C-11-III.1 PROGRAM DEVELOPMENT

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 three 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 overall evolution of the Program's monitoring efforts during this period are 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
- Address expanded set of issues
    - ♦Bioassessment (taxonomy) and physical habitat assessment
    - ♦Toxicity
    - ♦Pathogen indicators in coastal stormdrains and receiving waters
    - ♦Impacts to environmentally sensitive coastal receiving waters
    - ♦Enhanced dry weather reconnaissance of MS4 connections

Fourth Term Permit

- Track compliance
- Continue trends monitoring
- Continue pathogen monitoring of coastal stormdrains
- Continue monitoring environmentally sensitive coastal receiving waters
- Assess environmental quality with MLE (multiple lines of evidence) where possible e.g. chemistry, taxonomy, toxicity, physical habitat
- Address expanded set of issues
    - ♦Enhancement of source investigation methods
    - ♦Trash and litter impairment investigations
    - ♦Sediment chemistry and toxicity at bioassessment sites
    - ♦Wet weather discharges to the MS4 from major outfalls relative to stormwater action levels (SALs)
    - ♦Non-stormwater discharges to the MS4 from major outfalls relative to numeric action levels (NALs)

The Program's evolution is characterized by:

- Continued development of a longer-term perspective for tracking trends in key pollutants and at high-priority locations

- A specific focus on problem areas and issues

- Attention to an expanding set of concerns related to stormwater, e.g., bioassessment, ambient coastal receiving water quality.

C-11-III.1.2 Pre-NPDES Water Quality Monitoring

From 1973 to 1990, the Principal Permittee conducted routine water quality monitoring in drainage facilities that are tributary to water bodies identified as waters of the State by the Regional Boards. The receiving waters were also monitored routinely to assess the chronic effects on established beneficial uses.

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 stormdrain 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-III.1.3 First Term Permit Monitoring under Order 90-38

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 monitoring in regional flood control channels to assess aquatic chemistry relative to applicable water quality criteria: and receiving water monitoring in harbors and estuaries to evaluate the impacts of urban runoff during dry weather and stormwater runoff conditions.

C-11-III.1.4 Second Term Permit Monitoring under Order 96-03

While the First Term Permit monitoring program produced useful information, the Permittees recognized (as did many others across the nation) 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 vast array of 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 were:

- A focus on known sites (or Warm Spots) where constituents are substantially above system-wide averages;

- A parallel (and somewhat overlapping) focus on areas of critical aquatic resources (CARs); 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 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 included 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 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 to be used at any time throughout the life of the monitoring program to reevaluate 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 (1998-99 – 2002-03) for addressing the goals/objectives associated with each task.

C-11-III.1.5 Third Term Permit Monitoring under Order R9-2002-0001

In 2002-03, the Program completed development of the Third Term Permit monitoring programs for wet and dry weather, respectively. 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 monitoring plan more completely examined storm drains that discharge directly to the coast and pose a potential health risk to swimmers and bathers. In addition, the new program for the first time investigated the effects of urban runoff on the aquatic habitat of the nearshore marine environment. The impacts of marina operations and stormdrain discharges were evaluated with comprehensive monitoring of the water and sediments of Dana Point Harbor. These Dana Point Harbor evaluations included analyses of water and sediment chemistry and toxicity, as well as taxonomic assessments of benthic infaunal community. Inland, the new monitoring plan included semiannual bioassessment studies of creeks, along with toxicity testing. Combined with the existing measurement of chemical parameters, this “triad” approach was intended to describe impacts more fully; more accurately identify their sources, and target follow-up studies and BMPs more effectively.

C-11-III.1.6 Fourth Term Permit Monitoring under Order R9-2009-0002

On December 16, 2010, the California Regional Water Quality Control Board - San Diego Region adopted Order No. R9-2009-0002 “Waste Discharge Requirements for Discharges of Runoff from Municipal Separate Storm Sewer Systems (MS4s) Draining the Watershed of the County of Orange, the Incorporated Cities of Orange County, and the Orange County Flood Control District within the San Diego Region” (Permit). Attachment E of Order No. R9-2009-0002 contains the requirements of the “Receiving Waters and MS4 Discharge Monitoring and Reporting Program.”

C-11-III.2 MONITORING APPROACH

According to Order R9-2009-0002 the Fourth Term Permit monitoring program is intended to meet the following goals:

- Assess compliance with Order No. R9-2009-002
- Measure and improve the effectiveness of the Permittees' runoff management programs
- Assess the chemical, physical, and biological impacts to receiving waters resulting from MS4 discharges
- Characterize stormwater discharges
- Identify sources of specific pollutants
- Prioritize drains and sub-drainage areas that need management actions
- Detect and eliminate Illegal Discharges/Illicit Connections (ID/ICs) to the MS4
- Assess the overall health of receiving waters
- Provide information to implement required BMP improvements

Its design is intended to enable the Permittees answer the following questions:

1. Are conditions in the receiving waters protective, or likely to be protective, of beneficial uses?
2. What is the extent and magnitude of the current or potential receiving water problems?
3. What is the relative MS4 discharge contribution to the receiving water problem(s)?
4. What are the sources of MS4 discharge that contribute to receiving water problem(s)?
5. Are conditions in receiving waters getting better or worse?

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.

The monitoring program reflects the Program's increased focus on watershed management. As discussed in the following sections, monitoring sites in the various program elements have been located in specific watersheds, with the goal of improving the ability to understand stormwater processes and manage their impacts.

C-11-III.3 Description of Monitoring Procedures

C-11-III.3.1 Urban Stream Bioassessment

Multiple lines of evidence (MLOE) are used to assess the aquatic habitat at each monitoring location. The MLOE include aquatic chemistry, toxicity testing, bioassessment, and physical habitat assessment.

The monitoring locations include seven targeted urban sites and three reference sites from the Third Term Permit and sites within Region 9 annually selected by the Stormwater Monitoring Coalition (SMC) for their Monitoring Program "Regional Monitoring of Southern California's Coastal Watersheds."

During each bioassessment survey the Permittees collect grab samples for chemical, bacteriological, and toxicity testing analysis. The suite of chemical analytes includes pH, specific conductance, turbidity, nitrate, ammonia, total Kjehldahl Nitrogen (TKN), total phosphate, orthophosphate, dissolved and total organic carbon, total suspended and settleable solids, volatile suspended solids, TDS, surfactants, BOD_5, COD, organophosphate pesticides, and total recoverable and dissolved arsenic, cadmium, copper, chromium, lead, nickel, selenium, and zinc. An aliquot from each sample that is be submitted for total recoverable metals analyses is filtered with a 0.45 micron groundwater filtering capsule, preserved with ultra pure grade nitric acid, and submitted for analyses of dissolved metals. The aqueous toxicity is evaluated using three freshwater organisms: *Ceriodaphnia dubia*, *Selanastrum capricornutum*, and *Hyalella azteca*. For sites in the Aliso Creek watershed samples were also analyzed for toxicity to fathead minnow (*Pimephales promelas).*

Monitoring will be conducted once annually in the late spring after the rainy season to coordinate the urban site monitoring with the SMC regional program. Collection of benthic macroinvertebrates (BMIs) is conducted according to Surface Water Ambient Monitoring Program (SWAMP) protocols[1]. Calculation of the Index of Biotic Integrity (IBI) for each bioassessment will be performed using guidance from "A Qualitative Tool for Assessing the Integrity of Southern Coastal California Streams" by Ode, et al. 2005. Beginning in 2012, monitoring at each location will also include an assessment of the algae conditions using the EPA's 1999 Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers[2] and SWAMP's Incorporating Bioassessment using Freshwater Algae into California's SWAMP[3]. This algae assessment will include a taxonomic analysis and calculation of biomass.

Four of the sites in urban channels and one reference site were selected to evaluate sediment chemistry and toxicity. Sediment chemistry includes analyses of metals, particulate bound pesticides, pH, total organic carbon, total sulfide, ammonia, and particle size distribution. Acute and chronic toxicity testing of sediments is performed with *Hyalella azteca*.

Part of the intent of the regional monitoring program is to refine the characterization of reference quality streams so that benchmarks for baseline conditions can be made.

C-11-III.3.2 Long-term Mass Loading

[1] Ode, P.R.. 2007. Standard operating procedures for collecting macroinvertebrate samples and associated physical and chemical data for ambient bioassessments in California. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 001.

[2] EPA, 1999. *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers*. EPA-841-B-99-002.

[3] Fetscher, E. A., and K. McLaughlin. 2008. Incorporating bioassessment using freshwater algae into California's Surface Water Ambient Monitoring Program (SWAMP). Southern California Coastal Water Research Project. Costa Mesa, CA

The Permittees conduct mass emissions monitoring in six channels in the San Diego Region 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 waterbody as a "Water of the State" in the Water Quality Control Plan for the San Diego Region;
- 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 (Laguna Canyon Wash, Aliso Creek, San Juan Creek, Trabuco Creek, Prima Deshecha Channel, and Segunda Deshecha Channel);
- Safety from traffic and other hazards;
- Suitable for efficient operation of automatic sampling equipment; and
- Access for safely retrieving samples and maintaining equipment during storm conditions.

The Permittees use time-composite sampling and continuously recording streamgauges as the primary method of monitoring the concentration and load of constituents at Mass Emissions sites. This type of sampling is conducted with automatic samplers that consist of programmable pumps (peristaltic) which transport water from the channel to a collection reservoir in the autosampler base. The collection reservoir can be a single large composite bottle or a series of up to 24 bottles. The autosampler program can be modified to vary sample volumes and frequency of collection. Two automatic samplers are used at each Mass Emissions site. One autosampler is for monitoring water chemistry and the other is used for monitoring toxicity.

To collect samples for the analysis of water chemistry, 8, 1.8-liter glass bottles are used in the autosampler base. The water chemistry autosampler 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 autosampler base. The two samplers are programmed to collect at the same frequency to maintain the consistency between the composite samples produced by each.

The Permittees attempt to monitor two storms per year at each Mass Emissions site. For each storm the water chemistry is characterized with a series of 3 to 5 composite samples collectively spanning the entire period of stormwater runoff. The sampling for toxicity testing is coincident with just one of these composite samples. The Permittees selected the following temporal segments of storms to monitor toxicity.

- Storm 1 – first flush (first hour of storm);

- Storm 2 – 24-hour period beginning three hours after the initiation of the first flush sampling by the water chemistry autosampler.

During each storm the automatic sampling programs are initiated when the water level in the channel rises above a triggering device (level actuator or flowmeter) hardwired to the respective autosampler. 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/12 minutes. After the sixth sample is collected at the one-hour mark, the collection frequency is decreased to once every 2 hours through the end of stormwater runoff. The concentrations of dissolved heavy metals in each of the composite samples can be compared to acute toxicity criteria from the CTR. Concentrations of organophosphate pesticides can be compared to literature values of LC_{50}s for toxicity testing organisms.

Autosampler maintenance is performed periodically during the 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 stage hydrograph for the channel, or by evaluating the specific conductance of the samples in each bottle. Using hydrographs from the Principal Permittee's Automated Local Evaluation in Real Time (ALERT) system, samples collected beyond the first flush and representing the storm peak and recession are composited into a single sample. The samples collected from storms spanning multiple days are split into two or more composite samples.

Each composite sample is analyzed for the same constituents as are measured in the Bioassessment Program (see previous section). For the first flush sample of the first storm of the year, the analyses also include priority pollutants (except asbestos and dioxin). Toxicity of stormwater runoff samples is evaluated using multiple dilution toxicity tests with marine organisms. The toxicity due to pesticides is measured using the mysid (*Mysidopsis bahia* aka *Americamysis bahia*) survival/growth test. The toxicity due to dissolved metals is measured using the sea urchin (*Stronglyocentrotus purpuratus*) fertilization test. During this monitoring year, analyses for synthetic pyrethroid pesticides were also conducted on some samples to aid in the interpretation of toxicity testing results.

Time composite monitoring is supported by the Principal Permittee's precipitation and streamgaging network which consists of recording and/or transmitting ALERT (Automated Local Evaluation in Real Time) gauges. The recording, non-transmitting and the transmitting ALERT precipitation gages are tipping bucket type with dataloggers. Data are recorded and transmitted in digital format; the sensitivity of the non-transmitting high resolution rain gauges is 0.01 inches while the sensitivity of the ALERT transmitting gauges is 1 mm (0.04 inches) of accumulated rainfall.

The Principal Permittee uses several types of streamgauges to monitor changes in water level. The oldest design is the stilling well with water level float; the newer types are manometer gages or pressure transducers. Analog data (water level versus time) are recorded on stripcharts. The ALERT interface to these gages consists of a connection from the recorder chart drive to an ALERT shaft encoder. ALERT information is recorded on a datalogger and transmitted in digital format to the Principal Permittee's Operations Center 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.

C-11-III.3.3 Coastal Stormdrain Outfall and Aliso Creek Monitoring

The Permittees have selected twenty-six coastal stormdrain outfalls to monitor the effects of urban runoff on water contact recreation in the coastal areas. The following sampling site selection criteria were used:

- The outlet of the stormdrain must be posted with a warning sign by the Orange County Health Care Agency;
- The stormdrain has an equivalent circular diameter greater than 39-inches or a daily dry-weather, discharge volume exceeding 100,000 gallons; and
- The stormdrain and the surfzone are accessible by monitoring staff.

Monitoring is conducted on both the discharge from the stormdrain and the surfzone 25 yards up-coast (north) and 25 yards down-coast (south) of the stormdrain-ocean interface. Grab samples are collected weekly for the analysis of total coliform, fecal coliform, and *Enterococcus* bacteria. An estimate of the flowrate from the stormdrain is made and the temperatures of the stormdrain discharge and the surfzone down-coast is measured.

The following criteria were established for sample collection:

- Samples are not collected on the day of rainfall;
- Samples are not collected from a stormdrain outfall during the period when its discharge is diverted to a sanitation district; and during such a diversion only a sample from the surfzone (down-coast of the stormdrain-ocean interface) is collected.

C-11-III.3.4 Ambient Coastal Receiving Water Monitoring

The objective of the Ambient Coastal Receiving Waters (ACRW) monitoring program element is to evaluate the effect of urban runoff on the ecologically sensitive areas along the Southern Orange County coastline. During the first five years the ACRW Program monitoring consisted of sampling the discharges to these coastal areas. Beginning in the 2008-09 reporting period samples were collected in the surfzone receiving waters during dry weather and stormwater runoff conditions. Grab samples were collected using similar methods described in the Coastal Stormdrain Section. These grab-samples were analyzed for water chemistry and aqueous toxicity to marine organisms.

Dana Point Harbor and Dana Cove are included in the Ambient Coastal Receiving Waters Program. Prior to this reporting period, monitoring in these areas has included assessments of sediment chemistry, sediment toxicity, and benthic infaunal assemblage. On a semiannual schedule, benthic sediment was collected to evaluate concentrations of copper, chromium, cadmium, lead, zinc, silver, nickel, chlorinated hydrocarbon and organophosphate pesticides, Triazine herbicides, PCBs (arochlors and congeners), and Polynuclear Aromatic Hydrocarbons (PAHs). Sediment toxicity was evaluated using the 10-day amphipod (*Eohaustorius estuarius*) survival test. Benthic infaunal analyses were conducted using the methods developed by the Southern California Association of Marine Invertebrate Taxonomists (SCAMIT). Benthic sediment samples were collected using a petite ponar dredge. Samples for benthic infaunal analyses required five dredge samples per site to approximate the same sampling area used to establish the Regional Benthic Response Index (BRI).

Since the Permittees are participating in the Regional Harbor Monitoring Program (RHMP) with other marina operators in the San Diego Region, full scale monitoring of Dana Harbor has been suspended. One site, DAPTEB in the East Basin, was monitored in the fall of 2009 since it had previously shown a seasonal pattern of sediment toxicity.

The 2005-06 RHMP final report can be accessed through the San Diego Board's website at: http://www.swrcb.ca.gov/rwqcb9/water_issues/programs/303d_list/ref_reports/index.shtml

C-11-III.3.5 Wet Weather MS4 Discharge Monitoring

The Wet Weather MS4 Discharge Monitoring Program is intended to characterize the quality of stormwater runoff from the municipal stormdrain system exclusive of influences from non-municipal activities. The results of monitoring are compared to Stormwater Action Levels (SALs), statistically derived from the National Stormwater Quality Database. Thirteen major outfalls were selected for monitoring. Each outfall was selected to be representative of the stormdrain system within its respective Hydrologic Subwatershed Area (HAS). The selection criteria were as follows:

- The stormwater conveyance structure must be composed of reinforced concrete or corrugated metal pipe with no upstream earthen component,
- The outfall dimensions must meet EPA sizing criteria[4] for major outfalls, and the major outfall must discharge to waters of the United States.
- The outfall discharge quality must be measureable without interference from upstream receiving waters
- Discharge from the MS4 must be capable of being collected by an automatic sampler

Each site is monitored twice per year during a representative stormwater runoff event[5]. Monitoring is conducted with an automatic sampler programmed to collect one sample per hour for the duration of

[4] From 40 CFR Part 122.26 Part (b)(5) and (b)(6)

(5) *Major municipal separate storm sewer outfall* (or "major outfall") means a municipal separate storm sewer outfall that discharges from a single pipe with an inside diameter of 36 inches or more or its equivalent (discharge from a single conveyance other than circular pipe which is associated with a drainage area of more than 50 acres); or for municipal separate storm sewers that receive storm water from lands zoned for industrial activity (based on comprehensive zoning plans or the equivalent), an outfall that discharges from a single pipe with an inside diameter of 12 inches or more or from its equivalent (discharge from other than a circular pipe associated with a drainage area of 2 acres or more).

stormwater runoff or 24 hours, whichever is shorter. A grab sample of the receiving waters is collected to calculate the acute toxicity criteria for total metals from the California Toxics Rule. If a total recoverable metal concentration exceeds its respective SAL but does not exceed the hardness adjusted CTR acute criterion for that metal, the SAL shall not be considered as exceeded.

C-11.I.3.6 Dry Weather Non-Stormwater Action Level Monitoring Program

The objectives of the Dry Weather Non-Storm Water Action Level Monitoring Program are to assess compliance with non-stormwater dry weather action levels in Section C of Order R9-2009-0002 and with adopted dry weather Total Maximum Daily Loads Waste Load Allocations; and to assess the contribution of dry weather flows to 303(d) listed impairments.

Monitoring sites included the targeted outfalls of the Dry Weather Reconnaissance Program from the Third Term Permit and major outfalls in HSAs not represented by the targeted outfall list.

Monitoring at each site includes in-situ measurements of pH, temperature, specific conductance, and dissolved oxygen in the outfall discharge and the receiving waters upstream and downstream of the outfall-receiving water interface. A sample of the outfall discharge is analyzed in the on-site mobile laboratory for turbidity and surfactants. A sample of the receiving water downstream of the discharge is analyzed on-site for water hardness. Samples are collected from the outfall discharge and the receiving waters and submitted to contract laboratories for analyses of fecal indicator bacteria, genetic markers indicative of human fecal coliform sources, and the same list of chemical constituents monitored in the Mass Emissions Program. For outfalls which discharge to Prima or Segunda Deshecha Channel, samples are also submitted for analyses of synthetic Pyrethroid pesticides and carbamate pesticides.

[5] *Storm water discharges.* For storm water discharges, all samples shall be collected from the discharge resulting from a storm event that is greater than 0.1 inch and at least 72 hours from the previously measurable (greater than 0.1 inch rainfall) storm event. 40 CFR 122.21(g)(7)

C-11-III.4 METHODS OF DATA ANALYSIS

C-11-III.4.1 Comparison to Water Quality Criteria

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 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 Standards 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 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 as guidance to evaluate dissolved metals data collected from storm channels and harbors. Water quality criteria from the CTR for both freshwater and saltwater are found in **Table C-11.1** and sediment quality guidelines from other sources are presented in **Table C-11.2**.

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 this program element the former method is used for hardness values over 400 mg/L.

In applying the CTR as guidance in evaluating the 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 will constitute 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 will be considered an exceedance of the criterion.

When computing the time-weighted mean concentration during a sampled period with multiple composite samples, values below the detection limit were 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 toxicity guidance criteria. Since total chromium was analyzed only the criterion for trivalent chromium (Chromium III) was used.

C-11-III.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 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 surfzone 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 bahia, Americamyis bahia*, and *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 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 was no statistically significant effect in the organism response relative to the control sample response. The lower the NOEC, the more toxic the sample.

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% 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.

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 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.

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 conducted as part of the long term mass loading and ambient coastal receiving water monitoring program elements, 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 survival/growth (MSG) test tends to be very sensitive to pesticides and unionized ammonia but less sensitive to metals. The Sea Urchin Fertilization (SUF) test is sensitive to dissolved metals and unionized ammonia but not very sensitive to pesticides.

LC_{50} data from the *Americamysis bahia* 96-hour survival test 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 were obtained from SCCWRP research studies. EC_{50} data for the sea urchin 40-minute fertilization test for unionized ammonia, copper, and zinc were 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_as can be 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 monitoring program,
- Lack of available data for the same test evaluation periods used in our monitoring 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 additivity 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-III.4.3 Bioassessment and Index of Biotic Integrity (IBI)

Each site is evaluated in terms of a series of metrics (**Table C-11.3**), which are then scored (**Table C-11.4**) to provide a basis for determining the overall IBI scores for each site. These scoring ranges are based on data from the southern California region, from southern Monterey County to the Mexican border. This southern California IBI is more representative of reference conditions throughout the whole of the southern California area than was the original IBI, which was based only on data from streams in the San Diego region. The use of the more broadly applicable IBI follows the California Department of Fish and Game protocol. In addition, the Stormwater Monitoring Coalition is planning a number of efforts to improve the IBI's ability to monitor conditions in the urbanized coastal zone. These include developing an IBI for low-gradient urban streams, a perennial stream succession survey, and developing a regional bioassessment monitoring program for southern California. The Permittees participated in the regional monitoring program during the spring of 2009 and 2010. Because of late season rainfall in the spring of 2011, the 2011 survey was postponed until the early summer of 2011.

C-11-III.4.4 Evaluation of Triad Data

Evaluation of triad data (i.e., bioassessment, water chemistry, toxicity) is based on the framework developed by the Stormwater Monitoring Coalition's Model Stormwater Monitoring committee. This approach, which is described in detail in the SMC's report to the State Water Resources Control Board ftp://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/419_smc_mm.pdf is based on a weight of evidence approach that compares each of the three legs of the triad against each other. **Table C-11.5**, drawn from the SMC's report, summarizes the types of conclusions that can be drawn from various combinations of triad results. Thus, there is no routine or standard method for evaluating triad data. However, the triad data from the bioassessment stations for the most part has resulted in relatively clear interpretations of causal factors for observed conditions.

Three additional analyses are included in this year's report to more thoroughly examine the relationships among the three legs of the triad. In actuality, there are four legs if the physical habitat data collected as part of the bioassessment protocol are considered separately from the biological community data.

1. Thresholds were established for each of the four data types (IBI, physical habitat, aquatic chemistry, and toxicity) in order to divide the range of values for each data type into four categories representing conditions from excellent to poor. IBI categories were based on the SWAMP interpretation framework for these data types. The following thresholds for total physical habitat scores were used as the color scheme for the PHAB symbols on the maps showing the triad evaluation:

Color	SWAMP (0-60)
• Green:	48-60
• Blue:	36-47
• Yellow:	24-36
• Red:	<24

   Aquatic chemistry thresholds focus on dissolved metals. At each station, the total number of CTR exceedances at each sampling time is divided by the total number of constituents (Cd, Cr, Cu, Pb, Ni, Ag, Zn) with relevant CTR acute criteria, resulting in a proportion for each station between 0 and 1.0. The exceedance proportion for each station is then indicated on a map of the sampling sites, according to the following color scheme:

   - Green: 0 - < 0.14
   - Blue: 0.14 - < 0.40
   - Yellow: 0.40 - < 0.75
   - Red: 0.75 – 1.0

   Toxicity categories are based on the number of toxicity tests that showed toxicity above 25% mortality in the undiluted sample of a multiple dilution test with invertebrates or fish (*Ceriodaphnia* or Fathead minnow chronic survival or *Hyalella azteca* acute survival) or, if the value for TUc was greater than 1 in the *Selenastrum* growth test. For each site, icons on a map of the monitoring sites representing the four data types are then colored green, blue, yellow, or red to summarize the overall range of conditions at each site.

2. All data from the bioassessment sampling program were analyzed for spatial and temporal patterns in the benthic invertebrate community. Two methods were used to describe spatial and temporal patterns in the benthic invertebrate community: 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 a separate subgroup. The hierarchical nature of the dendrogram allows the analyst to choose groups of stations that represent a scale of 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.

Since the rows and columns of the two-way coincidence table are ordered according to the dendrograms, the two-way coincidence table is also used to help delimit the station and species groups defined by the cluster analyses. At each potential separation of subgroups defined by the dendrogram, the two way coincidence table is examined to see the corresponding group differences in terms of species presences and abundances. This allows the analyst to choose groups with a level of community differences consistent with the goals of the project.

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) [6]
- 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)[7]
- Calculation of similarities for cluster analysis of species, using flexible clustering (β=-0.25) (Clifford and Stephenson, 1975; Lance and Williams, 1967; Smith, 1982)[8]

[6] 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.

[7] 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.
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Williamson, M.H. 1978. The ordination of incidence data. J. Ecol. 66: 911-920.

[8] 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.

- Creation of the two-way coincidence table (Kiddawa, 1968; Smith, 1976)[9].

1. Biological Cluster Analysis

A more powerful set of analyses was used to discern relationships between the biological patterns in the benthic community and patterns in potential explanatory variables in the toxicity, aquatic chemistry, and physical habitat data.

As a first step, the species data from all surveys was clustered to identify groupings of sites that were similar in terms of their community composition. **Figure C-11.20** shows the cluster analysis of all sites during surveys conducted from 2009 to 2012 and **Figure C-11.21** the two-way coincidence table of the relative distribution of species in each site at each sampling time. Horizontal and vertical lines on the two-way coincidence table identify major groupings of species and sites, respectively. (Sites are identified by their site number and year of sampling. The average IBI score for the station group is provided. Relative species abundances are shown as symbols. The abundance of each species was standardized in terms of its maximum at each site over all surveys. Smaller symbols represent a lower proportion of maximum abundance and larger symbols a larger proportion.)

Finally, species with broader distributions across sites and times are concentrated in the upper three species groups (A, B and C) on the two-way coincidence table. Species with such broad distributions tend to be more pollution and/or disturbance tolerant. In contrast, species in the lower two species groups (D and E) half of the two-way coincidence table have much more restricted distributions and in fact are found primarily at the upper watershed sites. A closer examination of the species groups shown in the two-way table shows that species group D and E contain a diverse assemblage of several sensitive types of organisms. Species groups A, B and C (at the top of the two-way table) include moderately to very tolerant species characteristic of disturbed sites.

C-11-III.4.5 Mass Load Calculations

Mass loads are calculated using chemical and hydrographic data. Water level records from permanent streamgauging stations at or near the sampling site are processed using Hydstra hydrologic data management software. Water levels from the station's continuous stripchart recorder are digitized and converted to discharge rates using stage-discharge relationships (channel ratings). At sites that have ISCO water level recorders, the dataloggers are downloaded periodically and the information is stored in Hydstra. Using the respective rating tables for each site, the water level data are converted to flow rates. The total discharge in acre-feet during each sampled period is computed. By multiplying the total water discharge per sampled period by the pollutant concentration in the composite sample from the period and applying the proper conversion factors (acre-feet to lbs. of water), a mass load in

[9] 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.

pounds of contaminant is calculated. For data reported as Non-detected (ND), one-half of the laboratory reporting 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:

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

The annual site-mean EMCs are used to estimate mass loads from un-sampled storms at that site. To estimate these unsampled 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 the 75-120% of the total runoff volume of a storm is sampled are used to calculate the annual site-mean EMCs.

C-11-III.4.6 Evaluation of Coastal Stormdrain Outfall Data

Coastal stormdrain Outfall data include water temperature and concentrations of bacterial indicators in the discharge and in the surfzone upcoast (north) and downcoast (south) of these stormdrains. Five types of analysis are conducted:

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

2. Ranking drains in terms of the proportion of total possible exceedances of the AB411 standards. The actual number of microbiological analyses or tests conducted on receiving water samples collected at each drain throughout the year is summed. This does not always equal 312 (i.e., 52 weeks x 3 indicators per sample x 2 locations) because it was not always possible to collect the full suite of samples at each site throughout the entire year. 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:

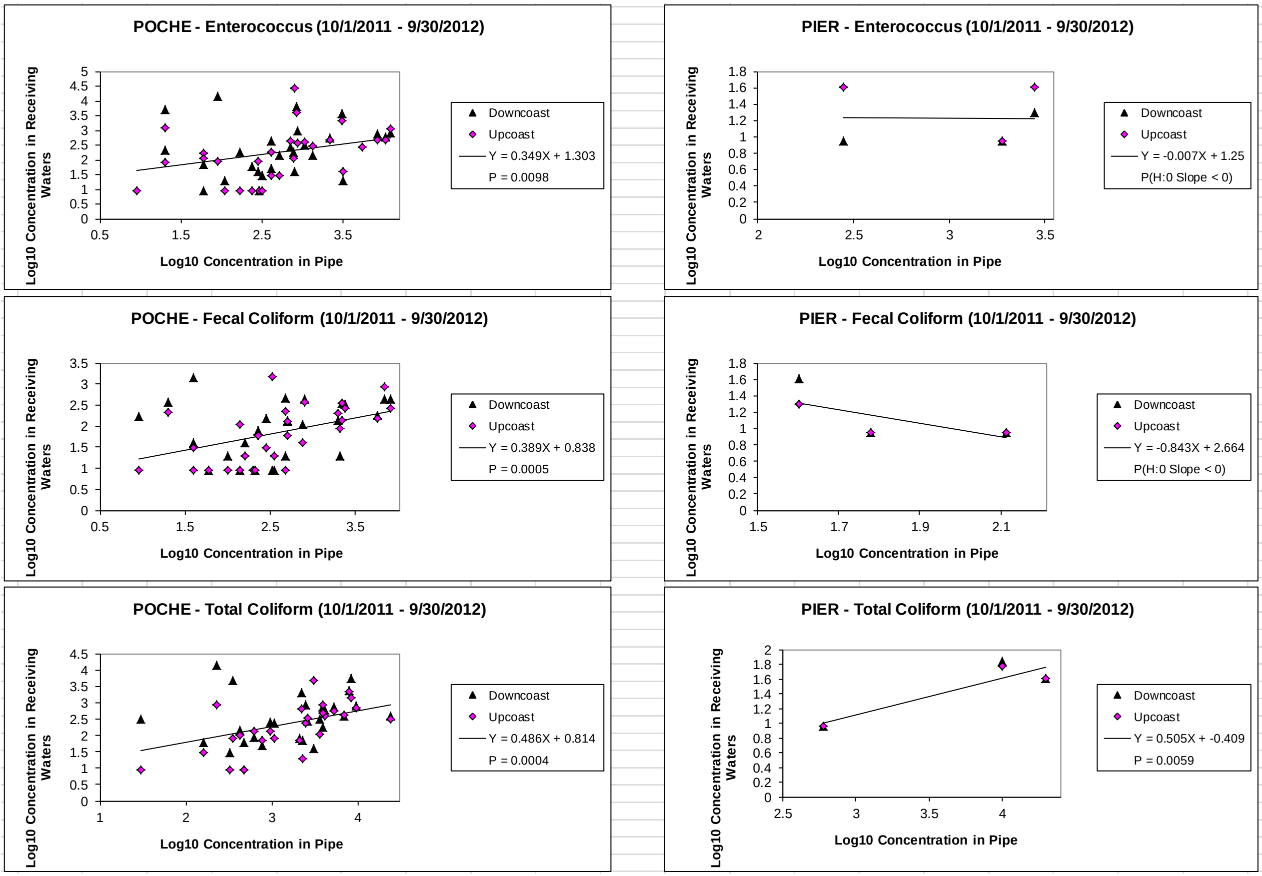
Green:	0 - < 0.14
Blue:	0.14 - < 0.40
Yellow:	0.40 - < 0.75
Red:	0.75 – 1.0

   It should be noted that this color scheme was developed to provide a relative ranking of the surfzone water quality at the outfalls of south Orange County stormdrains. The Heal the Bay Report Card scoring methodology uses a different evaluation process which also includes analyses of total to fecal coliform ratios and 30-day geometric mean concentrations of all three indicators.

3. Plotting indicator levels in the receiving water vs. those in the drain. The surfzone concentrations for each indicator are plotted vs. the indicator concentrations in the drain during the same sampling event, with receiving water values on the y-axis and drain values on the x-axis. Separate plots are presented for each indicator at each drain, with upcoast and downcoast data displayed with distinct symbols. The plots are divided into sectors suggesting the conclusions and possible management actions that would be appropriate when a preponderance of the data points fall into one sector or another.

4. Ranking drains in terms of the slope of the linear regression of receiving water indicator levels vs. those in the drain. The concentration data are log transformed and then a standard least squares linear regression calculated for relationship between receiving water indicator concentrations and stormdrain concentrations. A separate regression is calculated for each indicator / drain combination. Sites are then ranked in terms of the "p" value for the regression for each indicator. The "p" value reflects the strength of the drain – receiving water relationship. In combination with the other analyses, this can be used to help assess each drain's likely effect on receiving water

conditions.



The p-value derived from the linear regression plot demonstrates strong and weak correlations between Stormdrain and Receiving water. Poche has a strong correlation and Pier has a weak correlation.

5. Plotting percentages of sampled days in which at least one indicator bacteria concentration exceeded the AB411 concentration in the surfzone. Each day of surfzone 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 surfzone (upcoast or downcoast) is calculated. These percentages are calculated for the entire year and the AB411 season. The results are plotted, with the drains grouped by City jurisdiction on the x-axis. This method of analysis provides a better assessment of the health risk (compared to analysis #2) associated with water contact in the surfzone 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 surfzone.

Analysis results are then evaluated to identify consistent spatial and temporal patterns. Drains with exceedances and/or regression ranks are evaluated more carefully to identify potential explanatory factors in their drainage areas.

C-11-III.4.7 Evaluation of Ambient Coastal Receiving Water Data

The ambient coastal receiving water data are compared to CTR criteria for saltwater and each sampled area is ranked in terms of its relative degree of impact. In addition, the aqueous chemistry data are evaluated to identify potential explanations for any observed toxicity. These analyses have contributed to an assessment of the receiving water environment around each stormdrain outfall in terms of its ability to assimilate runoff, the presence of other sources of contamination, and the presence of sensitive marine resources. This information has been used to produce relative rankings of the potential impact of urban runoff on the aquatic habitat at each site, which provides a basis for prioritizing further studies of stormwater plume extent and impact.

C-11-III.4.8 Evaluation of Non-Stormwater Dry Weather MS4 Monitoring Data

The Permittees have developed guidelines for responding to results from the Non-Stormwater Dry Weather MS4 Monitoring Program which exceed the Numeric Action Levels (NALs) from Order R9-2009-0002. These guidelines were presented in the latest submission (September 1, 2011) of the annual Monitoring Plan and are primarily in the form of flowcharts. The flowcharts outline the beneficial use impairment assessments and source investigation prioritization processes. The latest versions of these flowcharts are included in this Attachment.

C-11-III.4.9 Evaluation of Trends in Water Quality

Section III.A.2.f in Attachment E of Order R9-2009-0002 requires the annual report "include identification and analysis of any long-term trends in storm water or receiving water quality. Trend analysis must use nonparametric approaches, such as the Mann-Kendall test, including exogenous variables in a multiple regression model, and/or using a seasonal nonparametric trend model, where applicable."

Trend analyses on CSDO and EMC data from Mass Emissions sites were conducted using the nonparametric seasonal Kendall test proposed by Hirsch, Slack, and Smith (1982). This analysis does not depend on assumptions about the underlying distribution of the data, and can be used even though there are missing, tied, or non-detect values. This approach can be used for non-detect values because the test uses only relative magnitudes of the data rather than their measured values. The seasonal Kendall test is an extension of the Mann-Kendall non-parametric test for zero slope, but is also appropriate when there may be seasonal cycles present in the data. First, the Mann-Kendall statistic is calculated for each month individually and then combined for an overall trend estimate. A test for homogeneity among months is used to determine if the season Kendall statistic is reasonable, following procedures in van Belle and Hughes (1984). The estimate of the magnitude of trend slope is computed as the median of all slopes between all data pairs of the same months.

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