copper (Cu)			0.002	mg/L	6M
Lead (Pb)			0.002	mg/L	6M
Nickel (Ni)			0.002	mg/L	6M
Selenium (Se)			0.005	mg/L	6M
Zinc (Zn)			0.02	mg/L	6M
Bacteriological					
Total Coliform	200 mL	SM 9221 B	*	MPN/100 mL	6H
Fecal Coliform		SM 9221 E	*	MPN/100 mL	6H
Enterococci		SM 9230	*	MPN/100 mL	6H
Toxicity	12 L				
Acute, chronic, and reproductive test with the cladoceran *Ceriodaphnia dubia*					
Chronic test with the freshwater algae *Selenastrum capricornutum*					
Acute survival test with the amphipod *Hyalella azteca*.					

* Bacteriological methods are quantified from 20-16,000,000 MPN/100 mL

Table 3-2. Additional Constituents Analyzed for Mass Loading Stations 2006-2007 (not required by permit).

Constituent	Volume Required	Method	MDL	Units	Holding Time
Organophosphorus Pesticides	2 L	EPA 625			Extraction-7 Days Analysis-40 Days
Bolstar			0.010	µg/L	
Coumaphos			0.010	µg/L	
Demeton (Total)			0.010	µg/L	
Dichlorvos			0.010	µg/L	
Disulfoton			0.010	µg/L	
Ethoprop			0.010	µg/L	
Fensulfothion			0.010	µg/L	
Fenthion			0.010	µg/L	
Guthion			0.010	µg/L	
Malathion			0.005	µg/L	
Merphos			0.010	µg/L	
Mevinphos			0.010	µg/L	
Parathion, methyl			0.010	µg/L	
Phorate			0.010	µg/L	
Ronnel			0.010	µg/L	
Stirofos			0.010	µg/L	
Tokuthion			0.010	µg/L	
Trichloronate			0.010	µg/L	

Table 3-3. Synthetic Pyrethroids Analyzed for Selected Mass Loading Stations during 2006-2007 (not required by permit).

Constituent	Volume Required	Method	MDL	Units	Holding Time
Synthetic Pyrethroids	2 L	EPA 625-NCI Mode			Extraction-7 Days Analysis-40 Days
Allethrin			0.005	µg/L	
Bifenthrin			0.005	µg/L	
Cyfluthrin			0.005	µg/L	
Cypermethrin			0.005	µg/L	
Danitol			0.005	µg/L	
Deltamethrin			0.005	µg/L	
Esfenvalerate			0.005	µg/L	
Permethrin			0.005	µg/L	
Prallethrin			0.005	µg/L	

3.1.6.2 Toxicity Testing

Toxicity testing is performed on flow-weighted composite samples collected from the mass loading stations at the same time as the chemistry constituents. Toxicity testing is an effective tool for assessing the potential impact of complex mixtures of unknown pollutants on aquatic life in receiving waters. Rather than performing chemical analysis on a sample for a host of compounds potentially toxic to aquatic life, this approach utilizes a laboratory test species to provide a direct measure of the toxicity of the sample. Interactions among the complex mixture of chemicals and physical constituents can lead to additive or antagonistic effects, potentially causing an individual compound to become either more or less toxic than it would be were it isolated. While the potential effects of these interactions cannot be derived from simple chemical measurements, they are directly accounted for in toxicity tests. If persistent toxicity is detected, specialized toxicity identification evaluations (TIE) may be used to help characterize and identify constituent(s) causing toxicity. Toxicity testing can provide information on both potential short-term or "acute" effects as well as longer-term "chronic" effects. Historically, toxicity tests, including TIEs, have been used to assess both short and long-term impacts of point source discharges (e.g., Publicly Owned Treatment Works (POTW), power plant and industrial effluents) on aquatic life in a receiving water body. However, these tools can be applied to non-point source discharges, such as urban runoff.

Toxicity testing provides the only direct means to assess the potential toxicity of storm water runoff on receiving waters. Living organisms are able to integrate effects of multiple contaminants and account for the inherent properties of the sample matrix (e.g., hardness and alkalinity of a storm water sample) that influence bioavailability and hence toxicity. However, the same elements that make these tools so effective can contribute to variability in the response. Living organisms respond to a host of factors other than contaminants. If test organisms are stressed in any way prior to testing, variability of the test organism response may increase and produce equivocal results. The use of controls and reference toxicant testing are quality assurance and quality control measures that have been put in place to identify changes in test organism sensitivity due to stress or other factors. Naturally occurring characteristics of the sample matrix can also affect organism response. For example, mortality of test organisms can result from extreme variations in water hardness. Consequently, understanding the importance of such features on test organism response is critical for the accurate interpretation of test results. The test procedures employed to date represent the culmination of some 40 years of research. While this does not guarantee that they are employed properly in every circumstance, there is a wealth of information to document the utility of such procedures.

Freshwater species were used to evaluate the potential impacts of storm water at mass loading stations. It is important to note that, ultimately, all of the receiving water bodies for these drainage basins are estuarine/marine habitats (e.g., San Diego Bay, Mission Bay, various coastal lagoons and estuaries). The extrapolation of these freshwater species tests to evaluate the potential impact in the downstream marine/estuarine environments can be problematic. For example, the organic ligands present in an estuarine environment may make contaminants unavailable for uptake and reduce toxicity. In addition, marine organisms often have different sensitivities to contaminants than freshwater organisms.

Three species were used in this monitoring program. The cladoceran, *Ceriodaphnia dubia*, represents the invertebrates that live in the water column and serve as a source of food for larger invertebrates and small fish. This species is known to be sensitive to metals and pesticides in water, as well as other contaminants. The freshwater amphipod, *Hyalella azteca,* is an invertebrate that is associated with the sediment at the bottom of streams and lakes. It again serves as a food source for larger invertebrates as well as fish. This species is generally sensitive to metals and pesticides, as well as nitrogen compounds such as ammonia. *Hyalella azteca* is also known to be sensitive to synthetic pyrethroids in low concentrations that tend to bind to sediments (Amweg et al., 2005; Anderson et al., In Press; and Maund et al., 2002). The freshwater plant, *Selenastrum capricornutum,* is a unicellular algae that is present in the water column of lakes and streams. It is at the base of the food chain in freshwater systems. It is sensitive to herbicides and metals, but its growth is also greatly affected by nutrient loads (e.g., nitrates and phosphorus) in a water body. Nutrients tend to stimulate the growth of *S. capricornutum* (causing an algal bloom) and, if the nutrient loads are high enough in a water body, they can offset the toxic effect that contaminants might otherwise produce. All toxicity tests were conducted by Weston's laboratory in Carlsbad, California.

Ceriodaphnia dubia

Samples from mass loading stations were tested for toxicity according to the USEPA protocol (EPA-821-R-02-013). This protocol was developed for testing the chronic toxicity of point-source discharges where the effluent is diluted considerably in the receiving waters. Laboratory test organisms are placed in small containers of effluent sample and monitored over time to compare the response of organisms placed in non-toxic control water to the sample water. The sample is diluted (with control water) to several known concentrations before the test and test organisms are added to each concentration. The standard USEPA recommended dilution series (100%, 50%, 25%, 12.5%, 6.25%, and a control) are used for all toxicity tests. The test solutions are renewed and test organisms are fed daily. In the *Ceriodaphnia* chronic test, single females are placed in individual test chambers (ten test chambers per concentration) and the number of dead organisms along with the number of offspring produced per organism is recorded each day. When the controls reach an average of at least fifteen young per surviving adult, and 60% of the controls have had three broods, the test is terminated (day six to eight). Additionally, the acute, 96-hour (4-day) endpoint data (survival) is also collected from the seven-day chronic test. Only the original test organisms with which the test was begun were used for the calculation of both the acute and chronic survival endpoints.

Test Acceptability

Acceptability of the test is determined by evaluating the response of the control organisms. The test is considered acceptable if control survival is greater than 80%, control reproduction is greater than or equal to an average of fifteen young per adult, and more than 60% of the adults produce three broods by day eight of the test. If any one of these test acceptability standards is not met then the test is considered invalid and no further analysis is performed.

A reference toxicant test is also run to establish whether the test organisms used fall within the normal range of sensitivity. The reference toxicant test is conducted with known concentrations of a given toxicant (e.g., copper sulfate is used for *Ceriodaphnia*). The effect on the survival and reproduction of the test organisms is compared to historical laboratory data for the test species and reference toxicant. If the values are within two standard deviations of the historical average, the test organisms are considered to fall within the normal range of sensitivity.

The concentration that causes 50% mortality of the organisms (the median lethal concentration, or LC_{50}) is calculated from the data for 96 hours (96-hour acute LC_{50}) and for day seven (seven-day chronic LC_{50}) using USEPA methods. The LC_{50} values are point-estimates expressed as "percent sample;" the lower the LC_{50} percentage the more toxic the sample. For acute regulatory standards, the LC_{50} acute value is used. For chronic regulatory standards, the No Observed Effect Concentration (NOEC), for both survival and reproduction is calculated. This is the highest concentration tested in which there was no effect on the survival or reproduction compared to the control response. The lower the NOEC, the more toxic the sample.

For regulatory purposes, the endpoints described above are transformed into toxic units (TU). Toxic units are further divided into toxic units acute (TUa) and toxic units chronic (TUc) for acute and chronic endpoints, respectively. As toxicity increases, the toxic units increase. If the TU limit in the permit is exceeded, the sample is out of compliance (similar to an exceedance of a chemistry limit). The permit limit for chronic toxicity is a TUc of 1 and the permit limit for acute toxicity is a TUa of 0 due to the differences in their derivation.

TUa and TUc values are calculated differently and are not interchangeable or related. The TUa equals $100/LC_{50}$. If the LC_{50} is greater than 50% but less than or equal to 99%, the TUa is calculated by the following formula: $TUa = \log(100-S)/1.7$ where S = percentage of survival in 100% sample. If $S > 99\%$, the TUa is reported as zero, which is the lowest TUa value possible. The percent survival in the 100% concentration used in this formula is expressed as a percentage of the control survival. The TUc equals 100/NOEC. The lowest TUc possible, which indicates no toxicity, is 1. TUc values were calculated separately for survival and reproduction endpoints.

Hyalella azteca

Storm water samples from each of the mass loading stations were also evaluated for acute toxicity using the freshwater amphipod, *Hyalella azteca,* according to a modified version of the USEPA protocol for testing sediment-associated contaminants with freshwater invertebrates (EPA-821-R-02-012). This protocol provides test methods for measuring acute toxicity in *Hyalella* exposed to freshwater sediments, as well as a test method for conducting a water-only acute reference toxicant test. The reference toxicant test protocol was modified to conduct the toxicity testing on samples collected from the mass loading stations. The test solution is prepared using the dilution series described above, and placed in 250-mL aliquots into 4 replicate test chambers. Clean sand is placed as a thin “monolayer” in the bottom of the test chamber and 10 organisms per replicate are added. The test organisms are exposed for four days and fed on day 2. At the end of the test, the survivors are removed from the sand and counted. A 96-hour LC_{50} is calculated from this data.

Prior to analysis of the data, test acceptability is determined by evaluating the response of the control organisms. The test is considered invalid if survival of control test organisms is less than 90%. As with *Ceriodaphnia*, a reference toxicant test using copper sulfate is also conducted with *Hyalella* to establish whether the test organisms used fall within the normal range of sensitivity.

If the test data meet acceptability criteria, the LC_{50} is calculated from the 96-hour test data. From this data, a toxic unit acute (TUa) is calculated as described above.

Selenastrum capricornutum*

In previous years, toxicity testing for the storm water monitoring program was conducted using a freshwater vertebrate species: the fathead minnow (*Pimephales promelas*). Results of tests conducted with this species failed to show any toxicity relative to the other species tested. Consequently, the San Diego Regional Water Quality Control Board (RWQCB) approved the replacement of this test with a chronic *Hyalella* toxicity test measuring a sublethal endpoint (e.g., growth). Attempts to develop a short-term sublethal toxicity test with *Hyalella* during the 1999-2000 and 2000-2001 storm seasons proved

* The name of this species has been changed to *Pseudokirchneriella subcapitata*, however, *Selenastrum capricornutum* will continue to be utilized for the purposes of continuity with previous testing.

unsuccessful, due to the variability of the growth endpoint. Consequently, it was recommended and the RWQCB subsequently approved replacing the proposed *Hyalella* chronic test with the *Selenastrum capricornutum* chronic test. This algal species has the potential to be sensitive to metals (in waters low in nutrients) and herbicides. This is the sixth season that this test has been used to assess toxicity in this storm water monitoring program.

Samples from the mass loading stations were tested for toxicity according to the USEPA protocol (EPA-821-R-02-013) using the unicellular algae *Selenastrum*. This protocol was developed for testing the 96-hour chronic toxicity of point-source discharges. The sample and the control water are spiked with equal amounts of nutrients and subsequently filtered to remove any unicellular algae that might be present prior to test initiation. The concentration series is prepared and 50-mL aliquots are placed into four replicate test chambers. Approximately 10,000 cells per mL are added to the test chamber and placed in random order under high-intensity 24-hour light for four days. The test chambers are shaken twice and randomized daily. At the end of the test period, chambers are analyzed for chlorophyll *a* concentrations (fluorescence).

Test acceptability is determined by evaluating the response of the control organisms. The test is considered invalid if the criterion of a mean cell density of 1,000,000 cells per mL in the control is not met. Variability between the control replicates should not exceed 20%. A reference toxicant test using copper sulfate is also run parallel with the test to establish the sensitivity of the organisms.

Alterations to the *S. capricornutum* testing protocol were put into effect with the promulgation of the updated EPA guidelines in October 2002. The most significant changes to the protocol involve the addition of ethylenediaminetetraacetic acid (EDTA) as a component of the nutrient stock for conducting the test. The addition of EDTA has been determined to greatly reduce the incidences of false positives and increase the precision of the test method. This chemical has the ability of reducing the toxicity of certain metals by making them unavailable to the test organism. The guidance document warns that this method may underestimate the toxicity of metals and should be used in conjunction with multiple species tests, such as in this program, to monitor toxicity. Another alteration to test protocol was increasing the acceptability criterion of a mean cell density 200,000 algal cells per mL in the control to 1,000,000 cells per mL.

If the test data meet acceptability criteria, inhibition concentrations, an IC_{25} and an IC_{50}, are calculated from the data: the concentrations that cause a 25% or 50% inhibition in the growth, or cell density, of the algae. A NOEC is also calculated from this data and the endpoint is recorded as a TUc, similar to the *Ceriodaphnia* test.

3.1.6.3 Microbiology Testing

Measures of bacteria from grab samples were made by the Weston microbiology laboratory located in Carlsbad, California. Samples were collected during the storm event using grab poles and aseptic techniques by Weston's field technicians and scientists and delivered to the microbiology laboratory within the six hour holding time requirement. Sample analyses were initiated immediately upon receipt for all three indicators by multiple tube fermentation; total coliform using SM 9221B, fecal coliform using SM 9221E, and enterococcus using SM 9230B. All results were reported to a most probable number value (MPN/100 mL). "Greater than" values were utilized for MPN values that exceeded 16,000,000.

3.2 Rapid Stream Bioassessment Methods

Weston conducted stream bioassessment pursuant to RWQCB Order No. 2001-01 to assess the ecological health of the watershed units in San Diego County. The assessment was undertaken utilizing a protocol that samples and analyzes populations of benthic macroinvertebrates (BMIs). This program supplements the monitoring program conducted by the California Department of Fish and Game (CDFG) Water Pollution Control Laboratory from 1997 to May of 2001, under contract to the RWQCB. Weston followed the sampling and analysis protocols of the California Stream Bioassessment Procedure (CSBP) (Harrington, 2003); a standardized procedure developed for California by CDFG and adapted from the U.S. Environmental Protection Agency (EPA) Rapid Bioassessment Protocols (Barbour et al., 1999). To further enhance data consistency and comparability, Weston sampled many of the same streams at similar locations as the previous CDFG surveys. CDFG selected the original sampling sites to complement the RWQCB's ongoing water quality monitoring programs.

The sampling protocol of the CSBP includes the collection of stream benthic macroinvertebrates and also assesses the quality and condition of the physical habitat. Utilizing species specific tolerance values and community species composition, numerical biometric indices are calculated, allowing for comparison of relative habitat health among streams in a region. Over time, this information is used to identify ecological trends and aid analyses of the appropriateness of water quality management programs (Yoder and Rankin, 1998). Benthic macroinvertebrates reside in streams for periods ranging from a month to several years, and have varying sensitivities to the multiple stressors associated with urban runoff. By assessing the invertebrate community structure of a stream, a cumulative measure of stream habitat health and ecological response is obtained. This information may complement monitoring programs that test the chemical and physical water quality parameters and provide a measure of habitat conditions at the moment sampling occurs. The addition of bioassessment to chemical, bacterial, and toxicological approaches to watershed monitoring programs gives a comprehensive indication of water quality and the effects of ecological impacts.

This report presents the results from stream bioassessment surveys conducted in October 2006 and May 2007. The data includes a taxonomic listing of all benthic macroinvertebrates identified in the surveys, and calculation of the biological metrics listed in the CSBP. Additionally, calculation of the Index of Biotic Integrity (IBI) for all monitoring reaches is included, following the most recent version developed by the CDFG Aquatic Bioassessment Laboratory specifically for coastal Southern California (Ode et al., 2005).

Benthic macroinvertebrate sampling

3.2.1 Materials and Methods

A general description of the methods incorporated in the sampling program is presented below. Weston personnel adhered to the protocols of the CSBP (Harrington, 2003) as closely as practicable, and this document may be referenced for more detailed procedural information.

3.2.2 Monitoring Reaches

A minimum of 23 monitoring reaches were sampled in each survey, including three reference sites per survey. Descriptions of the locations are presented in Table 3-4 and a map illustrating these locations is shown in Figure 3-1. The primary goal for each survey was to sample 2 monitoring reaches in each of the 10 watershed management areas that have storm water mass loading stations. Of the two monitoring reaches, one was located as far downstream in the watershed or as close to the MLS sites as was practicable, and the other was located farther upstream in the watershed, but where it was still affected to some degree by urban development. Where possible, sites were located in the same stream reach that CDFG has previously sampled. Ongoing reconnaissance of the streams, with the goal of finding riffles with the highest quality in-stream habitats, has resulted in slight re-location of some of the monitoring reaches since the beginning of the program.

Reference sites have been designated by CDFG and the RWQCB based on upstream land use characteristics as determined by GIS datasets. When selecting reference monitoring sites for comparison with urban affected sites, elevation was considered, and most of the reference sites were at similar elevation to the urban sites. One exception was the Doane Creek reference site (REF-DC), located on Palomar Mountain at an elevation of nearly 5,000 feet. It may be noted that the physical habitat quality at the reference sites was superior to some of the test monitoring sites.

Comparison of urban monitoring sites to reference sites is not limited to the three reference sites sampled in this program. The benthic community summary indices (described below in section 3.2.7) that provide community quality ratings already incorporate a broad range of historical reference sites throughout the region. For example, Ode et al used 275 different reference sites to develop the Index of Biotic Integrity, and the scoring criteria are based on mean metric values for all of these sites. Reference sites monitored concurrently with the urban sites provide a direct temporal correlation that includes seasonal environmental variables (e.g., rainfall).

Table 3-4. San Diego County: Stream Bioassessment Monitoring Sites. June 2001 to May 2007.

Watershed Name	Receiving Water	Station Identification	Site Description	Station Coordinates	Jun-01	Oct-01	May-02	Oct-02	May-03	Oct-03	May-04	Oct-04	May-05	Oct-05	May-06	Oct-06	May-07
Reference Sites																	
Santa Margarita River	Sandia Creek	REF-SC	Reach consisted of 5 riffles along Sandia Creek Drive	33 25.482' 117 14.942'	x	x	x	x	x	x							
Santa Margarita River	Sandia Creek	REF-SC2	Reach consisted of 5 riffles along De Luz Road	33 29.529' 117 16.020'							x	x	x	x	x	x	x
Santa Margarita River	Sandia Creek	REF-SCCR	Reach consisted of 5 riffles downstream of Carancho Road	33 29.529' 117 16.020'		x											
Santa Margarita River	San Mateo Creek	REF-SMC	Reach consisted of 3 riffles upstream of San Mateo Road	33 25.248' 117 32.000'	x												
Santa Margarita River	De Luz Creek	REF-DLC	Reach consisted of 5 riffles downstream of De Luz Road	33 26.483' 117 19.434'	x		x		x	x	x						
Santa Margarita River	De Luz Creek	REF-DLC3	Reach consisted of 5 riffles along De Luz-Murietta Road	33 27.574' 117 17.456'				x		x		x					

Table 3-4. San Diego County: Stream Bioassessment Monitoring Sites. June 2001 to May 2007.

Watershed Name	Receiving Water	Station Identification	Site Description	Station Coordinates	Jun-01	Oct-01	May-02	Oct-02	May-03	Oct-03	May-04	Oct-04	May-05	Oct-05	May-06	Oct-06	May-07
San Luis Rey River	Doane Creek	REF-DC	Reach consisted of 5 riffles upstream of Doane Pond in Palomar Mt. State Park	33 20.124' 116 53.496'							x	x	x	x	x	x	x
San Luis Rey River	Keys Creek	REF-KC	Reach consisted of 5 riffles at Old Lilac Road	33 17.744' 117 05.149'		x	x	x									
San Diego River	Boulder Creek	REF-BCR	Reach consisted of 5 riffles upstream of Boulder Creek Road	32 57.827' 116 39.731'										x	x	x	x
San Diego River	Cedar Creek	REF-CC	Reach consisted of 5 riffles upstream of Cedar Creek Road	33 01.154' 116 38.029'					x								
Tijuana River	Wilson Creek	REF-WC	Reach consisted of 5 riffles upstream of Lyons Valley Road	32 42.449' 116 44.231'									x				
Urban Influenced Sites																	
Santa Margarita River	Santa Margarita River	SMR-WGR	Reach consisted of 5 riffles upstream of Willow Glen Road	33 25.614' 117 11.861'				x	x	x	x	x	x	x	x	x	x
Santa Margarita River	Santa Margarita River	SMR-DLR	Reach consisted of 5 riffles downstream of De Luz Road	33 23.844' 117 15.734'				x									
Santa Margarita River	Santa Margarita River	SMR-CP	Reach consisted of 5 riffles downstream of Santa Margarita Road, Camp Pendleton	33 20.457' 117 19.897'					x	x	x	x	x	x	x	x	x
San Luis Rey River	San Luis Rey River	SLRR-BR	Reach consisted of 2 riffles near the USGS gauging station at Benet Road	33 13.095' 117 21.569'			x	x	x	x	x	x	x	x	x	x	x
San Luis Rey River	San Luis Rey River	SLRR-MR	Reach consisted of 3 riffles upstream of Mission Road	33 15.587' 117 14.176'	x	x	x	x	x	x	x	x	x	x	x	x	x
Carlsbad	Loma Alta Creek	LAC-ECR	Reach consisted of 3 riffles up and downstream of El Camino Real	33 11.995' 117 19.878'	x	x	x	x									
Carlsbad	Loma Alta Creek	LAC-CB	Reach consisted of 5 riffles of College Blvd.	33 12.363' 117 17.087'	x	x	x										
Carlsbad	Buena Vista Creek	BVR-ED	Reach consisted of 5 riffles downstream of Santa Fe Av.	33 10.840' 117 19.717'	x	x	x										
Carlsbad	Buena Vista Creek	BVR-CB	Reach consisted of 5 riffles downstream of College Blvd.	33 10.809' 117 17.918'		x	x	x		x						x	
Carlsbad	Buena Vista Creek	BVR-SVW	Reach consisted of 5 riffles downstream of South Vista Way.	33 10.840' 117 19.713'	x												
Carlsbad	Agua Hedionda Creek	AHC-MR	Reach consisted of 5 riffles downstream of Melrose Road	33 09.132' 117 14.454'	x	x	x	x	x	x	x	x	x	x	x	x	x

Table 3-4. San Diego County: Stream Bioassessment Monitoring Sites. June 2001 to May 2007.

Watershed Name	Receiving Water	Station Identification	Site Description	Station Coordinates	Jun-01	Oct-01	May-02	Oct-02	May-03	Oct-03	May-04	Oct-04	May-05	Oct-05	May-06	Oct-06	May-07
Carlsbad	Agua Hedionda Creek	AHC-ECR	Reach consisted of 5 riffles downstream of El Camino Real	33 08.940' 117 17.830'	x	x	x	x	x	x	x	x	x	x	x	x	x
Carlsbad	San Marcos Creek	SMC-M	Reach consisted of 5 riffles upstream of McMahr Road	33 07.831' 117 11.575'	x	x	x										
Carlsbad	San Marcos Creek	SMC-SP	Reach consisted of 5 riffles downstream of Santar Place	33 08.501' 117 08.740'	x	x	x										
Carlsbad	San Marcos Creek	SMC-RSFR	Rreach consisted of 4 riffles downstream of Rancho Santa Fe Road	33 06.191' 117 13.609'	x	x	x										
Carlsbad	San Marcos Creek	SMC-LCCC	Reach consisted of 5 riffles upstream of La Costa Country Club	33 05.466' 117 14.664'	x	x	x	x				x					
Carlsbad	Encinitas Creek	ENC-GVR	Reach consisted of 3 riffles southwest of El Camino Real and La Costa Blvd	33 04.697' 117 16.000'	x	x	x										
Carlsbad	Cottonwood Creek	CC-E	Reach consisted of 4 riffles downstream of Hwy 101 along Encinitas Blvd.	33 02.905' 117 17.629'	x	x	x										
Escondido Creek	Escondido Creek	ESC-HRB	Reach consisted of 5 riffles downstream of Harmony Grove Bridge	33 06.550' 117 06.688'	x	x	x	x	x	x	x	x	x	x	x	x	x
Escondido Creek	Escondido Creek	ESC-CC	Reach consisted of 5 riffles downstream of Country Club Road	33 05.925' 117 07.836'			x										
Escondido Creek	Escondido Creek	ESC-EF	Reach consisted of 5 riffles downstream of the old Elfin Forest Resort	33 04.417' 117 09.853'	x	x	x	x	x	x	x	x	x	x	x	x	x
Escondido Creek	Escondido Creek	ESC-VC	Reach consisted of 5 riffles in Vista Canyon	33 03.617' 117 10.802'			x										
Escondido Creek	Escondido Creek	ESC-RSFR	Reach consisted of 3 riffles upstream of Rancho Santa Fe Road	33 02.365' 117 13.837'	x	x	x										
San Dieguito River	Green Valley Creek	GVC-WB	Reach consisted of 5 riffles downstream of West Bernardo Drive	33 02.625' 117 04.567'				x	x	x	x	x	x	x	x	x	x
San Dieguito River	San Dieguito River	SD-DDH	Reach consisted of 5 riffles along Del Dios Highway downstream of Lake Hodges	33 02.459' 117 08.595'				x	x	x	x	x	x	x	x	x	x

Table 3-4. San Diego County: Stream Bioassessment Monitoring Sites. June 2001 to May 2007.

Watershed Name	Receiving Water	Station Identification	Site Description	Station Coordinates	Jun-01	Oct-01	May-02	Oct-02	May-03	Oct-03	May-04	Oct-04	May-05	Oct-05	May-06	Oct-06	May-07
Los Peñasquitos Creek	Los Peñasquitos Creek	LPC-CCR	Reach consisted of 5 riffles upstream of Cobblestone Creek Road	32 56.949' 117 04.214'	x	x	x		x	x	x	x	x	x	x	x	x
Los Peñasquitos Creek	Los Peñasquitos Creek	LPC-BMR	Reach consisted of 5 riffles downstream of Black Mountain Road	32 56.349' 117 07.864'	x	x	x	x									
Los Peñasquitos Creek	Los Peñasquitos Creek	LPC-805	Reach consisted of 5 riffles upstream of I-805 at Mass Load Station	32 54.288' 117 13.379'												x	x
Los Peñasquitos Creek	Los Peñasquitos Creek	CCC-805	Reach consisted of 5 riffles downstream of I-805 at Sorrento Valley Road	32 53.403' 117 12.717'	x	x	x	x	x	x	x	x	x	x	x		
Mission Bay	Rose Creek	MB-RC	Reach consisted of 5 riffles downstream of Highway 52	32 50.056' 117 13.887'				x	x	x	x	x	x	x	x	x	x
Mission Bay	Tecolote Creek	TC-TCNP	Reach consisted of 4 riffles downstream of Mt. Acadia Blvd	32 47.874' 117 11.339'	x	x	x	x	x	x	x	x	x	x	x	x	x
San Diego River	San Diego River	SDR-MT	Reach consisted of 5 riffles in Mission Trails Park	32 49.249' 117 03.866'			x	x	x	x	x	x	x	x	x	x	x
San Diego River	San Diego River	SDR-1	Reach consisted of 5 riffles downstream of Mission Valley Golf Course	32 45.736' 117 11.557'			x	x	x	x	x	x	x	x	x	x	x
San Diego Bay	Chollas Creek	CC-FB	Reach consisted of 5 riffles downstream of Federal Boulevard	32 43.606' 117 04.219'					x	x	x	x	x	x	x	x	x
Sweetwater River	Long Canyon Creek	SR-AD	Reach consisted of 5 riffles along Acacia Drive	32 39.394' 117 00.800'				x									
Sweetwater River	Sweetwater River	SR-WS	Reach consisted of 5 riffles along Bonita Road	32 39.436' 117 02.717'			x		x	x	x	x	x	x	x	x	x
Sweetwater River	Sweetwater River	SR-94	Reach consisted of 5 riffles at Highway 94	32 44.005' 116 56.348'			x			x	x		x	x	x	x	x
Tijuana River	Campo Creek	CC-C	Reach consisted of 4 riffles up/downstream of H94 bridge in Campo	32 36.552' 116 26.448'							x	x	x	x	x	x	x
Tijuana River	Campo Creek	CC-H94	Reach consisted of 4 riffles at the Highway 94 USGS gauging station	32 35.456' 116 31.551'					x								
Tijuana River	Tijuana River	TJ-BF	Reach consisted of 2 riffles near the International Boundary border fence	32 32.539' 117 02.619'													x
Tijuana River	Tijuana River	TJ-DM	Reach consisted of 5 riffles upstream of Dairy Mart Road	32 32.816' 117 03.741'					x				x		x		

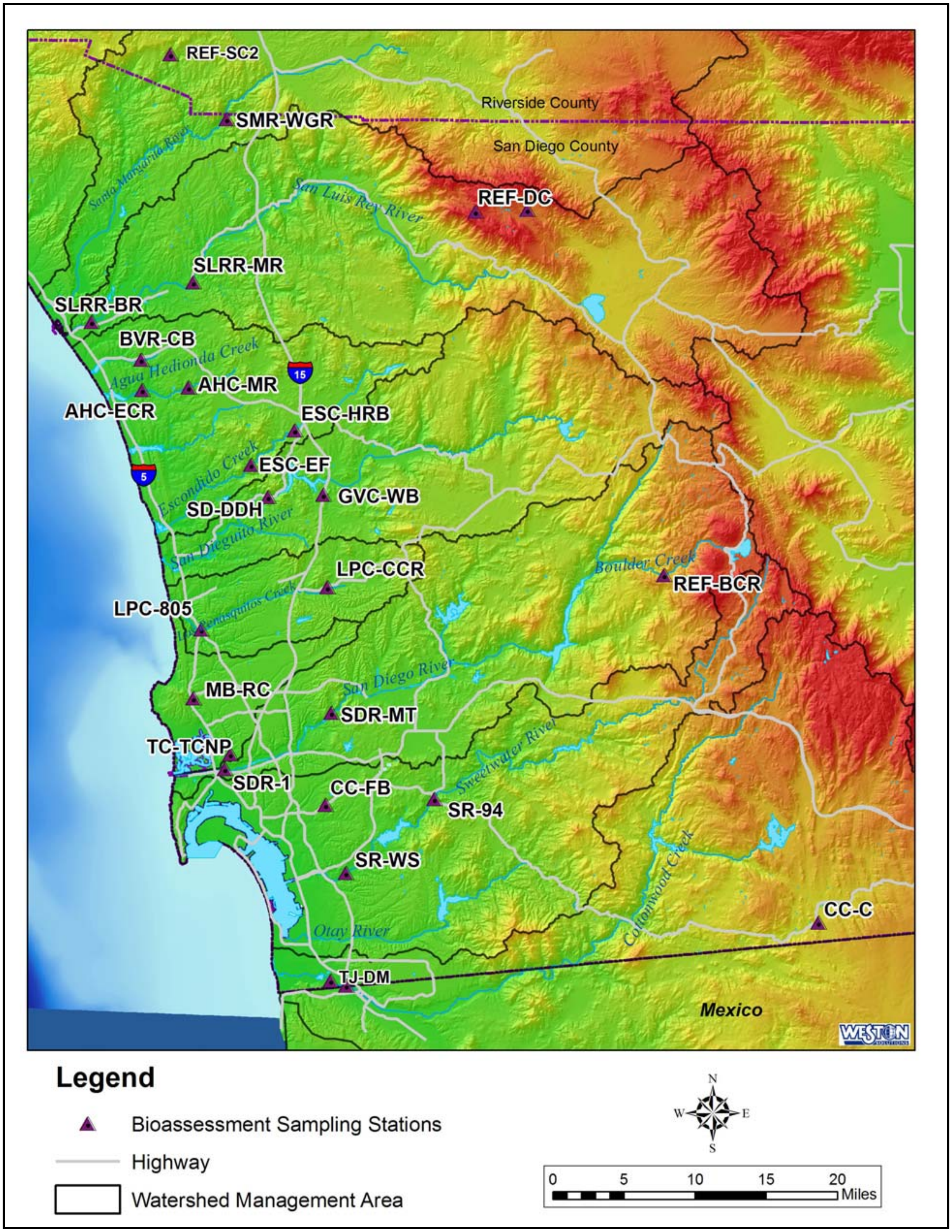

Figure 3-1. Stream Bioassessment Sites Sampled October 2006 and May 2007.

3.2.3 Monitoring Reach Delineation

The sampling points specified in the CSBP are located in a stream feature known as a riffle. An ideal riffle is an area of rapid flow with some surface disturbance and a complex and stable substrate. These areas generally provide increased colonization potential for benthic invertebrates. Riffles typically support the greatest diversity of organisms in a stream, and by selecting the optimal habitats available at each stream, comparability among streams is possible.

Under optimal conditions, five riffles constituted a monitoring reach and three of these were randomly selected for sampling. In some cases, particularly in low gradient streams, high quality riffles could not be located within a reasonable reach length, and best available habitat was sampled. Given sufficient riffle length, a sampling transect perpendicular to stream flow was selected randomly in the upper third of the riffle. In situations where the riffle was very short or narrow, the sample was taken to best represent available substrate types. Every monitoring reach was sampled from downstream to upstream. The locations and coordinates of the monitoring reaches are presented in Table 3-4, and a map of the locations is shown in Figure 3-1. Photographs were taken of every riffle sampled and one photograph representing each monitoring reach is presented in Appendix B.1.

3.2.4 Sample Collection

Once a sampling transect was established, benthic invertebrates were collected using a 1-ft-wide, 0.5-mm-mesh, D-frame kick-net. A 1-ft^2 area upstream of the net was sampled by disrupting the substrate and scrubbing the cobble and boulders, so that the organisms were dislodged and swept into the net by the current. The duration of the sampling generally ranged from 1 to 3 minutes, depending on substrate complexity. Three, 1-ft^2 areas were sampled along a transect and combined into a single composite sample representing 6 ft^2. The three sample points on the transect were selected to represent the diversity of habitat types present. This procedure was repeated for the next two riffles and all sample material was composited into a single sample. Samples were transferred to one-quart jars, and preserved with 95% ethanol, and returned to Weston's laboratory for processing.

3.2.5 Physical Habitat Quality Assessment

For each monitoring reach sampled, the physical habitat of the stream and its adjacent banks were assessed using U.S. EPA Rapid Bioassessment Protocols. Habitat quality parameters were assessed to provide a record of the overall physical condition of the reach. Parameters such as substrate complexity, channel alteration, frequency of riffles, width of riparian zones, and vegetative cover help to provide a more comprehensive understanding of the condition of the stream. Additionally, specific characteristics of the sampled riffles were recorded, including riffle length, depth, gradient, velocity, and substrate composition.

Physical habitat assessment

Water quality measurements were taken at each of the monitoring sites using a YSI Model 6600 environmental monitoring system. Measurements included water temperature, specific conductance, pH, dissolved oxygen, and relative chlorophyll. Chlorophyll was added to the water quality assessment in May 2003 to add information on phytoplankton productivity. Stream flow velocity was measured with a

Marsh-McBirney Model 2000 portable flow meter, or was visually estimated when the water was too shallow for the flow meter.

3.2.6 Laboratory Processing and Analysis

At the laboratory, samples were poured over a No. 35 standard testing sieve (0.5-mm stainless steel mesh), and the ethanol was retained for re-use. The sample was gently rinsed with fresh water, and large debris, such as wood, leaves, or rocks was removed. The sample was transferred to a tray marked with grids approximately 50 cm^2 in size. One grid was randomly selected, and the sample material contained within that grid was removed and processed. In cases where the test organisms appeared extremely abundant, a fraction of the grid may have been removed. The material from the grid was examined under a stereomicroscope, and all the invertebrates were removed, sorted into major taxonomic groups, and placed in vials containing 70% ethanol. If there were less than 500 test organisms in the grid, another grid was selected and processed. This process was repeated until 500 organisms were removed from the sample, or until the entire sample was sorted. Organisms from a grid in excess of the 500 were counted and placed in a separate vial labeled "remaining test organisms," so that estimated total organism abundance and density for the sample could be calculated. Terrestrial organisms, vertebrates, water-column associated organisms (e.g., copepods), and nematodes were not removed from the samples. Processed material from the sample was placed in a separate jar and labeled "sorted," and the unprocessed material was returned to the original sample container and archived. Sorted material was retained for quality assurance purposes.

All organisms were identified to standard taxonomic level I (Genus level for most insects, Class or Order for most non-insects) as defined by the most recent version of the *Southwestern Association of Freshwater Invertebrate Taxonomists List of Macroinvertebrate Taxa from California and Adjacent States and Ecoregions; and Standard Taxonomic Effort* (November 2006). Quality assurance of sample sorting was performed on a minimum of 10 percent of the samples to ensure at least a 90% removal rate of organisms. Taxonomic quality assurance was performed on 10% of the samples by taxonomists at the CDFG Aquatic Bioassay Laboratory in Rancho Cordova, CA.

3.2.7 Data and Statistical Analysis

A taxonomic list of BMIs identified from the samples was created using Microsoft Excel. Metric values based on the BMI community were calculated from the database. A list of these metric values are presented in Table 3-5, including a brief description of what they signify and how they respond to ecological stressors.

For every monitoring reach, an Index of Biotic Integrity (IBI) was calculated utilizing the most recent method developed by CDFG (Ode et al., 2005). The IBI is derived from seven individual metrics and gives a numeric value to the benthic community quality based on the range of reference conditions in the region. The IBI scores are then classified into quality rating categories that range from Very Poor to Very Good. The IBI can also be used to evaluate community conditions over time to monitor the effects of habitat degradation or the success of restoration efforts.

Additional analysis of the data included an analysis of the trends of the monitoring results since the beginning of the program in May of 2001 and calculation of the O/E ratio. Like the IBI, the O/E approach produces an easily understood and ecologically meaningful summary of the biological condition at a site. The O/E ratio is the number of taxa observed ("O") at a test site compared to the number of taxa expected to occur ("E") based on local reference conditions. O/E ratio values can theoretically vary from over 1 (better than mean reference conditions) to zero (completely degraded - all expected taxa are missing). O/E is not based on raw taxa richness. Instead, O/E is constrained to include only those taxa predicted to naturally occur at a site (e.g., non-native taxa are generally excluded from the analysis). The relative value of each taxon observed is not equal and each has a predetermined percent probability of capture and a sensitivity index that factor into the results. The predictive model for most San Diego County sites is associated with warm, dry, flashy stream types. This model uses the classification variables of longitude, percent sedimentary bedrock, and long-term mean annual precipitation. This model works well for low gradient depositional coastal streams that are dominated by fine particulate sediment.

Table 3-5. Bioassessment Metrics Used to Characterize BMI Communities.

BMI Metric	Description	Response to Impairment
Richness Measures		
Taxa Richness	Total number of individual taxa	Decrease
EPT Taxa	Number of taxa in the Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly) insect orders	Decrease
Dipteran Taxa	Number of taxa in the insect order (Diptera, "true flies")	Increase
Non-Insect Taxa	Number of non-insect taxa	Increase
Composition Measures		
EPT Index	Percent composition of mayfly, stonefly, and caddisfly larvae	Decrease
Sensitive EPT Index	Percent composition of mayfly, stonefly, and caddisfly larvae with tolerance values between 0 and 3	Decrease
Shannon Diversity Index	General measure of sample diversity that incorporates richness and evenness (Shannon and Weaver, 1962)	Decrease
Tolerance/Intolerance Measures		
Tolerance Value	Value between 0 and 10 weighted for abundance of individuals designated as pollution tolerant (higher values) or intolerant (lower values)	Increase
Percent Dominant Taxa	Percent composition of the single most abundant taxon	Increase
Percent Chironomidae	Percent composition of the tolerant dipteran family Chironomidae	Increase
Percent Intolerant Organisms	Percent of organisms in sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1 or 2	Decrease
Percent Tolerant Organisms	Percent of organisms in sample that are highly tolerant to impairment as indicated by a tolerance value of 8, 9 or 10	Increase
Functional Feeding Groups (FFG)		
Percent Collector-gatherers	Percent of macrobenthos that collect or gather fine particulate matter	Increase
Percent Collector-filterers	Percent of macrobenthos that filter fine particulate matter	Increase
Percent Scrapers	Percent of macrobenthos that graze upon periphyton	Variable
Percent Predators	Percent of macrobenthos that prey on other organisms	Variable
Percent Shredders	Percent of macrobenthos that shreds coarse particulate matter	Decrease
Percent Others	Percent of macrobenthos that are parasites, macrophyte herbivores, piercer herbivores, omnivores, and xylophages	Variable
Abundance		
Estimated Abundance	Estimated number of BMIs in sample calculated by extrapolating from the proportion of organisms counted in the subsample	Variable
Source: SDRWQCB, 1999		

3.3 Ambient Bay and Lagoon Monitoring

The Ambient Bay, Lagoon, and Coastal Receiving Water Monitoring Program (ABLM) completed three years of monitoring during the summer of 2005. The data collected under this program were evaluated to determine if any linkage was observed between sediment conditions in the bays, estuaries, and lagoons and the freshwater conditions at upstream mass loading stations. A final report was prepared and was included as Appendix J in the San Diego County Municipal Copermittees 2005-2006 Urban Runoff Monitoring Report (Weston, 2007).

The ABLM program was not conducted during the 2006-2007 monitoring season. The methods used to perform the ABLM program are described in the San Diego County Municipal Copermittees 2005-2006 Urban Runoff Monitoring Report (Weston, 2007).

3.4 Watershed Management Area Assessment and Long-Term Effectiveness Assessment Rating Methods

3.4.1 Watershed Management Area Assessment Methods

The watershed data assessments were prepared using the interim guidance document "Watershed Data Assessment Framework" (June 2004) which closely resembles the "Model Storm Water Monitoring Program for Municipal Separate Storm Sewer Systems in Southern California" developed by the Storm Water Monitoring Coalition's (SMC) Model Monitoring Technical Committee. A complete description of methods and tools used to perform the watershed assessment can be found in the guidance document.

The watershed assessments are intended to provide a management tool for Copermittees to utilize in the development of short and long-term actions to address potential or actual water quality problems in the watershed. During the annual water quality assessment, the high, medium or low frequency of occurrence for COC(s) is evaluated for each watershed using the latest data collected and potential water quality issues are determined. In some cases confirmation of water quality problems will require that additional data be collected or assessed to understand the extent of the problem. Additional information to assess if a water quality problem exists may be available from third party data or a special study that can be used to answer questions relating to sources of the COC(s). In some instances, data from third parties or special studies may be used to further define the problem both spatially and temporally. The watershed assessment process leads to a prioritization of water quality issues by individual Watershed Copermittees and should assist them in short and long-term planning efforts, and developing activities directed at maintaining or improving water quality.

The watershed assessment process can be broken into seven steps:

1) Compare chemistry results to action levels and water quality objectives
2) Examine exceedance percentages, bioassessment rankings and toxicity results
3) Apply the Interim Criteria Ranking System to results
4) Evaluate third party data and 303(d) listing information
5) Examine any available trend information
6) Apply triad decision matrix to data
7) Identify priorities and recommend actions

Wet Weather

Wet weather chemistry data (physical, chemical, and bacteriological measurements) from the mass loading stations (MLS) were compared to the benchmark Water Quality Objectives (WQO) shown in Table 3-6 to determine the constituents that are exceeded most often in the watershed. The tables are not inclusive of all analytical measurements that can be conducted, but represent the constituents that are most common to water quality monitoring. If other chemistry data are available, the appropriate standards or water quality objectives are identified. In general, water quality objectives are defined in the San Diego County Copermittee program as benchmarks for comparison to monitoring results and do not necessarily reflect regulatory compliance for municipal storm water discharges.

Table 3-6. Benchmark Water Quality Objectives for Wet Weather Monitoring at Mass Loading Stations.

Constituent	Units	WQO[1]	Source
General / Physical / Organic			
Electrical Conductivity	umhos/cm		
Oil And Grease	mg/L	15	USEPA Multi-Sector General Permit
pH	pH Units	6.5-8.5	Basin Plan
Bacteriological			
Enterococci	MPN/100 mL		
Fecal Coliform	MPN/100 mL	400/4,000	Basin Plan REC-1/REC-2
Total Coliform	MPN/100 mL		
Wet Chemistry			
Ammonia As N	mg/L		
Un-ionized Ammonia as N	µg/L	25 (a)	Basin Plan
Biochemical Oxygen Demand	mg/L	30	USEPA Multi-Sector General Permit
Chemical Oxygen Demand	mg/L	120	USEPA Multi-Sector General Permit
Dissolved Phosphorus	mg/L	2	USEPA Multi-Sector General Permit
Nitrate As N	mg/L	10	Basin Plan
Nitrite As N	mg/L	1	Basin Plan
Surfactants (MBAS)	mg/L	0.5	Basin Plan
Total Dissolved Solids	mg/L	750	Basin Plan by watershed
Total Kjeldahl Nitrogen	mg/L		
Total Phosphorus	mg/L	2	USEPA Multi-Sector General Permit
Total Suspended Solids	mg/L	100	USEPA Multi-Sector General Permit
Turbidity	NTU	20	Basin Plan
Pesticides			
Chlorpyrifos	µg/L	0.02	CA Dept. of Fish & Game
Diazinon	µg/L	0.08	CA Dept. of Fish & Game
Malathion	µg/L	0.43	CA Dept. of Fish & Game
Hardness			
Total Hardness	mg $CaCO_3$/L		
Total Metals			
Antimony	mg/L	0.006	Basin Plan
Arsenic	mg/L	0.34/0.05	40 CFR 131/ Basin Plan
Cadmium	mg/L	(b)	40 CFR 131
Calcium	mg/L	(b)	
Chromium	mg/L	(b)	CTR (Cr VI)
Copper	mg/L	(b)	40 CFR 131
Lead	mg/L	(b)/0.1	40 CFR 131
Magnesium	mg/L	0.02	
Nickel	mg/L	(b)	40 CFR 131/ Basin Plan
Selenium	mg/L	0.006	40 CFR 131
Zinc	mg/L	0.34/0.05	40 CFR 131
Dissolved Metals			
Antimony	mg/L	(e)	40 CFR 131
Arsenic	mg/L	0.34 (c)	40 CFR 131

Table 3-6. Benchmark Water Quality Objectives for Wet Weather Monitoring at Mass Loading Stations.

Constituent	Units	WQO[1]	Source
Cadmium	mg/L	(b)	40 CFR 131
Chromium	mg/L	(b)	40 CFR 131
Copper	mg/L	(b)	40 CFR 131
Lead	mg/L	(b)	40 CFR 131
Nickel	mg/L	(b)	40 CFR 131
Selenium	mg/L	0.2 (d)	40 CFR 131
Zinc	mg/L	(b)	40 CFR 131

[1] The Water Quality Objectives (WQO) are benchmarks for comparison of storm water results and were selected by the Copermittee Monitoring Workgroup for this program.

(a) Water Quality Objective is for unionized ammonia which may be calculated from ammonia as nitrogen using pH, temperature and salinity.

(b) Water Quality Objectives for total and dissolved metal fractions are based on total hardness and are calculated as described by the USEPA Federal Register Doc. 40 CFR Part 131, May 18, 2000.

(c) Water Quality Objectives for dissolved metal fractions are based on water effects ratios (WER) and are calculated as described by the USEPA Federal Register Doc. 40 CFR Part 131, May 18, 2000.

(d) Water Quality Objective is based on the total recoverable form as described by the USEPA Federal Register Doc. 40 CFR Part 131, May 18, 2000.

(e) USEPA has not published an aquatic life criterion value.

Sources

USEPA National Pollutant Discharge Elimination System (NPDES) Storm Water Multi-Sector General Permit for Industrial Activities, 65 Federal Register (FR) 64746, Final Reissuance, October 30, 2000.

Siepmann and Finlayson 2000.

Basin Plan, September 8, 1994.

Assembly Bill 411 - Title 17 of the California Code of Regulations, Section 7958.

USEPA Federal Register Document 40 CFR Part 131, May 18, 2000.

MLS wet weather results were compared to water quality objectives found in the following sources:

- San Diego Basin Plan (September 8, 1994)
- California Toxics Rule (CTR) 40 CFR 131 – 65FR 31682, May 18, 2000
- USEPA Multi-Sector General Permit (65FR 64746, October 30, 2002)
- California Department of Fish and Game

In order to allow for comparison with exceedances at the dry weather station (DWS), for which different Action Levels are used, modifications were made to the benchmark WQOs for bacterial indicators. Wet weather results were compared against the dry weather action levels to determine exceedances for total coliforms and enterococci.

The water quality objectives utilized are the same across all watersheds in San Diego County except for total dissolved solids and fecal coliform. Total dissolved solids objectives are applied by hydrologic area or hydrologic sub-area as noted in the 1994 Basin Plan. Fecal coliform REC-2 standards are applied at Tecolote Creek, Chollas Creek, and Tijuana River, while REC-1 standards are used for all other watersheds.

Total and dissolved metals are compared to both the hardness based CCC (chronic) and CMC (acute) benchmark WQO's. The benchmark WQO for each metal is based on the hardness measured in the specific sample collected. Samples with relatively lower hardness concentrations will have lower benchmark WQOs for those metals based on the CTR calculation. Metals results over the previous two monitoring seasons were only compared to the criterion maximum concentration (CMC) or acute water quality objective benchmark since it is believed to be representative of short term conditions. However, the metals results are now compared to both the CMC (acute) and criterion continuous concentration (CCC) or chronic benchmark WQO for comparison purposes.. The CMC (acute) standard is usually applied to grab samples where as flow weighted composites (though not a 4-day average) are typically compared to the CCC (chronic) criteria. Since flow weighted composite storm water samples collected under this program do not fit either of these criteria, the samples are compared to both criteria. This change has resulted in some metals (particularly lead) being identified as a constituent of concern in some watersheds where in prior years it was not identified as a constituent of concern.

Toxicity testing at the MLS does not measure a constituent. Toxicity testing determines if an analyte (chemical or other) or group of analytes is present in concentrations capable of causing toxicity in the selected species. If persistent toxicity is identified at a site (e.g. more than 50% frequency of occurrence) the source (compound or compound class) of the toxicity can be identified using toxicity identification evaluations (TIE).

The results reported for the Copermittee monitoring program focus on the acute toxicity limit as the LC_{50} for *(C. dubia)* >100% or NOEC of 100% (*H. azteca*) for the test sample. This limit will take into account any inherent variability in the test, yet still be protective of the watershed. The seven-day chronic effects are estimated using the NOEC for both survival and reproduction. This is the highest concentration tested in which there was no statistically significant effect on the survival or reproduction compared to the control response. Lower NOEC values equate to higher toxicity in the sample. Therefore, a concentration of less than 100% is considered to have some degree of toxic effect. The water quality objectives used in regional monitoring program are shown in Table 3-7.

Table 3-7. Toxicity Benchmark Water Quality Objectives for wet weather monitoring at Mass Loading Stations.

Species/Test	Units	WQO	Source[1]
Toxicity			
Ceriodaphnia 96-hr	LC_{50} (%)	>100	NPDES Order 2001-01; Appendix D-6
Ceriodaphnia 7-day survival	NOEC (%)	100	NPDES Order 2001; Appendix D-6
Ceriodaphnia 7-day reproduction	NOEC (%)	100	NPDES Order 2001; Appendix D-6
Hyalella 96-hr	NOEC (%)	100	NPDES Order 2001; Appendix D-6
Selenastrum 96-hr	NOEC (%)	100	NPDES Order 2001; Appendix D-6

(1) Modified from TUa to NOEC as noted in the text.

Persistent toxicity is evident when more than 50% of the toxicity tests conducted to date for any given species at a specific site have a NOEC of less than 100%. The results of this determination are then combined with the high frequency constituents of concern (chemistry data) and benthic data in the Triad Decision Matrix to determine the actions to be taken.

Ratio to Water Quality Objectives

Ratios to the benchmark WQO were determined for constituents that have most frequently been above the benchmark WQO across all watersheds for each storm event in 2006-2007. Mean ratios to the benchmark WQO were determined for each constituent from previous years to compare changes over time. Santa Margarita River was not sampled during 2004-2005 and 2006-2007, therefore only the mean ratios to the benchmark WQO are presented for this MLS. The ratio to the benchmark WQO for each constituent was determined by dividing the constituent result by its respective benchmark WQO for each storm event monitored. The mean ratio is the mean of all ratios to the benchmark WQO for each constituent from previous monitoring years. Toxicity ratios were determined by dividing the no observed effect concentration (NOEC %) by 100 and then subtracting one. For example, a NOEC of 50% indicates toxicity was only observed in the undiluted sample based on the dilutions presented in the toxicity methods section. The ratio to the benchmark WQO of an organism with a NOEC of 50% is 1 [(100/50)-1=1] which is indicative of a toxic effect.

Dry Weather

In addition to the wet weather monitoring discussed above, a separate dry weather monitoring program is carried out by each jurisdiction. Dry weather monitoring reports are provided separately by each jurisdiction in its Jurisdictional Urban Runoff Management Program (JURMP) Annual Report. Dry weather data are also provided in a regional data sharing format which is used for the watershed management area assessments and regional comparisons in this report. Dry weather monitoring sites with field parameter and chemistry results are summarized in each section of the individual WMA sections. Dry weather sample data are compared to dry weather action levels. The data are tabulated indicating the number of results above the action level, the total number of samples collected in each WMA, the average ratio of exceedance, and the standard deviation of the ratio of exceedance.

Dry weather action levels are established by the Copermittees to trigger investigations upstream of the sampling location and to eliminate illicit connections and illegal discharges (ICID). Dry weather action levels were initially established in 2002 and are updated on a yearly basis, as necessary. The WMA assessments compare wet and dry weather exceedances. In some cases, the wet weather water quality objectives are not comparable with dry weather action levels. For example, turbidity action levels in dry weather samples are evaluated using Best Professional Judgment; while in wet weather (at the MLS) the Basin Plan water quality objective of 20 NTU is used. In order to allow for direct comparison with exceedances at the MLS, when assessing dry and wet weather samples for turbidity at a watershed level the Basin Plan objective was used. See Table 3-8 for a summary of the dry weather action levels used to perform the data evaluation.

Table 3-8. Dry Weather Action Levels

Constituent	Action Level	Note
pH	<6.5 or >9.0	
Orthophosphate-P	2.0 mg/L	
Nitrate-N	10.0 mg/L	
Ammonia-N	1.0 mg/L	
Turbidity	20 NTU	Used Basin Plan benchmark WQO instead of BPJ when comparing with MLS data
Conductivity	5000 us/cm	Based on best professional judgment (BPJ)
MBAS	1.0 mg/L	
Oil and grease	15 mg/L	
Diazinon	0.5 ug/L	
Chlorpyrifos	0.5 ug/L	
Dissolved Cadmium	CTR	Used CTR table, 1-hour criteria. Action level is based on hardness. Where hardness data were not available, the average value for the watershed was substituted.
Dissolved Copper	CTR	
Dissolved Lead	CTR	
Dissolved Zinc	CTR	
Total Coliform	50,000 MPN/100 mL	2005 Action Levels defined by 95th percentile were applied at the MLS for comparison with DWS data. Basin Plan objectives are only available for Fecal coliform (REC-1 and REC-2).
Fecal Coliform	20,000 MPN/100 mL	
Enterococcus	10,000 MPN/100 mL	

Establishing Frequency of Occurrence

The monitoring results (including all monitoring years' data) are examined to establish if percentages of the data collected exceed water quality objectives or action levels, toxicity results are prioritized, and bioassessment results are ranked. The matrix of findings is developed for each watershed (Table 3-9). The matrix includes a number of observations that exceed water quality objectives.

The COC Frequency of Occurrence ranking of "high", "medium", or "low" is established using the 2002-03 interim criteria (Table 3-10). This was the same criteria used during each successive annual report including the 2006-2007 monitoring season. The interim criteria take into account the exceedances at the MLS, DWS and coastal outfalls; and classify each COC as high, medium or low frequency of occurrence in the watershed. The classification of COC can change from year to year in response to the changes in the levels of the pollutants.

Dry Weather Station (DWS) data were given less weight in the determination of watershed COC due to factors that include:

1) The dry weather monitoring program's main focus is to identify illicit connections and illegal discharges (ICID). Sample stations may not be representative of overall urban runoff quality since they include samples of ponded water.
2) Dry weather monitoring parameters are a subset of MLS monitoring parameters.
3) DWS may be located in the MS4 upstream of BMPs (detention basins, etc.) and samples may not be representative of urban runoff entering the receiving water.

Only DWS located upstream of the MLS are taken into account when applying the interim COC criteria. In addition, only DWS samples collected during routine monitoring and not as part of the ICID investigation phase of the program are used in the assessment. The majority of the 2006 dry weather data used for the assessment represented routine site visits.

If the number of DWS sampled was small, best professional judgment was used when applying the interim COC criteria. For example, if only three samples were collected and one exceedance was observed, then the 33% exceedance frequency may not be representative of watershed conditions.

Benchmarks for bacterial levels are assessed differently in the MLS and DWS. The MLS water quality objective for fecal coliform was derived from the Basin Plan (REC-1 and REC-2) while DWS levels are compared to Copermittee defined action levels for all three bacterial indicators (total and fecal coliform and enterococcus). In order to compare the two datasets, the DWS action levels are applied to the MLS total coliform and enterococcus data. Otherwise, identification of bacterial indicators as potential COCs in the watershed between these two different data sets would not have been feasible.

Table 3-9. Matrix of Findings.

San Luis Rey River																		
Constituents With Any Wet Weather (MLS) WQO or Dry Weather Action Level Exceedance	MLS (Wet Weather) Results														Dry Weather Results *		Frequency of Occurrence	Criterion No.
	2001/2002		2002/2003		2003/2004		2004/2005		2005/2006		2006/2007		CUMULATIVE		2006			
	#/3	%	#/3	%	#/3	%	#/3	%	#/3	%	#/3	%	#/18	%	#	%		
Conventional Parameters																		
pH	0	0	1	33	0	0	0	0	0	0	0	0	1	6	1	2	-	-
BOD	0	0	0	0	1	33	0	0	0	0	1	33	2	11	NA	NA	-	-
Total Dissolved Solids	3	100	3	100	3	100	3	100	3	100	3	100	18	100	NA	NA	♦♦♦	1
Total Suspended Solids	0	0	1	33	0	0	1	33	0	0	0	0	2	11	NA	NA	-	-
Turbidity	0	0	1	33	0	0	2	67	0	0	1	33	4	22	11	23	♦	8
Ammonia[1]	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	-	-
Nutrients																		
Orthophosphate	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	-	-
Nitrate as N	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	17	♦	8
Bacteriological																		
Total Coliform	0	0	0	0	0	0	1	33	0	0	1	33	2	11	2	11	♦	8
Fecal Coliform	0	0	1	33	1	33	3	100	3	100	1	33	9	50	0	0	♦♦♦	4
Enterococcus	0	0	1	33	0	0	2	67	0	0	1	33	4	22	1	5	-	-
Pesticides																		
Diazinon	1	33	0	0	0	0	0	0	0	0	0	0	1	6	0	0	-	-
Toxicity																	EVIDENCE OF PERSISTENT TOXICITY?	
Ceriodaphnia 7-day reproduction	1	33	0	0	1	33	0	0	0	0	0	0	2	11	NA	NA	No	
Hyalella 96-hour	0	0	0	0	0	0	0	0	0	0	1	33	1	6	NA	NA	No	
Selenastrum 96-hour	0	0	0	0	1	33	0	0	0	0	0	0	1	6	NA	NA	No	
Bioassessment	IBI Rating																EVIDENCE OF BENTHIC ALTERATION?	
San Luis Rey River, at Benet Rd. (DS)	Very Poor		Very Poor		Very Poor		Very Poor		Very Poor		Very Poor		Very Poor		NA		Yes	
San Luis Rey River, Mission Rd.	Very Poor		Very Poor		Very Poor		Very Poor		Very Poor		Very Poor		Very Poor		NA			

* = Total number of observations varied among constituents.
NA = Not assessed.
[1] Wet weather data is compared to the Basin Plan WQO for un-ionized ammonia, dry weather data is compared to the dry weather action levels.
- = Constituent results are below the defined requirements for a Low Frequency of Occurrence rating.
♦ = Low Frequency of Occurrence rating.
♦♦ = Medium Frequency of Occurrence rating.
♦♦♦ = High Frequency of Occurrence rating.
DS = Downstream of MLS.

Table 3-10. Interim Criteria for Evaluating Mass Loading and Dry Weather Station Data.

COC Frequency of Occurrence	Criterion No.	Definition
High ♦♦♦	1	Mass loading station tests results exceed benchmark WQO in greater or equal to 80% of samples.
	2	Six of the last consecutive storm samples at the MLS exceed benchmark WQO.
	3	Less than 80% and greater than or equal to 50% of the MLS samples exceed benchmark WQO and at least one DWS exceedance in the past year.
	4	Less than 80% and greater than or equal to 50% of the MLS samples exceed benchmark WQO and a significant increasing trend is found.
Medium ♦♦	5	Less than 80% and greater than or equal to 50% of the MLS samples exceed benchmark WQO and no exceedances or data available for DWS in the past year.
	6	Less than 80% and greater than or equal to 50% of the MLS samples exceed benchmark WQO and one or more exceedances found in last 2 years of monitoring at the MLS (generally applies to historical datasets).
	7	Greater than 50% of the DWS samples have exceedances in the past year.
Low ♦	8	DWS exceedances in 10 to 50% of the samples in the past year.
	9	MLS exceedances found in 25% to less than or equal to 50% of the samples and at least one exceedances found in last 2 years at the MLS (with or without DWS exceedances in the past year).
	10	Greater than 50% of the MLS samples have exceedances and no exceedances in the last 2 years at the MLS.
Coastal Program	11	Persistent exceedances (greater or equal to 80% of samples). Add one ♦ to bacteria determination (up to three ♦ maximum).

Note: Best professional judgment applies when unique situations arise (fewer samples at a site; sewage spills) and for toxicity once it is linked to a specific COC.

Triad Assessment

For each watershed, all three elements of the triad (chemistry, toxicity, and benthic community) are assessed. Chemistry data provide an indication of the pollutant load during a storm event and toxicity data an indication of the potential impacts to aquatic organisms during storm events. Dry weather chemistry data provides an indication of urban runoff pollutants. The benthic community data collected during stream bioassessment provides a more direct indication of the ecological health of the watershed in terms of insect/benthic community abundance and diversity.

The triad assessment does not consider fecal coliform and total dissolved solids for the purposes of triggering a decision or action. The bacteria parameters are not considered in the triad because they are not believed to influence toxicity responses in bioassay test organisms. Further, the REC-1 (water contact) and REC-2 (non-contact) benchmark WQOs for bacterial indicators are set for the protection of human health. Total dissolved solids are not considered since the water quality objectives for this constituent as defined in the Basin Plan are set for municipal drinking water and do not necessarily reflect impacts to the ecology of the watersheds. However, fecal coliform and total dissolved solids data may be used to define high priority COC that lead to management actions even though they bypass the application of the triad decision matrix. Persistence in several indicators provides an indication of an ecological concern that triggers the need to conduct short-term actions, such as a TIE to identify the constituents in the watershed that may be responsible for storm water toxicity and/or benthic community degradation. Where long-term datasets are available, all the data are evaluated to identify persistent conditions. The majority of the mass loading stations are in their sixth year (2006-07) of monitoring and have data from 18 storm events available for the triad assessment. Persistence was determined for three elements of monitoring (chemistry, toxicity, and benthic community assemblage) using the definitions in Table 3-11.

Table 3-11. Triad Definitions for San Diego Storm Water Monitoring Program.

Triad Component	Definition
Persistent Exceedance of Water Quality Objectives	A constituent of concern with a high frequency of occurrence based on wet and dry weather data exceedances compared to established list of benchmarks or action levels.
Evidence of Persistent Toxicity	More than 50% of the toxicity tests for any given species have a NOEC of less than 100%.
Indication of Benthic Alteration	IBI score indicates a substantially degraded community (very poor).

Once persistence is determined in each watershed, the determination of short-term actions, namely TIEs are made using the Tabular Decision Matrix, Table 3-12.

Table 3-12. Tabular Decision Matrix – Chemical, Toxicity, and Benthic Assemblage Data Available (adapted from SMC Model Storm Water Monitoring Program, 2004).

Chemistry	Toxicity	Benthic Alteration	Example Conclusions	Example Actions or Decisions
1. Persistent exceedance of water quality objectives (high frequency COC identified)	Evidence of persistent toxicity	Indications of alteration	Strong evidence of pollution-induced degradation	1) Toxicity tests at higher dilutions to better quantify toxicity; Use TIE to identify contaminants of concern, based on TIE metric. 2) Evaluate/identify upstream source as a high priority.
2. No persistent exceedances of water quality objectives	No evidence of persistent toxicity	No indications of alteration	No evidence of current pollution-induced degradation Potentially harmful pollutants not yet concentrated enough to cause visible impact	1) No immediate action necessary. 2) Conduct periodic broad scans for new and/or potentially harmful pollutants.
3. Persistent exceedance of water quality objectives (high frequency COC identified)	No evidence of persistent toxicity	No indications of alteration	Contaminants are not bioavailable Test organisms not sensitive to problem pollutants	1) TIE would not provide useful information with no evidence of toxicity. 2) Continue monitoring for toxic and benthic impacts. Consider whether different or additional test organisms should be evaluated. 3) Initiate upstream source identification as a low priority.
4. No persistent exceedances of water quality objectives	Evidence of persistent toxicity	No indications of alteration	Unmeasured contaminant(s) or conditions have the potential to cause degradation Pollutant causing toxicity at very low levels Synergistic effects of multiple chemicals at low levels causing toxicity	1) Recheck chemical analyses and evaluate detection limits relative to reported toxic levels. 2) Verify toxicity test results; Consider additional advanced chemical analyses. 3) Toxicity tests at higher dilutions to better quantify toxicity: Use TIE to identify contaminants of concern, based on TIE metric; Evaluate/investigate upstream source as a medium priority.
5. No persistent exceedances of water quality objectives	No evidence of persistent toxicity	Indications of alteration	Alteration may be due to physical impacts, not toxic contamination Test organisms not sensitive to problem pollutants Synergistic effects of multiple chemicals at low levels causing toxicity	1) No action necessary based on toxic chemicals. 2) Consider whether different or additional test organisms should be evaluated. 3) Consider potential role of physical habitat disturbance.

Table 3-12. Tabular Decision Matrix – Chemical, Toxicity, and Benthic Assemblage Data Available (adapted from SMC Model Storm Water Monitoring Program, 2004).

Chemistry	Toxicity	Benthic Alteration	Example Conclusions	Example Actions or Decisions
6. Persistent exceedance of water quality objectives high frequency COC identified)	Evidence of persistent toxicity	No indications of alteration	Toxic contaminants are bioavailable, but in situ effects are not demonstrable Benthic analysis not sensitive enough to detect impact Potentially harmful pollutants not yet concentrated enough to change community	1) Determine if chemical and toxicity tests indicate persistent degradation. 2) Recheck benthic analyses; consider additional data analyses. 3) Toxicity tests at higher dilutions to better quantify toxicity: • If recheck indicates benthic alteration, perform TIE to identify contaminants of concern, based on TIE metric. Evaluate/investigate upstream source as a high priority. • If recheck shows no effect, use TIE to identify contaminants of concern, based on TIE metric. Evaluate/investigate upstream source identification as a medium priority.
7. No persistent exceedances of water quality objectives	Evidence of persistent toxicity	Indications of alteration	Unmeasured toxic contaminants are causing degradation Pollutant causing toxicity at very low levels Synergistic effects of multiple chemicals at low levels causing toxicity Benthic impact due to habitat disturbance, not toxicity	1) Recheck chemical analyses and consider additional advanced analyses. 2) Toxicity tests at higher dilutions to better quantify toxicity. Use TIE to identify contaminants of concern, based on TIE metric. 3) Evaluate/investigate upstream source identification as a high priority. 4) Consider potential role of physical habitat disturbance.
8. Persistent exceedances of water quality objectives (high frequency COC identified)	No evidence of persistent toxicity	Indications of alteration	Test organisms not sensitive to problem pollutants Benthic impact due to habitat disturbance, not toxicity	1) TIE would not provide useful information with no evidence of toxicity. 2) Evaluate/investigate upstream source identification as a high priority. 3) Consider whether different or additional test organisms should be evaluated. 4) Consider potential role of physical habitat disturbance.

3.4.2 Water Quality Priority Ratings – Long-Term Effectiveness Assessment Methodology

The Baseline Long-Term Effectiveness Assessment (BLTEA) report (WESTON, MOE, & LWA, 2005) was used to create water quality priority ratings using the five years of monitoring data collected at the end of the 2005-2006 monitoring season. This data set was used by the Copermittees to prioritize activities based on the available data set for the next permit cycle. The water quality priority ratings establish a process to relate water quality information to the overall effectiveness of the management program. Water quality characterization and prioritization is achieved through the water quality priority rating process conducted for each of the constituent/stressor groups on a sub-watershed and watershed basis. These constituent groups include:

- Heavy Metals
- Dissolved Minerals (Manganese, TDS, Sulfate)
- Organic Compounds
- Oil and Grease
- Sediment (TSS, Turbidity)
- Pesticides (Chlorpyrifos, Diazinon, Malathion)
- Nutrients (forms of Phosphorus, Nitrogen)

- Gross Pollutants (pH, Ammonia, BOD, COD, MBAS)
- Bacteria/Pathogens

The tables are updated every five years and are presented for the purposes of reviewing program activities. The detailed methods used to prepare the 2005-2006 water quality priority ratings tables can be found in the San Diego County Municipal Copermittees 2005-2006 Urban Runoff Monitoring Report (Weston, 2007).

The water quality priority ratings were determined using the full data set collected over the five years for the program. The dry weather data set provided results on a sub-watershed basis. However, the data set was limited and focused on sampling of storm sewers as opposed to receiving waters. In order to augment the current data set, the wet weather data from the MLS was used to project results up into the watershed as discussed below. The assessment of the water quality on a sub-watershed basis for the constituent groups was also supplemented using the ABLM results for sediment analysis. Therefore, the water quality rating on a sub-watershed and watershed basis for the nine constituent groups was based on results from the dry weather program, data from the Surface Water Ambient Monitoring Program (SWAMP) and from Padre Dam Municipal Water District (Padre Dam), the wet weather results from the MLS, and the sediment results from the ABLM program.

The additional evaluated stressor groups included Benthic Alteration and Toxicity. These last two groups were evaluated separately as they represented a stressor group that may be impacted by multiple constituents and/or stressors, as compared to the other groups that represented specific constituents. The basis for the water quality ratings for the Toxicity stressor group included the toxicity testing results from the wet weather sampling at the MLS and the sediment sampling conducted as part of the ABLM program. Dry weather toxicity data from the SWAMP dataset (2002-2004) were also included. These results were projected up the watershed as discussed below to provide a rating on a sub-watershed basis. The Benthic Alteration stressor group rating was based on the results at the regional bioassessment stations (Index of Biological Integrity, IBI), and the ABLM benthic community structure results (Benthic Response Index, BRI) conducted on sediment samples.

The constituent data representing the highest frequency of exceedance were then used to develop the prioritization ratings based on a score of 0 – 3. From the numerical score, a prioritization rating was assigned. The highest priority rating is A, followed by a rating of B, C, and D. D therefore represents a low priority rating.

Six method steps were used in development of the water quality priority rating for the nine constituent groups listed above (Figure 3-2). The tables are updated every five years and are presented for the purposes of reviewing program activities. The detailed methods used to prepare the 2005-2006 water quality priority ratings tables can be found in the San Diego County Municipal Copermittees 2005-2006 Urban Runoff Monitoring Report (Weston, 2007).

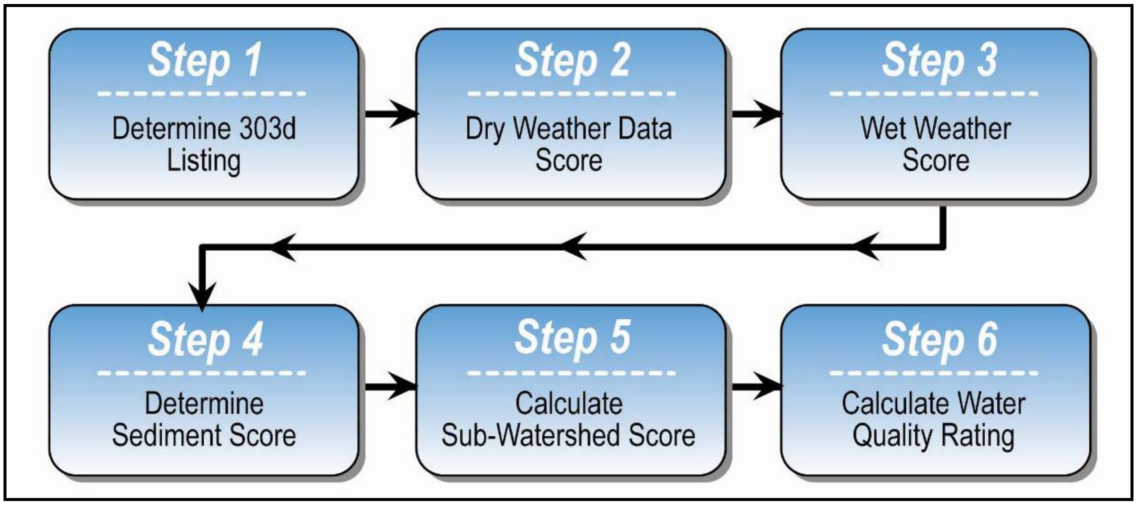

Figure 3-2. Water Quality Priority Rating Methodology.

3.5 Statistical Methods

The goals of the cross-watershed comparison are to assess all information from each watershed together to identify regional issues. Assessing all data from the region together also provides the ability to evaluate relationships among constituent and between toxicity effects and constituent.

3.5.1 Trend Analysis

Trend analysis was conducted for constituents and toxicity measured at each MLS station using current and historical data. Water quality data possess distributional characteristics that generally require specialized approaches to trend testing. Water quality data sets can contain censored (less than) values, outliers, multiple detection limits, missing values, and serial correlation. These characteristics commonly present problems in the use of conventional parametric statistics based on normally distributed data sets. The presence of censored data, non-negative values, and outliers generally lead to a non-normal data distribution which is common for many data sets. These skewed data sets require use of specific non-parametric statistical procedures for their analysis. Nonparametric statistical tests are more powerful when applied to non-normally distributed data, and almost as powerful as parametric tests when applied to normally distributed data (Helsel and Hirsch, 1992).

The nonparametric Mann-Kendall test for linear trend was used to evaluate whether a constituent or toxicity has increased or decreased significantly since the base year (Mann, 1945; Kendall, 1975). The test is non-parametric, rank order based, and insensitive to missing values. Sen's slope estimator (Sen, 1968) was used to estimate the magnitude of change over time when a significant trend was observed. Sen's slope estimator is a non-parametric method that is insensitive to outliers and can be used to infer the magnitude of a trend in the data.

The dataset contains constituent measurement with levels below the detection limit of the analytical method. These values were assigned the value of one-half the detection limit. Over time, several of the laboratory analytical techniques have lowered their limit of detection. An artifact of this advance is that the lower detection limit values of measurements later in the data record may be falsely detected as a downward trend. To avoid this, water quality values are censored to the one-half of highest detection limit of the analysis period as part of the data handling prior to analysis.

Data sets having large numbers of values below detection limit (BDLs) may create statistical problems for trend analyses. The Mann-Kendall test for trend adjusts variance estimates upward for ties in magnitude (Gilbert, 1990). Since BDL values in the raw data set produce such ties, trend analyses of data sets with high percentages of BDLs will be based upon greater variances than those without BDLs. Thus, the power of the trend analyses for the data sets with BDLs are reduced compared to those without detection limits censoring.

A simulation analysis on the effect of BDLs on Mann Kendall test and Sen slope estimator has provided standard guidelines for reporting trend statistics (Alden et al., 2000). These guidelines are widely accepted based on the percentage of BDLs present in the data set (Ebersole et al., 2002). The simulation analysis found that the power of the Mann-Kendall test begins noticeably to decline when censoring exceeds 35 %. However, if the Mann-Kendall test produces a significant result when the level of censoring is between 35% and 50%, this result may be valid in spite of the loss of power. If the Mann-Kendall test fails to produce a significant result when censoring is in the 35% to 50% interval, this failure may have resulted from a loss of power. Also; the Sen slope estimator begins to exhibit noticeable bias when censoring exceeds 15%. At levels of censoring of 15% or less, both the Mann-Kendall test results and the Sen slope estimator were found to be reliable.

The following guidelines were used to report trend information:

- If the percentage of BDL observations is 15 or less, report the trend test p-value, direction, and magnitude of the trend (i.e., Sen Slope).
- If the percentage of BDL observations is greater than 15 and less than or equal to 35, report the trend test p-value and direction only. Do not report the trend magnitude.
- If the percentage of BDL observations is greater than 35 and less than or equal to 50 and the trend test p-value indicates a significant trend, report the trend test p-value and direction. Do not report the trend magnitude.
- If the percentage of BDL observations is greater than 35 and less than or equal to 50 and the trend test p-value does not indicate a significant trend, report that there are too many observations below the detection limit to determine the presence or absence of trend.
- If the percentage of BDL observations is greater than 50, report there are too many observations below the detection limit to determine the presence or absence of trend.

The current and historical data used in the trend analysis are shown in a series of scatterplots (Appendix C). Scatterplots provide a visual comparison across all the years of data of collection. Scatterplots provide a visual representation of the relative concentrations of constituents between stations and storm events. Scatterplots are simple plots of concentrations of constituents plotted on the y-axis against time identified on the x-axis. Relevant trend information is reported with each scatterplot based on the guidelines described above.

Regional trend analysis was completed for constituents that showed similar trends in four or more watersheds by testing the homogeneity of stations. Following the methods outlined in Gilbert (1987), data collected at several different stations were analyzed to test if a regional-wide statement could be made about trends. A general statement about the presence or absence of monotonic trends is meaningful if the trends at all stations are in the same direction (i.e., all upward or all downward). In order to do this the Mann-Kendall statistic, computed for each station as described above, was used in the procedure developed by van Belle and Hughes (1984) to test for homogeneity of trends across the region. The van Belle and Hughes procedure does the following:

- Computes the homogeneity chi-square statistic
- Compares chi-square statistic with the critical value (M-1) in Table A19 (Gilbert, 1987)
- If the chi-square statistic exceeds the critical value, reject the null hypothesis (H_O) of homogeneous station trends (accepting the alternative hypothesis (H_A)). This would conclude that no regional-wide statements could be made about trend direction.
- Conversely, if the chi-square statistic is less than the critical value, accept the null hypothesis (H_O), concluding that homogeneity trend exists across the region (or stations) over the monitoring period.

3.5.2 Constituent Comparisons

Statistical analyses for regional assessment included the magnitude of the ratio of observed concentration to the benchmark WQOs, Mann-Kendall trend analysis, regional trend analysis (test of homogeneity) and multivariate cluster analysis. The regional assessment of the magnitude of benchmark WQO ratios for key constituents was based on the ratio of the annual mean concentration for the past six years of data to the appropriate benchmark WQO. These comparisons provide for identification of water quality issues specific to a watershed or common among several or all watersheds in the region. Scatterplots for each constituent for the years monitored were discussed in the individual watershed sections and presented in Appendix C. A regional analysis of constituents that indicate significant trends to date is presented in this section. The cluster analysis was used to identify mass loading stations and sampling dates with similar constituent patterns.

Scatterplots provide a visual representation of the relative concentrations of constituents between stations and storm events. Scatterplots are simple plots of concentrations of constituents plotted on the y-axis against time identified on the x-axis. Each constituent and toxicity test is represented by a series of scatterplots for each of the MLS. Non-detectable results were plotted at one-half the detection limit. All constituents were monitored at mass loading stations during three storms each year (with the exception of Santa Margarita River) and all points are included in scatterplots.

Multivariate cluster analysis, using agglomerative hierarchical cluster analysis and the Bray-Curtis dissimilarity index (Clifford, 1975) was completed to determine relationships between station/date and constituent. Agglomerative hierarchical cluster analysis is a method for grouping samples into unknown groups. Each sample begins as its own cluster, and samples most alike (or closest in multivariate space) are grouped together. These groups build until all samples are included. The groups are not decided before hand, and the number and characteristics of the groups are derived from the data (Afifi and Clark, 1990). For this analysis, the bacteriological measures were $\log_{10}$ transformed and the data for each constituent was square-root transformed and standardized by the overall mean value for each constituent. Constituent and station/date dendrograms were created that show the degree of dissimilarity among the entities in each. The dendrograms were combined with a two-way table of standardized values to demonstrate the relationships among stations/dates for the region.

3.6 Storm Event Loading Estimation

The primary measure of the quantity of a constituent is its concentration. Most constituents are measured in terms of their mass, and concentration usually has units such as mg/L. Concentration may also be defined for variables not measured in mass units. For example, bacteria are often measured as a number (e.g., most probable number or MPN) per unit volume. The impact of constituents on a water body may be influenced by both the concentration and by the load. Load is usually defined as the total mass delivered to a water body within a specific period of time (e.g., kg per day).

The event mean concentration (EMC) is the total storm load (mass) divided by the total runoff volume. EMC estimates are usually obtained from a flow-weighted composite of concentration samples taken during a storm. EMC values are obtained from a flow-weighted average and not simply a time average of the concentration. When the EMC is multiplied by the runoff volume, an estimate of the loading to the receiving water is provided. The instantaneous concentration at any time during a storm can be higher or lower than the EMC. The use of the EMC as an event characterisation replaces the actual time variation of concentration during a storm. This ensures that mass loadings from storms are correctly represented.

Just as instantaneous concentrations vary within a storm, EMCs, flows and loads vary from storm to storm (Figure 3-3). Non-point source flows originate from rainfall events and follow the temporal and spatial characteristics of rainfall to a large degree. A plot of concentration versus time is often called a pollutograph. The pollutograph frequently exhibits considerably higher concentrations near the beginning of the storm. This is known as the *first flush* phenomenon and is due to greater availability of solids and other associated pollutants that have built up on urban surfaces during dry weather. The wash-off of these pollutants is typically greater close to the beginning of a storm. The first flush is most evident in solids which are deposited during dry weather and scoured during the beginning of a wet weather event. As rainfall continues, the surface pollutant accumulation is depleted and pollutants are diluted by the larger flows in the storm water conveyance system. Also, the degree of the first flush depends on the intensity and the duration of rainfall and on the time between successive rainfall events.

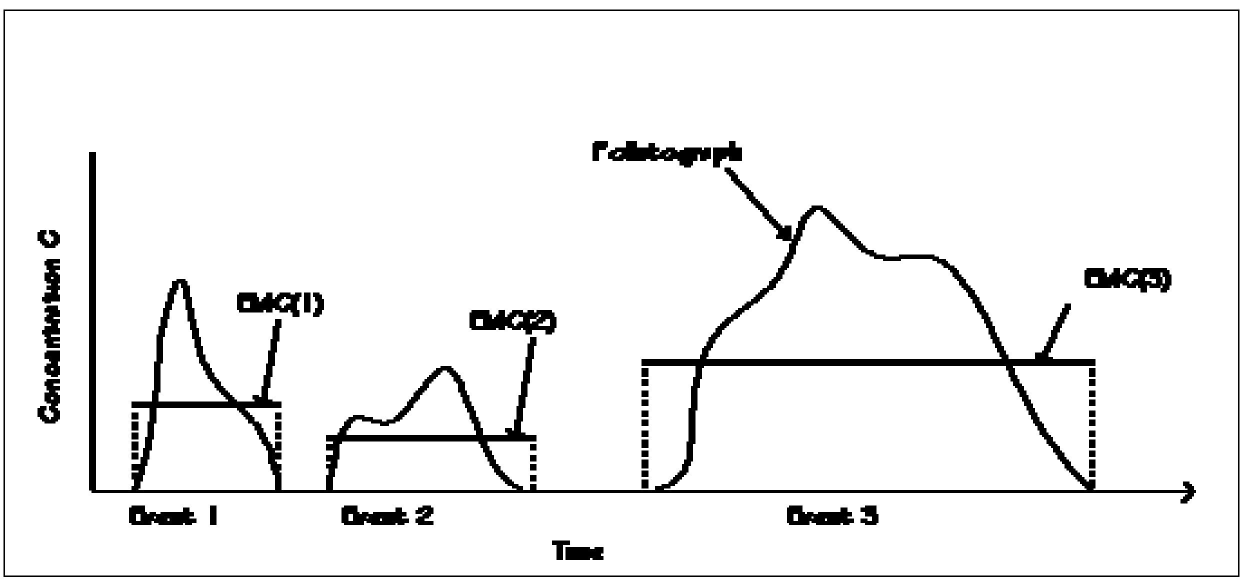

Figure 3-3. Interstorm Variation of EMCs

When site mean loads from different locations are aggregated, their variability can be quantified by their mean and coefficient of variation to achieve an overall description of the runoff characteristics of a constituent across various storms. Storm water contaminant concentrations have considerable variations. Different land uses affects the mass loads, since there are considerable differences in the percentage imperviousness between land use types or categories and thus in the volume of runoff. Pollutant loads can vary as a result of a large number of factors, including rainfall, soils, vegetation type, land use, and storm drainage management.

Loading values for each pollutant were derived using the EMC values obtained from composite samples collected at the MLS sites and the recorded volume of water discharged during the sampling period. Composite sampling at the MLS stations does not typically collect samples throughout the entire hydrograph before it returns to antecedent flows. Therefore, the EMC values and the resulting loads generally represent first flush conditions. At many of the MLS, the storm hydrograph can take many days to return to antecedent conditions. In larger watersheds, compositing of samples for longer periods would likely be representative of base flow from the upper watersheds and not the response due to storm water runoff. For those pollutants measured below the detection limit, one-half of the detection limit was used for the loading estimate.

Storm event loading values generally do not have associated water quality standards for comparison. When a TMDL is established for a particular surface water segment and constituent, the flow used to establish the TMDL is selected to represent critical conditions. For the MLS stations sampled these critical condition flows have not yet been established.

One method of evaluating measured storm event loads is to compare the results with what may be expected through land use runoff modeling. Pollutant loads were modeled using spatial data with a spreadsheet model. Load predictions were based three factors: (1) storm event rainfall interpolated across the watershed from the County's ALERT rain gage network, watershed's impervious surfaces, and the land use.

EMC values for each land use type were taken from the National Stormwater Quality Database (NSQD) (Pitt et al., 2004). This database represents monitoring data collected from nearly 4000 separate storm events over nearly a ten-year period from more than 200 municipalities throughout the country. The data characterize the EMCs from specific land use types (Figure 3-4). The range bars in Figure 3-4 indicate the 25^{th} and 75^{th} percentile values. In addition, the NSQD also contain data on the impervious surface areas measured for each land use.

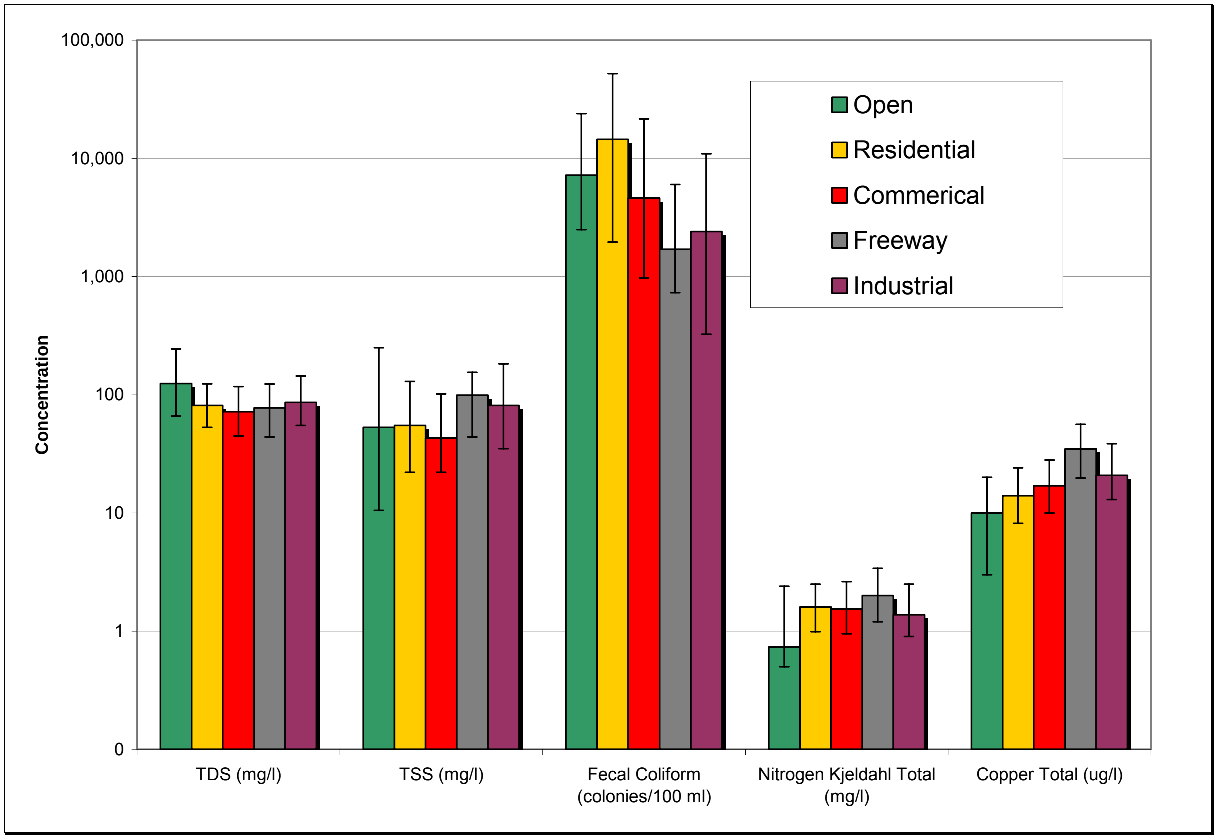

Figure 3-4. NSWQ Land Use Concentrations.

Adequate land use specific runoff EMC data are not available for the southwest U.S., so the national median values were used for this modeling. However, comparison of the national median concentrations against the median concentrations found in the southwest (EPA Rain Region VI) show similar values (Figure 3-5). Again, the range bars in Figure 3-5 indicate the 25th and 75th percentile values. The range bars give an indication of the magnitude of variation that might be expected from using NSQD land use EMCs in storm water runoff load modeling. Median impervious surface coverage for each land use was also taken from the NSQD.

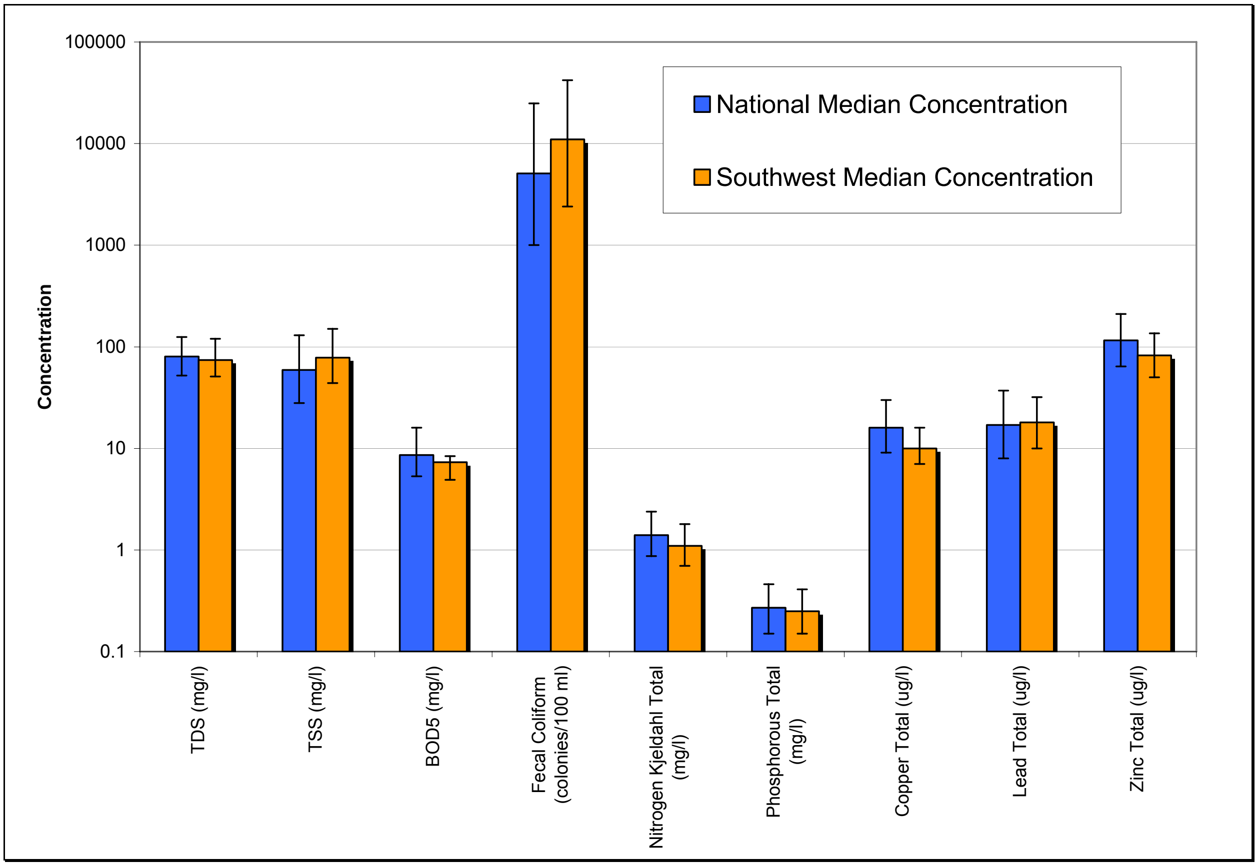

Figure 3-5. National and Regional NSWQ Median EMCs.

The San Diego Association of Governments (SANDAG) geographic information system (GIS) database and the SANDAG 2006 Generalized Land Use maps were used to determine land use within the catchments of the mass loading sites. SANDAG data was supplemented with information from the Center for Earth Systems Analysis Research at San Diego State University for catchment areas within Mexico (e.g., Tijuana River MLS). Land use information from 1995 was obtained for the Mexican portion of the Tijuana Hydrologic Unit.

The runoff volume for each storm event was predicted using the "Simple Method" (Schueler, 1987). The Simple Method calculates runoff volume as a product of precipitation volume and a runoff coefficient (Rv). Runoff volume is calculated as:

<u>R = P * Pj * Rv</u>

Where:

R = storm event runoff (inches)
P = storm event rainfall (inches)
Pj = Fraction storm event with runoff
Rv = Runoff coefficient

The fraction of the storm event with runoff is assumed as 1.0 since the entire precipitation volumes were measured. The runoff coefficient is calculated based on impervious cover in the MLS catchment. Land use specific median impervious surface percentages were taken from the NSQD. Catchment imperviousness was shown to be a reasonable predictor of Rv (R^2=0.71) (Schueler, 1987).

The predicted loading values for each mass loading station and storm event were estimated by multiplying the contributing runoff volume from each land use type by the NSQD land use based EMCs for each MLS catchment area (Figure 3-6). The Simple Method estimates pollutant loads for chemical constituents as a product of runoff volume and pollutant concentration, as:

$\underline{L = C * R * EMC * A}$

Where:

L = Annual load (lbs)
R = Runoff (inches)
EMC = Pollutant concentration (from NSQD)
A = Area (acres)
C = Unit conversion factor

Measured storm event loads were compared to the modeled storm event loads. As discussed above, measured storm event loads most often only represent the first flush of the storm event due to the sampling protocol used. The modeled storm event loads represent the entire volume of runoff from the entire rainfall volume of the event. In order to compare the measured loads with the modeled loads, the proportion of the storm volume sampled must be determined. This proportion can be expressed as the ratio of the modeled volume of runoff for the storm event to the volume of water that passes by the MLS during sample compositing. This ratio is then used to estimate what the measured load would be if the entire event runoff were sampled. The estimation of the full storm load allows the comparison to expected loading based on land use and rainfall event modeling.

Measured loading values for each constituent sampled and each storm event were derived using the EMC values obtained from composite samples collected at each MLS site and the recorded volume of water discharged during the sampling period. The entire runoff for each storm event runoff was derived using the "Simple Method" (Schueler, 1987) based on event rainfall amounts and impervious areas in the MLS catchment. Entire storm event loads were estimated from measured loads using the proportion of runoff estimated through modeling to that runoff measured during sample compositing.

Measured storm event loads were compared to loading values derived from the National Stormwater Quality Database (NSQD) (Pitt et al., 2004). For each land use, the 25^{th} percentile and the 75^{th} percentile EMC from the NSQD were used to derive area weighted EMC values for each MLS catchment. The interquartile range (between the 25^{th} and 75^{th} percentiles) of these area-weighted loads can be used as expected loads based on the national database. One can evaluate the degree of measured loading in terms of the range of expected loads.

Measured loads (estimated for the entire storm event) were compared to the 25^{th} and 75^{th} percentile loads estimated through land use and rainfall modeling. Measured loading values were identified that were greater than, less than or within the range of expected loads.

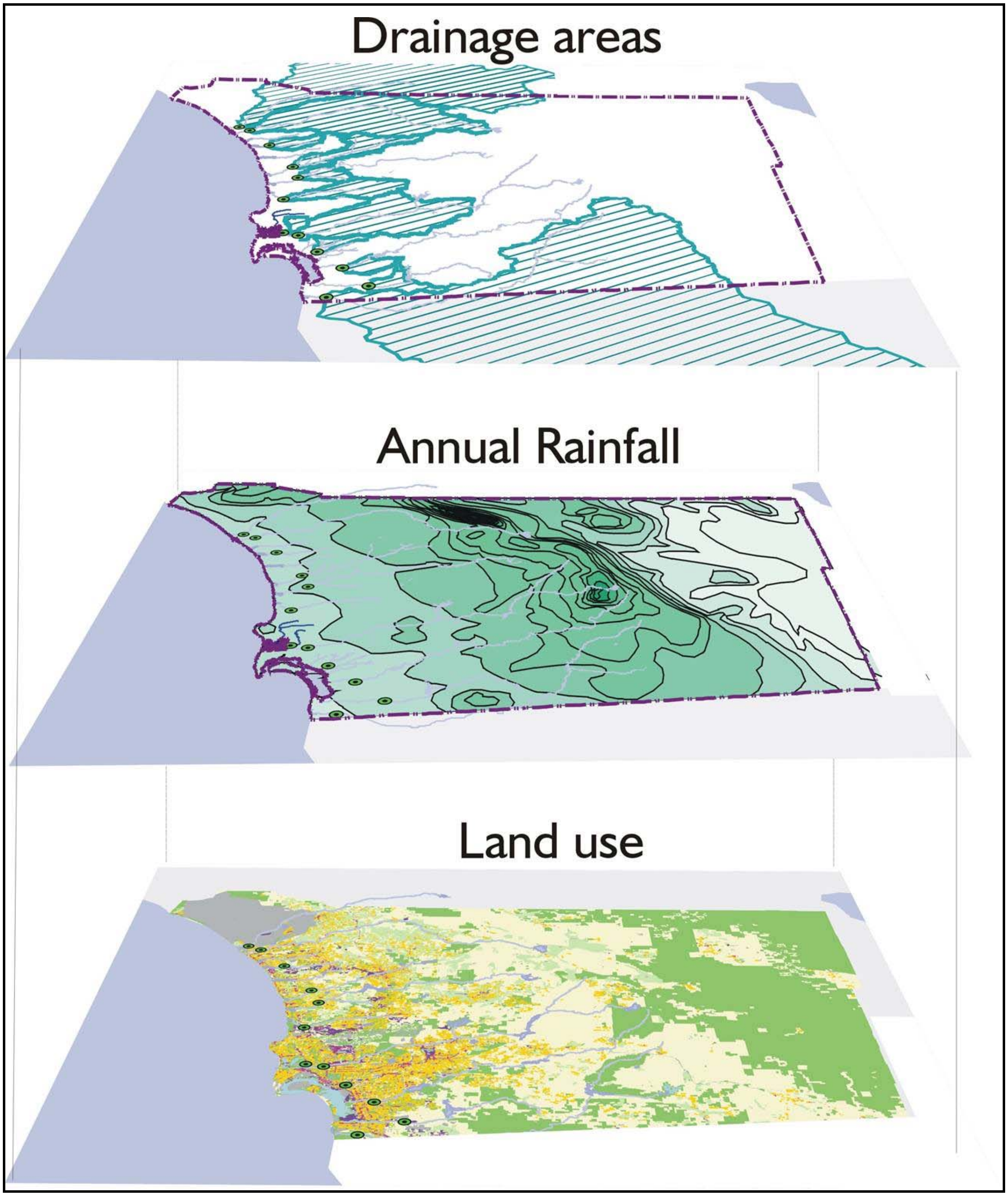

Figure 3-6. Spatial Data Use for the Loading Model Estimates.