3.1 Storm Water Monitoring Methods

The core monitoring program includes collection and analysis of storm water runoff at mass loading stations. Storm water was collected during three storm events at each mass loading station and analyzed for chemical constituents and toxicity to bioassay test organisms. This section describes storm water monitoring methodology.

3.1.1 Mass Loading Station (MLS) Site Selection

The 2003-2004 storm water monitoring program included eleven mass loading monitoring stations. The mass loading stations monitor large drainage areas with mixed land use characteristics. Their locations are shown in Figure 2-13. In 2000, the mass loading monitoring site locations were selected by MEC-Weston, 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 mass loading 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, suitable for measurements and 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 the storm season, 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 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 pollutants 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 A.

3.1.4 Stream Rating Methods

During storms, the flow rate at each of the monitoring sites was determined by water velocity and stream stage (water level) sensors that are typically secured to the bottom of the channel. However, to better quantify flow rates and produce a more complete rating curve, each of the streams was also assessed using the classical stream rating method developed by the USGS.

Stream rating on Peñasquitos Creek

The materials used for the stream rating included a Marsh-McBirney Model 2000 Portable Flow Meter connected via a cable to an electromagnetic open channel velocity sensor. The sensor is attached to a stainless steel top-setting wading rod. To make a 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. Generally, depth and flow were both zero at this point unless the bank was very steep. 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. Several stream ratings were measured for each of the streams where flow was measurable after a storm and combined to produce a rating curve for each stream. Information from the rating curve was used to more accurately predict expected flow rates and appropriate sampling frequencies during storms.

3.1.5 Sample Handling and Processing

In accordance with USEPA sampling protocols and the MEC-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) were as recommended by the Standard Methods for Examination of Waters and Wastewaters and the USEPA methods. All storm water samples were transported from the field to the laboratory under MEC-Weston chain-of-custody procedures. Samples moved between laboratories were transported under the laboratories' chain-of-custody procedures. Samples were submitted by MEC-Weston to EnviroMatrix Analytical, Inc. in San Diego, CRG Marine Laboratories in Torrance, and Aqua-Science in Davis, California.

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) and the organophosphate pesticides diazinon and chlorpyrifos. The field measurements were made by MEC-Weston field technicians and scientists during field sampling activities.

Both the enzyme-linked immunosorbant assay (ELISA) method and EPA 625 were utilized to test for diazinon and chlorpyrifos. During the 2002-2003 monitoring season the chemistry laboratory was not able to consistently meet the low reporting limit requirements using EPA 8141 and the ELISA data was utilized for organophosphate pesticides. Based upon the 2002-2003 results, the 625 method was added to provide a means of consistently meeting the low reporting limit requirements. The ELISA technique was continued in the event the chemistry laboratory was unable to consistently meet the low reporting limit required for these analytes.

The use of the ELISA method was originally adopted because the chemistry laboratory was unable to consistently provide low detection limit reporting for diazinon and chlorpyrifos throughout the 2000-2001 wet season. The changes in detection limit through the wet season and the use of qualifiers in the analytical data reports made an assessment of diazinon concentrations at mass loading stations difficult. Further, the higher detection limits reported by the laboratory in 2000-2001 precluded correlation of toxicity effects to diazinon concentrations because the reporting limits provided by the laboratory were above the concentrations at which diazinon is known to cause toxicity to aquatic organisms. For these reasons, in the 2001-2002 and 2002-2003 monitoring seasons, MEC-Weston utilized the ELISA technique performed by Aqua Science in Davis, California. The ELISA method has been used successfully in other monitoring programs to determine concentrations of diazinon in surface waters and urban runoff. This technique was used in the source identification study performed in Chollas Creek (MEC 2002). The use of ELISA has been shown to provide sensitive and reliable results (Sullivan 2000).

During the 2003-2004 monitoring season CRG Marine Laboratories also provided laboratory services for the analysis of diazinon and chlorpyrifos using the EPA 625 Method. CRG was able to consistently meet the low detection limits.

The following table (Table 3-1) lists chemical constituents measured in this monitoring program.

Table 3-1. Analytical requirements for mass loading stations.

Constituent	Volume Required	Method	Reporting Limit	Units	Holding Time
Conventionals, Nutrients, Hydrocarbons					
Total Dissolved Solids (TDS)	100 mL	SM 2540C	20	mg/L	7D
Total Suspended Solids (TSS)	100 mL	SM2540D	20	mg/L	7D
Turbidity	100 mL	SM 2130A-B	0.05	NTU	48H
Total Hardness	150 mL	SM 2340B	10	mg/L	6M
pH	In field	EPA 150.1	0.1	S.U.	1
Specific Conductance	In field	SM 2510B	1	umhos/cm	28D
Temperature	In field				1
Dissolved Phosphorus	250 mL	SM 4500PE	0.05	mg/L	48H
Total Phosphorus	250 mL	SM 4500PE	0.05	mg/L	28D
Nitrate and Nitrite	200 mL	SM4500NO2-NO3	0.1/0.05	mg/L	48H
Total Kjeldahl Nitrogen (TKN)	500 mL	SM4500C	0.05	mg/L	28D
Ammonia	250 mL	SM 4500NH3D	0.1	mg/L	28D
Biological Oxygen Demand, 5-day (BOD)	1000 mL	SM5210B	2	mg/L	48H
Chemical Oxygen Demand (COD)	25 mL	EPA 410.4	25	mg/L	28D
Total Organic Carbon (TOC)	125 mL	SM5310 B	1	mg/L	28D
Dissolved Organic Carbon (DOC)	125 mL	SM5310 B	1	mg/L	28D
Methylene Blue Active Substances (MBAS)	250 mL	SM 5540C	0.5	mg/L	48H
Oil and Grease (O&G)	500 mL	EPA 413.2	1	mg/L	14D
Pesticides					
Diazinon	1 liter	ELISA/ EPA 625/8270	0.05	µg/L	14D
Chlorpyrifos	1 liter	ELISA/ EPA 625/8270	0.05	µg/L	14D
Malathion	1 liter	ELISA/ EPA 625/8270	0.05	µg/L	14D
Metals, Total & Dissolved					
Antimony (Sb)	75 mL	EPA 200.8	0.002	mg/L	6M
Arsenic (As)	75 mL	EPA 200.8	0.001	mg/L	6M
Cadmium (Cd)	75 mL	EPA 200.8	0.001	mg/L	6M
Chromium (Cr)	75 mL	EPA 200.8	0.005	mg/L	6M
Copper (Cu)	75 mL	EPA 200.8	0.005	mg/L	6M
Lead (Pb)	75 mL	EPA 200.8	0.002	mg/L	6M
Nickel (Ni)	75 mL	EPA 200.8	0.002	mg/L	6M
Selenium (Se)	75 mL	EPA 200.8	0.004	mg/L	6M
Zinc (Zn)	75 mL	EPA 200.8	0.02	mg/L	6M
Bacteriological					
Total Coliform	200 mL	SM 9221B	*	MPN/100 mL	6H
Fecal Coliform	200 mL	SM9221E	*	MPN/100 mL	6H
Enterococcus	200 mL	SM 9230	*	MPN/100 mL	6H
Toxicity	20 L				

7-day chronic test with the cladoceran *Ceriodaphnia dubia*

Chronic test with the freshwater algae *Selenastrum capricornutum*

Acute survival test with the amphipod *Hyalella azteca*.

See Section 1, Table 1-4 for additional constituents monitored.

3.1.6.2 Toxicity Testing

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., 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 animals 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. These included the Santa Margarita River, San Diego River, Chollas Creek, Tecolote Creek, Escondido Creek, Peñasquitos Creek, San Luis Rey River, Sweetwater River, Tijuana River, Agua Hedionda Creek, and San Dieguito River. It is important to note that, ultimately, all of the receiving water bodies for these drainage basins are estuarine/marine (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. The core monitoring program includes ambient bay and lagoon monitoring to assess long term impacts to marine/estuarine receiving waters.

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. The freshwater plant *Selenastrum capricornutum* is a unicellular alga 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. Toxicity tests were conducted by MEC'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 animals 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 animals 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 NOEC, or No Observed Effect Concentration, for both survival and reproduction are calculated. This is the highest concentration tested in which there was no

statistically significant 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 very differently and are not interchangeable or related. The TUa equals $100/LC_{50}$. If the LC_{50} is greater than 100%, then 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 animals 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 animals 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 99/00 and 00/01 storm seasons proved 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 third 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.

*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.

3.1.6.3 Microbiology Testing

Measures of bacteria from grab samples were made by MEC-Weston microbiology laboratory located in Carlsbad, California. Samples were collected during the storm event using grab poles and aseptic techniques by MEC-Weston field technicians and scientists and delivered to the microbiology laboratory within the 6-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/100mL) with no "greater than" values reported.

3.2 Rapid Stream Bioassessment Methods

MEC-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. MEC-Weston followed the sampling and analysis protocols of the California Stream Bioassessment Procedure (CSBP) (Harrington 1999), 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, MEC-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). Invertebrates 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 2003 and May 2004. 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 for coastal southern California (Ode, Rehn, and May, In Press).

Benthic macroinvertebrate sampling

3.2.1 Materials and Methods

A general description of the methods incorporated in the sampling program is presented below. MEC-Weston personnel adhered to the protocols of the CSBP (Harrington 1999) 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 3-2 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 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 re-location of some of the monitoring reaches since the beginning of the program.

Table 3-2. San Diego County: Stream Bioassessment Monitoring Sites. June 2001 to May 2004.

Watershed Name	Receiving Water	Station Identification	Site Description	Station Coordinates	Jun-01	Oct-01	May-02	Oct-02	May-03	Oct-03	May-04
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
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	
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
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	Cedar Creek	REF-CC	Reach consisted of 5 riffles upstream of Cedar Creek Road	33 01.154' 116 38.029'					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
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			

Table 3-2. San Diego County: Stream Bioassessment Monitoring Sites. June 2001 to May 2004.

Watershed Name	Receiving Water	Station Identification	Site Description	Station Coordinates	Jun-01	Oct-01	May-02	Oct-02	May-03	Oct-03	May-04
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
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
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
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	
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
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
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	Reach 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			
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
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
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

Table 3-2. San Diego County: Stream Bioassessment Monitoring Sites. June 2001 to May 2004.

Watershed Name	Receiving Water	Station Identification	Site Description	Station Coordinates	Jun-01	Oct-01	May-02	Oct-02	May-03	Oct-03	May-04
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
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
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	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
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
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
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
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
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
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
Sweetwater River	Sweetwater River	SR-94	Reach consisted of 5 riffles at Highway 94	32 44.005' 116 56.348'			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
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-DM	Reach consisted of 5 riffles upstream of Dairy Mart Road	32 32.816' 117 03.741'					x		

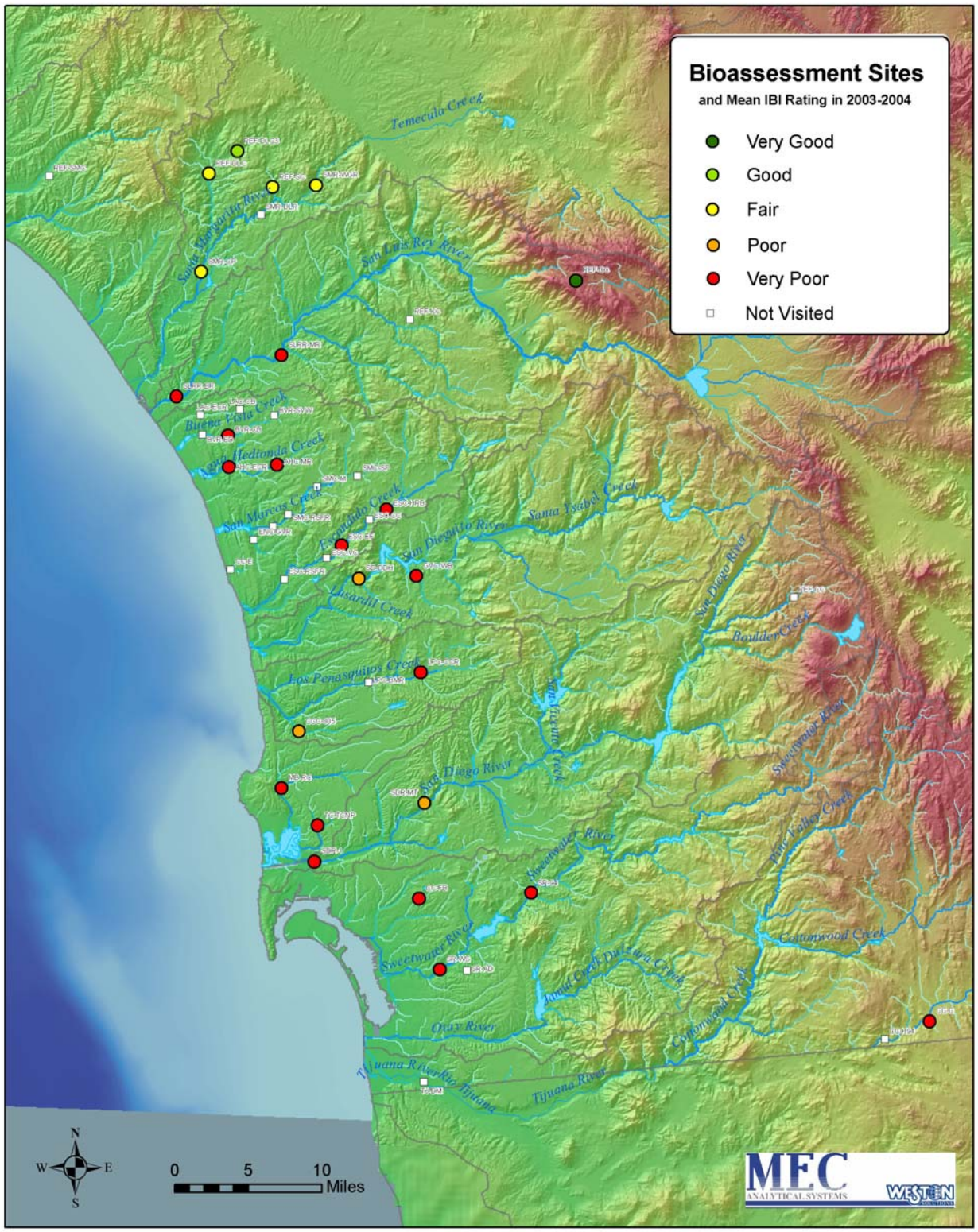

Figure 3-1. Stream Bioassessment Sites Sampled May 2003, October 2003, and May 2004.

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. It may be noted that the physical habitat quality at the reference sites was superior to some of the test monitoring sites.

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 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, only three riffles could be located within a reasonable reach length, and all three were 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 3-2, 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 2-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, 2-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 until three separate replicate samples were collected. Samples were transferred to one-quart jars, and preserved with 95% ethanol, and returned to MEC-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 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.

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 glass tray marked with grids 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 animals 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 300 animals in the grid, another grid was selected and processed. This process was repeated until 300 organisms were removed from the sample, or until the entire sample was sorted. Organisms from a grid in excess of the 300 were counted and placed in a separate vial labeled "remaining animals," so that a total abundance for the entire 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 the standard taxonomic level described in the CAMLnet List of Californian Macroinvertebrate Taxa and Standard Taxonomic Effort, using standard taxonomic keys. 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 and a brief description of what they signify are presented in Table 3-3.

For every monitoring reach, an Index of Biotic Integrity (IBI) was calculated utilizing the most recent method developed by CDFG (Ode, Rehn, and May, In Press). The IBI replaces the Benthic Macroinvertebrate Index (BMI) Ranking Score used in past analyses and is a significant improvement because it gives an absolute value to the benthic community quality based on the range of reference conditions in the region. 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 a comparison of IBI scores with habitat quality, and an analysis of the trends of the monitoring results since the beginning of the program in May of 2001.

Table 3-3. 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 1963)	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

Under the NPDES permit granted to the County of San Diego by the San Diego Regional Water Quality Control Board, the Copermittees are required to develop and implement a program to assess the overall health of the receiving waters and monitor the impact of urban runoff on ambient receiving water quality. This program, known as the Ambient Bay and Lagoon Monitoring (ABLM) Program, is intended to include San Diego Bay, Mission Bay, Oceanside Harbor, the Pacific Coastline, coastal lagoons and estuaries, and all Clean Water Act section 303(d) water bodies or other environmentally sensitive areas. To implement the first year of this monitoring program, evaluations of sediment chemistry, sediment toxicity, and ecological community (benthic infauna) structure in the coastal embayments (lagoons and bays) of San Diego County were monitored and analyzed. Data from these evaluations are intended to provide an indication of how aquatic life in the bays and lagoons is affected by pollution, and allow prioritization of outfall areas of coastal embayments for additional investigation in subsequent years. The data assessed in this report were from samples collected in the summer of 2003. Data collected in the summer of 2004 will be assessed in the 2004-2005 report.

3.3.1 Objectives and Approach

The ABLM program has several objectives:

- to fulfill NPDES requirements for San Diego County,
- to initiate a regional study of coastal embayments,
- to assess the overall health of the receiving waters, and
- to monitor the impact of urban runoff on ambient water quality.

The first step in fulfilling the objectives was to conduct a literature review to determine what information and data were available that could be used to design an appropriate monitoring program. The relevant data and information were used to create the sampling design, assess its validity using empirical data from other studies, and delineate the appropriate sampling effort.

The literature review covered southern California bays and lagoons: Newport Bay, Santa Margarita River and Estuary, Oceanside Harbor, San Luis Rey River and Estuary, Batiquitos Lagoon, San Elijo Lagoon, Aqua Hedionda Lagoon, Buena Vista Lagoon, San Dieguito Estuary, and Los Peñasquitos Lagoon. Documents and data more than 10 years old were considered non-reflective of current conditions in most of these bays and lagoons and therefore excluded from the review. The literature review targeted information related to sediment grain size, organic carbon concentrations, sediment toxicity, bacteria, infaunal communities, and contaminant concentrations. Data were sought that could be related to gradients within each water body, i.e. information near watershed inputs, middle lagoon or bay, and areas furthest from potential watershed inputs. Information was available for all these areas but there was little consistency on the parameters measured or the methods utilized. Most of the sampling and monitoring within the target sites related to water quality measures and/or only a few locations with other measured sediment parameters.

The results of the literature review demonstrated that the physical characteristics and depositional patterns within coastal embayments vary spatially in a longitudinal and lateral sense. There are wide variations in sediment characteristics within coastal embayments because of temporal variations in deposition patterns, the influence of stream and tidal channels, sequestering of contaminants by marshes

and grasses, and connectivity with the ocean. Sediments that accumulate in coastal embayments as a result of urban runoff are dispersed according to the different energy conditions that are encountered at stream outfalls and in the embayment. Fine-grained sediments tend to accumulate in lower energy conditions between active stream and tidal channels; whereas, coarser sediments accumulate in stream and tidal channels as point bars. This variability complicates measuring and assessing the concentration and distribution of contaminants and requires that care be taken to specify the frequency and locations of field samples. Site assessments are further complicated by seasonal effects, which can be regular, or atypical, caused by drought that can reduce sediment outflow or high-energy storms that can displace large amounts of sediments and significantly alter the distribution and availability of contaminants.

Accounting for this inherent variability in monitoring coastal embayments requires comprehensive site assessments that reflect the possible range of variability of both long-term, periodic variations and infrequent, but often high-energy, episodic events. Such comprehensive assessments can be extremely labor intensive and expensive. Thus, rather than trying to directly measure contaminant loading in the water, the approach that was used in the ABLM Program focuses on the receiving water sediments where contaminants are most likely to be found. It was clear from the literature review that fine-grained sediment particles in the size range typical of silts and clays (<64 microns in diameter) are favored adsorption sites for most contaminants found in the waters of coastal wetlands (Gibbs 1973, Moore et al. 1989, Kennish 1998). Fine-grained sediments tend to have large surface areas with unsatisfied surface charges that promote adsorption of ionic complexes of metals, PCBs, PAHs, and pesticides. This association is particularly strong where fine-grained sediments are associated with high levels of total organic carbon (TOC). Additionally, fine-grained, organic sediment in overabundance can overwhelm the endemic flora and fauna of lagoons and estuaries. Because of their ability to complex and adsorb pollutants, fine-grained sediments with high TOC content are the most likely to be influenced by watershed contaminants and thus pose the greatest threat to the biological communities in the embayment.

3.3.2 Validation of Approach

To validate this association, information from benthic sediment quality and toxicity monitoring conducted in Newport Bay, California in 1994 (EMAP 1997) was assessed to determine if the sediments with the highest TOC concentrations and greatest proportion of fines also had the highest concentrations of contaminants. Samples taken from 12 sites in Newport Bay (includes upper, middle, and outer areas of the Bay) were ranked according to their grain size and TOC concentration. The ranks were summed and the summed ranks were separated into four groups of three samples each, according to the sediment ranks. Group 1 was the group with the highest TOC concentration and finest grain sediments. Concentrations of several contaminants (16 metals, total DDT, total PAHs, and chlordane) and amphipod toxicity were then compared between the groups by analysis of variance (ANOVA). The purpose of the ANOVA was to see if Group 1 (the "finest grain, highest TOC" group) also had higher contaminant levels. The results of the analyses are presented in Table 3-4.

Table 3-4. Results of ANOVA on 1994 Newport Bay data.

Constituent of Concern	Prob > F	Tukey-Kramer Comparison Groups Highest to Lowest			
Aluminum	0.174	4	2	3	1
Antimony	0.007	1	2	3	4
Arsenic	0.726	1	3	2	4
Cadmium	0.006	2	1	3	4
Chromium	0.010	1	2	3	4
Copper	0.014	1	3	2	4
Iron	0.004	1	2	3	4
Lead	0.541	1	2	3	4
Manganese	0.485	1	2	4	3
Mercury	0.449	3	1	4	2
Nickel	0.014	1	2	3	4
Silver	0.127	2	4	3	1
Selenium	0.027	1	2	3	4
Tin	0.017	1	2	3	4
Zinc	0.003	1	2	3	4
DDT	0.001	1	2	3	4
PAH	0.129	1	2	3	4
Chlordane	0.007	2	1	3	4
R. abronius mortality	0.132	2	1	3	4

Eleven of the 20 ANOVAs were significant (at a 95% confidence). For nine of the contaminants, Group 1 was the highest in concentration and Group 4, with the lowest TOC and fine grains, was always the lowest in concentration. In the remaining nine tests with non-significant results, four contaminants also had highest concentrations in Group 1. The results of the analysis verify other studies that suggest that

areas with finer grain size and higher TOC concentration also tend to have higher contaminant levels and thus represent the "worst case" condition of the coastal embayment.

The ABLM Program utilized the association between small grain size, high TOC levels, and contaminants to spatially target areas in each embayment where contaminants were most likely to be found. The ABLM Program will be conducted over several years to assess the temporal trends of the major coastal embayments in San Diego County. During each year, the program will be conducted in two phases:

- **Phase I – Contaminant Targeting:** three areas in each embayment with the finest grain size and highest TOC concentration will be identified using a stratified random design.

- **Phase II – Sediment Assessment:** the areas identified in Phase I will be assessed using the same "triad" approach that is being utilized for the storm water runoff program: chemistry, toxicity, and biology of the sediments.

During the first year of the program, the field assessment was conducted in June 2003 for Phase I and in July 2003 for Phase II. The results are presented in this report.

3.3.3 Phase I – Contaminant Targeting

3.3.3.1 Site Locations

Twelve coastal embayments in San Diego County were monitored as part of the ABLM Program (Table 3-5).

Table 3-5. Coastal embayments monitored in the Ambient Bay and Lagoon Monitoring Program.

Name of Coastal Embayment	Site Designation	Watershed Management Area	Major Freshwater Tributary
Santa Margarita River Estuary	SME	Santa Margarita River	Santa Margarita River
Oceanside Harbor	OH	Santa Margarita River	None
San Luis Rey River Estuary	SLE	San Luis Rey River	San Luis Rey River
Buena Vista Lagoon	BVL	Carlsbad	Buena Vista Creek
Agua Hedionda Lagoon	AHL	Carlsbad	Agua Hedionda Creek
Batiquitos Lagoon	BL	Carlsbad	San Marcos Creek
San Elijo Lagoon	SEL	Carlsbad	Escondido Creek
San Dieguito Lagoon	SDL	San Dieguito	San Dieguito Creek
Los Peñasquitos Lagoon	LPL	Peñasquitos	Los Peñasquitos Creek
Mission Bay (includes Rose and Tecolote Creek outfalls)	MB	Mission Bay	Tecolote Creek and Rose Creek
Sweetwater River Estuary	SRE	San Diego Bay	Sweetwater River
Tijuana River Estuary	TRE	Tijuana River	Tijuana River

The embayments are shown graphically in Figure 3-2.

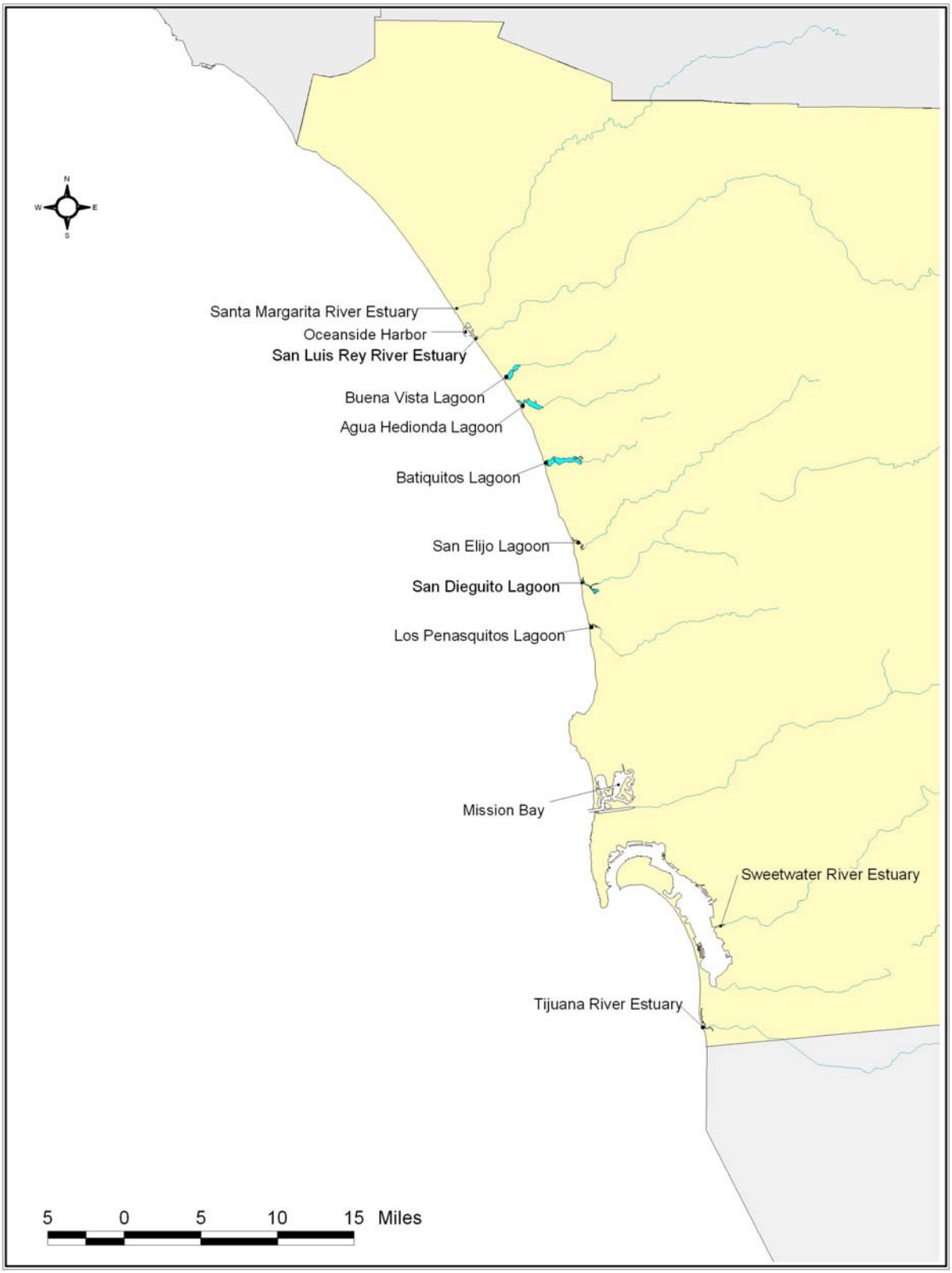

Figure 3-2. Map of coastal embayments monitored in the Ambient Bay and Lagoon Monitoring Program.

3.3.3.2 Sampling Design

A stratified random approach was used to select sampling sites within each embayment. First, the area of each embayment that is tidally influenced at mean lower low water (MLLW) was delineated on aerial photographs using GIS. Tidal extent was determined from U.S. Geological Survey topographical maps, published reports showing tidal extent, and visual observations. Then, to provide complete spatial coverage, each embayment was stratified into three strata using GIS:

1. **Stratum 1 -** an outer stratum located nearest the ocean;
2. **Stratum 2 -** a middle stratum, centered upon the lagoon; and
3. **Stratum 3 -** an inner stratum, located nearest the major watershed input source.

Each of these three strata was further divided into three areas roughly along the longitudinal axis of the embayment: right bank (looking downstream), center, and left bank. Thus, nine strata were delineated in each embayment. Each of these areas was digitized using GIS. Within the polygon representing each stratum, a series of random points was created using a random point's generator, an extension of ArcView that generates a user specified number of random points within polygons. A minimum distance of 100 feet was specified between points. The first random point generated by the program and the corresponding latitude and longitude coordinates for each of the nine strata was mapped on the aerial photographs for all of the coastal embayments. As many as five additional points per strata were also generated in case the first point selected was found to be inaccessible in the field. The sampling site locations identified by this process for each of the coastal embayments are presented in Table 3-6.

Table 3-6. Ambient Bay and Lagoon Phase I site locations.

Embayment	Site Number	Latitude	Longitude	Embayment	Site Number	Latitude	Longitude
SME	1L-1	N33° 13.881'	W117° 24.822'	BL	1L-1	N33° 05.082'	W117° 18.491'
SME	1M-1	N33° 13.964'	W117° 24.927'	BL	1M-1	N33° 05.285'	W117° 18.441'
SME	1R-4	N33° 14.000'	W117° 24.907'	BL	1R-4	N33° 05.314'	W117° 18.671'
SME	2L-2	N33° 14.059'	W117° 24.583'	BL	2L-4	N33° 05.318'	W117° 17.788'
SME	2M-2	N33° 14.056'	W117° 24.614'	BL	2M-1	N33° 05.378'	W117° 17.762'
SME	2R-1	N33° 14.061'	W117° 24.705'	BL	2R-6	N33° 05.453'	W117° 17.895'
SME	3L-1	N33° 14.154'	W117° 24.042'	BL	3L-2	N33° 05.336'	W117° 16.861'
SME	3M-2	N33° 14.142'	W117° 24.276'	BL	3M-5	N33° 05.396'	W117° 16.816'
SME	3R-2	N33° 14.239'	W117° 23.925'	BL	3R-2	N33° 05.464'	W117° 16.704'
OH	1L-3	N33° 12.441'	W117° 24.021'	SEL	1L-2	N33° 00.655'	W117° 16.435'
OH	1M-1	N33° 12.464'	W117° 24.169'	SEL	1M-1	N33° 00.804'	W117° 16.513'
OH	1R-1	N33° 12.688'	W117° 24.227'	SEL	1R-1	N33° 00.664'	W117° 16.451'
OH	2L-1	N33° 12.450'	W117° 23.970'	SEL	2L-1	N33° 00.459'	W117° 16.184'
OH	2M-1	N33° 12.643'	W117° 24.052'	SEL	2M-1	N33° 00.479'	W117° 16.240'
OH	2R-6	N33° 12.614'	W117° 23.931'	SEL	2R-1	N33° 00.454'	W117° 16.151'
OH	3L-1	N33° 12.271'	W117° 23.462'	SEL	3L-4	N33° 00.440'	W117° 15.976'
OH	3M-1	N33° 12.497'	W117° 23.818'	SEL	3M-1	N33° 00.389'	W117° 15.991'
OH	3R-1	N33° 12.363'	W117° 23.497'	SEL	3R-4	N33° 00.622'	W117° 15.824'
SLE	1L-1	N33° 12.203'	W117° 23.297'	SDL	1L-1	N32° 58.245'	W117° 15.774'
SLE	1M-1	N33° 12.191'	W117° 23.345'	SDL	1M-1	N32° 58.266'	W117° 15.801'
SLE	1R-1	N33° 12.221'	W117° 23.334'	SDL	1R-1	N32° 58.352'	W117° 15.986'
SLE	2L-1	N33° 12.276'	W117° 23.200'	SDL	2L-1	N32° 57.909'	W117° 15.121'
SLE	2M-1	N33° 12.303'	W117° 23.196'	SDL	2M-1	N32° 58.022'	W117° 15.399'

Table 3-6. Ambient Bay and Lagoon Phase I site locations.

Embayment	Site Number	Latitude	Longitude	Embayment	Site Number	Latitude	Longitude
SLE	2R-1	N33° 12.249'	W117° 23.272'	SDL	2R-1	N32° 58.076'	W117° 15.580'
SLE	3L-1	N33° 12.474'	W117° 22.912'	SDL	3L-1	N32° 58.328'	W117° 15.135'
SLE	3M-1	N33° 12.429'	W117° 22.999'	SDL	3M-1	N32° 58.315'	W117° 15.289'
SLE	3R-1	N33° 12.446'	W117° 22.971'	SDL	3R-2	N32° 58.299'	W117° 15.398'
BVL	1L-1	N33° 09.919'	W117° 21.468'	LPL	1L-1	N32° 55.898'	W117° 15.546'
BVL	1M-1	N33° 09.983'	W117° 21.464'	LPL	1M-1	N32° 55.944'	W117° 15.490'
BVL	1R-1	N33° 10.050'	W117° 21.507'	LPL	1R-1	N32° 56.035'	W117° 15.575'
BVL	2L-1	N33° 10.274'	W117° 20.995'	LPL	2L-3	N32° 55.962'	W117° 15.424'
BVL	2M-1	N33° 10.119'	W117° 21.213'	LPL	2M-1	N32° 55.966'	W117° 15.272'
BVL	2R-1	N33° 10.404'	W117° 21.094'	LPL	2R-1	N32° 55.965'	W117° 15.246'
BVL	3L-1	N33° 10.697'	W117° 20.514'	LPL	3L-1	N32° 55.866'	W117° 15.061'
BVL	3M-3	N33° 10.565'	W117° 20.857'	LPL	3M-1	N32° 55.820'	W117° 14.920'
BVL	3R-1	N33° 10.637'	W117° 20.925'	LPL	3R-1	N32° 55.890'	W117° 15.161'
AHL	1L-2	N33° 08.481'	W117° 20.402'	MB	1L-1	N32° 45.597'	W117° 14.178'
AHL	1M-1	N33° 08.713'	W117° 20.509'	MB	1M-1	N32° 45.722'	W117° 14.579'
AHL	1R-2	N33° 08.657'	W117° 20.362'	MB	1R-1	N32° 46.727'	W117° 14.770'
AHL	2L-6	N33° 08.580'	W117° 19.946'	MB	2L-1	N32° 46.338'	W117° 13.735'
AHL	2M-1	N33° 08.602'	W117° 19.892'	MB	2M-1	N32° 46.495'	W117° 13.756'
AHL	2R-1	N33° 08.749'	W117° 20.185'	MB	2R-1	N32° 47.116'	W117° 13.868'
AHL	3L-1	N33° 08.383'	W117° 19.469'	MB	3L-1	N32° 46.444'	W117° 12.888'
AHL	3M-1	N33° 08.455'	W117° 19.461'	MB	3M-1	N32° 46.568'	W117° 12.726'
AHL	3R-3	N33° 08.472'	W117° 19.306'	MB	3R-1	N32° 47.572'	W117° 13.135'
SRE	1L-1	N32° 38.853'	W117° 06.908'	TRE	1L-1	N32° 33.292'	W117° 07.671'
SRE	1M-1	N32° 38.934'	W117° 06.692'	TRE	1M-6	N32° 33.376'	W117° 07.693'
SRE	1R-5	N32° 38.943'	W117° 06.700'	TRE	1R-3	N32° 33.619'	W117° 07.850'
SRE	2L-1	N32° 39.067'	W117° 06.133'	TRE	2L-1	N32° 33.409'	W117° 07.300'
SRE	2M-1	N32° 39.122'	W117° 05.977'	TRE	2M-1	N32° 33.427'	W117° 07.533'
SRE	2R-2	N32° 39.018'	W117° 06.455'	TRE	2R-1	N32° 33.464'	W117° 07.421'
SRE	3L-1	N32° 39.217'	W117° 05.586'	TRE	3L-2	N32° 33.445'	W117° 07.372'
SRE	3M-1	N32° 39.162'	W117° 05.853'	TRE	3M-1	N32° 33.474'	W117° 07.300'
SRE	3R-2	N32° 39.254'	W117° 05.577'	TRE	3R-1	N32° 33.474'	W117° 06.402'

In the field, the aerial photographs with the identified sampling sites and a hand-held global positioning system (GPS) unit were used to locate the first sampling site identified by the random points generator. Each site was accessed by a survey team of two people with an inflatable boat or by land depending on the sampling location. If the first location was inaccessible or was not considered part of the delineated embayment, the next randomly selected site was located until an accessible sampling point was identified. Sites were considered inaccessible if the GIS coordinates generated by the random points generator were found in the field to be on land, in an area with impermeable substrate (e.g., rip rapped channels), or that could not be accessed by land or by boat. This process was repeated for all nine pre-determined areas of the embayment. Sediment samples were collected at each of the nine sampling points per embayment and analyzed for grain size and TOC content as described below. A summary of the Phase I sampling protocol is presented in Table 3-7.

Table 3-7. Summary of Phase I field and analytical activities of the Ambient Bay and Lagoon Monitoring Program.

Field Collection Parameter	Site	Analysis	Total Samples Analyzed per Embayment	Field Completion Date
Total Organic Carbon and Grain Size	Stratum 1			
	Right	Individual		
	Middle	Individual	3	
	Left	Individual		
	Stratum 2			
	Right	Individual		
	Middle	Individual	3	June 30, 2003
	Left	Individual		
	Stratum 3			
	Right	Individual		
	Middle	Individual	3	
	Left	Individual		

3.3.3.3 Sample Collection

Most of the sampling sites were accessed from the water with an inflatable raft powered by an 8 hp motor. Sites that were inaccessible by water were accessed by land where possible. Some sites were considered inaccessible due to difficult terrain or the presence of sensitive habitat, wildlife, or vegetation.

Sediment sample in push core

Once the sampling site had been located in the field, a sediment sample was taken with a push core. Upon retrieval, the bottom of the sediment in the core was removed so that only the top 5 cm of sediment remained in the core. Both ends of the core were then capped, labeled with the appropriate site information, and placed on ice in a cooler. All samples were transported on ice to the laboratory. In the laboratory, each sample was split and placed into two individual containers. The samples for TOC analysis were placed in the freezer and stored at –8°C. Samples for grain size analysis were stored in the refrigerator at 4°C.

In the laboratory, sediment TOC levels were analyzed by method ASTM D2579, modified. Sediment grain size was analyzed using a technique employed by Plumb (1981) based on procedures for Handling and Chemical Analysis of Sediment and Water Samples.

3.3.4 Phase II – Sediment Assessment

3.3.4.1 Priority Ranking

After sediment samples from the nine sites in each of the twelve embayments were analyzed, the sites in each embayment were ranked based on the percentage of fine grained sediments and TOC levels. The sites with the smallest grain size (i.e., the highest percentage of fine-grained sediments) received the

highest rank for grain size and the sites with the highest TOC content received the highest rank for TOC. The ranks for grain size and TOC at each site were then summed to produce an overall rank for that site. The three sites in each embayment with the highest ranks were assessed in Phase II of the program, which was conducted in July 2003. In the case of a tie in the summed ranks, the site with the higher fines rank was selected for Phase II assessment.

3.3.4.2 Sample Collection

Phase II sampling took place from July 7 to July 18, 2003. Stations were located with a hand-held GPS and accessed as described for Phase I. At each station, several water quality parameters were measured and sediment samples collected for analyses. The parameters and sample types are listed below.

- In situ water quality measurements and visual observations,
- Sediment chemistry,
- Sediment toxicity,
- Benthic Infauna.

At each station, water quality parameters were collected with a portable probe and recorded on data sheets in the field. Three separate sediment samples were collected with a 0.1 m^2 Van Veen sampler for sediment chemistry, sediment toxicity, and infaunal assessment.

Details of each of these parameters are discussed below.

3.3.4.3 Water Quality

At each station, a YSI model 6600 portable multi-probe was positioned approximately six inches above the sediment/water interface and the following parameters were measured: depth, temperature, DO, pH, and conductivity). The data was recorded on data sheets in the field.

In addition to water quality measurements, the following visual observations were also recorded at each site: percent cover of algae or grasses, sediment type, color, and odor (such as hydrogen sulfide). A photograph of a sediment sample at each station was taken in the field before the sample was disturbed.

3.3.4.4 Sediment Chemistry

At each of the three stations identified in Phase I, a separate grab sample was taken for sediment chemistry analysis utilizing a 0.1 m^2 Van Veen. Upon retrieval of the grab, the surface of the sample was inspected for acceptability. To be acceptable, the surface of the grab must be even, with minimal surface disturbance and little or no leakage of overlying water. If the grab was acceptable, the overlying water was carefully drained. If a grab was not acceptable, additional samples were taken.

For sediment chemistry analyses, the top 5 cm of sediment was removed for analyses. Care was taken not to disturb the sediment or remove sediment that was within 1 cm of the sides of the sampler. A total volume of approximately one liter was taken for analysis. Samples were placed into a labeled container, put on ice, and transported to the on-shore processing facility. Samples from each of the three stations per embayments were composited in the field in stainless steel bowls for analyses. Thus, one composite sample was analyzed from each embayment. Samples were then placed in appropriate containers, labeled, and placed on ice in a cooler.

Sediment samples for chemical analyses were sent on ice to EnviroMatrix Analytical Laboratories in San Diego, California for analysis. In the laboratory, the samples were analyzed for several metals, organochlorine and organophosphate pesticides, PCBs, and PAHs. Testing parameters and analytical procedures are listed in Table 3-8.

3.3.4.5 Sediment Toxicity

Sampling procedures described for sediment chemistry were also utilized for sediment toxicity testing. As described above, a single composite from three locations in each embayment were utilized for toxicity testing. In the laboratory, U.S. EPA guidelines (USEPA 1994) were used to assess sediment toxicity with a 10-day acute test using the estuarine amphipod *Eohaustorius estuarius* (Table 3-8).

This test consists of a 10-day exposure of *E. estuarius* to sediment under static conditions. Amphipods are placed in glass chambers containing seawater and a 2-cm layer of test sediment. The number of surviving amphipods is measured at the end of the test and is used to calculate the percentage survival. Individuals were visually inspected to confirm proper size and healthy condition prior to use in sediment testing. All tests were initiated within 10 days of collection. Water quality measurements were made at the beginning and end of exposure and temperature was continuously measured in the exposure room. The tests were performed at the MEC-Weston bioassay facility in Carlsbad, CA.

3.3.4.6 Benthic Infauna

For the benthic infauna assessment, a separate sample was collected at each station with a 0.1-m^2 Van Veen. The whole sample was placed into a labeled plastic bag and transported to shore to a mobile processing station. At the processing station, the sample was sorted through a 1.0-mm sieve. Retained organisms and sediments were fixed in a buffered formalin solution and returned to the laboratory for processing and preservation. The infaunal samples were taken from the same stations as samples for sediment chemistry and toxicity, however, the infaunal sample were not composited. Thus, there were three samples per embayment retained for infaunal analyses.

In the laboratory, infaunal samples were transferred from formalin solution to alcohol for processing. Organisms were separated from the sediments by trained technicians using dissecting microscopes into five major taxonomic groups: arthropoda (insects and crustaceans), annelida (worms), mollusca, echinodermata, and miscellaneous minor phyla. Upon completion of the sorting, the taxonomic groups were distributed to taxonomic experts in each of the categories for counting and identification of the organisms.

The field and analytical elements of Phase I and Phase II activities are summarized in Table 3-9.

Table 3-8. Analytical parameters for the Ambient Bay and Lagoon Monitoring Program.

Constituent	Volume Required	Method	MDL	Units
General Physical and Inorganic Non-Metals				
Temperature	In field	na	na	°C
DO	In field	na	na	mg/l
pH	In field	na	na	S.U.
Specific Conductance	In field	na	na	µmhos/cm
Turbidity	In field	na	na	na
Total Organic Carbon (TOC)	125 g	EPA 415.1	1.0	mg/L
Grain Size	125 g	Plumb 1981	1.0	% dry wt
PAHs				
Acenaphthene	100 g	GC/MS SIMS	3.60	µg/kg dry wt
Acenaphthylene	100 g	GC/MS SIMS	4.68	µg/kg dry wt
Anthracene	100 g	GC/MS SIMS	6.30	µg/kg dry wt
Benzo (a) anthracene	100 g	GC/MS SIMS	6.67	µg/kg dry wt
Benzo (b) fluoranthene	100 g	GC/MS SIMS	8.89	µg/kg dry wt
Benzo (k) fluoranthene	100 g	GC/MS SIMS	6.84	µg/kg dry wt
Benzo (g,h,i) perylene	100 g	GC/MS SIMS	9.72	µg/kg dry wt
Benzo (a) pyrene	100 g	GC/MS SIMS	7.38	µg/kg dry wt
Chrysene	100 g	GC/MS SIMS	3.96	µg/kg dry wt
Dibenz (a,h) anthracene	100 g	GC/MS SIMS	9.18	µg/kg dry wt
Fluoranthene	100 g	GC/MS SIMS	5.76	µg/kg dry wt
Fluorene	100 g	GC/MS SIMS	4.68	µg/kg dry wt
Indeno (1,2,3-cd) pyrene	100 g	GC/MS SIMS	10.0	µg/kg dry wt
Naphthalene	100 g	GC/MS SIMS	1.91	µg/kg dry wt
Phenanthrene	100 g	GC/MS SIMS	4.19	µg/kg dry wt
Pyrene	100 g	GC/MS SIMS	6.08	µg/kg dry wt
PCBs				
Aroclor 1016	100 g	EPA 8082	4.68	µg/kg dry wt
Aroclor 1221	100 g	EPA 8082	4.68	µg/kg dry wt
Aroclor 1232	100 g	EPA 8082	4.68	µg/kg dry wt
Aroclor 1242	100 g	EPA 8082	4.68	µg/kg dry wt
Aroclor 1248	100 g	EPA 8082	4.68	µg/kg dry wt
Aroclor 1254	100 g	EPA 8082	4.68	µg/kg dry wt
Aroclor 1260	100 g	EPA 8082	4.68	µg/kg dry wt
Chlorpyrifos	100 g	EPA 8141A	0.002	mg/kg
Diazinon	100 g	EPA 8141A	0.002	mg/kg
Metals (Total)				
Antimony (Sb)	200 g	EPA 6020	0.6	mg/kg dry wt
Arsenic (As)	200 g	EPA 6020	0.2	mg/kg dry wt
Cadmium (Cd)	200 g	EPA 6020	0.1	mg/kg dry wt
Chromium (Cr)	200 g	EPA 6020	0.4	mg/kg dry wt
Copper (Cu)	200 g	EPA 6020	0.4	mg/kg dry wt
Lead (Pb)	200 g	EPA 6020	0.1	mg/kg dry wt
Nickel (Ni)	200 g	EPA 6020	0.2	mg/kg dry wt
Selenium (Se)	200 g	EPA 6020	0.6	mg/kg dry wt
Zinc (Zn)	200 g	EPA 6020	2.2	mg/kg dry wt
Toxicity - 10 day acute with *Eohaustorius estuarius*	2.5 L	EPA 1995	na	na

na = not applicable

Table 3-9. Summary of Phase II field and analytical activities of the Ambient Bay and Lagoon Monitoring program.

Field Collection Parameter	Site	Analysis	Total Samples Analyzed per Embayment	Completion Date
Sediment Chemistry (Plus TOC & GS)	Station 1* Station 2 Station 3	Composite of 3 Individual samples	1	
Sediment Toxicity	Station 1* Station 2 Station 3	Composite of 3 Individual samples	1	July 30, 2004
Infaunal Community Analysis	Station 1* Station 2 Station 3	Individual Individual Individual	3	

* Locations of Stations 1, 2, and 3 were derived from the results of Phase I.

3.3.5 Data Assessment

3.3.5.1 Sediment Chemistry

Currently, there are no universally accepted criteria for assessing contaminated sediments. However, the Effect Range Low (ERL) and Effect Range Median (ERM) values originally developed by Long and Morgan (1990) and subsequently revised and expanded upon by Long and MacDonald (1992) and Long et al. (1995) can be used to evaluate the potential for sediment to cause adverse biological effects (Table 3-10). These parameters were developed from a large data set where results of both sediment toxicity bioassays (e.g., amphipod tests) and chemical analyses were available for individual samples. The guidelines were intended to provide informal (non-regulatory) effects-based benchmarks of sediment chemistry data (Long et al. 1998). Two effects categories have been identified:

ERL – Effects Range Low: concentrations below which adverse biological effects are rarely observed; and

ERM – Effects Range Medium: concentrations above which adverse biological effects are more frequently, though not always observed.

Sediment chemistry data from samples collected from each of the coastal embayments were compared to the ER-L and or the ER-M data. Because the ABLM program utilizes an approach that targets COCs in each embayment (using TOC and grain size parameters), the individual assessments represent a worst-case scenario rather than a representative assessment of the embayment. The data should be interpreted to reflect this important distinction.

Table 3-10. Sediment Effects Guideline Values.

Parameter	Effects Range-Low (ER-L)	Effects Range-Median (ER-M)
Metals (mg/Kg)		
Antimony	2.0	2.5
Arsenic	8.2	70
Cadmium	1.2	9.6
Chromium	81	370
Copper	34	270
Lead	46.7	218
Nickel	20.9	51.6
Zinc	150	410
Organics (µg/Kg)		
Acenaphthene	16	500
Acenaphthylene	44	640
Anthracene	85.3	1,100
Fluorene	19	540
Naphthalene	160	2,100
Phenanthrene	240	1,500
Low-molecular weight PAH	552	3,160
Benz(a)anthracene	261	1,600
Benzo(a)pyrene	430	1,600
Chrysene	384	2,800
Dibenzo(a,h)anthracene	63.4	260
Fluoranthene	600	5,100
Pyrene	665	2,600
High molecular weight PAH	1,700	9,600
Total PAH	4,022	44,792
Total PCBs	22.7	180

Source: Long et al. 1995
ER-L = Concentration at lower tenth percentile at which adverse biological effects were observed or predicted.
ER-M = Concentration at which adverse biological effects were observed or predicted in 50% of test organisms.
mg/Kg = milligrams per kilogram.
µg /Kg = micrograms per kilogram.

In addition, for each embayment ERM values were used to calculate a mean ERM quotient (ERM-Q). The concentration of each COC was divided by its ERM to produce a quotient, or proportion of the ERM equivalent to the magnitude by which the ERM value is exceeded or not exceeded. The mean ERM-Q for each embayment was then calculated by summing the ERM-Qs for each COC and then dividing by the total number of ERM-Qs assessed. ERM-Qs were not calculated for COCs below the detection limit and thus were not used in the generation of the mean ERM-Q. The mean ERM-Q thus represents an assessment for each embayment of the cumulative sediment chemistry relative to the threshold values. In this way, the cumulative risks of effect to the benthic community can provide a mechanism to compare embayments. This method has been used and evaluated by several researchers (Hyland et al. 1999, Carr et al. 1996, Chapman 1996, and Long et al. 1995) throughout the country.

The aggregate approach using an ERM-Q is a more reliable predictor of potential toxicity but should not be used to infer causality of specific contaminants. ERL and ERM values were originally derived to be broadly applicable and they cannot account for site-specific features that may affect their applicability on a

more local or regional level. Local differences in geomorphology can result in chemicals being more or less available and therefore more or less toxic than an ERL or ERM value might indicate. Additionally, some regions of the country are naturally enriched in certain metals and local organisms have become adapted.

3.3.5.2 Sediment Toxicity

Sediment toxicity results were obtained from the exposure of the test species (*E. estuarius*) to sediments collected from each of the embayments. The percent survival of test organisms in sediments from the embayments was compared to percent survival in a control sample to assess benthic infaunal toxicity levels from each of the embayments sampled. A statistical evaluation was conducted for each of the embayments to determine if there is a statistically significant difference (using ANOVA) between toxicity in sediments from the embayment verses toxicity in the control.

In addition to the individual assessments of each embayment, the toxicity results were used to rank each of the embayments. The ranking was based on the percent survival *of E. estuarius* in the 10-day acute test, where the highest survival (lowest toxicity) receives a rank of one and the lowest survival (highest toxicity) receives a rank of 12.

3.3.5.3 Benthic Infauna Data

The benthic infauna data from each of the embayments was assessed using a variety of indices common to ecological community structure evaluations. Some of the tools that are employed in the assessment include a species list, relative abundance, species diversity or richness, Shannon-Wiener Species Diversity Index, and an evaluation of the presence of sensitive and pollutant tolerant species. This information was incorporated into a two-way coincidence table that was used to perform a cluster analysis. The cluster analysis shows the relationship between the individual embayments and the various indicators used to describe the characteristics of the benthic infaunal community. Embayments with similar index or parameter scores will cluster together, providing a means by which the embayments can be ranked from best (least impacted community) to worst (most impacted community). The results of the cluster analyses were also used to provide an individual assessment of each embayment.

3.3.5.4 Data Integration

Once all the ABLM data were available, a triad matrix was developed so that the combination of sediment chemistry, sediment toxicity, and benthic infauna data was used to develop a ranking of the embayments across the County (or in a watershed).

For each of the embayments, the three elements of the monitoring program were ranked individually for each site (1 to 12 for the 12 embayments assessed) as follows:

Sediment Chemistry – The mean ERM-Q value was used, where 1 represents high potential for toxicity and 12 represents low potential for toxicity;

Sediment Toxicity – The results of the *E. estuarius* percent survival was used to rank each site, where 1 represents high toxicity and 12 represents low toxicity;

Benthic Infauna – The results of the benthic community indices were used to rank each site, where 1 represents the site with the least robust community and 12 represents the site with the most robust community.

3.4 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 Stormwater 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 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 Water Quality Objectives shown in Table 3-11 and dry weather station data were compared to the Action Levels 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 stormwater discharges.

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

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 (Table 3-11). 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 as shown in Table 3-11 below.

Table 3-11. Water Quality Objectives for Wet Weather Monitoring at Mass Loading Stations.

Constituent	Units	WQO	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
BOD	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

Table 3-11. Water Quality Objectives for Wet Weather Monitoring at Mass Loading Stations.

Constituent	Units	WQO	Source
Arsenic	mg/L	0.34 (c)	40 CFR 131
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

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

(b) Water Quality Objective 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.

Toxicity testing at the MLS does not measure a COC. Toxicity is a test to determine if an analyte (chemical or other) or group of analytes is present in concentrations capable of causing toxicity in the selected species. Once an analyte(s) is identified as the source of the toxicity through the TIE/TRE steps of the method, then it is possible to define toxicity as having a high frequency of occurrence because it has been positively linked to the actual constituent of concern identified to be causing the toxicity.

The results reported for the Copermittee monitoring program focus on the acute toxicity limit as the NOEC of 100% 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 statically 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 3-12.

Table 3-12. Toxicity 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.

Dry Weather

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. In order to allow for comparison with exceedances at the MLS, for which different water quality objectives are used, modifications are made that allow for comparison of MLS data and dry weather station (DWS) data. For example, the dry weather action levels for bacterial indicators were applied to the wet weather data instead of the Basin Plan REC-1 or REC-2 criteria in order to identify potential links between dry and wet weather constituents of concern. Similarly, 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. Therefore, when assessing dry and wet weather samples for turbidity at a watershed level the Basin Plan objective was used. See Table 3-13 for a summary of the dry weather action levels used to perform the data evaluation.

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.

Table 3-13. Dry Weather Action Levels for 2002.

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 WQO instead of BPJ when comparing with MLS data
Conductivity		Best professional judgment
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	2003 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) as shown in Table 3-11.
Fecal Coliform	20,000 MPN/100 mL	
Enterococcus	10,000 MPN/100 mL	

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) 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 COC 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 COCs 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 third year (2003-04) of monitoring and have data from nine 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 3-14.

Table 3-14. 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 trigger 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 is made using the Tabular Decision Matrix, Table 3-15.

Table 3-15. 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 3-15. 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.

Establishing Frequency of Occurrence

The monitoring results (including all monitoring years' data) are examined to establish if percentages data exceed water quality objectives or action levels, rank bioassessment results, and prioritize toxicity results. The matrix of findings is developed for each watershed (Table 3-16). The matrix includes number of observations and number of observations that exceed water quality objectives.

Table 3-16. Matrix of Findings.

SAN LUIS REY												
Constituents With Any Wet Weather (MLS) or Dry Weather WQO Exceedance	MLS (Wet Weather) Results								Dry Weather Results		Frequency of Occurrence	Criterion No.
	2001/2002		2002/2003		2003/2004		Cumulative		2003			
	#/3	%	#/3	%	#/3	%	#/9	%	#/23	%		
Conventionals												
BOD	0	0	0	0	1	33	1	11			-	-
Total Dissolved Solids	3	100	3	100	3	100	9	100			♦♦♦	1
Total Suspended Solids	0	0	1	33	0	0	1	11			-	-
pH	0	0	1	33	0	0	1	11	0	0	-	-
Turbidity	0	0	1	33	0	0	1	11	3	13	-	-
Oil and Grease	0	0	0	0	0	0	0	0	7	30	♦	8
Nutrients												
Nitrate as N	0	0	0	0	0	0	0	0	1	4	-	-
Bacteriological												
Total Coliform	0	0	0	0	0	0	0	0	1	4	-	-
Fecal Coliform	0	0	0	0	0	0	0	0	2	9	-	-
Pesticides												
Diazinon	1	33	0	0	0	0	1	11	0	0	-	-
Toxicity											**Evidence of Persistent Toxicity?**	
Ceriodaphnia 96-hr	0	0	0	0	0	0	0	0			No	
Ceriodaphnia 7 day survival	0	0	0	0	0	0	0	0			No	
Ceriodaphnia 7 day reproduction	1	33	0	0	1	33	2	22			No	
Hyalella 96-hr	0	0	0	0	0	0	0	0			No	
Selenastrum 96-hr	0	0	0	0	1	33	1	11			No	
Bioassessment	**IBI SCORE**										**Evidence of Benthic Alteration?**	
IBI Rating	Very Poor		Very Poor		Very Poor		Very Poor				Yes	

NA = Not Assessed
- = 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

The COC Frequency of Occurrence ranking of "high", "medium", or "low" is established using the 2002-03 interim criteria (Table 3-17). 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.

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.

For this evaluation, dry weather stations that only have field test kit results are not used in the assessment of COC. Only DWS monitored using laboratory analysis from grab samples including concurrent field test results are considered for comparison with MLS exceedances of water quality objectives. Only DWS located upstream of the MLS are taken into account when applying the interim COC criteria. Lastly, only DWS samples collected during routine monitoring and not as part of the ICID investigation phase of the program are used. The majority of the 2003 dry weather data used for the assessment represented routine site visits.

Table 3-17. 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 WQO in greater or equal to 80% of samples.
	2	Six of the last consecutive storm samples at the MLS exceed WQO.
	3	Less than 80% and greater than or equal to 50% of the MLS samples exceed 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 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 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 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.

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 judged 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, fecal 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.

3.5 Watershed Assessment Statistical Methods

3.5.1 Relationships and Trends

Relationships between toxicity and COCs were examined by MLS to determine which COC may have an effect on toxicity. A chi-square non-parametric test was used for this assessment. Each COC was compared to the appropriate water quality objective and scored as to whether the concentration was above or below the objective (1=above, 0=below). Likewise, the toxicity results for each of the five toxicity tests was also scored (1=toxicity, 0=no toxicity). The chi-square test counts the number of observations in each combination of scores (e.g., 1,1=toxicity and COC above WQO) and compares the resulting pattern in a 2X2 table to what would be normally expected. Significance was set at $p<0.05$ (or 95% confidence), with only nine observations, results with more than one observation in a mixed combination (1,0 or 0,1) were not significant.

In addition, long-term trends in the data for Agua Hedionda, Tecolote Creek, and Chollas Creek were examined by regression analysis to determine whether an observed upward or downward tendency of the data was statistically significant (significance was set at $p<0.05$). Trends were not tested at the other mass loading stations because only three years of data were available.

3.6 Cross Watershed Statistical Methods

The goals of the cross-watershed comparison are to assess all information from each watershed together to evaluate and rank watersheds across the region. Assessing all data from the region together also provides the ability to evaluate relationships among COC and between toxicity effects and COC.

3.6.1 COC Comparisons

The statistical tools used for the cross watershed comparison included scatterplot analysis, regression analysis, analysis of variance (ANOVA), and multivariate cluster analysis. Scatterplots provide a COC based comparison among watersheds and monitoring years. The ANOVA was used to determine statistical differences between the watersheds for the year as a whole (storms were used for replication), and cluster analysis was used to identify mass loading stations and sampling dates with similar COC loadings.

Scatterplots provide a visual representation of the relative concentrations of COC between stations and storm events. Scatterplots are simple plots of concentrations of COC plotted on the y-axis against the mass loading station identified on the x-axis. Each COC and toxicity test is represented by its own scatterplot with all sampling dates for the past three monitoring years plotted on a single graph. Where historical data for the longer-term mass loading stations (Agua Hedionda Creek, Tecolote Creek, and Chollas Creek) are available, trend data plots are included. The data shown in the trend data plots were tested by regression analysis to determine significant trends. When an upward or downward trend was statistically significant ($p<0.05$) the trend line is shown on the data plot. Non-detectable results were plotted at the detection limit. Also, when COC concentrations during separate storm events were equivalent, the scatterplot appears to have only one point at that concentration because the points are co-located. All COC were monitored at mass loading stations during three storms each year (with the exception of Santa Margarita) and all points are included in scatterplots.

ANOVA was used to determine differences between MLS for the COC. The term *analysis of variance* is sometimes a source of confusion. In spite of its name, ANOVA is concerned with differences between *means* of groups, not differences between *variances*. The analysis uses variances to detect whether the means are different. The ANOVA determines the variation (variance) *within* the groups that are being compared (e.g., monitoring stations), then compares that variation to the differences *between* the groups, taking into account how many subjects there are in the groups. If the observed differences between the means of groups are larger than those expected by chance relative to the underlying variance, statistical significance is achieved. For this report, each of the COC that were observed in any sample above the MDL was tested by ANOVA. Because this analysis needs to calculate a variance, the COC with results below the detection limit at a station were handled in the following manner. If only one sample was below the detection limit, one-half the detection limit was used. If more than one sample was below the detection limit, each of the values was set so that the mean of all the values would be one-half the detection limit. For example, if the detection limit was 0.6 and there were two values below the detection limit, one would be set to 0.15 and the other would be set to 0.45 so that the mean of the two values was 0.3 (one-half the detection limit). The bacteriological measures were $\log_{10}$ transformed for this analysis.

Multivariate cluster analysis was applied to the COC and the toxicity endpoints (in terms of NOEC values) for each MLS and sampling time. This approach groups the station/times by the commonality of the COC concentrations found at each one. Likewise, it groups the COC according to similar loadings at stations. Prior to the analysis the bacteriological measures were $\log_{10}$ transformed and the data for each COC was standardized by the overall mean value for each COC.

3.6.2 Relationships between Toxicity and COC

The relationship between toxicity and constituents of concern (COC) has been evaluated by two methods. The first method presented below uses a multiple regression model to correlate changes in toxicity to changes in COC levels in the water. This method groups data from all watersheds, is useful in providing general trends across the county, and evaluating the effects of several COC at once. Sometimes thresholds of chemical concentrations are involved with toxicity whereby the organisms do not respond negatively until a certain chemical level is reached. Concentrations of COC above a specific threshold may no longer illicit a linear response in organism toxicity. Consequently, thresholds detract from the regression model. Therefore, a second method, threshold analysis, was used to clarify relationships following the regression analyses using the COC that were significant components of the final multiple regressions. The threshold analysis uses COC levels reported to be toxic in the literature where available and compares them to COC levels in the storm water samples.

3.6.2.1 Multiple Regression Analysis of Toxicity Data

Multiple regression was the statistical tool used to look for relationships between toxicity results and the physical, chemical, and biological COC across all watersheds. This type of statistical analysis looks for the best relationship between the response variable (i.e., toxicity units for each endpoint) and the regressor variables (COC). To best fit a multiple regression model, the number of observations must be larger than the number of regressor variables. Because the number of COC was greater than the number of samples, it was first necessary to reduce the number of COC used in the analysis. To do this reduction, a principal component analyses (PCA) was performed on the COC. Two PCA analyses were run, the first for metal constituents and the second for the physical and organic results (excluding bacteria and pesticides). The PCA creates factor loadings along multiple axes that define (or explain) the variance in the data and identifies the contribution of each constituent to each axis. The resultant axes that

accounted for a significant portion of the variance were run as regressors in addition to bacteria and pesticide measurements for each toxicity endpoint.

The best-fit regression was selected for each endpoint by running a backward regression. This type of multiple regression starts with all regressors and eliminates them step-by-step according to their contribution to the model (least significant are dropped first) until all regressors remaining are significant. The adjusted R^2 values (adjusted for the number of observations and number of regressors) tend to stabilize when an adequate number of regressors remain in the model and are therefore used to determine the best model for the regression. When one of the PCA axes was retained as a significant regressor in the model, a second regression was run with the individual COC that were weighted at least 0.75 on the axis to further refine the analysis. Due to differences in detection limits for pesticides and dilutions for bacteria analyses for the data collected at Santa Margarita, this site was excluded from these analyses.

Additionally, another multiple regression was run combining the results from 2001-02, 2002-03, and 2003-04. With the additional observations, it was not necessary to screen the regressor variables and all COC that were measured in both years were included in the analyses.

3.6.2.2 Threshold Analyses

Threshold values from literature, the total maximum daily load (TMDL) Study in Chollas Creek (MEC 2002), and other studies not yet published (personal communication with Jack Word) were assigned to COC retained in the final regressions of each toxic response test (e.g., *Ceriodaphnia* chronic test for survival). Where threshold values were not available, "best-fit" values (those that gave the best match to the observed toxicity results) were selected. Values were available for diazinon, nickel, lead, zinc, nitrate, and conductivity.

Resources

The EPAs "Ecotox" database (www.epa.gov/ecotox) provides toxicity data by species and chemical, which is collected from a large number of independent studies. This resource also provides information on test duration, endpoints observed, as well as other parameters. Toxicity values for nitrate, metals, and all three test species were collected from this resource.

The Handbook of Environmental Data on Organic Chemicals (Vershueren 1983) provides data on air and water pollution factors, bioconcentration and toxicity for a variety of organic chemicals, including pesticides. Toxicity data are provided by species and endpoint. Toxicity values for diazinon, chlorpyrifos, and malathion for species related to *Ceriodaphnia dubia* and *Hyalella azteca* were collected from this resource.

Other resources included the Chollas Creek TMDL Study conducted over several storm seasons in Chollas Creek (MEC 2002) and private client studies not yet published conducted by MEC-Weston (personal communication, Jack Word).

Despite the usefulness of these resources, they have limitations. Toxicity values are not always provided for the test durations used in this storm water toxicity study. When using a value from a longer test period (say a 21-day test), the value will likely be a conservative estimate of what level would actually cause toxicity in a 7-day test. Data are also not provided for all COC or it is possible that the data provided is for a related species to the test species used in this study, which will most likely have a different sensitivity to the toxicants than the test species selected for this study. Criteria used in the

selection of the literature value reported in this study include the test period (close to that used for the current study), the endpoint measured (one that was measured in this study [e.g.: no behavioral endpoints]), the test species (either the test species used in this study or the one most closely related to it for which there is a value available), and the value itself (the lowest value reported).

These resources do not provide toxicity data of physical parameters (e.g., total dissolved solids, hardness, turbidity) to the test species. For the relationship between physical parameters and toxicity it is best to rely upon the regression analysis. These resources also do not provide information on possible interactions between chemicals or the interactions between chemicals and physical parameters.

The statistical testing procedure is used to establish a two-by-two matrix with one column of "less than the threshold" and the second column of "greater or equal to the threshold" and with one row of "no observed effect" and a second row of "effect observed". Fisher's Exact Test (2-tail) was used to establish the exact probability of the table outcome by chance. A small probability (<0.05) was used to determine if the assigned threshold values were significant in explaining the outcomes of the toxicity tests.