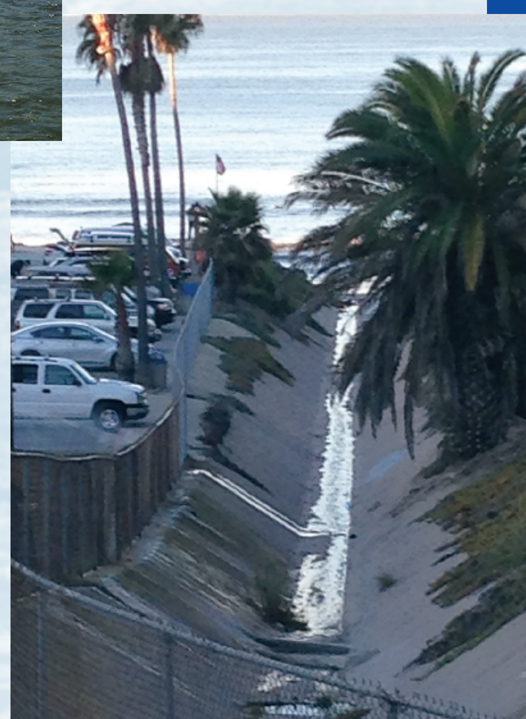
Southern California Stormwater Monitoring Coalition Unified Approach to Stormwater Monitoring



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Southern California Coastal Water Research Project
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Program Inventory and Workplan

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EXECUTIVE SUMMARY

The goal of this report is to provide a workplan for developing a unified approach to stormwater monitoring (UASM) in southern California. The workplan is based upon an inventory of Municipal Separate Storm Sewer System (MS4) monitoring programs maintained by the stormwater permittees within the Los Angeles, Santa Ana, and San Diego Regional Water Quality Control Boards and the collective needs of the Southern California Stormwater Monitoring Coalition (www.SoCalSMC.org). The Southern California Stormwater Monitoring Coalition (SMC) is a coalition of 14 regulated and regulatory agencies working together to improve the technical foundation for improved stormwater management. In the case of the UASM, the SMC is interested in leveraging monitoring effort and sharing data to compare progress and make regional assessments.

The inventory of MS4 monitoring programs was based upon reviewing seven National Pollutant Discharge Elimination System (NPDES) permits, four annual reports, and 39 monitoring plans, including enhanced watershed management plans (EWMPs), coordinated integrated monitoring plans (CIMPs), or water quality improvement plans (WQIPs). Based on the review, seven monitoring questions were identified to address priority management objectives that were held in common among all SMC member agencies. The seven standardized monitoring questions included:

Q1. What pollutants are associated with stormwater and non-stormwater runoff?

Q2. What are the sources of the identified pollutant(s)?

Q3. How effective are the BMPs for reducing flow and contaminant concentrations?

Q4. If (and how) runoff discharge is influencing the quality of receiving water?

Q5. What is the overall health of receiving waters?

Q6. If (and what) receiving waters need management actions based on its overall health?

Q7. How effective are the current water quality management plans?

Designing consistent monitoring elements, a core component of a standardized MS4 monitoring framework, is the key to ensure that the above-mentioned standardized monitoring questions are efficiently and effectively answered. The MS4 monitoring elements can be classified into four broad categories: design and planning, field techniques for sample collection, laboratory methods, and reporting. The details of the monitoring elements (e.g., qualifying storm events, sampling frequency, data analysis techniques, etc.) influence the efficacy and efficiency of a monitoring program for answering each monitoring question. The monitoring element details were compared across the various SMC monitoring programs for similarities and dissimilarities. Based on these similarities and dissimilarities of monitoring elements, and their linkage to the standardized monitoring questions, a list of monitoring elements to be standardized is recommended.

The recommendations identified some specific knowledge gaps that needed to be addressed for standardizing each monitoring element. The knowledge gaps are summarized below:

a) Standardize qualifying storm events
b) Standardize sampling site screening while planning for MS4 monitoring
c) Standardize field-sampling procedures
d) Standardize laboratory analytical methods
e) Standardize data analyses and reporting format

A workplan to address each knowledge gap is included for developing the final UASM guidance document. The recommended workplan is a critical pathway to standardized MS4 monitoring in southern California. The workplan can be used as a scope of work for the next step in the UASM process.

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INTRODUCTION

Background

Under the National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permits, stormwater dischargers in southern California are required to develop and maintain an urban runoff (both stormwater and non-stormwater associated) monitoring and reporting programs (MRP). The primary objectives of such programs are to monitor, document, and report the volume of urban runoff, runoff quality, pollutant loads for various contaminants, the source of the contaminants, and the physicochemical and biological impacts of MS4 discharge on the receiving water.

The municipalities develop watershed management plans incorporating the MRP requirements and submit to the respective Regional Water Quality Control Boards (RWQCB). Such watershed management plans are called watershed management plans/enhanced watershed management plans (WMPs/EWMPs) or water quality improvement plans (WQIPs). EWMPs/WMPs are supplemented with a coordinated integrated monitoring program (CIMP). The monitoring requirements that have been codified in these monitoring plans vary with each RWQCB setting requirements that reflect the continuing evolution of stormwater science, as well as that accommodate the unique challenges facing individual watersheds.

Because urban runoff monitoring requirements differ from permit to permit, variability among the regional permittees in terms of scope, extent, and magnitude of some of the monitoring elements is unsurprising. At the same time, the MS4 permittees share some common core monitoring objectives, including status, trends, and source identification monitoring for stormwater, non-stormwater, and receiving water quality. Considering the level of effort and the resources invested in these monitoring programs throughout the region, the monitoring data could collectively inform planning, management, and regulatory actions for protecting and improving the health of receiving water quality in a regional scale; however, due to the absence of a standard method for collecting MS4 monitoring data, a regional assessment of stormwater and receiving water quality is problematic. Over the past decade, monitoring requirements have evolved to the point that there is considerable variability in terms of sampling design, frequency, laboratory analyses, and reporting. For example, the formation of different watershed management groups in Los Angeles County per 2012 permit have resulted in a diverse and sometimes disjointed monitoring plans for the LA region. Given the significant success of Stormwater Monitoring Coalition (SMC)—an organization of stormwater management agencies and RWQCBs in southern California—in bringing standardization to other facets of stormwater monitoring, the SMC is seeking to develop standardized, best-practices designs for urban runoff monitoring programs that are grounded in the latest science.

Rationale for a unified approach to stormwater monitoring (UASM)

Developing a unified approach to stormwater monitoring (UASM) in southern California will offer great benefit to all the SMC members in terms of both cost and ease of MS4 monitoring data collection, data management, data sharing, and regional assessment of stormwater and receiving water quality. A unified monitoring guidance document can provide four advantages over the disjointed and disconnected MS4 monitoring that currently exists. First, a UASM will provide increased efficiency. Standardized methods will enable stormwater managers to optimally implement MS4 monitoring programs with specified levels of accuracy and precision. No longer will monitoring requirements be developed by "gut feeling", "best guesses", or just "because it was in an earlier permit". Second, a UASM will provide consistency. While not every element of every MS4 monitoring program can or should be identical, but there should be a set of core monitoring questions to be answered in common among all MS4 monitoring agencies, providing opportunities for comparisons among programs and significant cost-leveraging for shared monitoring responsibilities. Third, a UASM will provide equity. Differences in monitoring requirements among MS4 NPDES permittees should be based on the need for actionable information. The UASM will delineate the types and amounts of monitoring information necessary for decision-making. Thus, where differences in monitoring effort do occur, there is a rationale for why they are different. Fourth, a UASM will enhance communication. Once a standardized monitoring program is in place, it will be straightforward to share data confidently, without concern for comparability, ultimately enabling the SMC's goal of assessing data across jurisdictions.

History of standardized monitoring in Southern California

The SMC has made significant progress in recent years in the development of standardized water-quality monitoring programs across southern California. Such standardization has helped managers compile a comprehensive regional snapshot of condition, evaluate BMP effectiveness, and prioritize waterbodies for management intervention. The SMC's Regional Watershed Monitoring Program, conceptualized in 2007 and launched in 2009, has successfully integrated elements from several individual watershed monitoring programs to create a large-scale, comprehensive, bioassessment-based monitoring program that spans more than 7,000 stream-kilometers of southern California's coastal streams and rivers (http://socalsmc.org/completed-projects/592-2/). The SMC has developed laboratory guidance documents for increasing the uniformity and reproducibility of stormwater chemical and aquatic toxicity test results (http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/521_smc_lab_guide_2ed.pdf).

This is not the first time the SMC has invested in bringing standardization to MS4 urban runoff monitoring programs across the region. In 2004, the SMC published a model monitoring document that describes a framework for implementing regionally consistent approaches for status and trend monitoring of discharges and receiving waterbodies. The document was used to help bring best-practices standardization as a hallmark feature of compliance monitoring programs across southern California and is found widely in MS4 permits throughout southern California.

The scope and approach to MS4 monitoring has evolved considerably since 2004. In 2012, the SMC conducted a follow-up survey for assessing the level of standardization of various MS4 programs across the region. The survey, plus a subsequent workshop convened by the SMC, revealed that despite the SMC's standardization efforts in 2004, monitoring requirements had evolved so much that there was minimal similarity among the MS4 monitoring programs currently in use by SMC member agencies. The workshop participants, consisting of both stormwater regulators and dischargers, made several recommendations and expressed support for developing an updated guidance document that will enable SMC members to bring best-practices standardization to the current scope and range of MS4 monitoring program activities.

Scope of the proposed UASM

The vision for this UASM includes a) identifying the most important monitoring objectives shared by the stormwater dischargers and regulators and b) developing standardized monitoring methods to answer those questions in the best way possible. While the goal of standardized MS4 monitoring approach is to establish a standard set of methodologies for various monitoring activities, the standardized monitoring methods should be flexible to recognize the variability among the watersheds under different stormwater agencies in terms of hydrogeology, topography, climate and land use. The standardized methods described in the UASM guidance document should reflect the available scientific literature for stormwater monitoring, federal guidance documents from the United States Environmental Protection Agency (USEPA), and key State documents including Surface Water Ambient Monitoring Program (SWAMP) assessment framework. In addition, the UASM should be adaptive based upon periodic revisits of MS4 monitoring results and the needs of SMC member agencies for new issues and management decisions.

Monitoring plans and methods, data analysis techniques, and quality assurance protocols described in the UASM guidance document are meant to be used as the best practices for designing an MS4 monitoring programs. Unless the stormwater regulatory agencies incorporate the UASM recommendations into their permits, the UASM guidance document should not be used for regulatory purpose or criteria for regulatory compliance.

Objective of this document

This technical report is intended to serve as the first step toward establishing a unified, standardized approach to stormwater monitoring (UASM) in southern California. This document presents an updated inventory of all the major MS4 monitoring approaches and NPDES permit requirements that are currently in place across the region. Similarities and dissimilarities among various stormwater agencies and RWQCBs are chronicled, and a workplan is recommended to move towards standardization. Ultimately, a UASM guidance document can be written after the standardization steps in the workplan are undertaken.

Organization of the document

This report is organized in four sections. Introduction and background of UASM makes up the first section of this document. The second section (Section 2 and Appendix A) describes the methodologies and approaches followed in preparing this document. This section also discusses the primary elements of a MS4 monitoring programs. The monitoring elements include monitoring objectives, sampling location selection criteria, sampling frequency, sampling techniques for increased effectiveness and representativeness, list of minimum target analytes and methods, and data analysis techniques. A list of standardized monitoring questions is provided in this section based on the review of the management questions that various stormwater agencies are trying to answer. The third section (Section 3 and Appendix B) provides an inventory of current MS4 monitoring practices in southern California used to discuss each monitoring element. This section also identifies the monitoring elements that should be standardized to answer the standardized monitoring questions more effectively. The fourth section (Section 4) discusses possible strategies for standardizing the monitoring elements. The brief workplan for developing the UASM guidance document is presented under the Appendix C.

METHODOLOGY, MONITORING ELEMENTS, AND MONITORING OBJECTIVES

Methodology for inventory development

An inventory of MS4 monitoring was developed by reviewing the NPDES permits submitted to and approved by southern California's three RWQCBs (Los Angeles, Santa Ana, and San Diego regional boards). In addition, watershed management plans and stormwater monitoring plans developed by the SMC member agencies and their co-permittees were reviewed. The MS4 permits and monitoring plans were analyzed to compare MS4 monitoring approach, objectives, and core monitoring elements across the SMC member agencies.

A total of seven NPDES permits, 39 monitoring plans, and six annual reports were reviewed for core monitoring questions, as well as for monitoring and reporting requirements. In addition, the scientific literature was reviewed to compare the existing monitoring practices with relevant scientific information. The list of the permits, monitoring plans, annual reports, and the literature reviewed are presented in Appendix A. The NPDES permittees include Riverside County (RC), San Bernardino County (SBC), Orange County (OC), City of Long Beach (CLB), Los Angeles County (LAC), San Diego County (SDC), and Ventura County (VC). The list of monitoring plans and associated jurisdiction areas are listed in Table B1.

Standardized monitoring objectives

Defining a set of management questions for all SMC member agencies is a critical step for establishing a UASM in southern California. A question-driven monitoring framework improves the efficiency of the monitoring efforts in the following ways: a) it clearly demonstrates the success of monitoring programs by evaluating whether the data collected by the program can answer the defined monitoring questions; b) it transforms monitoring data into information; c) it eliminates the risk of collecting redundant data as well as the problem of missing data; d) it improves the communication among various stakeholders associated with MS4 monitoring efforts; and e) it can support the prioritization of limited monitoring funds. Therefore, the proposed standardized monitoring effort in southern California would be most useful if driven by a common set of management questions to be answered by MS4 monitoring activities.

The priority monitoring objectives of the SMC member agencies, as presented in the appendix B, should serve as a basis for deciding on the standardized management questions. Additionally, the standardized questions should address the permit requirements in the region and be agreed upon by the stormwater agencies, both by the regulators and dischargers. The answers to the questions should greatly inform the status, trends, and challenges for outfall discharge and receiving water quality in the region. While these questions provide a common platform to carry out MS4 monitoring in the region, such questions must not discourage member agencies from having additional permit-specific objectives for their individual monitoring efforts. Considering these factors, the standardized MS4 monitoring program in southern California should be able to answer the following questions:

Q1. What pollutants are associated with the stormwater and non-stormwater runoff?

Q2. What are the sources of the identified pollutant(s)?

Q3. How effective are the BMPs for reducing flow and contaminant concentrations?

Q4. If (and how) runoff discharge is influencing the quality of receiving water?

Q5. What is the overall health of receiving waters?

Q6. If (and what) receiving waters need management actions based on its overall health?

Q7. How effective are the current water quality management plans?

Among the seven abovementioned questions, the first two questions are core monitoring associated with stormwater and non-stormwater outfalls. These questions are key to runoff quality characterization, common and emerging contaminants listing, and contaminants source tracking. Answers to these questions should be documented at the watershed scale and to the extent practicable at the site-specific scale. In addition, data collected through the monitoring efforts should facilitate analyses at the both temporal and spatial scale to understand the status and trends of stormwater quality. Once the magnitude and sources of contamination are identified, managers may carry out special studies, including source reduction efforts. For example, such efforts may include effective BMP implementation to reduce the magnitude of contaminant concentrations at stormwater outfalls.

The third question is a planning question focused on gathering data on the effects of BMP implementation on stormwater quantity and quality. Such assessment, while primarily relevant to wet weather discharge, may also involve dry weather monitoring data. Note that answering this question under core monitoring should not substitute any special studies related to BMP performance evaluation, including BMP effectiveness monitoring. Investigating this question would not require any additional outfall monitoring efforts; however, a comprehensive documentation of land use, BMP implementation inventory, and pre-project implementation data, related to the drainage area of an outfall, would be needed.

Providing information on the quality of receiving water is the primary focus of management questions four to six. Question four is a planning question while questions five and six are core monitoring questions. The success of stormwater management efforts should be measured by protection of the receiving water quality for beneficial use. While highlighting such success over the short-term can be challenging for some programs, any efficient MS4 monitoring program should be able to readily describe the health of the receiving water bodies and answer whether stormwater discharge is significantly impacting their water quality. The receiving water monitoring data combined with the regional stream monitoring data would be the primary tool to assess the overall health of receiving water. Moreover, a side by side comparison of the receiving water quality monitoring data with the stormwater outfall monitoring data could elucidate the influences of stormwater discharge on the receiving water quality. Such assessment could be carried out based upon water quality standards or total maximum daily load numeric targets, or any other thresholds set by the water quality managers. If stormwater discharges appear not to be a significant contributor to receiving water quality degradation, managers may conduct special studies, including causal assessment to identify other sources impairing receiving water health.

The answer to question seven indicates how effective the current watershed management plans are for protecting receiving water quality for beneficial uses. This is a planning question focused on trend assessments of existing monitoring practices to achieve water quality objectives. Trend monitoring for runoff quality at outfalls or receiving waters could be an effective way to determine if the implemented management actions are having a desired improvement to water quality. Such trend monitoring can be either short-term (annually) or long-term (permit cycle or alternative compliance horizons) or both. Short-term monitoring would inform whether the set milestones for long-term compliance strategies, according to reasonable assurance analysis for instance, are likely to be met. Such evaluation of watershed management plans is critical for a successful adaptive management, which requires continuous re-evaluation of the effectiveness for current management practices and programs.

MS4 monitoring elements

The monitoring elements are fundamental core components of a MS4 monitoring framework. These elements ensure the objectives of a monitoring plan are met. Monitoring elements can be associated with planning monitoring efforts, sample collection and field measurement procedures, laboratory analytical methods, data analyses, and reporting. Decisions addressed by various monitoring elements include, but are not limited to, the following:

a) What storm events qualify for mobilizing sample collection efforts?
b) What sites to select for collecting stormwater samples?
c) What is the best procedure for collecting field-samples, e.g., number, type, duration?
d) What stormwater contaminants should be monitored in the collected samples?
e) How many storms per season should be monitored to ensure representative data collection?
f) What constitutes the best practice for data management and analyses?
g) How to best demonstrate the impact of stormwater management on the receiving water quality?

The answers to these questions guide the overall success of a MS4 monitoring program. Such success should be measured by the ability of the monitoring program to address the specific management questions or monitoring objectives.

Linkage between the monitoring objectives and monitoring elements

The key to effectively and efficiently answering monitoring questions is a function of the basic elements that comprise the monitoring program. In the case of an MS4 monitoring program, these monitoring elements include the selection of qualifying storm events and monitoring stations, field sampling procedure, laboratory analytical methods, and data analyses. Table 2 links the key monitoring elements to each of the seven monitoring questions. Note that not all monitoring elements are equally important to standardize for accurately answering each monitoring question. The current state of these monitoring elements and the need for standardization (if any) are discussed in the following section.

POTENTIAL MONITORING ELEMENTS TO BE STANDARDIZED

Background

The MS4 monitoring elements can be classified into four broad categories: design and planning; field techniques for data collection, laboratory methods, and data analyses and reporting. The robustness of the monitoring framework such as the extent and reliability of sampling efforts, accuracy of the data analyses, and reporting influences the effectiveness and efficiency of a monitoring program to answer each monitoring question.

This section provides an overview of current MS4 monitoring practices currently implemented by each of the SMC member agencies. A broad comparison among various monitoring programs is presented in Table 3. The existing monitoring programs are compared in detail in the following section. Based on the inventory of the stormwater monitoring programs and the standardized monitoring objectives, recommendations are provided on whether a certain monitoring element should be standardized.

Selection of qualifying storm events

Every SMC monitoring program describes what qualifies as a "sampleable" storm event. These typically fall into three categories including forecasted rainfall and antecedent dry period, first flush, and storm end (table 4).

The SMC member agencies have comparable antecedent rainfall requirements (three days) and precipitation forecast requirements. Typical required forecasts are at least 0.25 inches. Thus, standardization for these monitoring elements is not necessary. However, not all the programs collect first flush samples for individual qualifying storm events.

The "first flush" is commonly described as a phenomenon that causes significantly higher concentrations of pollutants at the beginning of a storm event compared to the rest of the storm. For geographical regions like southern California, an additional phenomenon like the "first flush" is known to occur which is called a "seasonal first flush". This phenomenon refers to the pollutant build up during long dry periods and their release during the first storm event of the wet season. Therefore, "what storm event to monitor?" is an important question to consider when deciding on a monitoring plan to address "seasonal first flush".

Monitoring programs specifically designed to characterize (seasonal) first flush may inform management questions related to the stormwater quality and pollutant sources: Q1 and Q2. Not accounting for "first flush discharges" may cause potential bias in total pollutant load calculation from stormwater discharges. However, the "first flush" may or may not occur depending on the drainage characteristics of a watershed and pollutant sources. The "first flush" is more likely to occur in a smaller watershed with more mobile, pollutant sources which are limited in supply. However, the effects of watershed characteristics and the type of pollutants on the occurrence of first flush phenomena are yet to be understood.

In addition to the "first flush" consideration, selecting an appropriate storm end criterion ensures the representativeness of the collected sample during MS4 monitoring. Such selection essentially involves deciding on how long the sample collection effort would last after a sampling event has initiated. The event-mean concentration (EMC) and mass emission can be greatly influenced by the duration of sampling event, especially in an urbanized watershed with best management practices (BMP). The removal efficiency of stormwater BMPs is likely to vary based on the influent pollutant load (for example, initial storm samples vs. subsequent samples) and hydraulic loading (shorter storm event vs. persistent storm event). As a result, the pollutant loading estimates could vary simply as the differences in sampling duration.

Table 4 also highlights storm end criteria, and a majority of the programs suggests sample collection for the duration of entire storm or 24 hours, whichever is shorter. However, some programs do not specify sampling duration in their monitoring plans. For receiving water sampling, storm end criteria are generally defined as the duration of the storm event.

Standardization of "first flush" and storm end criteria is recommended to inform MS4 monitoring programs in this region, particularly for answering the first and second monitoring questions. A challenge for setting such standard criteria is the variation in watershed characteristics (i.e., time of concentration, peak flow) or pollutant (i.e., priority pollutants) across the watersheds in southern California. Therefore, instead of coming up with a fixed criterion for first flush volume and storm end duration, developing a relationship between hydrologic parameters of a watershed and first flush criteria could be a better approach for such standardization.

Sampling frequency

Sampling frequency - the number of storm events to be sampled per monitoring station per season - is an important monitoring parameter. The sampling frequency determines the sample size of the data available for statistical and modeling analysis to be performed using the MS4 monitoring data. Such analyses are key to accurately answering all the monitoring questions with a specified level of confidence: particularly for answering questions two through four. Increasing the number of sampled storm events makes the MS4 monitoring data more representative and provides greater statistical power, but at the expense of higher financial burden. Therefore, a trade-off between the cost of investment and perceived benefits is required to optimize sampling frequency.

Figure 1 shows the frequency of dry weather and wet weather sampling at various outfall stations in the Los Angeles, San Diego, and Santa Ana regions. The sampling frequency maintained by different monitoring plans throughout the regions is generally set by the minimum sampling frequency required by their respective MS4 permits. Table 4 provides more details on every program listed under each region. Most of the sites are sampled three and two times per year during wet and dry weather, respectively. However, in San Diego region, many sites are sampled only once. In contrast, some sites in the Los Angeles region utilize a tiered approach. During the first year of monitoring, these sites are sampled four times, but the frequency can be reduced to three times (for wet weather) or two times (for dry weather) per year based on the data obtained from first year monitoring. Long-term receiving water monitoring frequency generally follows the same for stormwater outfall monitoring except for TMDL monitoring sites: for TMDL monitoring the frequency could be as high as weekly, i.e., bacterial TMDL for Bellona Creek in the LA region.

Standardizing the method for optimizing the number of storm events to be sampled (instead of minimum number set by the existing permits) is recommended. This standardized method should set a default sampling frequency to ensure the representativeness of runoff/receiving water quality results at each site. However, a monitoring program may choose to optimize sampling frequency using tools such as statistical power analysis, and this flexibility should be accommodated. This option allows for greater than the minimum default sampling frequency in order to achieve greater confidence in results (i.e., for comparing to numeric targets) or increased power to detect trends. Ultimately, the semi-arid environment of southern California limits how many storm samples can be collected, which means monitoring programs need to consider sampling frequency across multiple years. Standardizing sampling frequency would minimize the uncertainty in answering multiple monitoring questions, including questions Q1, Q4, Q7. In combination with standardized storm selection criteria, standardizing the method for sampling frequency should ensure more accurate quantification of pollutant load, more reliable trend analyses, and better estimate of BMP performance.

Screening for sampling locations

"Where to sample" is an important factor to consider when designing an MS4 monitoring program. While "when to sample (first flush and storm end criteria)" and "how many times to sample (sampling frequency)" are important monitoring elements, the resulting data are unlikely to be representative of the watershed without an appropriate sampling location. The criteria for selecting sampling locations including outfall and receiving water sites screening will depend on the specific management question. Such screening criteria along with the nature of the watershed could dictate how many outfalls or receiving water stations are required to monitor. Therefore, a careful selection of outfalls may reduce number of samples required to collect in a watershed without sacrificing the level of "representativeness" of the gathered data.

In addition, considering the characteristics of the upstream watershed when selecting a stormwater outfall location could enhance the utility of the data collected from an outfall. For example, when individual outfalls are located to represent a certain land use type (instead of a representative mixed land use) in the upstream watershed, the pollutant concentrations in the samples collected at the outfall can be translated to inform land use-event mean concentrations (EMC) of various pollutants. Such strategic positioning of outfall locations will result in valuable data that reduce the uncertainty of the watershed models used for planning management actions and monitoring efforts in the region.

Following are 24 different criteria mentioned in various watershed management plans for selecting sampling sites: for dry weather and wet weather monitoring. Table 5 relates every program to the stated outfall selection criteria. The receiving water sampling locations may depend on a variety of factors, including the proximity to stormwater outfall, existing TMDL, or location identified based on special studies or regional monitoring programs like SMC bioassessment monitoring.

Wet Weather

1) Representative land use
2) Safe and easy access; can deploy sampling equipment
3) Linkage with receiving water
4) Feasibility and reliability of flow measurements.
5) Larger drainage area than other sites evaluated
6) One outfall per major drainage area
7) Possibility of sub-basin drainage area
8) LSPC modeling results from LCC metals TMDL
9) Ability to isolate major portion of the watershed
10) Population density
11) Traffic density
12) Age of the infrastructure
13) At least one site per co-permittee within the permit management area
14) Public property
15) Do not receive runoff from other municipalities

Dry Weather

16) Non-stormwater flow status
17) Historical monitoring data; supplement long-term data set and long-term trend monitoring
18) Flow rate
19) Surrounding land use/potential sources/threat to receiving water quality
20) Outfall discharge status (transient, no-flow, persistent)
21) Representative flow duration, pollutant loading
22) Proximity to the receiving water monitoring sites
23) Containing discharge attributed to illicit discharge per dry season
24) Controllability

The details of the outfall selection criteria vary not only between dry and wet weather monitoring in the same watershed management group but also between projects or programs. Most of the programs have chosen “representative land use” as a primary criterion for selecting wet weather sites followed by safe/easy access for sampling. In contrast, such criteria are not documented well for selecting dry weather sites except for the San Diego region. Historical monitoring data, flow rate, and surrounding land use appear to be the most common criteria used by the San Diego region. Note that, according to the most updated information, outfall screening for dry weather monitoring is ongoing for the LA region. However, the corresponding monitoring plans do not describe what criteria are being used for the screening process.

We suggest standardizing the primary criteria for selecting dry-weather, wet-weather, and receiving water monitoring stations to help answer multiple monitoring questions, including Q1, Q2, Q3, Q4, Q6, and Q7. Such standardization may include incorporating probabilistic sampling of MS4 locations to avoid bias in site selection and to ensure representative sampling of the area/population under the jurisdiction. The location of receiving water monitoring sites could also be influenced by the choice of outfall sites and vice versa. For example, whether stormwater discharge is influencing the health of the receiving water would be determined by the linkage between outfall location, associated drainage area, and the receiving water. Similarly, the strategic selection of an outfall location may delineate the efficacy of a certain stormwater control measures, i.e., BMP, without extensive on-site monitoring of the BMP.

Outfall description

While a detailed description of an outfall may not directly enhance the quality of the MS4 monitoring data, it provides more depth and context to the data collected at the selected outfall. Outfall descriptions may include geographical coordinates of the outfall site, the size and shape of the outfall, the build or materials of the outfall, land use description of the drainage area associated with the outfall, and description of any linkage of the outfall with receiving water along with the intended beneficial use of the receiving water.

Table 6 shows the inventory of total of 442 outfalls and 435 receiving water sites (includes long-term monitoring and TMDL monitoring sites) monitored across 39 different programs. Some of these outfalls are sampled only during dry weather or wet weather, and some are sampled during both dry and wet weather monitoring. Information about size of the outfalls is only available for 115 sites. About 75% of the programs have not specified the size (pipe diameter) or type of their outfalls. Among the reported sites, most of the outfalls are made of concrete with a dimension ranging from 8 inches to 315 inches. Additionally, some outfalls are made of corrugated metal pipes or earthen channels.

While we think standardizing outfall descriptions is a low priority item, we strongly recommend establishing a data standard for describing the sampling outfalls for wet-weather and dry-weather monitoring. Such descriptions should include extensive information about the outfall, which may aid in answering the standardized monitoring questions related to data analyses: Q2, Q3, and Q7. Outfall descriptions may also help answering additional monitoring questions for adaptive stormwater management. For example, having historical information on land use change in the drainage area could inform changes in stormwater quality and contamination source(s). On the other hand, size and shape of the outfall would provide insight on planning for sample collection efforts.

Field-sampling and flow measurement

While only a continuous measurement of stormwater runoff can provide a complete picture of the variation in flow and contaminant concentration during a storm event, conducting such measurements could be impractical due to resource (e.g., time, equipment, and labor) limitations. The field sampling procedure and flow measurement techniques for MS4 monitoring should be adequately illustrative of typical runoff and pollutant generation events from a watershed. The use of appropriate sampling techniques and accurate flow measurements are critical for answering all the standardized management questions presented earlier.

A well-designed field sampling procedure involves answering two key questions: a) how many samples to be collected per storm event? and b) what would be the approach for sample collection (e.g., *in-situ*, on-site, grab or automatic)? While answers to both questions are critical for ensuring the effectiveness and accuracy of the monitoring program, an answer to one influences the other. The number of required samples per storm event depends on the chosen sampling approach. Therefore, the sampling approach needs to be adjusted for the constituents that are targeted for monitoring. A combination of approaches may be necessary for monitoring a wide range of contaminants in stormwater runoff.

Tables 7 and 8, respectively, summarize the current wet weather and dry weather sampling practices in various MS4 monitoring programs in southern California. It appears that most of the programs use composite samples (collected by automatic samplers) for wet weather monitoring with exceptions for some contaminants, including bacteria and oil and grease. However, details like how many samples to be collected per storm event, how the compositing is performed (flow-weighted vs. time-weighted) are not mentioned in the monitoring plans. In contrast, grab samples are commonly used for dry weather monitoring, however volume and timing of the grab samples are not mentioned in the monitoring plans. At least one program recommends preparing time-weighted composites from multiple grab samples collected over a short period. Out of the 39 programs, 6 programs have not provided any wet weather sampling details and 14 programs have not discussed their dry weather sampling approach. Procedures for collecting receiving water samples merely follow the stormwater and non-stormwater sampling procedures during dry or wet weather.

In addition to collecting samples for measuring contaminant concentration, measurement or estimation of flow is required to assess total pollutant load discharged through an outfall site. While total flow can be estimated using rainfall amount and drainage characteristics, actual flow rate is required for designing flow-weighted composite sampling techniques. Flow measurements can be performed using primary, e.g., weir or flume, or secondary, e.g., floats or transducers, devices or a combination of both devices. Sampling location, desirable accuracy, likelihood of turbulence, and the range of expected flow rate influence what flow-measurement device would be appropriate.

Flow-measurement procedures are invariably missing in the monitoring plans. Only seven programs mentioned flow-measurement techniques for wet weather monitoring and three programs mentioned the same for dry weather monitoring. Tables 6 and 7 summarize the techniques suggested by various programs according to their most updated monitoring plans. Some programs provided a suite of options ranging from the rainfall-runoff estimation method to using ISCO auto-sampler for flow measurement. The San Diego region explicitly mentioned that the chosen flow-measurement technique would depend on the co-permittee's discretion. As apparent from the table, flow measurement techniques are likely to vary between dry weather and wet weather events. Dry weather approaches include stopwatch-bucket, float, and electromagnetic flowmeter.

Standardizing various aspects of field-sampling, including sampling approach, optimum number of samples, and flow measurement is recommended. Developing a standardized approach for field-sampling would ensure comparability of water quality data across different programs in the region. A documented standardized approach for sample collection could decrease variability of sampled events, thereby increasing the power of statistical analyses and reducing the necessary number of storm events or sites. Standardized field-sampling procedures, supported by the latest scientific studies, should constitute the best practice for sample collection and flow measurement.

Analytes, analytical methods, and reporting limits

Stormwater contaminants can be categorized as conventional parameters, metals, inorganic constituents, and organics. A critical element of an MS4 monitoring program is to decide which analytes are to be monitored, what laboratory methods should be used for determining analyte values/concentrations, and reporting limits for individual contaminants. These decisions directly influence the ability to answer the first two monitoring questions with some indirect consequence on the accuracy of the rest of the monitoring questions.

The MS4 monitoring data both for dry and wet weather samples from three stormwater agencies, the counties of Ventura, Orange, and San Diego, were reviewed for 2015-16 season. The goal was to compare the list of monitored water quality parameter, analytical methods, and reporting limits across these agencies. Table 9 shows 20 conventional parameters that are monitored under all three programs. In addition to these parameters, volatile suspended solids (VSS) and total petroleum hydrocarbon as oil are monitored by the Ventura and Orange counties; and coliphage is monitored only by the Orange County. In general, field and laboratory methods and reporting limits used for investigating these parameters are similar across the agencies.

Tables 10 and 11 list the metal, inorganic, and organic constituents that are monitored by all three agencies. In addition to the metals listed in the Table 10, the following constituents were monitored by individual agencies: Orange and San Diego Counties monitor for Cr, Fe, Mg, Mn; Orange County monitors for B, Co, Hg, Mo, Sn, V, Sr. The list of additional organic constituents monitored by individual agencies are long. For example, Orange County MS4 monitoring program monitors 180 additional constituents besides the ones mentioned in Table 10. These numbers are 44 and 79 for San Diego and Venture County, respectively. Moreover, while there is a significant overlap among the agencies regarding the analytical methods for these constituents, their reporting limits not only vary among the agencies, but also within the same agency depending on the sampling location and date.

Developing a list of criteria to select what constituents should be monitored as a part of an MS4 and receiving water monitoring program is recommended. Given the constituents list for every agency is different, such criteria would help prepare a common list of priority contaminants to be monitored to inform the standardized monitoring questions, especially questions Q1, Q2, and Q5. Also, it is critical to develop guidance on what minimum reporting limits should be used for a chosen constituent. Note that developing a standardized list of constituents or reporting limits is meant to act as a consensus on minimum monitoring requirements. Individual agencies could monitor additional constituents based on any additional management questions they might have.

Methods for data analysis

The final step of an MS4 monitoring program is to utilize the monitoring data to answer monitoring questions with stated levels of confidence. The SMC member agencies have stated a desire to take utilize various data analysis tools helping transform MS4 monitoring data into actionable information. The purposes of such analyses may include, but are not limited to, comparing pollutant concentrations in field samples to water quality thresholds, TMDL numeric targets, BMP effectiveness assessments, trend analysis, and validation of watershed models. The purpose of data analysis should dictate what data analysis technique could be used. Table 12 illustrates example data analysis approaches used to answer the seven standardized management questions by the SMC.

Although the monitoring plans developed by the individual programs provide guidance on the items to be included in annual reports, detailed guidance on data analysis techniques are not available in those plans. A review of past annual reports indicates that the existing data analysis techniques for MS4 monitoring programs mostly focus on answering five questions described in the model monitoring document (SMC 2004). However, not every monitoring plan uses quantitative techniques to answer all five questions. In general, the data analyses are centered on ensuring compliance and trend monitoring.

Developing detailed guidance on MS4 data analysis techniques to reliably answer the standardized monitoring questions is recommended. Standardizing data analysis techniques would entail identifying the best data analysis approaches for answering individual monitoring questions and adopting those as standard techniques. Standardized data analyses would not only facilitate developing and maintaining a vast regional database, but would also allow for comparing various watershed management plans in terms of what works and what does not. For example, there are several techniques to estimate the effectiveness of a certain stormwater BMP for removing certain contaminants based on a given set of influent and effluent concentrations. These techniques include, but are not limited to, percent removal, reference watershed method, and effluent probability method (Erickson et al. 2013a,2013b; Kayhanian 2009). If different methods are used to calculate the pollutant removal efficiencies of various BMP types, or of similar BMPs from different jurisdictions, may lead to inaccurate comparisons and false conclusions. Therefore, using a consistent (and the most effective) data analysis procedure is key to reliably compare among various stormwater control measures and/or watershed management plans.

SYNTHESIS AND NEXT STEPS

MS4 monitoring programs maintained by the SMC member agencies are driven by NPDES permit requirements. While considerable similarities exist among various monitoring programs regarding their core objectives, there are inconsistencies in how those objectives are met. Except for antecedent conditions for qualifying storms, no monitoring element is identical across all the agencies. Therefore, standardizing monitoring elements to answer a common set of monitoring questions could greatly improve data comparability and inform regional water quality assessment methods.

Standardization of an individual monitoring element can be performed in one of the three following ways: a) a majority-driven approach where the procedure followed by the majority SMC member becomes the standard; b) a result-driven approach where procedures identified in the inventory are compared and tested, then the optimal procedure is chosen; c) a guidance-based approach where a decision support tool is developed to identify the optimal approach based on the given watershed and storm characteristics.

The first approach is the easiest to follow; however, there is a lack of scientific justification to do so. In contrast, the result-driven approach could be research-based and backed by experimental data. Standardizing these procedures throughout the region for some monitoring elements (i.e., first flush criteria) could be challenging because co-occurring and confounding variables (i.e., size of the watershed, storm frequency, duration) naturally lead to differences between monitoring programs. Therefore, a combination of the result-driven and guidance-based approaches to standardization is recommended for the proposed UASM.

Regardless of the approach chosen, the paucity of scientific information and regional studies are a common barrier for suggesting detailed standardized protocols for the MS4 monitoring elements. While few studies have investigated some of the monitoring elements (e.g., number of storm events per station or number of samples per storm), most of these studies are outdated because of the recent change in MS4 monitoring requirements. Studies on some monitoring elements (e.g., BMP effectiveness assessment or outfall selection criteria) are non-existent for southern California.

Therefore, research is needed to establish the best practices for runoff sample collection, data analyses, and data management to reliably answer the standardized monitoring questions. Given the resource constraints and legal framework under which the stormwater agencies operate, developing an effective monitoring guidance document with detailed instructions on optimum monitoring activities would be ideal for all stakeholders. Such a guidance document could be used by all SMC member agencies for developing MS4 monitoring and reporting programs.

The research for developing a UASM guidance document could utilize a combination of lab and field-studies, review of historical data, and statistical analysis. Based on the seven standardized monitoring questions, the following questions need to be addressed prior to developing a complete UASM guidance document:

- What watershed characteristics result in (seasonal) first-flush phenomenon in a watershed?
- What stormwater contaminants demonstrate first-flush phenomenon during their release from pollutant sources in a watershed?
- What factors to consider when selecting an outfall for dry weather monitoring?
- How many storms should be monitored per water year?
- What should be the minimum sampling frequency per site and optimum sampling duration per sampling event?
- What organic contaminants should be in the priority list for every MS4 program?
- How to best use MS4 monitoring results to evaluate gradual improvement of stormwater quality?
- How to best evaluate the effectiveness of watershed management plans?
- What standardized measure(s) to use for describing overall health of receiving water?
- How to integrate MS4 monitoring results with reasonable assurance analyses for adaptive stormwater management?

The Appendix C describes a workplan designed to gather information for answering these questions.

Not all recommended studies have equivalent priority and not all studies require similar levels of effort. The SMC has already begun some studies including lists of contaminants included in existing SMC Laboratory Guidance Manuals or Water Quality Indices for describing overall health of receiving waters. Other studies have not been started by the SMC, but have been initiated by others such as seasonal first-flush, sampling frequency, and trend analysis. Finally, some studies may have little background research including adaptive management in southern California. Regardless, all of these studies will be necessary to create a robust and useful UASM.

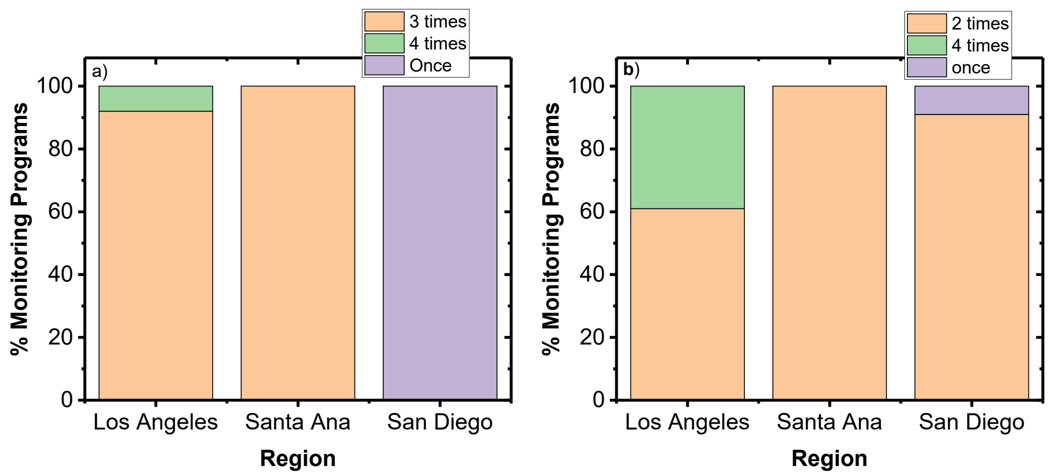

Figure 1. Sampling frequencies (per station/year) for a) wet weather and b) dry weather MS4 monitoring in different regions of southern California

Table 1. Scope of the review of MS4 monitoring inventory

Region	No. of programs	Jurisdiction	Area (mi^2)
Los Angeles	26	Alamitos Bay/Los Cerritos Channel Group	37.5
		Ballona Creek	123
		Beach Cities Watershed Management Group	31
		Dominguez Channel Watershed Management Area Group	79
		East San Gabriel Valley Watershed Management Area	38
		El Monte	-
		Gardena	5.9
		Irwindale	9.6
		La Habra Heights	6.2
		Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	-
		Los Cerritos Channel Watershed	27.7
		Lower Long Beach Bays estuaries and coastal San Pedro beaches	10.9
		Lower Los Angeles River	43.7
		Lower San Gabriel River	78.5
		Malibu Creek Watershed	109
		Marina del Rey	2.2
		North Santa Monica Bay Coastal Watersheds	86
		Palos Verdes Peninsula EWMP Agencies	
		Rio Hondo/San Gabriel River Water Quality Group	41
		Santa Monica Bay Watershed Jurisdiction 7	1.65
		Santa Monica Bay Watershed Jurisdictions 2 & 3	39
		Upper Los Angeles River Watershed Management Group	377
		Los Angeles River, Upper Reach 2	22.2
		Upper San Gabriel River	96
		Upper Santa Clara River Watershed	190
		Walnut	3.48
Santa Ana	2	Riverside county, Santa Ana Region	-
		San Bernardino	620
San Diego	11	Carlsbad	211
		Los Penasquitos	94
		Mission Bay	64
		Riverside County, Santa Margarita Region	-
		San Diego Bay	444
		San Diego River	434
		San Dieguito River	346
		San Luis Rey	562
		Santa Margarita River	741
		South Orange County	259
		Tijuana	467

Table 2. Relevant monitoring elements with individual monitoring questions

Core Monitoring Question	Storm event selection	Sampling frequency	Field sampling procedure	Flow measurement	Outfall selection	Outfall description	Laboratory methods & reporting limits	Data analyses
Q1. What pollutants are associated with stormwater runoff?	x		x		x		x	
Q2. What are the sources of the identified pollutant(s)?	x	x				x	x	
Q3. What are the sources (and magnitudes) of illicit discharge/illegal connections?					x	x	x	x
Q4. How effective the BMPs are for reducing flow and contaminant concentrations?	x			x	x		x	x
Q5. What is the overall health of receiving water?		x						x
Q6. If (and what) receiving water needs management actions based on its overall health?		x			x			x
Q7. How effective are the current water quality management plans?	x	x	x	x	x		x	x

Table 3. A broad comparison of the existing monitoring programs in terms of different monitoring elements

MS4 program element	Comparable	Different	Unknown	Remarks
Monitoring objective	X			-
First flush and sampling trigger	X			seasonal first flush monitored, not within the storm
Number of storm sampled		X		varies from 1-4 per station per season
Outfall screening		X		unknown for dry weather
Sampling method			X	primarily composites, details for compositing unknown
Sampling duration		X		Varies from 3 to 24 h to storm duration
Flow measurement		X		methods vary from float to commercial flow-meter
Pollutants monitored		X		different for organic pollutants
Analytical methods	X			primarily modified EPA methods
Reporting limits for pollutant concentration		X		varies up to 2 orders of magnitude
Data analyses		X		answers status and trend monitoring questions, methods vary

Table 4. Criteria described by different programs for sampling trigger, frequency, and duration related to MS4 monitoring

Region	Program	Sampling frequency Per outfall/year		First flush requirement	Storm end criteria	Qualifying storm	
		Wet	Dry			Antecedent condition	Sampling trigger after first flush
Los Angeles	Alamitos Bay/Los Cerritos Channel Group	3	4	No	24 h or SD[1] whichever is shorter	Yes	SAFF[2]
	Ballona Creek	3	2	Yes	24 h or SD whichever is shorter	Yes	SAFF
	Beach Cities Watershed Management Group	3	2	Yes	24 h or SD whichever is shorter	Yes	SAFF
	Dominguez Channel Watershed Management Area Group	3	2	Yes	24 h or SD whichever is shorter	Yes	0.1-0.5 inch In 6-12 h
	East San Gabriel Valley Watershed Management Area	3	2	Yes	NS	Yes	SAFF; 0.1-0.5 inch In 6-12 h
	El Monte	3	2-4	Yes	24 h or SD whichever is shorter	Yes	>1 inch with 70% probability
	Gardena	3	2-4	Yes	24 h or SD whichever is shorter	Yes	>0.1 inch
	Irwindale	3	2-4	Yes	24 h or SD whichever is shorter	Yes	>0.1 inch
	La Habra Heights	3	2-4	Yes	24 h or SD whichever is shorter	Yes	NS[3]
	Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	3	2-4	Yes	24 h or SD whichever is shorter	Yes	>1 inch per day
	Los Cerritos Channel Watershed	3	2	No	24 h or SD whichever is shorter	Yes	NS
	Lower Long Beach Bays estuaries and coastal San Pedro beaches	3	2-4	Yes*	NS	Yes	>0.25 inch with 70% probability
	Lower Los Angeles River	3	2	No	NS	Yes	>0.25 inch rain
	Lower San Gabriel River	4	2	No	NS	Yes	>0.25 inch rain
	Malibu Creek Watershed	3	2	Yes		Yes	NS
	Marina del Rey	3-4	2	Yes	SD if 3<SD<24 min 3 h, max 24 h	Yes	SAFF

Region	Program	Sampling frequency Per outfall/year		First flush requirement	Storm end criteria	Qualifying storm	
		Wet	Dry			Antecedent condition	Sampling trigger after first flush
	North Santa Monica Bay Coastal Watersheds	3	2	Yes	NS	Yes	SAFF
	Palos Verdes Peninsula EWMP Agencies	3	4	Yes	3 h or SD whichever is shorter	Yes	SAFF
	Rio Hondo/San Gabriel River Water Quality Group	3	2	Yes	24 h or SD whichever is shorter	Yes	SAFF; >0.15 inch in 6 h
	Santa Monica Bay Watershed Jurisdiction 7	3	2	Yes	24 h or SD whichever is shorter	Yes	SAFF
	Santa Monica Bay Watershed Jurisdictions 2 & 3	3	2	Yes	24 h or SD whichever is shorter	Yes	0.1-0.5 inch In 6-12 h
	Upper Los Angeles River Watershed Management Group	3	3-4	Yes	24 h or SD whichever is shorter	Yes	0.1-0.5 inch In 6-12 h
	Los Angeles River, Upper Reach 2	3P, 1R	2	Yes	24 h or SD whichever is shorter	Yes	6 inch depth
	Upper San Gabriel River	3	2	Yes	24 h or SD whichever is shorter	Yes	SAFF, 20% base flow in receiving water
	Upper Santa Clara River Watershed	3	2	Yes	24 h or SD whichever is shorter	Yes	>1 inch rain with 70% probability
	Walnut	3	2-4	Yes	24 h or SD whichever is shorter	Yes	>260 cfs flow at USGS station
	Riverside county, Santa Ana Region	3	2	Yes, NS	NS	Yes	>0.3 inch in 6 h and/or >0.5 inch in 24 h (60% probability)
	San Bernardino	3	2	Yes, NS	NS	Yes	>0.25 inch
San Diego	Carlsbad	1	2	No		NS	>0.1 inch
	Los Penasquitos	1	2	No	NS	Yes	NS
	Mission Bay	1	2	No	NS	Yes	>0.1 inch
	Riverside County, Santa Margarita Region	1	1	No	24 h or SD whichever is shorter	Yes	>0.3 inch in 6 h and/or >0.5 inch in 24 h (60% probability)

Region	Program	Sampling frequency Per outfall/year		First flush requirement	Storm end criteria	Qualifying storm	
		Wet	Dry			Antecedent condition	Sampling trigger after first flush
	San Diego Bay	1	2	No	24 h or SD whichever is shorter	Yes	>0.1 inch
	San Diego River	1	2	No	24 h or SD whichever is shorter	Yes	>0.1 inch
	San Dieguito River	1	2	No	NS	Yes	>0.1 inch
	San Luis Rey	1	2	No	24 h or SD whichever is shorter	NS	>0.1 inch
	Santa Margarita River	1	2	No	24 h or SD whichever is shorter	NS	>0.1 inch
	South Orange County	1	2	No	NS	NS	NS
	Tijuana	1	2	No	24 h or SD whichever is shorter	Yes	>0.1 inch

Yes=>=70% probability of 0.25 in precipitation
Yes*=>=50% probability of 0.2 in precipitation
Yes, NS= First viable storm requirement, but specifics not mentioned

Antecedent dry period: 72 h with <0.1 inches rain (mentioned for receiving water, not for outfalls)

[1]SD = storm duration

[2]SAFF = same requirement as first flush

[3] NS = Not specified

Table 5. Criteria for screening suitable sites for stormwater and non-stormwater outfalls

Region	Program	Outfall selection criteria	
		Wet	Dry
Los Angeles	Alamitos Bay/Los Cerritos Channel Group	1, 8,9	NM
	Ballona Creek	1,2,10	NM
	Beach Cities Watershed Management Group	1	NM
	Dominguez Channel Watershed Management Area Group	1,2,3	NM
	East San Gabriel Valley Watershed Management Area	1,2,14	NM
	El Monte	1,4,6,15	NM
	Gardena	1	NM
	Irwindale	1,6	NM
	La Habra Heights	1,2	23
	Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	1	NM
	Los Cerritos Channel Watershed	1,8,9	17,18,19
	Lower Long Beach Bays estuaries and coastal San Pedro beaches	1,7,18WD	NM
	Lower Los Angeles River	NM	NM
	Lower San Gabriel River	13	
	Malibu Creek Watershed	NM	NM
	Marina del Rey	1,2	NM
	North Santa Monica Bay Coastal Watersheds	1,2,3,4	NDWS
	Palos Verdes Peninsula EWMP Agencies	1	NM
	Rio Hondo/San Gabriel River Water Quality Group	1,5	NM
	Santa Monica Bay Watershed Jurisdiction 7	NM	NM
	Santa Monica Bay Watershed Jurisdictions 2 & 3	1	NM
	Upper Los Angeles River Watershed Management Group	1,6	NM
	Los Angeles River, Upper Reach 2	NM	NM
	Upper San Gabriel River	1,2,5	NM
	Upper Santa Clara River Watershed	NM,WD	NM,WD
	Walnut	1,2,6,11	NM
Santa Ana	Riverside county, Santa Ana Region	NM,WD	NM,WD
	San Bernardino	1,21,22WD	NM,WD
San Diego	Carlsbad	1,13	NM
	Los Penasquitos	1	17,18,19
	Mission Bay	1	17,19,24
	Riverside County, Santa Margarita Region	1,5,10,11,12WD	
	San Diego Bay	1	17,18,19,24
	San Diego River	1	16,19
	San Dieguito River	1,13	16,19
	San Luis Rey	1,13	19
	Santa Margarita River	NM	NM
	South Orange County	1	21
	Tijuana	1	NM

NM = Not mentioned; WD = Both wet and dry weather outfall

Table 6. Information available in the EWMP/CIMP/WQIP for the selected wet and dry weather outfalls in different programs

Program	**Total no. of outfalls**		**Location given**	**Land use given**	**Outfall size**		**Outfall type**		**Receiving water sites**
	Wet	Dry			Wet	Dry	Wet	Dry	
Alamitos Bay/Los Cerritos Channel Group	1	4	1W	1W	NM	4D	NM	RCP, CMP RCB	4
Ballona Creek	3	TBD	3W	3W	3W	TBD	RCB, RCP	TBD	12
Beach Cities Watershed Management Group	3	TBD	3W	3W	NM	TBD	RM, RCC	TBD	2
Dominguez Channel Watershed Management Area Group	6	TBD	6W	6W	NM	TBD	NM	TBD	11
East San Gabriel Valley Watershed Management Area	4	TBD	4W	4W	4W	TBD	RCP, RCB	TBD	4
El Monte	2	TBD	2W		NM		RCP	TBD	2
Gardena	2	2	2W	NM	2W	NM	RCB	NM	1
Irwindale	3	TBD	2W		NM		RCB	TBD	4
La Habra Heights	2	1	2W	1W	NM	NM	NM	NM	6
Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	2	TBD	2W	2W	NM	TBD	NM	TBD	24
Los Cerritos Channel Watershed	4	TBD	4W	4W	NM	TBD	NM	TBD	6
Lower Long Beach Bays estuaries and coastal San Pedro beaches	2	2TBD	2W	NM	NM	TBD	NM	TBD	16
Lower Los Angeles River	4	TBD	4W	4W	NM	TBD	NM	TBD	10
Lower San Gabriel River	3	TBD	3W	3W	NM	TBD	NM	TBD	8
Malibu Creek Watershed	4	TBD	4W	4W	4W	TBD	RCP	TBD	15
Marina del Rey	5	TBD	5W	5W	NM	TBD	NM	TBD	18
North Santa Monica Bay Coastal Watersheds	2	TBD	2W	2W	NM	TBD	NM	TBD	29
Palos Verdes Peninsula EWMP Agencies	3	TBD	3W	3W	NM	TBD	RM	TBD	7
Rio Hondo/San Gabriel River Water Quality Group	5	TBD	5W	5W	5W	TBD	RCP, RCB	TBD	8

Program	Total no. of outfalls		Location given	Land use given	Outfall size		Outfall type		Receiving water sites
	Wet	Dry			Wet	Dry	Wet	Dry	
Santa Monica Bay Watershed Jurisdiction 7	1	TBD	1W	4W	4W	TBD	RCP	TBD	3
Santa Monica Bay Watershed Jurisdictions 2 & 3	4	TBD	4W	4W	4W	TBD	RCB, RCP, RCC	TBD	24
Upper Los Angeles River Watershed Management Group	12	TBD	12W	12W	12W	TBD	Recta ngula r	TBD	21
Los Angeles River, Upper Reach 2	1P, 6R	TBD	6W	6W	NM	TBD	RM	TBD	1
Upper San Gabriel River	6	TBD	6W	6W	6W	TBD	RCB, RCP	TBD	6
Upper Santa Clara River Watershed	6	6	6WD	6WD	6WD	TBD	RCB, RCP	TBD	3
Walnut	2	2TBD	2WD	2WD	2WD	TBD	RCP	TBD	1
Riverside county, Santa Ana Region	7	7	7W	NM	NM	NM	NM	NM	3
San Bernardino	3	3P;7-9R	3WD	NM	NM	NM	NM	NM	3
Carlsbad	8	38	3W, 38D	NM	NM	38D	NM	RCC, RCB CMP, OC, CNG, EC	2
Los Penasquitos	5	11	5W	5W	NM	NM	NM	NM	14
Mission Bay	5	5	4W, 5D	4W,5D	NM	NM	NM	NM	2
Riverside County, Santa Margarita Region	7	7	7WD	NM	NM	NM	NM	NM	6
San Diego Bay	9	26	9W,26D	NM	NM	NM	NM	NM	9
San Diego River	5	25	5W,25D	NM	NM	NM	NM	NM	16
San Dieguito River	6	13	6W,13D	6W,13D	NM	NM	NM	NM	18
San Luis Rey	5	12	5W,12D	5W,12D	NM	12D	NM	CMP, RCP	12
Santa Margarita River	38	30	38W,30D	38W,30D	NM	NM	NM	NM	87
South Orange County	14	51	14W,51D	NM	NM	NM	NM	NM	12
Tijuana	5	11	5W,11D	5W,3D	5W	3D	RCP, outfall	Pipe, outfall	5

TBD = To be decided; NM = Not mentioned; W = Wet weather outfall; D = dry weather oufall; RCC: Reinforced concrete channel; RCP: RC pipe; CMP: Corrugated metal Pipe; EC: Earthen channel; CNG: Curb and Gutter; RM: Round manhole

Table 7. Details of field sampling and flow-measurement techniques for wet weather outfall monitoring

Watershed	Sampling method	Flow measurement details	
		Measured?	Method
Alamitos Bay/Los Cerritos Channel Group	CNS[2] excepting bacteria, oil & grease	NM[1]	-
Ballona Creek	CNS excepting bacteria, oil & grease	NM	-
Beach Cities Watershed Management Group	CNS	NM	-
Dominguez Channel Watershed Management Area Group	CNS	NM	-
East San Gabriel Valley Watershed Management Area	CNS excepting bacteria, oil & grease	Yes	NS[3]
El Monte	CFW[4] or CTW[5]	Yes	Time required to fill a container of known volume
Gardena	CNS	NM	-
Irwindale	CNS	NM	-
La Habra Heights	CNS	NM	-
Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	CFW excepting bacteria, oil& grease, cyanide, VOC	Yes	ISCO flowmeter, bubbler, submerged pressure transducer
Los Cerritos Channel Watershed	CNS	NM	-
Lower Long Beach Bays estuaries and coastal San Pedro beaches	CNS	NM	-
Lower Los Angeles River	CNS	NM	-
Lower San Gabriel River	NM	NM	-
Malibu Creek Watershed	NM	NM	-
Marina del Rey	CFW excepting bacteria, oil & grease	NM	-
North Santa Monica Bay Coastal Watersheds	NM	NM	-
Palos Verdes Peninsula EWMP Agencies	CNS excepting bacteria, oil & grease, PAH, VOC, cyanide, phenol	Yes	Automated flowmeter, manual measuring device; or rainfall-runoff relationship
Rio Hondo/San Gabriel River Water Quality Group	CNS excepting bacteria, oil & grease	NM	-
Santa Monica Bay Watershed Jurisdiction 7	CNS	NM	-
Santa Monica Bay Watershed Jurisdictions 2 & 3	CNS	NM	-

Watershed	Sampling method	Flow measurement details	
		Measured?	Method
Upper Los Angeles River Watershed Management Group	NM	NM	-
Los Angeles River, Upper Reach 2	**CNS**	NM	-
Upper San Gabriel River	CNS excepting bacteria, oil & grease	NM	-
Upper Santa Clara River Watershed	NM	NM	-
Walnut	CNS	NM	-
Riverside county, Santa Ana Region	CNS excepting bacteria	NM	-
San Bernardino	Grab	NM	-
Carlsbad	CNS excepting bacteria, conventional parameters	NM	-
Los Penasquitos	CNS excepting bacteria, conventional parameters	NM	-
Mission Bay	Grab	Yes	Data from USGS station, USEPA guidance document or co-permittee discretion
San Diego Bay	CNS excepting bacteria, environmental parameter	Yes	USEPA guidance document or co-permittee discretion
San Diego River	CNS excepting bacteria, environmental parameter	Yes	Data from USGS station, USEPA guidance document or co-permittee discretion
San Dieguito River	Grab and composite	NM	-
San Luis Rey	CNS excepting bacteria, environmental parameter	NM	-
Santa Margarita River	NM	NM	-
South Orange County	NM	NM	-
Tijuana	Grab and composite	Yes	USEPA guidance document

[1]NM = Not mentioned; [2]CNS = Composite, but details not specified; [3]NS = Not specified; [4]CFW = Composite, flow-weighted; [5]CTW = Composite, time-weighted

Table 8. Details of field sampling and flow-measurement techniques for dry weather outfall monitoring

Watershed	Sampling method	Flow measurement details	
		Measured?	Method
Alamitos Bay/Los Cerritos Channel Group	NM	NM	-
Ballona Creek	Grab	NM	-
Beach Cities Watershed Management Group	Grab	NM	-
Dominguez Channel Watershed Management Area Group	Grab and composite	NM	-
East San Gabriel Valley Watershed Management Area	Grab	NM	-
El Monte	Grab and CNS	NM	-
Gardena	Composite excepting bacteria	NM	-
Irwindale	Grab	NM	-
La Habra Heights	Grab	NM	-
Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	Grab taken from a vessel	NM	-
Lower Long Beach Bays estuaries and coastal San Pedro beaches	NM	NM	-
Lower Los Angeles River	NM	NM	-
Lower San Gabriel River	NM	NM	-
Malibu Creek Watershed	NM	NM	-
Marina del Rey	NM	NM	-
North Santa Monica Bay Coastal Watersheds	NM	NM	-
Palos Verdes Peninsula EWMP Agencies	Grab	NM	-
Rio Hondo/San Gabriel River Water Quality Group	NM	NM	-
Santa Monica Bay Watershed Jurisdiction 7	Grab	NM	-
Santa Monica Bay Watershed Jurisdictions 2 & 3	Grab	NM	-
Upper Los Angeles River Watershed Management Group	NM	Yes	Electromagnetic sensor
Los Angeles River, Upper Reach 2	NM	NM	-
Upper San Gabriel River	NM	NM	-
Walnut	C: 3 grab samples collected 15 min interval	NM	-
San Bernardino	Grab and composite	Yes	Float method
Carlsbad	Grab	NM	-
Los Penasquitos	NM	NM	-
Mission Bay	Grab	NM	-
San Diego Bay	Grab	NM	-

Watershed	**Sampling method**	**Flow measurement details**	
		Measured?	Method
San Diego River	Grab	NM	-
San Dieguito River	Grab	NM	-
San Luis Rey	Grab	NM	-
Santa Margarita River	NM	NM	-
South Orange County	NM	NM	-
Tijuana	Grab	Yes	Float method; bucket and stopwatch method

NM = Not mentioned; CNS = Composite, but details not specified

Table 9. Conventional parameters monitored under all three stormwater programs and analytical methods

Parameter	Ventura County	Orange County	San Diego County
Alkalinity as CaC03	SM 2320 B	-	SM 2320 B
Ammonia N	EPA 350.1	EPA 350.1	EPA 350.1, FieldMeasure, SM 4500-NH3
BOD	SM 5210 B	EPA 405.1	EPA 405.1, SM 5210 B
Chemical Oxygen Demand	EPA 410.4	EPA 410.4	EPA 410.4
E. coli	MMO-MUG, SM 9223 B	EPA 1603, colilert	SM 9223 B
Enterococcus(Idexx)	Enterolert, SM 9230 D	IDEXX Enterolert, EPA 1600	Enterolert, EPA 1600, EPA 1600, SM 9230 B
Fecal coliform	SM 9221 E	MF (APHA 9222 D)	SM 9221 B
Hardness as $CaCO_3$	EPA 200.7	SM 2340B	EPA 200.7, SM 2340
NO_3-N	EPA 353.2	EPA 353.2	EPA 353.2, SM 4500-NO3 E
pH	Field Measure	150.1, EPA 9045, NA	Field Measure
Phosphorus As P	EPA 365.1	EPA 365.3, NA	EPA 365.1, EPA 365.3, Hach Method 8190, SM 4500-P C
Salinity	Field Measure	Field Measure	Field Measure
Settleable Solids		SM 2540F	
Specific Conductivity	Field Measure	EPA 120.1	Field Measure, SM 2510 B
TDS	SM 2540 C	EPA 160.1	SM 2540 C
Temperature	Field Measure	Field Measure	Field Measure
TKN	EPA 351.2	EPA 351.2	ASTM 1426-93BM, EPA 351.2, SM 4500-N C
Total coliform	MMO-MUG, SM 9223 B	MF (APHA 9222 B)	SM 9221 B
TSS	SM 2540 D	SM 2540D	SM 2540 D
Turbidity	EPA 180.1, Field Meter	EPA 180.1	EPA 180.1, Field Measure, SM 2130 B

Table 10. Metallic and inorganic constituents monitored under all three stormwater programs and analytical methods

Parameter	Orange County	Ventura County	San Diego
Ag	EPA 6020, EPA 200.8, EPA 1640	EPA 200.8	EPA 200.7, EPA 200.8, EPA 6020
Al	EPA 200.8	EPA 200.8	EPA 200.8, EPA 6010C, EPA 6020
As	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.8, EPA 6010C, EPA 6020
Ba	EPA 6020, EPA 200.8	EPA 200.8	EPA 6020
Be	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 6020
Ca	EPA 200.7	EPA 200.7	EPA 200.7
Cd	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.7, EPA 200.8, EPA 6010C, EPA 6020
Cl	EPA 325.3	EPA 300.0	EPA 300.0, SM 4500-Cl C
Cu	EPA 6020, 200.8, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.7, EPA 6010C, EPA 6020
F	EPA 625, 8270, EPA 8270D	EPA 300.0	EPA 625, EPA 8270C
K	EPA 200.7	EPA 200.7	EPA 200.7
Na	EPA 200.7, EPA 200.8	EPA 200.7	EPA 200.7
Ni	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.7, EPA 200.8, EPA 6010C, EPA 6020
Pb	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.7, EPA 200.8, EPA 200.8, SM 3113 B
Se	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.7, EPA 200.8, EPA 6020
SO_4	EPA 300	EPA 300.0	EPA 300.0, SM 4500-SO4
Tl	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.8
Zn	EPA 6020, EPA 1640, EPA 200.8	EPA 200.8	EPA 200.7, EPA 6010C, EPA 6020

Table 11. Organic constituents monitored under all three stormwater programs and analytical methods

Constituent	Orange County	San Diego County	Ventura County
2,4'-DDD	EPA 625, Dry Weight, EPA 8270C, EPA 8270D	CAS SOP SOC-PESTMS2, EPA 608, EPA 8081A	EPA 608
2,4'-DDE	EPA 625, Dry Weight, EPA 8270C, EPA 8270D	CAS SOP SOC-PESTMS2, EPA 608	EPA 608
2,4'-DDT	EPA 625, Dry Weight, EPA 8270C, EPA 8270D	CAS SOP SOC-PESTMS2, EPA 608	EPA 608
4,4'-DDD	EPA 625, EPA 8270C, EPA 8270D	CAS SOP SOC-PESTMS2, EPA 608, EPA 8081A	EPA 608
4,4'-DDT	EPA 625, EPA 8270C, EPA 8270D	CAS SOP SOC-PESTMS2, EPA 608	EPA 608
Acenaphthene	EPA 625, EPA 8270D	EPA 625, EPA 8270C, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Acenaphthylene	EPA 625	EPA 625, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Aldrin	EPA 625, EPA 8270D	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Allethrin	EPA 8270C, EPA 8270C	EPA 625M, EPA 8270D, GCMS-NCI-SIM	-
Anthracene	EPA 625, EPA 8270D	EPA 625M, EPA 8270D, GCMS-NCI-SIM	EPA 625, EPA 8270C
Azinphos methyl (Guthion)	EPA 525.2	EPA 625M	EPA 525.2m
Benzo (A) Anthracene	8270	EPA 625, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Benzo (A) Pyrene	8270	EPA 625, EPA 8270C, EPA 8270D	EPA 525.2, EPA 625, EPA 8270C
Benzo (K) Fluoranthene	8270	EPA 625, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Benzo(b)Fluoranthene	8270	EPA 625, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Benzo(e)pyrene	8270	EPA 625, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Bolstar	EPA 525.2	EPA 625M	EPA 525.2m
Chlordane	Dry Weight	EPA 8081A	EPA 608
Chlorpyrifos	EPA 525.2	CAS SOP SOC-PESTMS2, EPA 625M, EPA 8081M, EPA 8141A, EPA 8141B	EPA 525.2m
Chrysene	EPA 625, EPA 8270D	EPA 625, EPA 8270C, EPA 8270D	EPA 625, EPA 8270C
Coumaphos	EPA 525.2	EPA 625M	EPA 525.2m
Demeton-o	EPA 525.2	EPA 625M	EPA 525.2m
Demeton-s	EPA 525.2	EPA 625M	EPA 525.2m
Diazinon	EPA 525.2	EPA 625M, EPA 8081M, EPA 8141A, EPA 8141B	EPA 525.2
Dichlorvos	EPA 525.2	EPA 625M	EPA 525.2m
Dieldrin	EPA 625, Dry Weight, EPA 8270C	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Dimethoate	EPA 525.2	EPA 625M	EPA 525.2
Dimethyl Phthalate	EPA 625	EPA 625, EPA 8270C, EPA 8270D	EPA 625

Constituent	Orange County	San Diego County	Ventura County
Endosulfan sulfate	EPA 625, EPA 8270C	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Endosulfan-I	EPA 625, EPA 8270C	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Endosulfan-II	EPA 625, EPA 625	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Endrin	EPA 625, Dry Weight, EPA 8270C	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Endrin Aldehyde	EPA 625, Dry Weight, EPA 8270C	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Fenthion	EPA 525.2	EPA 625M	EPA 525.2m
Heptachlor	Dry Weight, EPA 8270C, EPA 625	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Heptachlor Epoxide	Dry Weight, EPA 8270C, EPA 625	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 608
Indeno[1,2,3-c,d]pyrene	EPA 625	EPA 625, EPA 8270C, EPA 8270C SIM, EPA 8270D SIM	EPA 625, EPA 8270C
Merphos	EPA 525.2	EPA 625M	EPA 525.2m
Methoxychlor	Dry Weight, EPA 8270C, EPA 625	CAS SOP SOC-PESTMS2, EPA 8081A	EPA 525.2
Mevinphos	EPA 525.2	EPA 625M	EPA 525.2m
Mirex	Dry Weight, EPA 8270C, EPA 625	CAS SOP SOC-PESTMS2	EPA 608
Naled	EPA 525.2	EPA 625M	EPA 525.2m
Naphthalene	EPA 625, 8270, EPA 8270D	EPA 625, EPA 8270C, EPA 8270C SIM, EPA 8270D SIM	EPA 625, EPA 8270C
Nitrobenzene	EPA 625	EPA 8270C	EPA 625
Pentachlorophenol	EPA 625, EPA 8151	EPA 625, EPA 8270C	EPA 515.3, EPA 625, EPA 8270C
Phenanthrene	EPA 625, EPA 8270D	EPA 625M-NCI, EPA 8270D_NCI, EPA 8270M_NCI	EPA 625, EPA 8270C
Phenol	EPA 625	EPA 8270C	EPA 625, EPA 8270C
Phorate	EPA 525.2	EPA 625M	EPA 525.2m
Pyrene	EPA 625, EPA 8270D	EPA 625, EPA 8270C, EPA 8270C SIM, EPA 8270D SIM	EPA 625, EPA 8270C
Tokuthion	EPA 525.2	EPA 625M	EPA 525.2m
Toxaphene	EPA 625, Dry Weight, EPA 8270C	EPA 8081A	EPA 608
Trichloronate	EPA 525.2	EPA 625M	EPA 525.2m

Table 12. Possible data analysis techniques to answer specific monitoring questions

Core Monitoring Question	Data Analyses
Q1. What pollutants are associated with stormwater and non-stormwater runoff?	Comparison to water quality criteria
Q2. What are the sources of the identified pollutant(s)?	Frequency/persistence analyses/ source tracking
Q3. How effective the BMPs are for reducing flow and contaminant concentrations?	BMP effectiveness assessment
Q4. If (and how) runoff discharge is influencing the quality of receiving water?	Pollutant load & temporal trend analyses
Q5. What is the overall health of receiving waters?	Persistence analyses/ Regional water quality index
Q6. If (and what) receiving waters need management actions based on its overall health?	Pollutant load analyses: TMDL/MAL
Q7. How effective are the current water quality management plans?	Validation of models & trend analyses

APPENDIX A: DOCUMENTS REVIEWED FOR DEVELOPING THE INVENTORY OF MS4 MONITORING IN SOUTHERN CALIFORNIA

Permits

1. National Pollutant Discharge Elimination System (NPDES) Permit and Waste Discharge Requirements for Discharges from The Municipal Separate Storm Sewer Systems (Ms4s) Draining the Watersheds Within the San Diego Region: Order No. R9-2013-0001; NPDES No. CAS0109266

2. National Pollutant Discharge Elimination System (NPDES) Permit and Waste Discharge Requirements for The San Bernardino County Flood Control District" The County of San Bernardino, and The Incorporated Cities of San Bernardino County Within the Santa Ana Region: Order No. R8-2010-0036; NPDES No. CAS618036

3. Waste Discharge Requirements for Municipal Separate Storm Sewer System (MS4) Discharges Within the Coastal Watersheds of Los Angeles County, Except Those Originating from The City of Long Beach MS4: Order No. R4-2012-0175; NPDES Permit No. CAS004001

4. Waste Discharge Requirements for Municipal Separate Storm Sewer System Discharges from The City of Long Beach: Order No. R4-2014-0024; NPDES Permit No. CAS004003

5. Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the Incorporated Cities of Orange County within the Santa Ana Region Areawide Urban Storm Water Runoff Orange County: Order No. R8-2009-0030; NPDES No. CAS618030

6. Monitoring and Reporting Program for Riverside County Flood Control and Water Conservation District, The County of Riverside and the Cities of Riverside County Within the Santa Ana Region AREA-WIDE Urban Storm Water Runoff Management Program: Order No. R8-2010-0033; NPDES No. CAS618033

7. Waste Discharge Requirements for Storm Water (Wet Weather) And Non-Storm Water (Dry Weather) Discharges from The Municipal Separate Storm Sewer Systems Within the Ventura County Watershed Protection District, County of Ventura and the Incorporated Cities Therein: Order No. R4-2010-0108; NPDES Permit No. CAS004002

Annual Reports

1. Ventura Countywide Stormwater Quality Management Program: 2015-2016 Annual Report
2. Orange County 2015-16 San Diego Region Transitional Monitoring and Assessment Report
3. San Bernardino County Areawide Stormwater Program Annual Report: Fiscal Year July 2015 to June 2016
4. City of Long Beach Stormwater Monitoring Report 2006/2007
5. Santa Ana Region Monitoring Annual Report: Monitoring Year 2016-2017
6. Santa Margarita River Watershed Management Area (WMA): Monitoring Report, November 2017

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Appendix B: Overview of Monitoring Questions Posed by Various Permits and Programs

Even though all the permittees have five core management questions in mind, 16 different goals in total have been mentioned in the permits reviewed. Following are the goals:

1) Define water quality status, trends, and pollutants of concern (RC, SBC, OC)
2) Identify stormwater pollutants
    a) Characterize pollutants associated with urban runoff (OC, RC, SBC, LAC, CLB, VC)
    b) Characterize stormwater discharge (SDC)
3) Assess the contribution of stormwater to receiving water quality
    a) Influence of urban land use on water quality and identify water quality problems associated with urban runoff (OC, RC, SBC)
    b) Chemical, physical, and biological impacts to receiving water by MS4 (SDC, LAC, CLB, SDC, VC)
4) Identify other sources (e.g., atmospheric deposition, contaminated sediment) of pollutants in runoff (RC, SBC, OC)
5) Identify and prohibit illicit discharge (RC, SBC, OC, SDC)
6) Identify receiving water that needs additional actions for TMDL compliance (all permittees)
7) Determine mass loading rates for different urban land use categories (OC)
8) Determine runoff pollutant concentrations and loads at the source level (e.g., near a golf course or restaurants) (OC, RC)
9) Evaluate effectiveness of BMP (OC, RC, SBC, SDC) or pollutant control technologies (LAC, CLB, VC)
10) Evaluate cost and benefits of proposed stormwater quality control programs and share with the stakeholders, including public (OC, RC, SBC)
11) Develop and support an effective runoff management plan (RC, SBC)
12) Analyze and interpret collected data to determine the impact of urban runoff on receiving water and/or validate relevant water quality models (RC)
13) Identify and permit or prohibit illegal connections (RC, SBC)
14) Evaluate the effectiveness of water quality management plan (SDC, RC)
15) Identify the source(s) of a specific pollutant (SDC, CLB, LAC)
16) Assess the overall health of receiving water (SDC)

The monitoring goal or objectives mentioned in the monitoring plans primarily stem from corresponding permit requirements; however, in some cases monitoring plans developed by the individual permittees have more specific goals or objectives in mind. The stormwater program objectives, stormwater outfall monitoring objectives, and non-stormwater outfall monitoring objectives mentioned across 39 monitoring plans are summarized below. Table 2 provides a detailed inventory of these objectives related to the specific monitoring plan.

Stormwater Program Objectives

1. Assess the chemical, physical, and biological impacts of discharges from the MS4 on receiving waters.

2. Assess compliance with receiving water limitations (RWLs) and water quality-based effluent limitations (WQBELs) established to implement Total Maximum Daily Load (TMDL) wet weather and dry weather waste load allocations (WLAs)
3. Characterize pollutant loads in MS4 discharges
4. Identify sources of pollutants in MS4 discharges
5. Measure and improve the effectiveness of pollutant controls implemented under the Permit

Stormwater Outfall Monitoring Objectives

1. Determine the quality of stormwater discharge relative to municipal action levels
2. Determine whether stormwater discharge is in compliance with applicable stormwater WQBELs derived from TMDL waste load allocations (WLAs)
3. Determine whether the discharge causes or contributes to an exceedance of receiving water limitations
4. Identify pollutants in storm water discharges
5. Guide pollutant source identification efforts
6. Determine the relative contribution of MS4 outfalls to priority water quality conditions during wet weather
7. Investigate how discharge concentrations, loads, and flows change over time at representative MS4 outfalls
8. Determine the effectiveness of water quality improvement strategies associated with the pathogen health risk for highest priority water quality condition (HPWQC)

Non-stormwater Outfall Monitoring Objectives

1. Determine whether a discharge is in compliance with applicable non-stormwater WQBELs derived from TMDL WLAs
2. Determine whether a discharge exceeds non-stormwater action levels
3. Determine whether a discharge contributes to or causes an exceedance of receiving water limitations
4. Assist in identifying illicit discharges
5. Determine the relative contribution of MS4 outfalls to priority water quality conditions during dry weather
6. Determine the sources of persistent non-stormwater flows
7. Inform the prioritization of outfall retrofits and feasibility of planned outfall capture strategies associated with the unnatural water balance and flow regime HPWQC

Table 13. MS4 monitoring objectives as described in watershed management plans developed by various MS4 monitoring programs

Region	Program	Program objective	Stormwater outfall monitoring objective	Non-stormwater outfall Monitoring objective
Los Angeles	Alamitos Bay/Los Cerritos Channel Group	NM	1,2,3	1,2,3,4
	Ballona Creek	NM	1,2,3	1,2,3,4
	Beach Cities Watershed Management Group	NM	2,4,5	3,4
	Dominguez Channel Watershed Management Area Group	NM	1,2,3	1,2,4
	East San Gabriel Valley Watershed Management Area	NM	1,2,3	1,2,3,4
	El Monte	NM	1,2,3	NM[1]
	Gardena	NM	1,2,3	NM
	Irwindale	NM	NM	NM
	La Habra Heights	1,2,3,4,5	NM	NM
	Long Beach Inner and Outer Harbor, and eastern San Pedro Bay	NM	NM	NM
	Los Cerritos Channel Watershed	1,2,3,4,5	1,2,3	1,2,3,4
	Lower Long Beach Bays estuaries and coastal San Pedro beaches	NM	1,2,3	1,2,3,4
	Lower Los Angeles River	NM	NM	1,2,3,4
	Lower San Gabriel River	NM	NM	NM
	Malibu Creek Watershed	1,2,3,4,5	1,2,3	1,2,3,4
	Marina del Rey	NM	1,2,3	1,2,3,4
	North Santa Monica Bay Coastal Watersheds	NM	NM	1,2,3
	Palos Verdes Peninsula EWMP Agencies	1,2,3,4,5	1,2,3	NM
	Rio Hondo/San Gabriel River Water Quality Group	1,2,3,4,5	1,2,3	1,2,3,4
	Santa Monica Bay Watershed Jurisdiction 7	NM	1,2,3	1,2,3,4
	Santa Monica Bay Watershed Jurisdictions 2 & 3	NM	1,2,3	1,2,3,4
	Upper Los Angeles River Watershed Management Group	NM	1,2,3	1,2,3,4
	Los Angeles River, Upper Reach 2	NM	1,2,3	1,2,3,4
	Upper San Gabriel River	NM	1,2,3	1,2,3,4
	Upper Santa Clara River Watershed	1,2,3,4,5	1,2,3	1,2,3,4
	Walnut	1,2,3,4,5	2	1
	Riverside county, Santa Ana Region	NM	NM	NM
	San Bernardino	NM	NM	NM
San Diego	Carlsbad	NM	2,4,5	3,4
	Los Penasquitos	NM	1,6,7	
	Mission Bay	NM	1,6,7	2,4
	Riverside County, Santa Margarita Region	NM	1,3,5,6	NM
	San Diego Bay	NM	1,3,6,7	3
	San Diego River	NM	2,3	3
	San Dieguito River	NM	1,2,4,5,6,7	2,4
	San Luis Rey	NM	2,4,5	2,4

Region	Program	Program objective	Stormwater outfall monitoring objective	Non-stormwater outfall Monitoring objective
	Santa Margarita River	NM	NM	NM
	South Orange County	NM	2,3,4,5,6,7	2,3,4,5,7
	Tijuana	NM	1,5,6	2,5,7

[1]NM = Not mentioned

APPENDIX C: WORKPLAN FOR CREATING A STANDARDIZED MONITORING GUIDANCE DOCUMENT

Introduction

A review of MS4 monitoring programs in southern California indicates similarities among SMC member agencies in terms of monitoring objectives. However, considerable differences exist in terms of the details of monitoring elements. Standardizing these monitoring elements, based on a list of standardized monitoring questions, is key to establishing a unified approach for standardized MS4 monitoring (UASM) in the region. A detailed analysis of the monitoring questions, inventory of existing monitoring methods and designs, and rationale for recommended standardization is described in this Technical Report. This Workplan describes the efforts required to improve monitoring effectiveness and develop a UASM for all Southern California Stormwater Monitoring Coalition members.

Problem Statement

Detailed investigation into the following five monitoring elements are needed to improve the effectiveness and standardization of MS4 monitoring in the Southern California Region:

1. Standardize qualifying storm events
2. Develop a guideline on how to select sampling sites while planning for MS4 monitoring
3. Standardize field-sampling procedure
4. Standardize laboratory analytical methods
5. Standardize data analyses and reporting format

Tasks

The contractor shall use a combination of lab and field-studies, review of the historical data, and/or statistical analysis to gather required information for answering seven standardized monitoring questions

1) Standardize qualifying storm events

The goal of this task is to investigate whether an initial portion of a storm event qualifies for first-flush consideration. This also includes investigation on what watershed characteristics result in (seasonal) first-flush phenomenon in a watershed. Such investigation should incorporate first-flush strength analyses for priority contaminants. The strength analyses should be designed to determine what stormwater contaminants demonstrate first-flush phenomenon during their release from pollutant sources in a watershed. The outcome of this analysis will dictate which sites are susceptible to first flush and should be selected for first flush monitoring.

Deliverables:

a) A ranking of pollutants for first-flush consideration

b) Correlation matrix for watershed characteristics-first flush prevalence
c) Of the existing watersheds being monitored, which should be monitored for first flush

2) Develop a guideline on how to select sampling sites while planning for MS4 monitoring

Identify the set of criteria that can be used to select outfall sites for dry weather monitoring. In addition, already established wet weather outfall screening criteria should be examined to assign relative significance for each criterion listed. Based on the list of the criteria, an equitable number of dry and wet weather outfalls should be specified for each MS4 monitoring program.

Deliverables:

a) Standardized list of selection criteria for dry weather outfall monitoring
b) Standardized list of selection criteria for wet weather outfall monitoring

3) Standardize field-sampling procedure

Field-sampling procedures focus on monitoring design details such as deciding how many storms should be monitored, how frequently each site should be monitored, what the duration of each sampling event is, and what type of samples should be collected. In identifying these parameters influence of relevant factors, including storm duration, watershed characteristics, type of monitoring, should be taken into consideration. This task will provide decision support tools for each of these monitoring design details. Activities under this task should specify the minimum requirements for the UASM in southern California.

Deliverables:

a) A statistical tool based on power analysis that determines the optimum number of storm events per year at each station
b) Statistical analysis of the effects of sampling duration on the representativeness of stormwater samples
c) A decision support tool to standardize the optimum number of samples for both flow and time-weighted composite samples

4) Standardize laboratory analytical methods

Develop a guideline for standardizing chemical analyses, including conventional parameters, metals, inorganic, and organic constituents. Especially, from the wide range of organic contaminants that the SMC member agencies monitor, a subset of organics should be identified that represent the quality of stormwater and non-stormwater runoff in the region.

Deliverables:

a) A priority list for contaminants that needs to be monitored in every MS4 program

b) A list of optional contaminants that needs to be monitored at selected locations, and what criteria will be used to select these optional contaminants
c) Uniform reporting limits for individual analytical methods

5) Standardize data analyses and reporting format

Develop a standard framework for monitoring and assessing the effectiveness of the MS4 programs, including the performance evaluation of BMPs, describing the health of the receiving water, and quantifying the effects of runoff on receiving water quality. Moreover, a comprehensive guideline should be established on how to use MS4 monitoring results to evaluate gradual improvement of stormwater quality per reasonable assurance analyses and modify watershed improvement plans as needed by adaptive management.

Deliverables:

a) A standard operating protocol to evaluate the effectiveness of watershed management plans
b) A standard operating protocol for monitoring BMP effectiveness for stormwater capture and treatment
c) An interactive database that standardizes comparisons between receiving water quality and stormwater quality, then identifies the outfalls immediately upstream that could be degrading receiving water quality
d) A standardized measure for describing overall health of receiving water
e) A guideline to integrate MS4 monitoring results with reasonable assurance analyses for adaptive stormwater management