# C-11-I.0 MONITORING APPROACHES AND METHODS OF ANALYSIS

## C-11-I.1 Introduction

Passage of an amendment to the Clean Water Act in 1987, the Water Quality Act, brought stormwater discharges into the NPDES Program and subsequent EPA regulations required municipal NPDES Permit applicants to develop a management program to effectively address the requirements of the Act.

In response to these regulations, the County of Orange (the Principal Permittee), the Orange County Flood Control District and incorporated cities (all collectively referred to as Permittees) obtained NPDES Stormwater Permits No. CA 8000180 and No. CA 0108740 (subsequently referred to as the First Term Permits) from the Santa Ana and San Diego Regional Water Quality Control Boards. In 1996, the First Term Permits were replaced by Permits Nos. CAS0108740 and CAS618030 (subsequently referred to as the Second Term Permits). These were subsequently replaced by the Third Term Permits in 2002 and by the Fourth Term Permits in 2009.

The monitoring programs developed and implemented to address the requirements of these permits were fairly consistent between regions (with respect to sampling methods and analytes) for the First and Second Term Permits. For the Third Term Permits the monitoring programs for each region began to diverge with each program containing elements to address specific issues such as selenium and organochlorine pesticides in the Newport Bay watershed, or impacts of urban runoff on the ecologically sensitive coastal receiving waters in southern Orange County.

The evolution of the monitoring efforts conducted for the NPDES Municipal Stormwater Permits issued by the Santa Ana Regional Board for Orange County is illustrated in the diagram below.

**First Term Permit**

●Track compliance
●Estimate stormwater pollutant loads
●Identify pollutant sources with wet/dry weather field screening
●Address areas of special concern

**Second Term Permit**

●Continue First Term Permit monitoring
●Track compliance
●Re-evaluate priority issues
●Develop 99-04 Plan

**Second Term 99-04 Plan**

●Track compliance
●Document environmental quality trends at "Warm" Spots
●Assess conditions at Critical Aquatic Resources (CARs)
●Evaluate stormwater's contribution to beneficial use impairment

**Third Term Permit**

●Track compliance
●Continue trends monitoring
●Enhanced monitoring of bay, estuary, marsh receiving waters
  ♦Expanded chemical analyses of water and benthic sediments
  ♦Benthic infaunal analyses
  ♦Sediment toxicity
●Stream bioassessment and physical habitat assessment
●Toxicity testing of dry weather and stormwater runoff
●Pathogen indicators in coastal stormdrains and regional channels
●Impacts from changing landuses in the San Diego Creek watershed
●Enhanced dry weather reconnaissance of MS4 connections
●TMDL monitoring
●Participation in regional monitoring programs

**Fourth Term Permit**

●Track compliance
●Continue trends monitoring
●Continue bay, estuary, marsh receiving water monitoring
●Continue pathogen monitoring of coastal stormdrains/regional channels
●Continue bioassessment monitoring through participation in SCCWRP regional program
●Address expanded set of issues
  ♦Enhancement of source investigation methods
  ♦Stormwater load characterization of specific landuse types
  ♦Stormwater load characterization from reference areas
  ♦More comprehensive pollutant source characterizations

C-11-I.1.1 Pre-NPDES Water Quality Monitoring

From 1973 to 1990, the Principal Permittee conducted routine water quality monitoring on drainage facilities which are tributary to water bodies identified as waters of the state by the Regional Boards. Beginning in 1978, the receiving waters (Newport Bay, Huntington Harbour, Bolsa Bay, and Dana Point Harbor) were also monitored routinely to assess impacts from discharges of storm drain runoff on the beneficial uses of those receiving waters.

When the monitoring program was initiated in 1973, monthly nutrient and trace element sampling was performed at several flood control channels, creeks and streams. Sediment samples were collected semiannually to assess the impact of contaminant deposition and adsorption. Additional constituents such as mercury, selenium, organochlorine pesticides, PCBs and radioactivity were also evaluated on a semiannual basis to address public concerns regarding the pollution threat from these constituents. In 1978, the monitoring expanded to the receiving waters of the County's storm drain system. Several locations in the Upper and Lower Newport Bay, Huntington Harbour, and Dana Point Harbor were monitored to assess the impacts of urban runoff.

C-11-I.1.2 First Term Permit Water Quality Monitoring

In order to bring the pre-NPDES water quality monitoring program into conformance with the 1990 federal NPDES regulations and the First Term Permit objectives, a field screening element was added and the spatial extent of monitoring was expanded (more flood control channels and receiving water sites).

The First Term Permit water quality monitoring program consisted of field screening for illegal discharges and illicit connections (channels only); dry weather and stormwater runoff monitoring in regional flood control channels to assess aquatic chemistry relative to applicable water quality criteria, and to calculate pollutant loads; and receiving water monitoring in harbors and estuaries to evaluate the impacts of urban runoff during dry weather and stormwater runoff conditions.

C-11-I.1.3 Second Term Permit Water Quality Monitoring

While the First Term Permit monitoring program produced useful information, the Permittees recognized (as did many others across the Country) the high degree of uncertainty regarding the link between urban stormwater runoff and actual impairment of beneficial uses within the aquatic resources of Orange County.

Therefore, in response to the Second Term Permit objectives, the Permittees conducted a systematic re-evaluation of the water quality monitoring program which led to a re-statement of the monitoring program's primary goals. The primary and parallel goals of the monitoring program were re-stated as:

- To determine the role, if any, of urban stormwater discharges in the impairment of beneficial uses; and
- To provide technical information to support effective urban stormwater management program actions to reduce the beneficial use impairment determined to be associated with urban stormwater.

In order to organize the monitoring activities needed to carry out the objectives and goals, the Permittees identified three separate key elements within the Final Monitoring Program (May 1999). These three key elements are:

- A focus on known sites (or warm spots) where constituents were substantially above system-wide averages;
- A parallel (and somewhat overlapping) focus on areas of critical aquatic resources; and
- A countywide reconnaissance program to identify specific sources of contamination from sub-watershed areas as well as specific land use investigations in order to evaluate the effectiveness of a variety of Best Management Practices (BMPs).

The monitoring program included: an underlying rationale for each monitoring element; a discussion of how monitoring data would be used in decision making; identification of potential links to other relevant monitoring programs being carried out by other agencies; a description of the basic monitoring design; identification of additional study design steps; and a description of anticipated monitoring activities.

These monitoring elements include many locations from the pre-NPDES and First Term Permit water quality monitoring programs that were of value because of the length of their historical record. Each key element of the Second Term Permit monitoring program contained a description of the monitoring activities proposed to accomplish the objectives described above, as well as a description of the process for making decisions about how the monitoring program would respond to incoming data over time. This process was intended be used at any time throughout the life of the monitoring program to re-evaluate the direction of the program, or to reassess the appropriate allocation of resources within the program.

The Second Term monitoring program and subsequent elements utilized a five-year timeline (1998 - 2003) for addressing the goals/objectives associated with each task.

<u>C-11-I.1.4 Third Term Permit Monitoring under Order R8-2002-0010</u>

In the fall of 2005, the Permittees began implementation of the Third Term Permit monitoring program in the Santa Ana Region (following approval of the program by the Executive Officer of the Santa Ana Regional Water Quality Control Board in July of 2005). The design of the monitoring program was based on “The Model Monitoring Program for Municipal Separate Storm Sewer Systems in Southern California” developed by the Southern California Monitoring Coalition (SMC). The SMC is a multi-agency group of southern California municipal stormwater agencies, Regional Water Boards, Region 9 of the USEPA, and the Southern California Coastal Water Research Project (SCCWRP). Orange County played a major role in the development of that model program.

The Third Term Permit monitoring program continued and expanded the previous monitoring program’s emphasis on assessing impacts on aquatic resources, documenting long-term trends in water quality, targeting problematic discharge sites for more focused investigations, and added additional monitoring elements. This program extended stormwater monitoring to a broader range of locations and to a wider array of methods for measuring impacts. For example, the Third Term Permit monitoring plan more completely examined storm drains that discharge directly to the coast and pose a potential health risk to swimmers and bathers. In the Upper and Lower Newport Bays, Huntington Harbour, Bolsa Bay and Talbert Marsh, sediments were analyzed for chemistry, benthic infaunal assemblage, and toxicity. Inland, the monitoring plan included bioassessment and physical habitat assessment of creeks, along with aquatic toxicity testing. These assessments using multiple lines of evidence were intended to describe impacts more fully, more accurately identify their sources, and target follow-up studies and BMPs more effectively.

C-11-I.1.5 Fourth Term Permit Water Quality Monitoring under Order R8-2009-0030

Section III.1 of the Monitoring and Reporting Program in Order R8-2009-0030 states that the Permittees shall continue to implement the monitoring program approved for implementation under the Third Term Permit, review it on an annual basis, and determine the need for any modifications. A description of the core program elements and their relationship to the overall program objectives are included in **Section C-11.0.**

Any additional water quality monitoring conducted individually by one of the Permittees would be described and summarized within the jurisdictional PEA.

**C-11-I.2 Monitoring Approach**

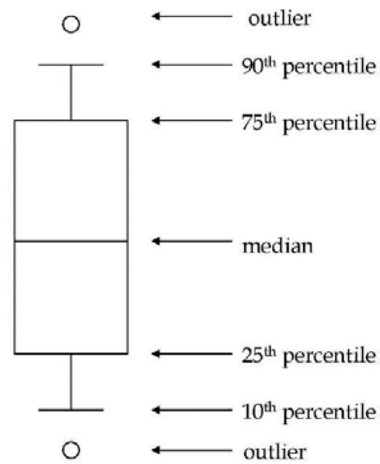
**Section C-11.2** outlines the program goals and objectives for the monitoring programs. The Fourth Term Permit monitoring program contains many of the same elements of the Third Term Permit monitoring program with in some cases, changes in monitoring frequencies, analytes, and types of toxicity tests.

Additionally, the approach for evaluating water quality monitoring data includes comparisons to various benchmarks, including as appropriate:

- Basin Plan Objectives for Inland Waters and Enclosed Bays;
- California Toxics Rule (CTR) criteria for toxics and priority pollutants;
- Shoreline recreational water contact objectives established by Assembly Bill 411 (AB411);
- Water Quality Control Policy thresholds for aquatic and sediment toxicity;
- US Environmental Protection Agency aquatic life benchmarks;
- The California Stream Condition Index (CSCI); and
- Reference stream thresholds from the Stormwater Monitoring Coalition's Regional Watershed Monitoring Program.

Data products in this report and its associated attachments have been included in various formats: data tables, charts, maps, and associated figures. Certain data products are commonly presented using the box and whisker diagram to convey the distribution of data with respect to the specific analysis presented. An explanation of the various components of the box and whisker plot is provided in the following diagram:

**Explanation of the Box and Whisker diagram**




**C-11-I.3 Description of Monitoring Procedures**

C-11-I.3.1 Long Term Mass Emissions Monitoring

The Permittees conduct Mass Emissions monitoring at multiple stations in the Santa Ana Region of Orange County to evaluate dry weather and stormwater runoff relative to applicable water quality criteria and to assess trends in mass loading. The monitoring site selection criteria included the following:

- Classification of the water body as a "Water of the State";
- 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;
- Safety from traffic and other hazards;
- Suitability for efficient operation of automatic sampling equipment; and
- Access for safely retrieving samples and maintaining equipment during storm conditions.

Time-composite sampling and continuously recording stream gauges are used as the primary methods of monitoring the concentrations and loads of constituents at Mass Emissions sites. The sampling is conducted with automatic samplers that consist of programmable pumps (peristaltic) that transport water from the channel to a collection reservoir in the sampler base. The collection reservoir can be a single large composite bottle or a series of up to 24 bottles. The sampler program can be modified to vary sample volumes and frequency of collection. Two automatic samplers are used at each Mass Emissions site: one sampler is used for monitoring water chemistry, and the other is used for monitoring aqueous toxicity. Each dry weather composite sample is analyzed for suites of chemical analyses and toxicity tests as specified in the Fourth Term Municipal Stormwater Permit.

To collect samples for the analysis of water chemistry, eight 1.8-liter glass bottles are typically used in the sampler base. The water chemistry sampler is programmed to collect three discrete samples per 1.8-liter bottle. To collect samples for toxicity testing, a single 5-gallon glass bottle is used in the second sampler base. The two samplers are programmed to collect at the same frequency to maintain the consistency between the composite samples produced by each.

*Storm Monitoring*

The Program attempts to monitor three storms at each Mass Emissions site during the year. For each storm the water chemistry is monitored with a series of 3 to 5 composite samples collectively spanning approximately 96-hours. The sampling for toxicity testing is coincident with just one of these composite samples. The Permittees following temporal segments of storms are monitored for toxicity.

- Storm 1 – first flush (first hour of storm);
- Storms 2 – 24-hour period beginning three hours after the initiation of the first flush sampling by the water chemistry sampler.

For dry weather discharge evaluations, the automatic samplers are programmed to collect a discrete sample once an hour for a 24-hour period. During each monitored storm the automatic sampling programs are initiated when the water level in the channel rise above a triggering device (level actuator or flow meter) connected to the respective sampler. When possible, a single triggering device is used to trigger both samplers simultaneously. For the water chemistry sampler (and the toxicity sampler during the first storm) the frequency of collection during the first hour of a storm is set at 1 sample per 12 minutes. After the sixth sample is collected at the one-hour mark, the collection frequency is decreased to once every 2 hours. The first flush of the first storm of the year is modified slightly to collect additional volume for additional chemistry analyses (1 sample per 7 minutes). The concentrations of dissolved heavy metals and selenium in each of the composite samples collected during a storm can be compared to acute and/or chronic toxicity criteria from the CTR. The concentrations of organophosphate pesticides can be compared to literature values of $LC_{50}$s for the pesticide-sensitive toxicity testing organisms used. Sampler maintenance is performed periodically throughout a storm to change sample bottles, icepacks, and power supplies.

The first six samples collected during the first hour of each storm are composited and represent the "first flush". The remaining bi-hourly storm samples are used to prepare composite samples that are representative of the subsequent parts of the storm. Unless a 24-hour composite sample is prepared for comparison to toxicity testing results, the samples beyond the first flush are composited using the water level hydrograph for the channel, or by evaluating the specific conductance of the samples in each bottle. Using water level hydrographs from the Principal Permittee's Automated Local Evaluation in Real Time (ALERT) system as a guide, samples collected beyond the first flush and representing the storm peak and recession are composited into a single sample. Storms spanning multiple days are split into two or more composite samples.

Each stormwater-influenced composite sample is analyzed for suites of chemical analyses as specified in the Fourth Term Municipal Stormwater Permit. Water chemistry samples are analyzed for pH, specific conductance, turbidity, nitrate + nitrite, ammonia, total Kjehldahl Nitrogen (TKN), total phosphate, orthophosphate, dissolved and total organic carbon, total suspended and settleable solids, volatile suspended solids, chloride, sulfate, and total recoverable and dissolved cadmium, copper, chromium, lead, nickel, selenium, silver, and zinc. Priority pollutant scans (except asbestos and Dioxin) are performed on the first flush of the first monitored storm of the year at each site. Grab samples are collected at the time of sampler servicing and submitted for bacteriological analyses.

An aliquot of each sample collected for total recoverable metals analyses are filtered with a 0.45 micron groundwater filter. The filtered and the unfiltered fractions are then preserved with ultra-pure grade nitric acid prior to submittal for analysis.

Toxicity of stormwater runoff samples are evaluated using three toxicity tests with marine organisms. Aliquots from each stormwater sample are salinity-adjusted by the laboratory to the proper range for the respective testing organism. The toxicity due to pesticides is measured using the mysid (*Americamysis bahia*) survival and growth tests. The toxicity due to dissolved metals is measured using the sea urchin (*Stronglyocentrotus purpuratus*) fertilization test. *Ceriodaphnia dubia* is also analyzed for toxicity.

During dry weather monitoring, the toxicity tests are conducted with freshwater organisms. The tests include *Ceriodaphnia* survival and reproduction, *Selenastrum* growth, and *Hyalella azteca* survival. Sediment toxicity is evaluated by a 10-day survival test with *Hyalella azteca* at four sites in the Newport Bay watershed.

Time-weighted composite sampling is supported by the Principal Permittee's precipitation and streamgaging network which consists of recording and/or transmitting Automated Local Evaluation in Real Time (ALERT) gauges. The ALERT precipitation gauges are tipping bucket type with data loggers. Data are recorded and transmitted in digital format. The sensitivity of the ALERT transmitting gauges is 1 mm (0.04 inches) of accumulated rainfall. The recording non-transmitting gauges have a sensitivity of 0.01 inch of rainfall.

Several types of stream gauges are used to monitor changes in water level. The oldest design is the stilling well with water level float; the newer types are manometer gauges or pressure transducers. Data (water level versus time) are recorded in analog form on strip charts and/or in digital form on data loggers. The ALERT interface to these gauges consists of a connection from the recorder chart drive to an ALERT shaft encoder. ALERT information is recorded on a data logger and transmitted in digital format to the Principal Permittee's base station in Orange. Sensitivity of the transmitted and recorded ALERT record is user-variable with the greatest sensitivity being a change in water level of 0.01 feet. The sensitivity of these water level gauges however is generally set to a higher increment (e.g. 0.1 foot) to prevent excessive radio transmissions during a storm.

### C-11-I.3.2 Estuary / Wetlands Monitoring

Estuary / Wetlands monitoring focuses on three receiving waters and their major tributaries. These receiving waters are Newport Bay, Huntington Harbour / Bolsa Bay, and Talbert Marsh. Monitoring is conducted at 12 locations in these receiving waters during dry weather and storm runoff conditions, with additional monitoring for certain parameters at Rhine Channel in lower Newport Bay. Because there are significant equipment and manpower demands for monitoring receiving waters and their respective tributaries for a dry weather or stormwater event, each receiving water system is monitored separately. Dry weather monitoring consists of 24-hour composite sampling of the tributaries and monitoring the respective receiving waters on the subsequent day. Stormwater monitoring of the tributaries is conducted according to the Mass Emissions monitoring protocol. Sampling of the receiving waters during a storm is conducted over a 4-day period with three samplings, with each sampling separated from the prior sampling by two days. Sampling procedures may be adjusted or reduced based on the duration of storm events and storm flow conditions. Staff will use specific conductivity as a guide to evaluate the extent of stormwater influence remaining in the receiving water compared to base flow conditions.

All the tributary channel sites, with the exception of Talbert Channel, are also Mass Emissions sites. The mass emissions data for these channels assist in identifying potential relationships between patterns and trends in the estuaries / wetlands and the inputs of key pollutants.

Some sites in receiving waters are situated near the mouths of channels that represent major inputs of runoff, and there is a minimum of one site in each estuary that is free of direct runoff influences from the channels. Comparisons between these two types of sites may help identify differences between the impacts from localized effects (e.g. marina operation) and urban runoff. During an average rainfall year, an attempt is made to sample the Estuary / Wetlands sites in Huntington Harbour, Bolsa Bay, and Talbert Marsh during two storm events per year and twice during the dry season.

Routine dry weather monitoring at every site is conducted semi-annually: once prior to the beginning of the storm season (October) and once after the end (May). Dry weather monitoring is also conducted quarterly at the sites that are part of the Toxics TMDL. Sites in Upper Newport Bay have a somewhat different sampling regime because they are also part of the Nutrient TMDL program, which has a separate set of monitoring requirements outlined in the Revised Regional Monitoring Program for the Newport Bay Watershed Nutrient TMDL (issued December 12, 2014).

The constituents measured in the tributary input channels are the same as those sampled in the Mass Emissions element. The constituents measured in the Estuary / Wetlands sites depend on the season, on whether the sample is an aqueous or a sediment sample, and on the location of the monitoring site.

During stormwater events, the monitoring in the receiving waters includes chemical analyses for nutrients, total and dissolved metals, total and dissolved organic carbon, and organophosphate pesticides. In-situ measurements of physical properties are made in the water column from the surface to the bottom at 1-meter increments. These measurements include specific conductance, pH, temperature, and dissolved oxygen. Samples are evaluated for aqueous toxicity using the sea urchin fertilization test and the mysid survival / growth tests. The nutrients samples are collected at the surface to evaluate impacts on plant growth in the photic zone. The other samples (trace metals, pesticides, TOC, DOC, and toxicity) are collected using a depth-integrating, composite technique to determine the average concentrations in the water column.

Quarterly and/or Semi-annual dry weather monitoring in the receiving waters includes the aqueous analyses described above and a benthic sediment component to evaluate sediment chemistry and sediment toxicity. The sediment chemistry analytes include total organic carbon, particle size distribution, metals, organochlorine pesticides and polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs), organophosphate pesticides, and pyrethroid pesticides. Sediment toxicity is evaluated using the 10-day amphipod (*Eohaustorius estuarius)* survival test in solid-phase sediment (conducted quarterly) and the 48-hour bivalve (*Mytilus galloprovincialis*) embryo development test (conducted annually in the late summer) at the sediment water interface (SWI).

Once a year, in addition to the *Mytilus* test, the benthic sediment sampling also includes monitoring of the benthic invertebrate community for taxonomy.

The Nutrient TMDL program includes routine dry weather sampling of Newport Bay to evaluate the effects from nutrients in the discharge from the San Diego Creek as prescribed in the Revised Regional Monitoring Program for the Newport Bay Watershed Nutrient TMDL dated December 12, 2014.

C-11-I.3.3 Bacteriological / Pathogen Monitoring

On July 1, 2012, the Permittees entered into a unified regional shoreline monitoring program under the Fourth Term MS4 Permit. Participants in this unified regional program include the Permittees, Orange County Health Care Agency, and Orange County Sanitation District. The unified regional shoreline monitoring program has and continues to support multi-agency objectives, such as:

- The opportunity for partners to share knowledge about bacteriological conditions and site histories while working together to monitor beach water quality.
- The implementation of a monitoring program that assists the Regional Board in achieving the statewide goal of developing a sustainable beach water quality monitoring program for public health protection purposes.
- Consolidating monitoring programs so that sites are evaluated using comparable procedures, which provide a better contextual understanding of issues observed and ensures that site issues are appropriately prioritized by the collective workgroup.
- The opportunity for partners to more effectively leverage existing resources while expanding the collective set of technical capabilities overall to address water quality issues as needed.

As part of this consolidation, the nine coastal storm drains historically monitored by the Permittees were incorporated into the regional monitoring efforts. These include five stations in Huntington City Beach (HB1 – HB5), Buck Gully Creek (BGC), Pelican Point Creek (PPC), Water Fall Creek (WFC), and Muddy Creek (BDC). In addition to these nine coastal storm drains, seven inland channels and/or creeks that are currently impaired for pathogens are also monitored: East Costa Mesa (CMCG02), Bolsa Chica (BCC02), Sunset (SUNC07), East Garden Grove-Wintersburg (EGWC05), Santa Ana-Delhi Channel (SADF01), San Diego Creek (SDMF05), and Talbert Channel (TBOD02).

For each coastal site, samples are collected at the storm drain outfall and within the surf zone. Three analyses for pathogen indicator bacteria (total coliform, fecal coliform and *Enterococcus*) are conducted on each sample. Monitoring is conducted on both the discharge from the storm drain and the surf zone 25 yards up-coast and 25 yards down-coast of the storm drain-ocean interface. At the time of sample collection an estimate of the flow rate from the storm drain is made and the temperatures of the storm drain discharge and the surf zone down-coast are measured. During storm drain diversion or if the storm drain is not flowing to the ocean only a sample from the surf zone (down-coast of the storm drain-ocean interface) is collected. Samples are not collected on the day of rainfall.

C-11-I.3.4 Bioassessment

When the Third Term Permit Monitoring Program was first implemented, the Permittees monitored nine urban channels and three reference sites using the California Stream Bioassessment Procedure established by the California Department of Fish and Wildlife. A contract laboratory conducted the bioassessment sampling and taxonomic analyses on behalf of the Permittees.

The Permittees are currently participating in a multi-year regional bioassessment monitoring program with the Stormwater Monitoring Coalition (SMC), comprised of a group of Southern California stormwater agencies, the Regional Boards, and the Southern California Coastal Water Research Project (SCCWRP). The original 5-year study spanned 2009-13 with 2014 acting as a transitional year. The second 5-year study began in 2015, which included new metrics and field protocols designed to more accurately assess the state of the biological health of streams. 2015 included a new probabilistic site draw of potential monitoring locations, including non-perennial and first order streams. Four SMC bioassessment sites were sampled in 2016. The site assessments are made using Surface Water Ambient Monitoring Program (SWAMP-2016) protocols which were authorized for statewide use by SWAMP. These protocols can be found at:
http://www.waterboards.ca.gov/water_issues/programs/swamp/

In order to more thoroughly assess the habitat quality of each bioassessment site, monitoring is conducted using a multiple lines of evidence (LOE) approach. At the time of bioassessment monitoring, the Permittees collect grab samples for water chemistry, benthic macroinvertebrates and algae, and physical habitat condition in accordance with the new SMC protocols. Additionally, the Permittees participate in the San Gabriel River Regional Monitoring Program (SGRRMP), a multi-stakeholder coalition across Los Angeles and Orange Counties, designed to improve water quality impairments in the San Gabriel River Watershed. Two SGRRMP bioassessment sites were sampled in 2016. The LOE include the SWAMP and SMC protocols detailed above, a suite of chemical constituents similar to the Mass Emissions program, and aquatic toxicity analysis. The aquatic toxicity was evaluated using *Ceriodaphnia dubia* survival and reproduction tests.

C-11-I.3.5 Dry Weather Reconnaissance

The Dry Weather Reconnaissance element focuses on over 60 storm drains in the Santa Ana Region. Most of these drains were identified or “targeted” by the Permittees as potential conduits for illegal discharges and illicit connections. Included in the group of monitored storm drains is a subset of 16 randomly selected drains from which monitoring data are used to compute regional statistics to establish triggers for source investigations. Monitoring of the “targeted” drains involves five separate visits to each site during the dry season (May 1 – September 30). The random sites are monitored three times during the dry season. Each site visit consisted of a visual reconnaissance, in-situ measurements of physical characteristics (flow rate, specific conductance, pH, temperature, turbidity and dissolved oxygen), and field analysis of nitrate + nitrite, ammonia, reactive orthophosphate, total chlorine, surfactants, dissolved copper and hexavalent chromium, and water hardness. Samples are collected and submitted for laboratory analysis of total suspended solids, dissolved metals, oil and grease, pathogen indicator bacteria and organophosphate pesticides.

Unusual observations or measurements in the field are reported immediately to the respective Permittee representative. Field observations (photographs, in-situ measurements, field laboratory analyses, and comments) are uploaded into a web-based GIS map which allows real time access by the Permittees. The field and laboratory results are also entered into a statistical database, which is used to determine if those results warrant additional reconnaissance by the respective Permittee. The “average” condition is determined from analysis of results from randomly selected storm drains in the region. There are two triggers for upstream watershed reconnaissance. The first is exceedance of the tolerance interval bound based on the average condition established by the random sites. The second is exceedance of the site-specific control chart bound, which has been tentatively established as 3.9 standard deviations above the average (mean) value for any monitored parameter at that site. If two consecutive measurements exceed either trigger level, reconnaissance for the source will be initiated by the Permittee.

C-11-I.3.6 TMDL / 303(d) Listed Waterbody Monitoring (Nutrient TMDL)

*Dry Weather Monitoring*

During dry weather, composite samples are collected using the methods described in the Mass Emissions section.

*Stormwater Runoff Monitoring*

During storm events, unless the monitoring location is part of the Mass Emissions program, composite surface water samples are collected at one hour intervals over a 24 hour cycle (up to a 96-hour period, depending on the storm length) using automatic samplers with Tygon or Teflon-lined strainer tubing. This protocol is different from the Mass Emissions program in that no "first flush" sample is collected.

*Discharge Rate Data*

The discharge rate or flow data used to calculate nutrient loadings are collected year round from nine streamgauges in the Newport Bay watershed. Of these nine gauges, seven are operated by the Principal Permittee (the County) and two are operated by the United States Geological Survey (USGS). The locations of these gauges are listed below:

- San Diego Creek at Campus Drive (County)
- Santa Ana-Delhi upstream of Irvine Avenue (County)
- Peters Canyon Wash at Barranca Parkway (County)
- San Diego Creek at Culver Drive (County)
- El Modena-Irvine at Michelle Drive (County)
- Lane Channel at McCabe Way (County)
- Costa Mesa Channel at Westcliff Drive (County)
- Bonita Canyon Creek at MacArthur Boulevard (USGS)
- Agua Chinon Channel at Irvine Boulevard (USGS).

Six of the seven County operated stream gauge stations are equipped with a continuous water-stage recorder, precipitation gauge, and ALERT transmitter/data logger which provide the ability for the County to monitor rainfall and channel water level in real-time. The seventh station, Costa Mesa Channel at Westcliff, has the same field equipment as the other stations with the exception of the real-time reporting capability.

The USGS stations are equipped with continuous water-stage recorders and a satellite telemetry system that can be viewed (with minimal time delay) on the USGS internet home page.

**C-11-I.4 Methods of Data Analysis**

<u>C-11-I.4.1 Comparison to Water Quality Criteria</u>

California Water Code Section 13170 authorizes the State Water Resources Control Board (SWRCB) to adopt water quality control plans for waters where standards are required by the Federal Clean Water Act (CWA). According to Section 303(c)(2)(B) of the CWA, these plans must contain water quality objectives for priority pollutants that could be reasonably expected to affect the beneficial uses of the waters of the State.

On March 2, 2000, the State adopted the United States Environmental Protection Agency's (USEPA) Rules establishing numeric water quality criteria for priority toxic pollutants (commonly referred to as the California Toxics Rule or CTR) for the State of California. The CTR sets criteria for dissolved heavy metals in freshwater that are based on water hardness, and separate criteria for saltwater. The SWRCB's 2005 *Policy for Implementation of Toxic Standard for Inland Surface Waters, Enclosed Bays, and Estuaries of California*, exempts stormwater discharges from the CTR. Despite this exemption the concentrations of dissolved metals in both dry weather and stormwater discharges are compared in this report to CTR criteria, with the stormwater comparisons made for discussion purposes only.

Acute (CMC-Criteria Maximum Concentration) and chronic (CCC-Criteria Continuous Concentration) aquatic toxicity criteria from the CTR are used to evaluate dissolved metals data collected from storm channels (freshwater CTR criteria) and estuaries/wetlands sites (saltwater CTR criteria).

According to the CTR, for waters with a hardness of 400 mg/l or less as calcium carbonate, the actual ambient hardness of the surface water shall be used in those equations. For waters with a hardness of over 400 mg/l as calcium carbonate, a hardness of 400 mg/l as calcium carbonate shall be used with a default Water-Effect Ratio (WER) of 1, or the actual hardness of the ambient surface water shall be used with a WER. For hardness levels exceeding 400 mg/L, the Permittees use the former method.

In applying the CTR as guidance in evaluating freshwater monitoring program elements, if the time period to which the criteria applies is less than the length of the sampled period, a measured concentration greater than that guidance value is considered an exceedance. For example, if the 1-hour criterion for lead (at a hardness of 100 mg/L as $CaCO_3$) is 65 μg/L, a concentration of 68 μg/L during a 24-hour period is considered an exceedance of the criterion.

When computing the time-weighted mean concentration for a sampled period with multiple composite samples, values below the detection limit are assumed to be zero. This assumption allows for a more consistent evaluation from year to year as laboratory detection limits are lowered with alternative methods of analysis or new technology. The assumption also gives greater confidence to a designation of an exceedance of a criterion as it reduces the likelihood that the exceedance was caused by an erroneous estimation of a non-detected value.

In applying the CTR as guidance in evaluating the saltwater monitoring program elements, the dissolved metals concentrations in each grab sample were compared to the respective 1-hr acute and chronic toxicity guidance criteria. Since total chromium was analyzed only the criterion for trivalent chromium (Chromium III) was used.

C-11-I.4.2 Toxicity Testing Data

Toxicity tests span varying time periods depending on the type of organism function (survival, growth, reproduction, etc.) being evaluated. Endpoint data are used to compute statistics that can be compared against regulatory criteria. These statistics include Acute Toxicity Units (TUa) and Chronic Toxicity Units (TUc).

Each stormwater sample is analyzed by monitoring organism responses in a series of sample dilutions (e.g. 100, 50, 25, 12.5, and 6.25% sample concentration). Due to analytical cost constraints, the dilution series for dry weather samples and some surf zone samples were limited to two concentrations (100 and 50%). The responses measured in each dilution are validated by a number of replicates. Responses are also monitored in laboratory control water.

The concentration that causes 50% mortality of the organisms (the median lethal concentration, or $LC_{50}$) is determined using a statistical calculation with the endpoint data from an acute toxicity test. The acute toxicity test spans 48 hours for *Ceriodaphnia, Americamyis*, and fathead minnow (*Promelas pimephales*), and 96 hours for *Hyalella azteca*. The $LC_{50}$ values are 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 chronic effects are estimated using the "No Observable Effects Concentration" (NOEC), for both survival and reproduction. For the *Ceriodaphnia* reproduction, *Americamysis* growth, and fathead minnow growth tests the endpoint of the test is at seven days. For the *Selenastrum* growth test the endpoint is at 96 hours. The NOEC is the highest concentration tested in which there is no statistically significant difference in the organism response relative to the control sample response. The lower the value of the NOEC, the more toxic the sample would be.

For purposes of assessment between sites or between samplings, 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.

TUa and TUc values are calculated very differently and are not interchangeable or related. The TUa equals 100/acute $LC_{50}$. If the $LC_{50}$ is greater than 100% (i.e. more than 50% survival in the undiluted sample), then the TUa is calculated by the following formula:

$$TUa = \log(100-S)/1.7$$

Where S = percentage of survival in 100% (undiluted) 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 are calculated separately for survival and reproduction endpoints.

For some tests, if the test data meet acceptability criteria, inhibition concentrations, an $IC_{25}$ and an $IC_{50}$, are calculated. These are the concentrations that cause a 25 percent or 50 percent inhibition of an organism's function such as growth, or cell density, in the *Selanastrum* growth test.

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 chloride 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.
A description of the methods used in each toxicity test can be found by consulting the references cited at the end of this attachment.

For toxicity tests available $LC_{50}$ and $EC_{50}$ data on key contaminants can be used to compare the observed toxicity (measured as toxic units) to the expected toxicity. The toxicity testing organisms used in this Program tend to be more sensitive to some categories of toxicants than others. For example, the mysid (*Americamysis bahia*) survival/growth test tends to be very sensitive to organophosphate pesticides and unionized ammonia but less sensitive to metals. The sea urchin fertilization test is sensitive to dissolved metals and unionized ammonia but not very sensitive to OP pesticides.

$LC_{50}$ data from the *Americamysis bahia* survival tests with ammonia, Chlorpyrifos, Diazinon, Dimethoate and Malathion were obtained from the PAN Exotoxicity database http://www.pesticideinfo.org/Search_Ecotoxicity.jsp which contains the results of over 220,000 toxicity tests. Results can be sorted by species, chemical or effect. Additional data are available from SCCWRP research studies. $EC_{50}$ data for the sea urchin 40-minute fertilization test for unionized ammonia, copper, and zinc can be obtained from the same sources. The observed concentration of each chemical constituent (from the aquatic chemistry samples collected at the same time) can be divided by the appropriate $LC_{50}$ or $EC_{50}$ value to produce an estimated $TU_a$ from each constituent. These estimated $TU_a$s are then summed and compared to the observed $TU_a$ from the toxicity test, as in the following equations:

$$\frac{\text{Concentration of toxicant}}{\text{Average literature value of } LC_{50} \text{ or } IC_{50} \text{ of toxicant}}$$

The total predicted toxicity from n toxicants is $\sum_{i}^{n} \frac{[toxicant_i]}{[LC_{50} or IC_{50}]_i}$

The calculated TUa from the toxicity test can be compared to this predicted toxicity.

This approach to comparing observed and predicted toxicity has potential shortcomings, including:

- The lack of availability of relevant $LC_{50}$ and $EC_{50}$ data for the full range of chemical constituents of concern,
- Lack of available data for the same life stages (e.g. larval vs. juvenile, or adult) of the organisms evaluated in our program,

- Lack of available data for the same test evaluation periods used in our program (e.g. 48-hr $LC_{50}$ for mysids and *Ceriodaphnia* and 96-hr $LC_{50}$s for *Hyalella azteca*),
- Ranges of responses from multiple studies in the literature,
- The implicit assumption of simple compounding of toxic effects. While probably not true, there is no clear guidance on how to accurately represent synergistic effects, which could very well vary from site to site and over time.
- The fact that the predicted toxicity in several instances is larger than the observed toxicity, which serves to weaken confidence in the reliability of the $LC_{50}$ and $EC_{50}$ data.

Despite these shortcomings, this approach is useful for:

- Assessing the overall accuracy or reliability of the toxicity results,
- Identifying specific chemicals that appear to contribute most to toxicity and that are therefore targets for further study and/or source identification and reduction efforts, and
- Identifying monitoring locations that may have consistently high levels of unexplained toxicity. In these cases, more sophisticated studies may be called for.

C-11-I.4.3 Mass Load Calculations

Mass loads are calculated using chemical and hydrographic data. Water level records from permanent streamgaging stations at or near the sampling site are processed using Hydstra hydrologic data management software. Analog records from a station's continuous strip chart recorder are digitized and converted to discharge rates using stage-discharge relationships (channel ratings). At sites which have water level gauges with digital dataloggers, the digital records are downloaded periodically and stored in Hydstra. Using the respective rating tables for each site, the water level data are converted to flow rates. The total discharge volume (in acre-feet) during each sampled period is computed. By multiplying the total water discharge per sampled period by the pollutant concentration of the composite sample from the period and applying the proper conversion factors (acre-feet to lbs. of water), a mass load in pounds or tons of contaminant is calculated. For data reported as ND (non-detected), one-half of reported laboratory detection limits are used in the calculations.

An EMC is the flow-weighted average concentration during a storm. It is calculated from composite sample concentrations and measured stormwater volumes represented by those composite samples. The annual mean EMC represents the flow-weighted mean of all storms sampled at a site during the monitoring year.

$$MeanEMC = \frac{\sum_{i=1}^{n} V_i EMC_i}{\sum_{i=1}^{n} V_i}$$

where n storms are monitored and $V_i$ is the stormwater volume of the *i*th storm. The EMC for a storm *i* is defined as

$$EMC_i = \frac{\sum_{j=1}^{m} SWL_j}{k\sum_{j=1}^{m} SWV_j}$$

where SWL$j$ is the stormwater load from composite sample $j$ , SWV$j$ is the stormwater volume used to calculate SWL$j$, $m$ is the total number of composite samples collected during storm $i$ and k is a conversion factor to produce the appropriate concentration units.

Annual site-mean EMCs are used to estimate mass loads from un-sampled storms during the monitoring year for two purposes:

1. To estimate total annual loads on a site-by-site basis, and
2. To estimate the loads on a watershed basis.

To estimate these un-sampled loads in pounds, the site mean EMC (in mg/L) for each stormwater contaminant is multiplied by the total annual volume of water (in acre-ft) discharged during un-sampled storms, and the unit conversion factors [2.718 liter • lbs/mg • ac-ft]. If the units of the EMC are ug/L the conversion factor is 2.718 X $10^{-3}$. The watershed load is calculated by simply summing the total estimated annual loads from each monitoring site in the watershed. Only EMCs in which 75-120% of the total runoff volume of a storm was sampled are used to calculate the annual site EMCs.

C-11-I.4.4 Evaluation of Bacteriological / Pathogen Data

Coastal storm drain data include water temperature and concentrations of bacterial indicators in the discharge and in the surf zone upcoast (north) and downcoast (south) of these storm drains. Data analysis may consist of:

1. Comparing indicator levels at each drain to the state's AB411 single sample standards for ocean water sports contact

2. Listing the drains in terms of the proportion of total possible exceedances of the AB411 standards. The proportion of exceedances for each monitoring site is calculated as:

$$\frac{\text{Number of exceedances of a single sample standard}}{\text{Number of samples X number of analyses per sample}}$$

The total number of AB411 exceedances is then divided by the total number of sample tests, resulting in a proportion for each drain between 0 and 1.0. The exceedance proportion for each site is then indicated on a map of the sampling sites, according to the following color scheme:

| Symbol Color | Proportion |
|---|---|
| Green | 0 - < 0.10 |
| Blue | 0.14 - < 0.40 |
| Yellow | 0.40 - < 0.75 |
| Red | 0.75 – 1.0 |

It should be noted that this color scheme was developed to provide a relative ranking of the surf zone water quality at the outfalls of Orange County storm drains.

3. Heal the Bay's Beach Report Card grading system which uses an evaluation process that includes:
   - Indicator bacteria thresholds (namely the total-to-fecal ratio) developed by the Santa Monica Bay Restoration Commission in the 1996 health effects studies of Santa Monica Bay beachgoers.
   - Standard deviations for each indicator bacteria threshold which was developed by the Southern California Coastal Water Research Project and Orange County Sanitation Districts during the 1998 Southern California Bight Study.
   - Use of rolling 30-day geometric mean for bacterial indicators and greater weight for the Enterococcus single sample standard relative to total coliform and fecal coliform.
   - A firm zero-to-100 point scale for a standard A through F grading system based on the following formula:

$$\% \text{ Grade} = \frac{\text{Total Points Available} - \text{Total Points Lost}}{\text{Total Points Available}}$$

<u>Grading System</u>
A= 100% – 90%
B = 89% – 80%
C = 79% – 70%
D = 69% – 60%
F = <60%

4. Depicting percentages of sampled days in which at least one indicator bacteria concentration exceeded the AB411 concentration in the surf zone. Each day of surf zone sampling is evaluated with respect to the AB411 standards for the three indicators. For each drain, the percentage of sampled days in which at least one standard was exceeded in the surf zone (upcoast or downcoast) is calculated. These percentages are calculated for the entire year and the AB411 season (April 1-October 31). This method of analysis provides a better assessment of the health risk (compared to analysis #2) associated with water contact in the surf zone near the discharges from the drains.

These analyses are performed for the entire year and for the AB411 season alone. Analyses also focus on only those instances where field notes indicate that the outflow of a drain is flowing to the surf zone.

Data analysis for the inland channels proceeded somewhat differently because sampling consists simply of grab samples in the channel, rather than samples from a coastal storm drain discharge and from surf zone stations upcoast and downcoast. Although the AB411 standards apply to ocean water sports contact, the concentrations of the indicators in each channel sample are compared to AB411 standards for discussion purposes only. As with the surf zone data the proportion of exceedances were calculated, for both the entire year and the AB411 season. The sites are then compared in terms of their percent of exceedance to the prior year results.

C-11-I.4.5 Bioassessment and the California Stream Condition Index (CSCI)

The Permittees have participated in the regional Stormwater Monitoring Coalition (SMC) bioassessment program since 2009. The stations in this program are evaluated in terms of a series of metrics, which are then scored to provide a basis for determining the overall California Stream Condition Index (CSCI) scores for each site. Historically, the Southern California Index of Biotic Integrity (SoCal IBI) was used as the scoring metric, and was based on data from the southern California region, from southern Monterey County to the Mexican border. However, the CSCI was created using a more robust dataset of reference sites from a wide variety of streams across multiple climate zones throughout California. The CSCI has become the standard index for scoring biotic integrity, and is the tool used to analyze the complex biological data in this report.

*CSCI Methods*

The CSCI is a new statewide biological scoring tool that translates complex data about benthic macroinvertebrates (BMIs) found living in a stream into an overall measure of stream health. The CSCI was finalized in 2015 and represents the latest generation of biological indicators for assessing stream health in California. The CSCI combines two separate types of indices, each of which provides unique information about the biological condition at a stream: a multi-metric index (MMI) that measures ecological structure and function, and an observed-to-expected (O/E) index that measures taxonomic completeness. Unlike previous MMI or O/E indices that were applicable only on a regional basis or under-represented large portions of the state (SoCal IBI), the CSCI was built with a statewide dataset that represents the broad range of environmental conditions across California. The CSCI provides consistency and accuracy in the interpretation of biological data collected by both statewide and regional monitoring programs and will be the basis of the new statewide Biological Integrity Plan. CSCI results are included in **Attachment C-11-V**. Full details of CSCI development can be found in the following references for calculation method, index development, and index development summary, respectively:

- Mazor, R. D., P. R. Ode, A. C. Rehn, M. Engeln, T. Boyle, E. Fintel, S. Verbrugge, and C. Yang. 2015. The California Stream Condition Index (CSCI): Interim instructions for calculating scores using GIS and R. SCCWRP Technical Report #883. SWAMP-SOP-2015-0004.
- Mazor, R. D., P. R. Ode, A. C. Rehn, M. Engeln, K. A. Schiff, E. Stein, D. Gillett, D. Herbst, and C. P. Hawkins. 2015. Bioassessment in complex environments: designing an index for consistent meaning in different settings. Freshwater Science. 14:31. http://www.jstor.org/stable/10.1086/684130.
- Rehn, A.C., R.D. Mazor and P.R. Ode. 2015. The California Stream Condition Index (CSCI): A New Statewide Biological Scoring Tool for Assessing the Health of Freshwater Streams. Swamp Technical Memorandum SWAMP-TM-2015-0002.

*Application of CSCI to Additional Lines of Evidence*

Historical CSCI scores from 2009 through 2016 were compared against several other lines of evidence that are collected in the bioassessment program. Chief among them are measures of instream habitat such as physical habitat (phab) and the California Rapid Assessment Method (CRAM). Further analysis uses the Southern California Algal Index of Biotic Integrity (SoCA Algal IBI) and the hybrid sub-index H20 for soft algae and diatoms. Thresholds have been established for each of these metrics, which allow for spatial and temporal analysis. Correlations to aquatic chemistry and toxicity are difficult to definitively correlate. Further summaries and graphics regarding the water quality component are discussed in **Attachment C-11-V**.

Further analysis was conducted for spatial and temporal patterns in the benthic invertebrate community from 2009 through 2016: dendrogram cluster analysis and two-way coincidence tables.

a. Cluster analysis defines groups of stations with similar community composition. The results are displayed in a hierarchical tree-like structure called a dendrogram. On the dendrogram, two groups are first defined, and within these groups, subgroups are defined. Subsequently, subgroups within the subgroups are defined. This process is continued until all stations are their own separate subgroup. The hierarchical nature of the dendrogram allows the analyst to choose groups of stations that represent a scale of taxonomic community differences relevant to the present project. Cluster analysis is also used to define groups of species that tend to have similar distributional patterns among the stations.

b. A two-way coincidence table is the station-species abundance data matrix displayed as a table of symbols indicating the relative abundances of the species at the stations. The rows and columns of the table are arranged to correspond to the order of stations and species along the respective station and species dendrograms. Since similar entities (stations or species) will tend to be closer together along a dendrogram, the row and column orders will efficiently show the pattern of species over the stations and station groups.

   The species data from all surveys were clustered to identify groupings of sites that were similar in terms of their community composition. The cluster analysis dendrogram of all historical sites (2009 – 2016) and the two-way coincidence table of the relative distribution of species in each site are included in the bioassessment analysis. On the two-way coincidence table, horizontal and vertical lines identify major groupings of species and sites, respectively. Sites are identified by their site number and year they were sampled. Relative species abundances are shown as symbols. Smaller symbols represent a lower proportion of maximum abundance and larger symbols a larger proportion. The abundance of each species was standardized in terms of its maximum at each site over all surveys.

The specific steps are as follows:

- Preliminary biotic data transformation, using a square root transformation and standardization by species mean of values >0 (Smith, 1976; Smith et al., 1988) [1]

[1] Smith, R.W. 1976. Numerical Analysis of Ecological Survey Data. PhD thesis, Univ. of S. Calif., Los Angeles. 401 pp. Smith, R.W., B.B. Bernstein, and R.L. Cimberg. 1988. Community-Environmental Relationships in the Benthos: Applications of Multivariate Analytical Techniques. Chapter 11 In: Marine Organisms as Indicators. Springer-Verlag. New York: 247-326.

- Calculation of a Dissimilarity Index for cluster analysis of stations, using the Bray-Curtis Index, step-across procedure for dissimilarity >0.8 (Bradfield and Kenkel, 1987; Clifford and Stephenson, 1975; Smith, 1984; Williamson, 1978)[2]
- Calculation of similarities for cluster analysis of species, using flexible clustering ($\beta$=-0.25) (Clifford and Stephenson, 1975; Lance and Williams, 1967; Smith, 1982)[3]
- Creation of the two-way coincidence table (Kiddawa, 1968; Smith, 1976)[4].

Results from the Biological Cluster Analysis are included in **Attachment C-11-V**.

C-11-I.4.6 Phase I Sediment Quality Objectives Analyses of Harbor / Estuary / Wetlands Data

California Water Code section 13393 requires the State Water Resources Control Board to develop sediment quality objectives (SQOs) for toxic pollutants in California's enclosed bays and estuaries. In 1991 the SWRCB adopted a work plan to develop these SQOs but due to budgetary constraints was not able to implement this work plan. Litigation by several environmental groups ensued and in August 2001, the Sacramento County Superior Court ruled that the SWRCB must initiate development of the SQOs. With the aid of a multi-agency scientific steering committee Phase 1 SQOs were developed and became effective on August 25, 2009.

With Phase 1 SQOs, the assessment of sediment quality consists of the measurement and integration of three LOE. The LOE, as described by the SWRCB, are:

- Sediment Toxicity—Sediment toxicity is a measure of the response of invertebrates exposed to samples of surficial sediments (those sediments representing recent depositional materials and containing the majority of the benthic invertebrate community) under controlled laboratory conditions. The sediment toxicity LOE is used to assess both pollutant related biological effects and exposure. Sediment toxicity tests are of short durations and may not duplicate exposure conditions in natural systems. This LOE provides a measure of exposure to all pollutants present, including non-traditional or unmeasured chemicals.

---

[2] Bradfield, G.E. and N.C. Kenkel. 1987. Nonlinear ordination using shortest path adjustment of ecological distances. Ecology 68(3): 750-753.
Clifford, H.T. and W. Stephenson. 1975. An Introduction to Numerical Classification. Academic Press, New York: 229 pp.
Smith, R.W. 1984. The re-estimation of ecological distance values using the step-across procedure. EAP Technical Report No. 2.
Williamson, M.H. 1978. The ordination of incidence data. J. Ecol. 66: 911-920.

[3] Clifford, H.T. and W. Stephenson. 1975. An Introduction to Numerical Classification. Academic Press, New York: 229 pp.
Lance, G.N., and W.T. Williams. 1967. A general theory of classificatory sorting strategies. I. Hierarchical systems. Computer J. 9: 373-380.
Smith, R.W. 1982. Analysis of ecological survey data with SAS and EAP. Proc. 7th Annual SAS Users' Group International (SUGI). SAS Institute Inc. P.O. Box 8000, Cary NC 27511: 610-615.

[4] Kikkawa J. 1968. Ecological association of bird species and habitats in Eastern Australia; similarity analysis. J. Anim. Ecol. 37: 143-165.
Smith, R.W. 1976. Numerical Analysis of Ecological Survey Data. PhD thesis, Univ. of S. Calif., Los Angeles. 401 pp.

- Benthic Community Condition—Benthic community condition is a measure of the species composition, abundance and diversity of the sediment-dwelling invertebrates inhabiting surficial sediments. Benthic community composition is a measure of the biological effects of both natural and anthropogenic stressors.
- Sediment Chemistry—Sediment chemistry is the measurement of the concentration of chemicals of concern in surficial sediments. The chemistry LOE is used to assess the potential risk to benthic organisms from toxic pollutants in surficial sediments. The sediment chemistry LOE is intended only to evaluate overall exposure risk from chemical pollutants. This LOE does not establish causality associated with specific chemicals.

With assistance from SCCWRP, the SWRCB has developed an LOE integration tool using Microsoft Excel. To use the tool, data from the three LOE at each site are entered into the Excel workbook and a score is generated for each LOE. Using the matrix of 64 possible combinations of LOE scores a final assessment score is produced. This final assessment score can be unimpacted, likely unimpacted, possibly impacted, likely impacted, or clearly impacted. A comprehensive description of this sediment quality assessment method can be found on SCCWRP's website at http://sccwrp.org/Data/DataTools/SedimentQualityAssessment.aspx .

Additional information is included in **Attachment C-11-III**.

C-11-I.4.7 Prioritization of Reconnaissance Sites for Source Identification

Concentrations of monitored constituents at dry weather reconnaissance sites are compared to the upper bounds (lower bound for dissolved oxygen) of tolerance intervals around the 90$^{th}$ percentile calculated from the set of random urban background sites. The concentrations are also compared to the limits from the site-specific control charts. These control charts are time series plots of each measurement at a site. The upper control limit for each measurement is set at 3.9 standard deviations above the mean of all measurements at the site. Instances in which data values for a specific contaminant exceeds either of these two qualifiers for two consecutive monitoring events are flagged for further source identification efforts to identify upstream sources of pollution.

C-11-I.4.8 Evaluation of Trends in Water Quality

**Section C-11.4** and **Attachment C-11-VI** include assessments that utilize the water quality index, a tool based on the CCME Water Quality Index (CCME WQI). Additional information on the CCME WQI can be found at http://www.ccme.ca/en/resources/canadian_environmental_quality_guidelines/calculators.html. This index is capable of accounting for a broad suite of contaminants and measures of condition (i.e., toxicity and biology) and produces a measure, scored from 0 – 100, with lower scores representing worse conditions and higher scores better conditions. The index accounts for the number of indicators that exceed standards (Scope), the percentage of samples that exceed standards (Frequency), and the average magnitude of any exceedances (Amplitude). Each of the three components that comprise the water quality index are calculated as follows:

- Scope ($F_1$)

$$F_1 = \left(\frac{Number\ of\ failed\ constituents}{Total\ number\ of\ constituents}\right) \times 100$$

- Frequency ($F_2$)

$$F_2 = \left(\frac{Number\ of\ failed\ samples}{Total\ number\ of\ samples}\right) \times 100$$

- Amplitude ($F_3$)

$$F_3 = \left(\frac{nse}{0.01nse + 0.01}\right)$$

where *nse* refers to the normalized sum of excursions, or collective amount by which individual samples exceed standards

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{number\ of\ samples}$$

and *excursion* describes the number of times by which an individual sample exceeds standards when the test must not exceed or fall below the objective

$$excursion_i = \left(\frac{Failed\ test\ result}{Objective}\right) - 1$$

$$excursion_i = \left(\frac{Objective}{Failed\ test\ result}\right) - 1$$

The overall water quality index result is a summation of the three factors:

$$CCME\ WQI = 100 - \left(\frac{\sqrt{F_1{}^2 + F_2{}^2 + F_3{}^2}}{1.732}\right)$$

Further discussion of the technical details of the CCME WQI calculation can be found at the following links:

- http://www.ccme.ca/files/Resources/calculators/WQI%20User's%20Manual%20(en).pdf
- http://www.ccme.ca/files/Resources/calculators/WQI%20Technical%20Report%20(en).pdf

Water quality indices presented in **Section C-11.4** were compared to the following objectives:

| Parameter | Upper Limit |
|---|---|
| **TC (CFU/100mL)** | 4000.00 |
| **FC (CFU/100mL)** | 200.00 |
| **ENT (CFU/100mL)** | 35.00 |
| **Bifenthrin (ng/L)** | 2.00 |
| **Chlorpyrifos (ng/L)** | 40.00 |
| **Cyfluthrin (ng/L)** | 7.00 |
| **Cypermethrin (ng/L)** | 69.00 |
| **Diazinon (ng/L)** | 110.00 |
| **Dimethoate (ng/L)** | 500.00 |

| | |
|---|---|
| **Malathion (ng/L)** | 35.00 |
| **Permethrin (ng/L)** | 5.00 |
| **TDS (mg/L)** | 1000.00 |
| **Total Nitrogen (mg/L)** | 1.00 |
| **Total Phosphorus (mg/L)** | 0.10 |
| **Metals** | CTR Values |

For **Attachment C-11-VI**, samples were compared to the most recent tolerance interval calculations (as described in **Section C-11-I.3.5** above).

| Parameter | Lower Objective | Upper Objective | Class |
|---|---|---|---|
| **DO (mg/L)** | | 3.87 | Physicals |
| **EC (µS/cm)** | | 3853 | Physicals |
| **pH** | 7.19 | 8.47 | Physicals |
| **Water Temperature (C)** | | 25.24 | Physicals |
| **Turbidity (NTU)** | | 13.5 | Physicals |
| **Hardness (mg/L)** | | 1020 | Physicals |
| **Ammonia As N (mg/L)** | | 0.56 | Nutrients |
| **Nitrate As N (mg/L)** | | 5.9 | Nutrients |
| **Anionic Surfactants (mg/L)** | | 0.45 | Other |
| **Reactive Phosphorus (mg/L)** | | 2.94 | Nutrients |
| **Total Chlorine (mg/L)** | | 0.14 | Other |
| **TSS (mg/L)** | | 42.11 | Other |
| **Oil And Grease (mg/L)** | | 5 | Other |
| **Dissolved Copper (mg/L)** | | 0.2 | Other |
| **Dissolved Hexavalent Chromium (mg/L)** | | 0.05 | Other |
| **TOC (mg/L)** | | 17.4 | Other |
| **TC (CFU/100mL)** | | 300000 | Bacteria |
| **FC (CFU/100mL)** | | 42000 | Bacteria |
| **ENT (CFU/100mL)** | | 25000 | Bacteria |
| **Diazinon (ng/L)** | | 20 | Pesticides |
| **Chlorpyrifos (ng/L)** | | 20 | Pesticides |
| **Malathion (ng/L)** | | 20 | Pesticides |
| **Dimethoate (ng/L)** | | 20 | Pesticides |
| **Disulfoton (ng/L)** | | 20 | Pesticides |
| **Cr (µg/L)** | | 1.3 | Metals |
| **Ni (µg/L)** | | 12 | Metals |
| **Cu (µg/L)** | | 14 | Metals |
| **Zn (µg/L)** | | 52 | Metals |
| **Ag (µg/L)** | | 0.5 | Metals |
| **Cd(µg/L)** | | 0.88 | Metals |

| | | | |
|---|---|---|---|
| **Pb (µg/L)** | | 0.65 | Metals |
| **As (µg/L)** | | 7.1 | Metals |
| **Se (µg/L)** | | 7.6 | Metals |
| **Hg (µg/L)** | | 0.1 | Metals |

## REFERENCES FOR TOXICITY TESTING


Chapman, G.A. 1994. *Sea urchin* (*Strongylocentrotus purpuratus*) *and sand dollar* (Dendraster excentricus) *fertilization test method*. USEPA. Newport, Oregon (draft).

Dinnel, P.J. et.al. 1987. *Improved methodology for sea urchin sperm cell bioassay for marine waters*. Archives of Environmental Contamination and Toxicology. 16:23-32.

Hunt, J., Anderson, B. *Abalone development: Short-Term Toxicity Test Protocol. Procedures Manual for Conducting Toxicity Tests Developed by the Marine Bioassay Project*. State Water Res. Control Board. Sacramento (Current Ed.).

State Water Resources Control Board. 1996. *Procedures Manual for Conducting Toxicity Tests Developed by the Marine Bioassay Project*. 96-IWQ.

USEPA. 1988. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms*. EPA-600/4-87/028.

USEPA. 1989. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Fresh-water Organisms*. EP A-600/4-89/001.

USEPA. 1991. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Fresh-water Organisms*. EP A-600/4-91/002.

USEPA. 1991. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Marine and Estuarine Organisms*. EPA-600/4-91/003.

USEPA. 1995. *Short-Term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to West Coast Marine and Estuarine Organisms.* EPA/600/R-95/136.

USEPA, March 2000, *Methods for Measuring the Toxicity and Bioaccumulation of Sediment-associated Contaminants with Freshwater Invertebrates Waters to Freshwater and Marine Organisms.* (2nd ed). EPA600/R-99/064

USEPA, July 2000, *Method Guidance and Recommendations for Whole Effluent Toxicity (Wet) Testing (40 CFR Part 136).* EPA/821/B-00/004

USEPA. 2002. *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms*. (5th ed). EPA-821-R-02-012