Bay Area Reasonable Assurance Analysis White Paper

Prepared for

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ACRONYMS

BASMAA	Bay Area Stormwater Management Agencies Association
BMP	Best Management Practice
CCRWQCB	Central Coast Regional Water Quality Control Board
EWMP	Enhanced Watershed Management Plan
Hg	Mercury
LACDPW	Los Angeles County Department of Public Works
MRP	Municipal Regional Permit
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
PCBs	Polychlorinated Biphenyls
RAA	Reasonable Assurance Analysis
SFRWQCB	San Francisco Regional Water Quality Control Board
US EPA	United States Environmental Protection Agency
WLA	Wasteload Allocation
WMP	Watershed Management Plan
WQBEL	Water Quality Based Effluent Limit

1.0 INTRODUCTION AND PURPOSE

The purpose of this white paper is to objectively describe a "reasonable assurance analysis" (RAA) in the context of the reissued Municipal Regional Stormwater Permit (MRP) (Order No. R2-2015-0049) requirements to conduct a RAA, and to outline the potential options for conducting a RAA in the Bay Area. This RAA White Paper will be used to inform the countywide stormwater programs and MRP Permittees on this topic as they move forward with RAA development.

2.0 MUNICIPAL REGIONAL STORMWATER PERMIT REQUIREMENTS

2.1 Plan and Implement Green Infrastructure

MRP Provision C.3.j requires the Permittees to develop a Green Infrastructure Plan for inclusion in the 2019 Annual Report. The Green Infrastructure Plan must be developed using a mechanism to prioritize and map areas for potential and planned green infrastructure projects, both public and private, on a drainage-area-specific basis, for implementation by 2020, 2030, and 2040.

MRP Provisions C.11.c and C.12.c require the Permittees to prepare a RAA for inclusion in the 2020 Annual Report that quantitatively demonstrates that mercury load reductions of at least 10 kg/yr and PCBs load reductions of at least 3 kg/yr will be achieved by 2040 through implementation of green infrastructure throughout the permit area.

This RAA should do the following:

1. Quantify the relationship between the areal extent of green infrastructure implementation and mercury and PCBs load reductions. This quantification should take into consideration the scale of contamination of the treated area as well as the pollutant removal effectiveness of green infrastructure strategies likely to be implemented.
2. Estimate the amount and characteristics of land area that will be treated by green infrastructure by 2020, 2030, and 2040.
3. Estimate the amount of mercury and PCBs load reductions that will result from green infrastructure implementation by 2020, 2030, and 2040.
4. Quantitatively demonstrate that mercury load reductions of at least 10 kg/yr and PCBs load reductions of at least 3 kg/yr will be realized by 2040 through implementation of green infrastructure projects.
5. Ensure that the calculation methods, models, model inputs, and modeling assumptions used have been validated through a peer review process.

2.2 PCBs/Mercury Control Measure Implementation Plan

Additionally, MRP Provisions C.11.d. and C.12.d. require the Permittees to prepare plans and schedules for mercury and PCBs control measure implementation and a RAA demonstrating that sufficient control measures will be implemented to attain the mercury TMDL wasteload allocations by 2028 and the PCBs TMDL wasteload allocations by 2030. The implementation plans, which will also be included in the 2020 Annual Report, along with the green infrastructure-based RAA outlined above, must:

1. Identify all technically and economically feasible mercury or PCBs control measures (including green infrastructure projects, but also other control measures such as source property identification and abatement, managing PCBs in building materials during demolition, enhanced operations and maintenance, and other source controls) to be implemented;
2. Include a schedule according to which technically and economically feasible control measures will be fully implemented; and
3. Provide an evaluation and quantification of the mercury and PCBs load reduction of such measures as well as an evaluation of costs, control measure efficiency, and significant environmental impacts resulting from their implementation.

3.0 WHAT IS REASONABLE ASSURANCE ANALYSIS?

This section defines the term "reasonable assurance analysis" and provides example RAA approaches used in other regions of California.

3.1 Definition

A RAA is a demonstration that proposed implementation measures will achieve compliance with applicable water quality-based effluent limitations (WQBELs) and receiving water limitations, such as the mercury and PCBs load reductions including in the MRP. The green infrastructure RAA (C.11.c/C.12.c) should provide a method for evaluating the necessary type, size, number, location, and phasing of green infrastructure measures to comply with the TMDL load reduction requirements attributed to green infrastructure (i.e., 10 kg/yr mercury load reductions and 3 kg/yr PCBs load reductions by 2040). The PCBs/Hg Implementation Plan RAA (C.11.d/C.12.d) should do the same for the overall TMDL POC load reductions (i.e., a mercury load reduction of approximately 35 kg/yr[1] and an overall PCBs load reduction of 14.4 kg/yr[2]) and may also be used to justify extending the TMDL compliance schedules (if needed).

The MRP provides flexibility for Permittees to define what constitutes an acceptable RAA and the Fact Sheet provides the following details:

- Preparing the RAA will be a step-wise process.
- The RAA will require the use of one or more models.

[1] Based on MRP Fact Sheet page Attachment A-106, Finding C.11-8, this represents the additional mercury load reduction needed beyond what has been achieved to date based on environmental data.

[2] This is the overall load reduction for the MRP Permittees and includes load reductions achieved to date and those that will be achieved during the current permit term.

- The Los Angeles Regional Water Board guidelines for conducting a RAA are a starting point for the RAA required in MRP C.11.c/C.12.c in terms of the mechanics of the analysis, control measure identification, critical condition selection, choice of models, model calibration criteria, modeling inputs, and model outputs.
- The crucial feature of the existing Southern California RAAs is that they must demonstrate with sufficient analytical rigor that the suite of foreseeable control measures to reduce loads will result in compliance with final TMDL wasteload allocations (WLAs). The RAA performed for PCBs and mercury for the San Francisco Bay Area will likely be similar in many respects to the type of analysis described in the Southern California guidance document, but must also account for the local watershed characteristics as well as what has been learned about the distribution, fate, and transport characteristics of PCBs and mercury.

Additionally, Tom Mumley (San Francisco Regional Water Quality Control Board, SFRWQCB) and Dave Smith (United States Environmental Protection Agency, US EPA) made the following statements about RAAs at the *Integrating Reasonable Assurance Analysis and Stormwater/Green Infrastructure Plans* workshop held on September 23, 2015:

- RAAs use robust analytical models and tools to:
    - Evaluate pollutant sources,
    - Site management solutions,
    - Determine controls needed to meet permit requirements,
    - Guide infrastructure planning and funding decisions, and
    - Support control tracking, evaluation, and reporting;
- Available modeling tools vary in sophistication, capability, and cost; and
- RAAs provide a long term analytical foundation for robust stormwater programs.

3.2 RAA Approaches from other Regions in California

This section and Table 1 summarize and compare RAA requirements and approaches taken in four other regions in California. The critical feature of all of the RAA requirements is that they must demonstrate with sufficient analytical rigor that a suite of selected control measures will result in compliance with WQBELs and/or TMDL WLAs. Some Municipal Separate Storm Sewer (MS4) permits (e.g., Los Angeles and Lahontan-Lake Tahoe) specifically recommend models and requirements within the MS4 permit, whereas other MS4 permits (e.g., San Diego and Phase II Central Coast) provide only the analysis objectives, by which permittees (e.g., San Diego Transportation and Storm Water Department and the Central Coast MS4 Support Program) have developed and demonstrated specific models and their effectiveness.

3.2.1 Los Angeles Region

The Los Angeles Regional Water Quality Control Board (LARWQCB) adopted a revised Los Angeles County MS4 permit (Order No. R4-2012-0175) in 2012 that allowed the permittees to develop a watershed management program (WMP) or enhanced watershed management program (EWMP) to implement the requirements of the permit on a watershed scale through customized strategies, control measures, and best management practices (BMPs). The WMPs/EWMPs were required to ensure that discharges from the MS4: 1) achieved TMDL-based WQBELs, 2) did not cause or contribute to exceedances of water quality standards in the receiving waters, and 3) eliminated non-allowable dry weather runoff discharges. The permittees were required to submit a RAA as part of their draft WMP/EWMP to demonstrate that applicable WQBELs and receiving water limitations would be achieved through implementation of the watershed control measures proposed in the WMP/EWMP.

An important difference between the Bay Area and Los Angeles area permit requirements is that in Los Angeles, the first steps in developing the WMPs/EWMPs were to:

- Identify all of the pollutants of concern (POCs) for each water body in each watershed,[3]
- Quantify the current/baseline pollutant loading and runoff volume from the MS4,
- Quantify the allowable MS4 pollutant loading (wasteload allocation/WQBEL), and
- Quantify the required pollutant load reduction needed to attain applicable WQBELs.

In contrast, these items have already been identified and quantified in the MRP (i.e., the San Francisco Bay mercury and PCBs TMDL baseline loads and required urban runoff load reductions).

A similarity between the Bay Area and Los Angeles requirements is that the next steps in developing the RAA are to quantify the:

- Pollutant removal/effectiveness for the types of control measures selected for implementation,
- Full suite of control measures to be implemented across a watershed to attain applicable WQBELs/TMDL load reductions, and
- Water quality outcomes associated with implementation of the full suite of proposed control measures (that is, the cumulative effectiveness of implementation measures across the watershed).

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[3] The WMP/EWMP were required to classify and list all water body-pollutant combinations into one of the following three categories: Category 1: Water body-pollutant combinations subject to a TMDL; Category 2: Water body-pollutant combinations identified on the 303(d) List; and Category 3: Water body-pollutant combinations with exceedances of receiving water limitations.

The LARWQCB prepared a fairly prescriptive guidance document (Nguyen et al., 2014) to provide clarification on the regulatory requirements of the MS4 permit along with recommended criteria to prepare an appropriate RAA for LARWQCB approval. This document includes the following items related to preparing a RAA as part of a WMP/EWMP:

- The specific models that may be used. These models were selected based on the following model capabilities:
    - Dynamic continuous long-term simulation for modeling pollutant loadings, flows, and concentrations.
    - Can represent rainfall and runoff processes above soil surface as well as baseflow contributions in subsurfaces of urban and natural watershed systems.
    - Can represent variability in pollutant loadings, based on land use, soil hydrologic group, and slope.
    - BMP process-based approach or empirically-based BMP approach.
    - Decision support to evaluate BMP performance.
- The required model input data and allowable data sources to obtain required data.
- Model calibration criteria, including calibration tolerances, data sources, and initial starting values for key calibration parameters, land use-based EMCs and BMP performance parameters for selected pollutants, and model output content and formats.

3.2.2 San Diego Region

The San Diego Regional MS4 Permit (Order No. R9-2013-0001) requires the permittees to develop Water Quality Improvement Plans (WQIPs) for specified watersheds to guide the permittees' management programs towards achieving improved water quality through an adaptive planning and management process that identifies the highest priority water quality conditions within a watershed and implements strategies to achieve improvements in the quality of discharges from the MS4s. The WQIPs were not required specifically to include a RAA, but a WQIP that provides reasonable assurance is one method for showing compliance with numerous TMDLs. No models were specified in the permit or subsequent guidance, but the WQIP must be approved by the San Diego Regional Water Quality Control Board Executive Officer. If significant issue arise during the WQIP public comment period that cannot be resolved informally through discussions, the WQIP must be considered at a San Diego Water Board public meeting.

Drew Kleis, Deputy Director of the Stormwater Division of the City of San Diego, described the RAA analyses conducted by the City for the purposes of TMDL compliance at the September 2015 *Integrating Reasonable Assurance Analysis and Stormwater/Green Infrastructure Plans* workshop. In his presentation, he stated that the City of San Diego also used their RAAs for other purposes than just TMDL compliance, including asset management, cost estimating, and developing CIP plans.

3.2.3 Central Coast Region

The Central Coast Regional Water Quality Control Board's (CCRWQCB) current focus has shifted to a watershed-based approach to municipal stormwater program implementation and assessment for its Phase I (City of Salinas) and Phase II (33 cities, five counties) municipalities, with a greater emphasis on quantifying pollutant loads in urban runoff. The Central Coast permittees are required to shift to a quantifiable load-based approach to assessing program effectiveness on a watershed or urban catchment scale. CCRWQCB staff and the Central Coast Low Impact Development (LID) Initiative and its subcontractor are assisting the permittees with development of urban catchment mapping protocols and design of a method for estimating urban catchment pollutant loads that integrates stormwater BMP assessment and tracking.

Current work on the Central Coast MS4 Support Project builds from earlier work completed in the Lake Tahoe Water Board Region (Region 6) to provide a useable, transparent and scientifically-credible tool to estimate baseline pollutant loads, determine relative spatial risks to receiving water quality, and quantify the expected load reduction associated with water quality improvement actions. Rather than attempting to model multiple pollutant types, the methodology uses proxies (total suspended solids and runoff volume) to create a ranking of urban catchments in terms of relative risk to the receiving water. The result is an effective communication tool between municipal stormwater program staff and their elected officials, as well as between municipal staff and CCRWQCB staff.

3.2.4 Lahontan/Lake Tahoe Region

The Lake Tahoe TMDL established pollutant load estimates and load reduction requirements for total nitrogen, total phosphorus, and fine sediment particles that source categories must meet on an average annual basis. The Lake Clarity Program (Crediting Program) defines a system to evaluate and track pollutant load reductions to demonstrate compliance with the load reduction requirements for fine particle sediment in the TMDL. This system provides methods for consistently linking implementation of pollutant controls to average annual pollutant load reduction estimates using numeric modeling tools. It establishes Lake Clarity Credits (credits) for actions taken to reduce pollutant loads as required by the Lake Tahoe TMDL.

The Lake Tahoe TMDL load reduction requirements were incorporated into the El Dorado County, Placer County, and City of South Lake Tahoe MS4 Permit (Order No. R6T-2011-101A1). Similar to the MRP, the Lake Tahoe MS4 Permit required the permittees to develop a Pollutant Load Reduction Plan that identifies the areas where control measures will be implemented, describes the control measures, provides an estimate of the baseline pollutant loading and expected load reductions, and describes a schedule for achieving the permit's pollutant load reduction requirements with an estimate of expected pollutant load reductions for each year of the permit term based on numeric modeling results.

4.0 MODELING ALTERNATIVES

Pollutant loads are a function of runoff volume and pollutant concentration. Models, from simple to complex, can be used to estimate both of these components of pollutant load. Model selection depends greatly on the objectives and desired complexity, with modeling costs generally increasing and scientific uncertainty generally decreasing with greater model complexity. Note that models can be used both as a decision-making tool (i.e., to select and site control measures) as well as a predictive tool (i.e., to estimate loads reduced by a specified control measure or control measure plan).

4.1 Modeling Overview

4.1.1 Hydrologic Models

Hydrologic models are used to estimate runoff volume. Hydrologic models simulate watershed hydrologic processes using representations of hydrologic cycle elements. Such processes include rainfall, hydrologic losses (i.e., infiltration and evapotranspiration), and runoff. Hydrologic models are used for a wide variety of conditions and scales. Hydrologic models can also include hydraulic elements such as pipe flow, which account for physical restrictions on water flow and how those restrictions may affect volume and timing of flow.

Hydrologic models vary in complexity, from single equation representations of individual storm events (e.g., the Rational Method Equation, where stormwater discharge is calculated as the product of a runoff coefficient (i.e., imperviousness), rainfall, and drainage area) to dynamic continuous simulations involving sophisticated algorithms which calculate runoff, losses, and other hydrologic metrics at each model "time step" over a selected simulation period. Complex models often require input of data or assumptions for dozens of parameters (e.g., the Bay Area Hydrology Model (BAHM)).

4.1.2 Water Quality/Pollutant Loading Models

Water quality or pollutant loading models are models that estimate the amount of a specific pollutant or pollutants reaching a receiving water body through hydrologic processes, primarily runoff. These models typically estimate pollutant loads using land use-based information to calculate runoff volume and assign land use-specific pollutant concentrations (based on empirical values). Many pollutant loading models also estimate the pollutant-removing effects of various stormwater BMPs.

4.1.3 GIS-Based Analyses

GIS-based analyses incorporate geospatial data into modeling calculations, typically through the development of inputs. ArcGIS is often used as the platform for these analyses, and many models are compatible and/or integrated with ArcGIS. For simpler models, these GIS inputs allow for spatially accurate representations of modeled areas. In 3-D models (i.e., those that calculate how outputs behave in a topographically and spatially unique area), geospatial data may be used dynamically to show the effect of model output in a 3-D space (e.g., spatially-accurate areas of flooding).

Green Plan-IT[4] is an example of a GIS-based analysis tool. Green Plan-IT consists of a GIS Site Locator Tool, a Modeling Tool, and an Optimization Tool. The GIS Site Locator Tool can create maps of suitable locations for different types of green infrastructure by analyzing user-defined goals, land use, soil type, water quality, installation feasibility, and other factors. The Modeling Tool is hydrologic model built upon USEPA's Storm Water Management Model (SWMM)[5], which evaluates the relative effectiveness of LID BMP implementation with regard to runoff volume and pollutant loading. The Optimization Tool works in concert with the GIS Site Locator and Modeling Tools to evaluate the benefits and costs of various LID BMP implementation plans and to compare their performance. Tool outputs can be combined with maps produced by the GIS Tool to create a map of the most effective implementation locations.

4.1.4 Spreadsheet-Based Models

Spreadsheet-based models are models built within a spreadsheet format (e.g., using Microsoft Excel). Spreadsheet models can be used to calculate both simple hydrologic processes and pollutant loading by applying specific hydrologic equations and relationships. Spreadsheet models can also be used to process geospatial data and calculate hydrologic output and pollutant loads.

The Regional Watershed Spreadsheet Model (RWSM) is an example of such a model (Wu et al., 2015). The RWSM is a regional-scale planning tool developed by SFEI primarily to estimate long-term average annual loads from the small tributaries surrounding San Francisco Bay and secondarily to provide supporting information for prioritizing large watersheds or areas within watersheds for management actions. The RWSM is structured with three stand-alone empirical models[6]: A hydrology model, a sediment model, and pollutant models. The hydrology model uses runoff coefficients based on land use-soil-slope combinations to estimate annual runoff from a watershed. The sediment model uses a function of geology, slope, and current land use to simulate suspended sediment generation and transport while adjusting for watershed storage factors. The pollutant model is essentially a "concentration map" that can be driven by either the hydrology model (for pollutant concentrations in water) or the sediment model (for pollutant concentrations on fine sediment particles as particle ratios for specific land use or source areas). The RWSM was

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[4] See: http://greenplanit.sfei.org/.

[5] USEPA's Storm Water Management Model (SWMM) is a dynamic rainfall-runoff simulation model which can be used for both single event and continuous (long-term) simulation of runoff volume in urban areas. SWMM can be used to model subcatchment areas, which generate runoff, as well as routing of runoff through pipes, channels, and storage units (i.e., BMPs).

[6] Empirical models rely on empirical observations rather than on mathematically-described relationships of the system modeled.

developed at a coarse spatial scale (i.e., for large tributary watersheds), so may not be useful for the purposes of RAA analysis at smaller watershed/catchment scales.

4.2 Summary of Existing Models

Table 3 presents a summary of hydrologic and pollutant loading models[7] that could be used to develop a RAA. Models considered feasible for use are those which would provide the needed output (namely, pollutant loading from land uses and anticipated load reductions from various BMPs) without substantial pre- or post-processing requirements and without unnecessary additional model functionality (for example, inclusion of sanitary sewer modeling, which is not needed for the RAA). Models that were not included in Table 3 may be appropriate for use if the intent of the modeling exercise is to answer multiple watershed questions, and/or if the user has specific datasets or tools which may complement these models better. There may also be other models available which have not been included in this table that meet the analyses requirements of the RAA.

Some of the terms used in Table 3 are defined below:

BMP Calculator: BMP calculators focus on how a BMP treats or reduces influent volumes, concentrations, and loads as stormwater flows into and out of the BMP.

Input Complexity: Relative input complexity is indicated. Complexity ranges from Low (limited data inputs) to High (multiple long-term data inputs, including historical hourly weather data, detailed land use areas, etc.).

Simulation Type: The simulation type refers to the time frame for which the output is generated. An event-based simulation provides results for a single storm event. Continuous simulation provides long-term output (generated using long-term historical weather and other inputs), which allows the user to look at varying event types and scenarios like back-to-back rainfall events (i.e., rainfall events occurring in quick succession). Average annual results are typically produced from average annual inputs and/or statistical methods, such as Monte Carlo methods, which examine tens of thousands of potential scenarios to estimate a statistically robust average.

Type of Water Quality Model:

- Loading – these models provide an estimate of the total pollutant load discharged from a drainage area. The modeled drainage area may include BMP treatment, routing, or other features depending on the complexity of the model.
- Receiving Water – these models provide an estimate of the pollutant load and/or concentration in the receiving water and vary in complexity depending on the flow states

[7] An adaptation of a model matrix developed by the Minnesota Pollution Control Agency, see: http://stormwater.pca.state.mn.us/index.php/Available_stormwater_models_and_selecting_a_model.

the model analyzes (i.e., steady state, dynamic flow, etc.). This model type is generally not recommended for the RAA.

- BMP – These models provide loading estimates out of a BMP if influent is provided. In general they will not provide calculation of influent loading.

Built-in BMPs: Model built-in BMPs are present when there are assumed inputs and/or configurations already provided within the model which represent BMP treatment function. These models do not require the user to develop configurations or treatment assumptions that would be used to model BMPs (unless desired).

5.0 CONCLUSIONS AND RECOMMENDATIONS

Based on information presented above, this section draws conclusions and makes recommendations for RAA development in the Bay Area.

5.1 Conclusions

There are two types of RAAs required by the MRP, one for green infrastructure and one for the overall PCBs/Mercury Control Measure Implementation Plan. The analytical methods used to develop these two different RAAs do not need to be the same and likely could differ, although the following goals and objectives should apply to both:

- The Bay Area RAAs should reflect our current understanding of POC distribution, fate, and transport.
- The Bay Area RAAs should incorporate the appropriate level of accuracy and precision given the level of uncertainty and variability in the data, assumptions, and TMDL load estimations.
- The Bay Area RAA approach should allow for using the simplest method possible that meets the MRP requirements.
- The Bay Area RAA methodologies should provide sufficient analytical rigor that is validated through a peer review process and will be acceptable to SFRWQCB staff.

5.2 Recommendations

5.2.1 Green Infrastructure RAA

The green infrastructure RAA should be the more rigorous of the two RAAs. The approach taken for the green infrastructure RAA should be similar to the modeling approaches taken in the other areas of California, as summarized in Section 3.2, perhaps building on the RWSM or Green Plan-IT, or an equivalent level of hydrology and water quality modeling. The focus of the SFRWQCB will likely be the green infrastructure RAA.

5.2.2 PCBs/Hg Implementation Plan RAA

The PCBs/Hg Implementation Plan RAA should incorporate the results of the green infrastructure RAA for green infrastructure control measures and should be a refined version of the Interim Accounting Methodology for all other control measures. The refinements should be informed by data collected during this permit term, such as:

- Revisions to the estimated land used-based yields or equivalent using the most recent empirical data (perhaps by SFEI with the RWSM).
- Improved estimates of the percent of material collected by full trash capture devices that is sediment, the sediment density, and the average particle concentration in the captured sediment.
- Improved estimates of all of the metrics that were used to estimate the loads of PCBs that are prevented from entering the MS4 during building renovation and demolition.
- Data to support the quantity of PCBs-containing caulks and sealants in public infrastructure such as parking garages, bridges, dams, storm drain pipes, and joints between pavement (e.g., curb and gutter); how much is currently being released to the MS4 prior to and during infrastructure improvements, and how much is prevented from entering the MS4 as a result of implementing proper controls.

5.2.3 Process Moving Forward

Based on this review, we recommend the following next steps:

- Setting up a RAA Technical Committee that would include BASMAA representatives, SFRWQCB staff, SFEI, and other technical experts to help to flush out RAA details going forward; and
- Developing a RAA guidance document specific to the Bay Area and similar in scope to the LARWQCB's guidance document, which defines the specific models that may be used, required model input data and allowable data sources, and model calibration criteria.

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TABLES

Table 1: RAA Permit Requirements and Modeling for Four Regions within California

Region	Permit	Plan/Program Name(s)	Analysis Objective	Acceptable Models	Model/ Analysis Requirements	Model Input/ Output Timeframe	General BMP Requirements	POCs	Compliance Timeframe	Reporting/ Updating Requirements
Los Angeles Region	Phase I MS4 Permit for Los Angeles Region. Order No. R4-2012-0175. Amended 2015.	• Watershed Management Program (WMP) • Enhanced Watershed Management Program (EWMP)	Demonstrate the ability of WMPs and EWMPs to ensure that Permittees discharges achieve applicable water quality-based effluent limitations and do not cause or contribute to exceedances of receiving water basin plan objectives.	• Watershed Management Modeling System [WMMS- Loading Simulation Program in C++ (LSPC) and System for Urban Stormwater Treatment and Analysis Integration (SUSTAIN)] • Hydrologic Simulation Program-FORTRAN (HSPF) • Structural BMP Prioritization and Analysis Tool (SBPAT)	Nguyen et al. (2014) has model requirements.	RAA must use watershed data within last 10 years.	BMP performance data for model input must come from peer-reviewed sources.	Nitrogen Compounds, Chloride, Trash, Debris, Indicator Bacteria, DDT, PCBs, Nutrients, Toxic Pollutants, Metals, Sediment, Invasive Exotic Vegetation, Pesticides, Selenium	TMDL compliance schedule	• Comparison of the effectiveness of the control measures to the results projected by the RAA for the adaptive management process • Each Permittee shall submit a TMDL Compliance Report as part of its Annual Report detailing compliance with the applicable interim and/or final effluent limitations.
San Diego Region	Phase I MS4 Permit for San Diego Region. Order No. R9-2013-0001. Amended 2015.	Water Quality Improvement Plan (WQIP)	• The analysis, with clearly stated assumptions included in the analysis, must quantitatively demonstrate that the implementation of the water quality improvement strategies will achieve the final numeric goals within the schedules. • The Copermittees must develop and incorporate schedules for achieving the numeric goals into the WQIP. The schedules must demonstrate reasonable progress toward achieving the final numeric goals.	• Include an analysis in the WQIP, utilizing a watershed model or other watershed analytical tools, to demonstrate that the implementation of the BMPs required achieve compliance with Specific Provisions. • Transportation and Storm Water Department WQIPs modeling system based on LSPC and SUSTAIN (SFB RWQCB and U.S. EPA Region 9, 2015)	• The development of the analysis must include a public participation process which allows the public to review and provide comments on the analysis methodology utilized and the assumptions included in the analysis. Public comments and responses must be included as part of the analysis documentation included in the WQIP. • Analysis must be accepted by the San Diego Water Board as part of the WQIP.	None specified in MS4 permit.	Achieve water quality standards through an iterative approach requiring the implementation of improved and better-tailored BMPs over time.	Diazinon, Dissolved Copper, Dissolved Lead, Dissolved Zinc, Total Nitrogen, Total Phosphorus, Indicator Bacteria, Sediment	TMDL compliance schedule	• The analysis must be updated as part of the iterative approach and adaptive management process • Management strategies proposed in the WQIP have been integrated within the City's Watershed Asset Management Plan to provide a comprehensive financial analysis of the City's stormwater planning needs (SFRWQCB and U.S. EPA Region 9, 2015)

Region	Permit	Plan/Program Name(s)	Analysis Objective	Acceptable Models	Model/ Analysis Requirements	Model Input/ Output Timeframe	General BMP Requirements	POCs	Compliance Timeframe	Reporting/ Updating Requirements
Central Coast Region	Phase II Small MS4 Permit. Order No. 2013-0001-DWQ.	• Program Effectiveness Assessment and Improvement Plan (PEAIP) • Wasteload Allocation Attainment Programs (WAAP) • Central Coast MS4 Support Project	• A statistical analysis of the monitoring data to assess progress, and an assessment of the effectiveness of implemented BMPs, in progressing towards attainment of wasteload allocations within the TMDLs' specified timeframes. • Quantification of pollutant loads and pollutant load reductions achieved by the program as a whole.	• None specified in MS4 permit. • Models that have been used for MS4 Support Project are Tool for Estimating Load Reductions (TELR) and BMP Rapid Assessment Methodology (BMP RAM).	• None specified in MS4 permit. • Tools for MS4 Support Project will be available to any municipality in late 2016 (SFB RWQCB and U.S. EPA Region 9, 2015).	None specified in MS4 permit.	Reduce pollutants from the MS4 to the maximum extent practicable (MEP).	Sediment, Pathogens, Diazinon, Pesticides, Methylmercury	TMDL compliance schedule	The Permittee shall use State Water Board Storm Water Multi-Application Reporting and Tracking System (SMARTS) to submit a summary of the past year activities and certify compliance with all requirements of this program element. The summary shall also address the relationship between the program element activities and the Permittee's PEAIP that tracks annual and long-term effectiveness of the storm water program.
Lahontan Region (El Dorado County, Placer County, City of South Lake Tahoe within the Lake Tahoe Hydrologic Unit)	Phase I MS4 Permit. Order No. R6T-2011-101A1.	• Lake Clarity Crediting Program (Crediting Program) • Pollutant Load Reduction Plan (PLRP)	• The Lake Tahoe TMDL baseline pollutant loading and load reduction requirements are provided as average annual estimates. • The schedule shall include an estimate of expected pollutant load reductions for each year of this Permit term based on preliminary numeric modeling results.	• Pollutant Load Reduction Model (PLRM) • Permittees shall use the BMP RAM and the Road Rapid Assessment Methodology (Road RAM) or their equivalents (subject to Water Board acceptance) to assess, score, and document the actual condition of treatment BMPs and roadways.	• PLRM User's Manual has model requirements (NHC, 2015) • BMP RAM technical has model requirements (2NDNATURE et al., 2009) • Road RAM technical document has model requirements (2NDNATURE et al., 2010)	The pollutant load reduction estimate shall differentiate between estimates of pollutant load reductions achieved since May 1, 2004 and pollutant load reductions from actions not yet taken.	Implement BMPs to prevent or reduce any pollutants that are causing or contributing to the exceedance of water quality standards.	Fine Sediment Particles (FSP), Total Nitrogen (TN), and Total Phosphorus (TP)	Each jurisdiction must reduce FSP, TP, TN loads by 10%, 7%, and 8%, respectively, by September 30, 2016.	By March 15 of each subsequent year of the Permit term, each Permittee shall submit a comprehensive electronic report that summarizes cumulative stormwater monitoring results from the catchment load monitoring and BMP effectiveness evaluations conducted during the previous water year (October 1 – September 30).

References:

2NDNATURE LLC, Northwest Hydraulic Consultants and Environmental Incentives. (2009). BMP RAM Technical Document, Lake Tahoe Basin. Prepared for USACE, Sacramento District. September.

2NDNATURE LLC, Northwest Hydraulic Consultants and Environmental Incentives. (2010). Road RAM Technical Document, Tahoe Basin. Final Document. Prepared for the California Tahoe Conservancy and Nevada Division of Environmental Protection. November.

CC RWQCB. (2015). Staff Report for Regular meeting of September 24, 2015. Prepared on August 25, 2015. Item No. 11

Nguyen, T., Lai, C.P, Ridgeway, I., and Zhu, J. (2014). Guidelines for Conducting Reasonable Assurance Analysis in a Watershed Management Program, Including an Enhanced Watershed Management Program. March 25.

Northwest Hydraulic Consultants (NHC). (2015). Pollutant Load Reduction Model. Version 2.1. User's Manual Version. May

SFB RWQCB and U.S. EPA Region 9. (2015). Stormwater Workshop-"Integrating Reasonable Assurance Analysis and Stormwater/Green Infrastructure Plans". Agenda and Case Studies. September 23.

Table 2: RAA Model Comparison

Model or Tool	*Model Type* Hydrologic Model	Hydrologic and Hydraulic Model	Water Quality Model	BMP Calculator	Notes	Input Complexity	Simulation Type(s)	Public Domain	Type of Water Quality Model	Built-in BMPs
BASINS			X		Better Assessment Science Integrating point and Nonpoint Sources model incorporates GIS and can be used for a variety of watershed analyses.	Varies	Event or Continuous	Yes	Loading	No
BMP RAM			X	X	Currently developed for specific regions (Lake Tahoe and Central Coast).	Low	Continuous (Average Annual)	Yes	Loading, BMP	Yes
EPA SWMM		X	X		SWMM can be used on its own or in combination with separate pollutant loading models.	Medium/ High	Event or Continuous	Yes	Loading, Receiving Water	Yes
InfoSWMM		X	X		Typical use requires more detailed hydraulic information.	Medium/ High	Event or Continuous	No	Loading, Receiving Water	Yes
i-Tree Hydro			X	X	Specific to vegetation effects on hydrology.	Low	Event	Yes	Loading	Yes
LSPC		X	X		Developed for Los Angeles but has been modified for other regions (not SF Bay Area). Can be linked to BASINS and SUSTAIN.	High	Event or Continuous	Yes	Loading, Receiving Water	Yes
MIKE URBAN (SWMM or MOUSE)		X	X		Can be used to cover all water networks, including stormwater, drinking water, and wastewater.	Medium/ High	Event or Continuous	No	Loading, Receiving Water	Yes
Optimizer					Used accompanying other models to provide iterative prioritization of inputs.	Medium/ High	Event or Continuous	No	--	No
P8			X		Website states program is "more accurate for relative predictions (i.e., removal efficiencies) than absolute predictions (concentrations and loads)"	Medium	Event or Continuous	Yes	BMP, Loading	Yes
PCSWMM		X	X		Proprietary version of EPA's SWMM. Provides linkage to GIS.	Medium/ High	Event or Continuous	No	Loading, Receiving Water	Yes
PLOAD			X		Must be linked to BASINS for functionality.	Low	Event	Yes	Loading	Yes
QHM			X		Includes limited number of BMPs.	Medium	Event or Continuous	No	Loading	Yes
Road RAM			X		Specifically estimates risk of specified roads to impact downstream water quality.	Low	Average Annual	Yes	Loading, BMP	No
SBPAT			X		Used to prioritize BMP activities in a watershed to optimize water quality return on investment.	Medium	Average Annual	Yes	Loading, BMP	Yes
SELDM			X	X	Used for highway sites only.	Low		Yes	Stochastic	No
SELECT				X	Allows for comparison of effectiveness and whole life costs of alternative BMP scenarios.	Low	Event	Yes	--	Yes
SUSTAIN	X		X		Used to develop, evaluate, and select optimal BMP combinations at various watershed scales based on cost and (user-defined) effectiveness.	Medium	Event or Continuous	Yes	--	Yes
Tahoe PLRM			X		Customized version of SWMM currently specific to Tahoe region.	Low/ Medium	Average Annual	Yes	Loading, BMP	Yes
TELR			X		Available mid-2016. Currently focused on Phase II requirements.	Medium	Average Annual	Yes	Loading, BMP	Yes
WARMF		X	X		Allows development and evaluation of water quality management alternatives for a river basin.	Medium	Event or Continuous	Yes	Loading, Receiving Water	No
WinHSPF		X	X		Key component of BASINS Version 3.0 (distributed with BASINS).	High	Event or Continuous	Yes	Loading, Receiving Water	Yes
WinSLAMM			X		Evaluates runoff volume and pollution loading for each source area within each land use for each rainfall event.	Medium	Event	No	BMP, Loading	Yes
WMM			X		Developed specifically to estimate annual/seasonal nonpoint pollutant loads from direct runoff on watersheds and subbasins.	Low	Average Annual	Yes	Loading	No
XPSWMM		X	X		Proprietary version of SWMM that can be used for hydrodynamic analyses of flood, sanitary/CSO, and stormwater.	Medium/ High	Event or Continuous	No	Loading, Receiving Water	Yes

Note: This table is adapted from a model matrix developed by the Minnesota Pollution Control Agency, see: http://stormwater.pca.state.mn.us/index.php/Available_stormwater_models_and_selecting_a_model.