Alameda Countywide
Clean Water Program

Contra Costa
Clean Water Program

Fairfield Suisun
Urban Runoff
Management Program

Marin County
Stormwater Pollution
Prevention Program

Napa County
Stormwater Pollution
Prevention Program

San Mateo Countywide
Water Pollution
Prevention Program

Santa Clara Valley
Urban Runoff Pollution
Prevention Program

Sonoma County
Water Agency

Vallejo Sanitation
and Flood
Control District

B A S M A A

Regional Monitoring Coalition
Urban Creeks Monitoring Report
Water Year 2012

Submitted pursuant to
Provision C.8.g.iii of Order R2-2009-0074
on behalf of all Permittees

Bay Area

Stormwater Management

Agencies Association

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March 15, 2013

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C. Sediment Delivery Estimate/Budget (C.8.e.vi)

Provision C.8.e.(vi) of the MRP requires Permittees to develop a design for a robust sediment delivery estimate/sediment budget in local tributaries and urban drainages, and implement the study by July 1, 2012. The purpose of the sediment delivery estimate is to improve the Permittees' ability to estimate urban runoff contributions to loads of POCs, most of which are closely associated with sediment. To determine a strategy for a robust sediment estimate/budget, RMC representatives reviewed recent sediment delivery estimates developed by the RMP, and determined that these objectives will be met through sediment-specific modeling with the regional watershed model. The implementation of the sediment delivery/budget study is occurring in coordination with the STLS Multi-Year Plan. BASMAA-funded sediment work will also enhance the model development for PCBs and other sediment-bound POCs. A more detailed work plan and schedule for the integration of the sediment load estimation with other regional watershed modeling work is included as **Appendix D1**.

D. Emerging Pollutants Work Plan

In compliance with Provision C.8.e.v, Permittees are required by March 2014 to develop a work plan and schedule for initial loading estimates and source analyses for the following emerging pollutants:

1) Endocrine-disrupting compounds;
2) Perfluorooctane Sulfonates (PFOS);
3) Perfluoroalkyl Sulfonates (PFAS); and,
4) Nonylphenols/nonylphenol esters—estrogen-like compounds (NP/NPEs).

The intent of the work plan is to begin planning for implementation during the next permit term (i.e., post December 2014).

BASMAA representatives to the STLS Team will coordinate efforts with the Emerging Contaminants Strategy being developed by the RMP through the Master Planning process. The compliance date for completion of this work plan is in 2014. Initial discussions of the scope of this project were conducted by the RMC participants during this reporting period.

Appendix D

Pollutants of Concern Monitoring (Provision C.8.e)

D1 - Small Tributaries Loading Strategy (STLS) Multi-Year Monitoring Plan (Version 2013)

D2 - Pollutants of concern (POC) loads monitoring data progress report (Water Year 2012)

D1

Small Tributaries Loading Strategy (STLS) Multi-Year Monitoring Plan (Version 2013)

Small Tributaries Loading Strategy Multi-Year Plan - Version 2013

Prepared for

Bay Area Stormwater Management Agencies Association (BASMAA)

And

Regional Monitoring Program for Water Quality in the San Francisco Estuary
Sources Pathways and Loadings Workgroup (SPLWG)
Small Tributaries Loading Strategy (STLS)

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Final: March 7, 2013

Small Tributaries Loading Strategy Multi-Year Plan

Contents

Acknowledgments

This document was developed collaboratively by the Small Tributaries Loading Strategy Local Team of the Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP):

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- Arleen Feng (ACCWP) and Chris Sommers (EOA/SCVURPPP) for BASMAA
- Richard Looker, Tom Mumley and Jan O'Hara (SFRWQCB)

BASMAA and ACCWP provided funding for preparation of the draft text and Appendix A incorporating information from many working products by RMP and BASMAA. [SFEI staff are responsible for preparation of Appendices B, C, D, E and G – if not credited in those respective appendices];

Additional technical advice to the STLS Work Group was provided in early meetings by Mike Stenstrom (UCLA) and Eric Stein (SCCWRP), who also participated in reviews by the RMP Sources Pathways and Loadings Workgroup and more recently since October 2011, by Roger Bannerman, retired and formerly of DNR Wisconsin.

Members of the BASMAA Monitoring and Pollutants of Concern Committee and stormwater program staff also participated in development and review of the Multi-Year Plan, especially Jamison Crosby and Khalil Abu-Saba (Contra Costa Clean Water Program) and Jon Konnan and Lucy Buchan (San Mateo Countywide Water Pollution Prevention Program).

Introduction

The Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP) was established to provide the scientific information needed to support water quality management. In the 21st century, the RMP's activities are shifting to provide more direct support for answering specific Management Questions through multi-year Strategies consisting of coordinated activities centered on particular pollutants or processes. The Small Tributaries Loading Strategy (STLS, SFEI 2009) presented an initial outline of potential activities to address four key Management Questions regarding local watershed contributions of Pollutants of Concern to San Francisco Bay. The objective of this Multi-Year Plan (MYP) is to provide a more comprehensive description of the suite of activities to be included in the STLS over the next 5-10 years. It provides a detailed rationale for the methods and locations of proposed activities, including watershed monitoring of local tributaries.

Some of these activities will be conducted by stormwater programs to fulfill the requirements of the Municipal Regional Stormwater Permit (MRP, SFRWQCB 2009) for Pollutants of Concern (POC) loads monitoring[1]; this MYP documents an improved alternative monitoring approach for addressing these MRP needs that is integrated with the RMP-funded activities.

The MYP includes continuing development of the Regional Watershed Spreadsheet Model as a tool for estimating regional loads. It also clarifies the linkage between the STLS and the RMP's developing Modeling Strategy for pollutant fate and transport in the Bay as a whole and also in the Bay margins which are a vital link between the local watersheds and the Bay.

The first version of the MYP (Version 2011) was prepared in September 2011. Updated Versions 2012A and 2012B incorporated additional information and STLS activities through July 2012, including:

- Development of the Regional Watershed Spreadsheet Model including preliminary explorations and recommendations for developing Event Mean Concentrations to parameterize the model for priority POCs and planning submodel construction for individual POCs .
- Initiation of watershed monitoring at four initial sites, supported by preparation of a draft Quality Assurance Project Plan (QAPP) and Field Manual, and coordination among field crews.
- Coordination and standardization of laboratory contracting and management and Quality Assurance/Quality Control (QA/QC) of watershed monitoring data

Version 2013 incorporates additional information and STLS activities through January 2013, including:

[1] Described in MRP Provisions C.8.e and its sub-provisions i, iii, iv and v. Sub-provisions vi and vii are also related to the same objectives, see Appendix A.

- Development of a user interface for the RWSM, and spatial datasets for modeling of copper, mercury and PCBs.
- Review of lessons learned from the first year of watershed monitoring
- Startup of two additional watershed monitoring sites in addition to the four previously selected.

Previous MYP versions included Appendices with supporting information and details of individual MYP elements[2]. Updated or new versions of some Appendices will be provided in the future.

Background

Based on data collected by the RMP and others, the San Francisco Regional Water Quality Control Board (Water Board) has determined that San Francisco Bay is impaired or potentially impaired by a number of POCs. For some of these, the Water Board has adopted water quality attainment strategies including Total Maximum Daily Loads (TMDLs) for mercury and PCBs (SFRWRCB 2006, 2008) due to their persistence in the environment and accumulation in aquatic food webs that pose threats to wildlife and human consumers of fish from the Bay.

Each TMDL identifies sources and pathways contributing to the impairment or detrimental effects associated with the subject pollutant, as illustrated for PCBs (Figure 1). The sizes of the arrows on the figure illustrate, conceptually, the importance of each source, pathway or process. For PCBs, urban runoff, deposition of associated sediment, and transfer from sediment up through the food chain are the important pathways and processes. For each source, the TMDL estimates current annual loads and identifies reductions in those loads that would be required to eventually eliminate the impairment. Each TMDL is adopted along with an implementation plan consisting of management actions to be taken by various discharger groups in order to achieve these load reductions.

Urban runoff from local watersheds is a significant pathway for many pollutants of concern into the Bay, and the MRP contains several provisions requiring management actions and studies to address mercury and PCB its (see Appendix A for details). The MRP's monitoring provisions also include other pollutants for which storm water data are needed. The MRP also encourages coordination of storm water program activities with the RMP are other regional collaborative groups.

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[2] On behalf of MRP Permittees, the Bay Area Stormwater Management Agencies Association (BASMAA) provided MYP Version 2011 and available Appendices A, C, D, E and F to the San Francisco Regional Water Quality Control Board as attachments to a Monitoring Status Report (Part B of a composite document that also included a Regional Pollutants of Concern Report for required annual reporting) in September 2011. In September 2012, MYP version 2012B was attached to another semiannual Monitoring Status Report along with Appendix B, ; Internet links for the above Appendices are listed at the end of this document. This version of the MYP is included in the BASMAA Regional Monitoring Coalition Urban Creeks Monitoring Report (UCMR) of March 2013, as UCMR Appendix D-1.

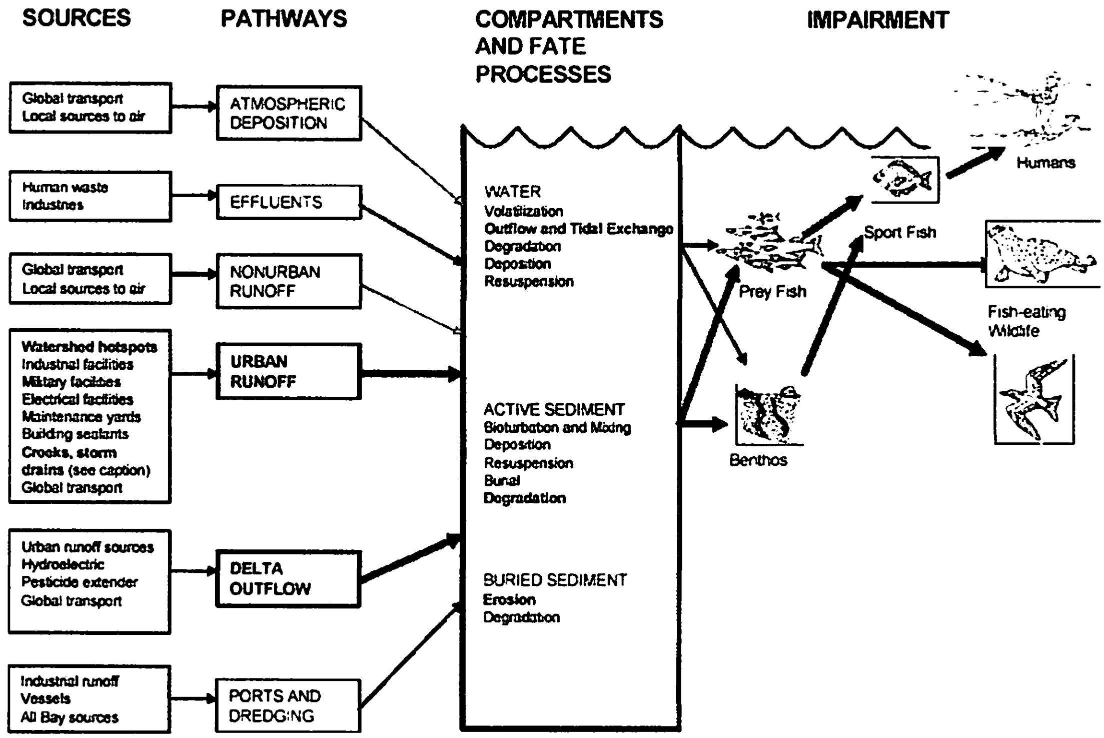

Figure 1. Conceptual Model of PCBs in San Francisco Bay (from Davis et. al 2006)

The STLS MYP is a major component of the RMP Multi-Year Plan, which integrates the efforts of many workgroups and strategy teams to develop five-year plans addressing the highest priority management information needs identified by the RMP stakeholders. The intent of the Multi-Year Plan is to anticipate regulatory or management decisions and policies that are on the horizon, so that the specific scientific knowledge needed to inform the decisions will be available at the required times.

The RMP's Multi-Year Planning Process, initiated as the "Master Planning Process" in 2010[3], articulates several "strategies" which coordinate studies across the pre-existing process-oriented work groups (see Appendix A). The STLS is a major strategy with linkages to other strategies for mercury, PCBs and forecasting/ modeling. The Water Board has given a high priority to refining and tracking load estimates of PCBs and mercury to assess progress towards the reductions in the TMDLs. Initial estimates of stormwater contributions to annual loads of mercury and PCBs to the Bay were based on limited data and one of the RMP's goals has been to improve both data collection and the conceptual framework for developing load estimates. Understanding trends from individual watersheds will also be important, whether in response to general demographic

[3] RMP activities are planned on a calendar year basis, while BASMAA and most of its member agencies operate on a Fiscal Year (FY) that begins on July 1.

and climatic changes or targeted management actions to reduce local discharges of PCBs and mercury.

Depending on the state of existing knowledge and potential impairment status, loading information needs may be a somewhat lower priority for other POCs such as copper (for which the highest priority information gaps are about effects and not loading) or legacy organochlorine pesticides (for which the monitoring objective may be tracking a long-term "recovery" curve of diminishing concentrations in the Bay). A third group of POCs are present in the Bay at concentrations that cause concern; since existing data are insufficient to assess the amount of contribution from stormwater conveyance, initial STLS work will contribute to a general characterization of spatial occurrence and ranges of concentrations. This differential prioritization is reflected in the MRP's partitioning of required stormwater monitoring parameters into two groups with different levels of minimum sampling frequency:

- Category 1 (minimum 4 events per year): Total and Dissolved Copper; Total Mercury; Total Methyl Mercury; Total PCBs; Suspended Sediments (SSC); Total Organic Carbon; Water Column Toxicity; Nitrate as N; Hardness.
- Category 2 (minimum 2 events in alternate years): Total and Dissolved Selenium; Total PBDEs (Polybrominated Diphenyl Ethers); Total PAHs (Poly-Aromatic Hydrocarbons); Chlordane; DDTs (Dichloro-Diphenyl-Trichloroethane); Dieldrin; Nitrate as N[4]; Pyrethroids - bifenthrin, cyfluthrin, beta-cyfluthrin, cypermethrin, deltamethrin, esfenvalerate, lambda-cyhalothrin, permethrin, and tralomethrin; Carbaryl and fipronil; Total and Dissolved Phosphorus.

The RMP Sources Pathways and Loadings Work Group (SPLWG) was initiated in 1999 to address pollutant loading to the Bay. It has overseen monitoring studies of high-priority POCs in small tributaries at the Guadalupe River (McKee et al., 2004; 2005; 2006) and at Zone 4 Line A (a small flood control channel in Hayward) (McKee et al., 2009; Gilbreath et al., in review) as well as at Mallard Island (Leatherbarrow et al., 2005; McKee et al., 2006; David et al., 2009, David et al., in review) where the Sacramento River enters the region.

Development of the draft MRP led to an RMP initiative in 2007 to develop the STLS as a framework for coordinating stormwater requirements and RMP activities. In recognition of those discussions already initiated prior to its adoption, the MRP allows Permittees to pursue an alternative approach to answer the same information needs underlying the STLS. The STLS Work Group, a subgroup of SPLWG, includes representatives from BASMAA and Water Board staff to ensure close coordination, as well as SFEI staff and technical advisors recruited through the RMP. A series of meetings during 2008 and 2009 and associated meeting support materials led to the finalization of the draft Strategy (SFEI, 2009). In 2009 and 2010 SFEI provided further planning support through the completion of several data synthesis reports (Greenfield et al., 2010; Melwani et al., 2010). An initial draft MYP presented the STLS Work Group's recommended approach

[4] Erroneous duplication in MRP language.

for implementing the STLS, was reviewed by the SPLWG at its May 2011 meeting, followed by brief review of the completed Version 2011 at its meeting on October 25, 2011; at this meeting the SPLWG agreed to a communications strategy for informing the SPLWG of further MYP updates produced by the STLS Work Group.

MYP updates in 2012 reviewed the status of planning and implementation for coordinated watershed monitoring beginning October 1, 2011[5]. This 2013 version updates the plan as of the second season of watershed monitoring begun in October 2013[6]. Further details and documentation of watershed monitoring and other work plan activities for later years will be added in future MYP versions as needed (see Adaptive Updates below).

Management Questions and Strategy Elements

The stakeholder process established the following Management Questions for the STLS:

1. Which Bay tributaries (including stormwater conveyances) contribute most to Bay impairment from POCs;
2. What are the annual loads or concentrations of POCs from tributaries to the Bay;
3. What are the decadal-scale loading or concentration trends of POCs from small tributaries to the Bay; and,
4. What are the projected impacts of management actions (including control measures) on tributaries and where should these management actions be implemented to have the greatest beneficial impact.

STLS technical activities are grouped into three Elements, listed with their sub-elements in Table 1. Figure 2 shows the main linkages between Management Questions and individual Elements; some Elements also support each other, as suggested by the dotted lines and described in the following MYP sections. Other activities outside the scope of the STLS also have bearing on these Management Questions; see Appendix A for background and context of regional projects to evaluate the potential effectiveness of management actions to reduce PCB and mercury loads to the Bay.

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[5] The Water Year (WY) designation used by USGS begins on October 1 of the previous year, which is the nominal start of the wet weather monitoring season in the Bay Area. Stormwater monitoring beginning in October is customarily budgeted by the RMP with funds for the following calendar year and by BASMAA with funds for the Fiscal Year beginning the previous July.

[6] Monitoring results for Water Year 2012 are reported separately in the main body and Appendix D-2 of the UCMR.

Table 1. Small Tributaries Loading Strategy Elements and projected implementation roles.

Element	RMP	Stormwater Programs
1. Watershed and associated Bay Modeling		
A. Regional Watershed Spreadsheet Model	X	
B. Coordination with Bay Margins Modeling	X	
C. HSPF dynamic modeling (potential)	(X)	
2. Source Area Runoff Monitoring and EMC Development	X	
3. Small Tributaries Monitoring		
A. Monitor Representative Small Tributaries	X	X
B. Monitor Downstream of Management Actions		X

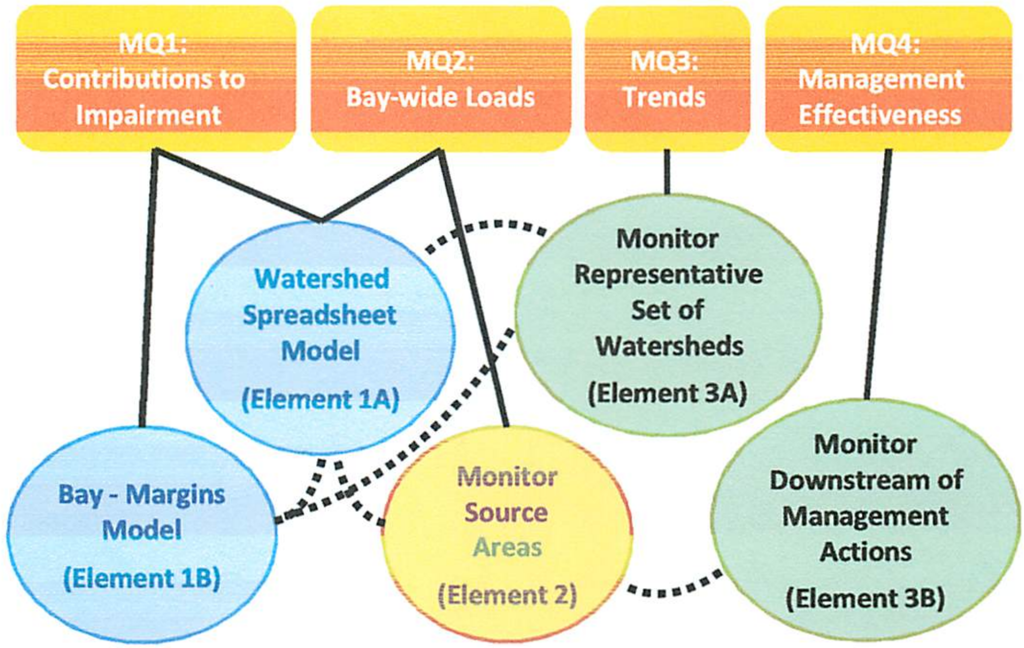

Figure 2: Primary relationships between Small Tributaries Loading Strategy management questions and Elements.

The first element, Modeling, includes a watershed spreadsheet model specifically designed to estimate Bay-wide loads of POCs (Management Question 2) which will also clarify the relative contribution of small tributary loads to the overall Bay impairment for each pollutant (Management Question 1). The spreadsheet model will provide first order estimates of relative load contributions from individual watersheds around the Bay and will help to identify high-leverage watersheds or more likely clusters[7] of watersheds that may be having a greater local impact to sensitive reaches of the Bay margin[8]. However, the model is of limited use for this question without comparable understanding of the spatial variation within the Bay and local contributions from non-runoff sources; these will be provided through a Bay margins model being developed by the RMP as part of a separate Forecasting or Modeling Strategy. In the future, dynamic modeling of one or more individual watersheds may be useful to deepen the understanding of underlying mechanistic behavior not captured by the spreadsheet model. The finer temporal scale of dynamic models may also be helpful in linking the tributary loads to the time scales of biological processes represented in the Bay margins model.

The second element, Monitor Source Areas, is intended to provide Event Mean Concentrations (EMCs) of targeted POCs to parameterize the watershed loadings spreadsheet model. Such monitoring would require catchments that are relatively homogenous in terms of land use or other source area characteristics, which would differ from the watersheds selected for Element 3. The STLS is exploring a number of desktop approaches to estimate EMCs for initial work on the Regional Watershed Spreadsheet Model. Understanding that is gained through this element about the range of EMCs and the factors that affect them can also inform the approach to monitoring downstream of management actions.

Element 3, Watershed Monitoring, has two sub elements to address Management Questions 3 and 4. Initial monitoring efforts focus on six watersheds which represent a range of size and land uses among urban watersheds. Two stations added in WY 2013 are located in pump stations that drain catchments where management actions for reducing PCB loads will be implemented by stormwater programs.

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[7] Given the lumped one-dimensional nature of the RWSM rainfall run-off model that is based on annual average rainfall, land use, and land use specific coefficients, it is considered unlikely that the model outputs will be reliable at the scale of the individual watersheds despite sub-regional and regional calibrations of potentially as good as +/-75% with less than +/-5% bias.

[8] Another group of spreadsheet models is being used by the stormwater programs to address Management Question 4 by providing quantitative scenarios of PCB and mercury load reductions from implementation of source control measures in local watersheds. Monitoring data from pilot projects begun in 2010 to refine and test these "desktop evaluation" models are also likely to provide useful input for running scenarios on the RWSM. See Appendix A.

Strategy Elements

Load Estimation and Modeling

The Regional Watershed Spreadsheet Model (RWSM) is the primary STLS tool for estimation of overall loads to the Bay. Spreadsheet runoff models are based on the simplifying assumption that unit area runoff for each homogenous subcatchment can be represented by a constant concentration (called an event mean concentration) for each POC. Given the large number of small tributaries, initial STLS Work Group discussions indicated this is more suitable as a framework for regional load estimation than simulation models such as HSPF and SWMM that require large and detailed calibration datasets. The RWSM is structured similarly to the model presented by Ha and Stenstrom (2008), using GIS-derived data for land use, imperviousness, average soil type/slope and annual precipitation. It uses recent local data on land use based concentrations collected in the Bay Area and augmented using data and information extracted from recent stormwater literature. The input coefficients such as EMCs for each target pollutant in the model can be updated periodically as new data become available through the monitoring elements of the STLS or related compatible efforts.

RWSM Development

This section summarizes the details and development of the RWSM which are described in reports submitted to the SPLWG and cited or provided in Appendix B in the 2012B version of the MYP. The model's spatial extent covers the entire region overseen by the Region 2 Water Board boundary (corresponding closely to the Calwater outline in Figure 3). Within this region, the spatial resolution of individual watershed areas is provided by several data sources:

- Watershed boundaries for Central and South Bay. The urban portions of this dataset are based on compilations by the Oakland Museum of California (OMC) Creek and Watershed Mapping Project (a long term collaboration between William Lettis and Associates, OMC, and SFEI funded by cities and counties http://www.sfei.org/content/gis-data). Begun in 1993, and largely completed in 2008 through a state bond-funded Proposition 13 grant awarded to SFEI, this dataset incorporates further corrections by stormwater managers and is provides a fairly accurate depiction of urbanized catchments, although many of the smaller catchments have been arbitrarily aggregated and the dataset is not fully conformant to data standards of the National Hydrography Dataset.
- Contra Costa Flood Control District's watershed boundaries to fill in the eastern portion of Contra Costa County (CCCDD, 2003)
- Provisionally, Calwater Hydrologic Areas are used to fill in remaining portions of the North Bay, Contra Costa, SF & coastal peninsula. Later versions of the RWSM could use increased spatial resolution provided by NHD or other sources if needed.

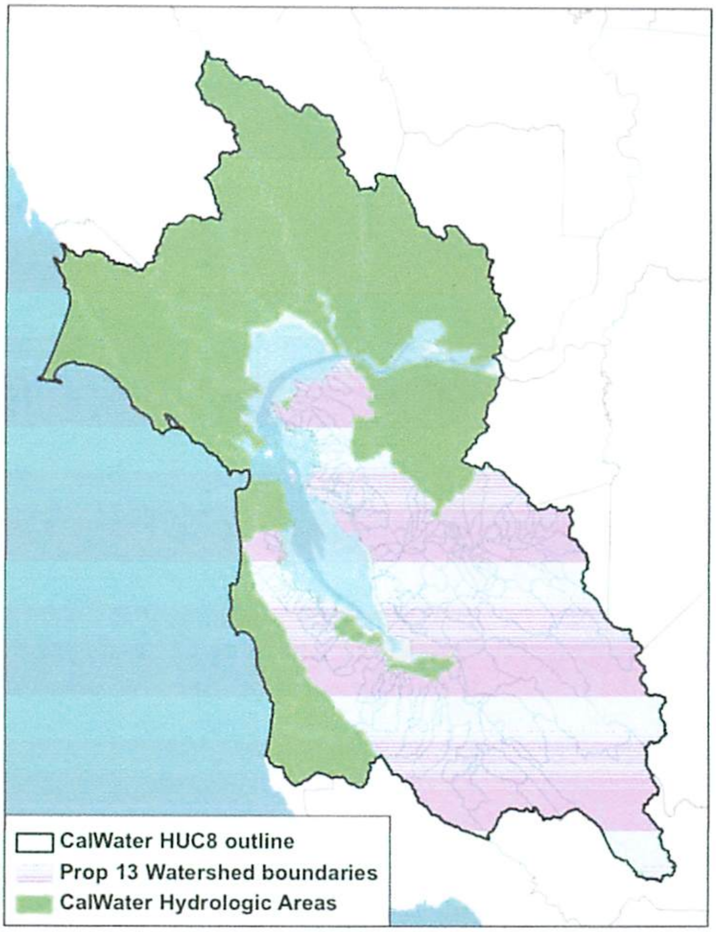

Figure 3: Spatial extent of RWSM and detailed watershed boundaries[9]

The outcomes of the first year included the development of two parallel hydrological models, one using land use based runoff coefficients and the other using imperviousness based runoff coefficients. The model outcomes were compared to empirical observations in 18 calibration watersheds. Preliminary loads of suspended sediment were also generated but the loads generated were quite different from the empirical observations (of which there are many).

The RWSM's land use dataset for the Bay Area (ABAG, 2005) is based on a combination of remote sensing and local assessor's parcel information. The first construction of the RWSM used the land use categories of Ha and Stenstrom (2008), with Event Mean Concentrations (EMCs) in initial runs taken from literature. Other categories could be substituted following further analyses from Element 2 studies to develop a framework for

[9] Watershed boundaries based on the Oakland Museum of California Guide to San Francisco Bay Area Creeks (http://museumca.org/creeks/GIS/index.html) and compiled and improved through a Proposition 13 grant awarded to SFEI (http://www.sfei.org/content/gis-data).

specific loads based on land use or other source area characteristics such as age or condition of development.

Work for the RWSM in 2011 included preparation of the Year 1 report (Lent and McKee 2011a) and follow-up on several of its recommendations to refine the hydrology model by:

- Adding several calibration watersheds to ensure watershed characteristics that span a wider range of imperviousness. Since the original calibration data set used in the RWSM year 1 model lacked representation at the high end of the imperviousness range, three high imperviousness catchments were added to the calibration data set. All three of these catchments drain to pump stations and required conversion of pump logs to estimated flow; these records were only available for short periods.
- Removing gage records for some watersheds and time periods with pre-development land use / impervious characteristics differing significantly from present conditions
- Refining land use categories with the updated ABAG 2005 dataset used as base. This improved the consistency of the spatial dataset among counties, particularly in the treatment of transportation land uses which are highly impervious.

The Year 2 progress report (Lent et al 2012) describes these model refinements and is incorporated as part of Appendix B, along with a workplan for further model development. The year 2 tasks served to correct or reduce errors and biases in the hydrological model that were noted in the year 1 report. The hydrologic model will need to be re-visited, in the context of further model development such as calibrating the sediment model or the pollutant models, which are the focus of RWSM work in year 3 (See Appendix B).

Each pollutant has a unique set of properties that determines its uses, the resulting products and environmental attributes such as in-use spatial distribution, potential for reuse, and mechanisms of inadvertent environmental pollution. A series of "pollutant profile" fact sheets will summarize these properties and frame conceptual models of source areas and other information needed to build each POC specific model using the RWSM. The initial version of the RWSM focuses on load estimates for sediment, mercury and PCBs. The year 1 report presents the available information and proposed modeling approaches for the highest priority POCs, along with discussion of data gaps:

- There is little direct EMC information about PCBs, so the sediment surrogate will initially be used to understand the potential range of loadings. Refining the spatial characterization of the particular types of land uses and source areas for PCBs is a high priority as described below.
- The sediment model does not have the same structure as other POCs and will be represented as a hybrid of available USGS datasets for larger mixed-use watersheds and a more land use oriented source area model for highly urbanized watersheds which are generally smaller.

- Mercury will likely follow a similar conceptual model to the sediment model.

Copper was also included in the first round of RWSM development because extensive data are available both from the Bay Area and in the world literature, and also because as a primarily dissolved constituent it serves to define the limitations of the hydrologic model alone and helps to set up realistic definitions for success for the other more difficult pollutants.

Parameter estimation (also known as inverse optimization) is an approach for back-calculating multiple source concentrations from downstream storm runoff concentrations that has been successfully used for more conventional analytes (Silverman et al., 1988; Ha and Stenstrom, 2008). Using methodology based in part on Ha and Stenstrom (2008), an optimization procedure was run repeatedly within a Monte Carlo loop that fed the optimization a set of randomly chosen observed concentration data points, one from each calibration watershed. The optimization then searched the parameter space of land use specific concentrations, and computed "simulated" downstream concentrations from these parameters, using a simple model that incorporated categorized land use and runoff coefficients with an underlying hydrological model.

Initial parameter estimation results for mercury and PCBs were presented to the SPLWG in October 2012, indicating promise for using this method to estimate loads. Mercury seemed to exhibit fairly consistent land use associations while PCBs showed less consistent land use associations, likely due to the tendency for its sources to be highly localized. While this would make it difficult to get good fit at the scale of individual catchments, reasonable results are still likely at more aggregated scales as long as the calibration data set is representative of the area modeled. To fully assess the potential of this approach, recommendations for follow-up work included further development of input data sets, both spatial data sets (GIS layers) and calibration/validation data sets for hydrology. SFEI and BASMAA began working collaboratively on development of more specific GIS layers for source areas, primarily of land uses and source areas associated with PCBs and secondarily those associated with mercury.

In March 2012 the STLS Work Group reviewed a draft multi-year planning matrix for RWSM-related activities, which is included in the Year 3 and RWSM multi-year work plan in Appendix B. The planning matrix includes all tasks and POCs that are of interest to the STLS, BASMAA and other RMP strategies, which are potential funding sources for specific tasks. The draft matrix projects construction of a version 2 model for each of the above POCs in 2012; due to a slow down on the GIS layer development, this is now slated for 2013. Pollutant profiles will also be drafted for the next tier of POCs to be examined, which were selected based on MRP priorities with the concurrence of Water Board staff as described in the next section. Work plan details will be updated as findings of further model testing and calibration are incorporated in future versions of Appendix B. These updates will also describe recommendations for further testing and verification, for example selection of monitoring locations that would be supportive for improving model weaknesses; EMC-related data needs and proposed future activities will be detailed in Appendix G for future versions of the MYP.

RWSM Uses

In 2011 and 2012 the RWSM framework contributed to the watershed monitoring design and influenced the selection of the fifth and sixth watershed monitoring sites. When coupled with monitoring data in the near future, it will provide improved estimates of current loading. Other near-term functions will be as a tool to help stormwater programs address two related MRP requirements:

- Provision C.8.e(vi) requires developing a design for a robust sediment delivery estimate/sediment budget in local tributaries and urban drainages. RWSM model coefficients will also be developed for sediment, which will provide improvements to the methodologies and regional load estimates previously developed by Lewicki and McKee (2009).
- Provision C.14.a(v) requires developing information required to compute loads to San Francisco Bay of PBDEs, legacy pesticides, and selenium from urban runoff conveyance systems throughout the Bay. The RWSM workplan includes developing input information and a framework for initial load characterization with available data from RMP and STLS monitoring. Further recommendations may be made for additional studies as needed to improve these initial estimates.

Water Board staff have indicated that the RWSM is an appropriate tool for addressing these provisions, and BASMAA has approved regional project budgets to support work on sediment, PBDEs and the legacy pesticides chlordane, dieldrin and DDTs[10]. These budgets are incorporated in the workplan Table 11 and will be integrated with the RWSM multi-year planning matrix that is presented in Appendix B. In particular the sediment modeling work in 2012 and 2013 will address both the MRP requirements and also may improve the calibration of the hydrological model to support development of the PCB and mercury models.

A related model that was discussed in the STLS but is not part of the STLS workplan is a desktop model for evaluating the effectiveness of management options to reduce loads of POCs from local watersheds (see description of Proposition 13 products in Appendix A). As storm water programs collect monitoring data from sites of pilot management projects, these can be used in conjunction with existing EMC information to run scenarios for wider application of various management strategies and predict regional load reductions using the RWSM. Other medium and long term uses will be determined by the STLS Work Group, which will provide ongoing stakeholder discussion forums to update priorities as described in Adaptive Updates below.

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[10] A status update on the RWSM sediment modeling is included in the March 2013 UCMR as Appendix E. Lent and McKee (2011a) also includes a contaminant profile for selenium.

Coordination with Bay Modeling and Other Modeling Efforts

The RMP has also prepared a Bay Margins Conceptual Model as part of a separate Bay Modeling Strategy overseen by the Contaminant Fate Work Group (CFWG). The draft report (Jones et al., 2012) reviews ecosystem characteristics and physical, chemical and biological processes affecting contaminant fate, and identifies desirable characteristics for more refined modeling of the Bay. Challenges of linking physical models to biological endpoints are noted and Recommendations for a general framework for a modeling strategy are presented; development of a full-Bay 3-D model is suggested as an example of mechanistic physical modeling that could be used to address management questions, such as the STLS priority to identify high-leverage watersheds whose POC loadings contribute disproportionately to Bay impacts. Until the RMP Modeling Strategy is developed to a point that offers practical guidance on characterizing the relationship of specific tributaries or groups of tributary POC sources to contaminant fate in local portions of the Bay margin, working versions of the RWSM will not apply special weighting or other spatial considerations when estimating individual tributary inputs.

Dynamic Watershed Modeling (Potential)

The SPLWG supported development of a dynamic watershed model for the Guadalupe River Watershed as a pilot effort with funds from 2008 and 2009. This watershed is the subject of a separate TMDL for legacy mercury from the historic New Almaden Mining district. An abundance of local water, sediment, and pollutant data made this watershed a logical place for an initial exercise in mechanistic modeling using Hydrologic Simulation Model-Fortran (HSPF). The basic proof-of-concept Guadalupe watershed model for hydrology was completed (Lent et al., 2009) and the final report was presented (Lent and McKee, 2011b).

Further dynamic modeling work for the Guadalupe River watershed, or initiation of modeling for other watersheds, may be recommended in the future depending on specific information needs of the STLS or Bay Modeling Strategy. STLS need for detailed watershed modeling would be identified through the Adaptive Update process.

Watershed Monitoring

This MYP element outlines a cost-effective and flexible approach to watershed monitoring that can be implemented in the context of both the RMP Multi-Year Plan and MRP permit requirements. As part of STLS development, the RMP conducted several related projects in 2010 through 2011 to evaluate potential design considerations:

- Desktop methods optimization study
- Preliminary watershed classification
- Watershed characterization sampling study

Results of these studies were evaluated along with several other considerations, including analytical sensitivity and cost, to develop several alternative scenarios for implementation of the MYP watershed monitoring element.

Table 2 shows the six STLS watershed monitoring stations and their phasing for start-up during the first two years of sampling, beginning in (WY 2012. The assignment of responsibilities for operation of the stations were based on funding sources and availability of staffing by SFEI and BASMAA consultants. The rest of this section summarizes various aspects of the watershed monitoring and the discussions that informed the decisions made by the STLS Work Group.

In 2011, frequent STLS meetings and communications focused on decisions regarding site selection and procedures for setup and operation of the first four (Phase 1) watershed monitoring stations. In the WY 2012 wet season SFEI operated two stations for the RMP and one station (Guadalupe River) under contract to the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP), while the fourth site is operated by contractors for the Contra Costa Clean Water Program (CCCWP). In WY 2013 SFEI operated two stations for the RMP; one continuing from WY 2012 (Sunnyvale East Channel) and one new for WY 2013 (North Richmond Pump Station). Contracting for the continuing operation of the San Leandro Creek station was assumed by the Alameda Countywide Clean Water Program and contracting for the Guadalupe River station was assumed by SCVURPPP, while contractors for the San Mateo Countwide Clean Water Pollution Prevention Program (SMCWPPP) operated the other new WY 2013 site at Pulgas Creek Pump Station. The STLS work group continued to coordinate details of setup and monitoring throughout the second half of 2012.

BASMAA has supported preparation of a draft Quality Assurance Project Plan (QAPP) and BASMAA and RMP funds were used to draft a Field Manual to document standard procedures for field sampling and Quality Assurance. These documents address the MRP requirement for protocols and data quality comparable to the Surface Water Ambient Monitoring Program. The QAPP and Field Manual will be finalized and incorporated in the MYP later in 2013, to include the lessons of the first field season and additional protocol variations associated with the Phase 2 locations in pump stations.

Table 2. Watershed Monitoring Stations for the STLS

Station Name (County)	Funding source WY 2012	Funding source WY 2013
Phase 1		
Lower Marsh Creek (Contra Costa County)	CCCWP in-kind	CCCWP in-kind
San Leandro Creek (Alameda County)	ACCWP in-kind (setup) RMP (operation & maintenance)	ACCWP in kind
Guadalupe River - (Santa Clara County)	SCVURPPP in-kind (SFEI contract)	SCVURPPP in-kind
Sunnyvale East Channel (Santa Clara County)	RMP	RMP

Additional Phase 2		
North Richmond Pump Station (Contra Costa County)	N/A	RMP
Pulgas Creek Pump Station (San Mateo County)	N/A	SMCWPPP in-kind

Monitoring Methods

A standard approach for stormwater monitoring is composite sampling in which multiple discrete samples from one storm event are combined into one sample for analysis. This concept is the basis for basic requirements in 40CFR121.21(7)(g)(ii), referenced in the MRP as the default procedure to be used. A common practice for collecting stormwater samples is to use automated samplers with onset of the storm event sampling triggered by increase in flow (as indicated by a change in stage height of the monitored channel or conveyance) with subsequent discrete aliquots sampled at pre-programmed intervals that may represent equal increments of elapsed time or of discharge volume.

The SPLWG oversaw RMP load studies on the Guadalupe River in Water Years (WYs) 2003-06, 2010, and at Zone 4 Line A (Z4LA) in WYs 2007-10, collecting multiple discrete depth integrated point samples (loosely referred to as grab samples for STLS purposes) during many storm and base flow events. These studies were based on the use of continuous turbidity monitoring as a more sensitive way to identify the onset of storm discharge, as well as for characterizing the within-storm variations in transport of sediments and POCs associated with fine sediments. The turbidity record was used as a surrogate for continuous estimation of finer fractions of SSC and the associated POCs to generate highly accurate and precise load estimates at 5-15 minute intervals which could then be summed to any other desired time interval (e.g. event, day, month or season).

Using the Guadalupe and Z4LA datasets, an optimization study was conducted to recommend sampling methods and style of sampling that would be useful for assessing loads and determining trends. Using methods similar to those outlined in Leecaster et al (2002) and Ackerman et al. (2011), a series of analyses were performed to assess the optimal number of samples and style of sampling for SSC, PCBs and mercury within storms as well as approaches for choosing which storm events to sample. Detailed methods and results are presented in Appendix C. Results differed somewhat for Guadalupe vs. Z4LA and for PCBs vs. mercury, but preliminary review of tested scenarios suggested the following:

- Turbidity triggering was slightly better than flow for defining the start of the storm, but no particular trigger strategy for within-storm sampling was identified that was consistently more accurate for characterizing the POC loads of a particular event.
- To use regression on the turbidity surrogate records for estimating annual loads, at least 10 but ideally 16 samples per year should be collected at each site; however

focusing this number of samples on just a few randomly selected storms would likely cause spurious loads estimates of poor accuracy and precision.

- Strategies for selecting a more representative set of storms to sample (e.g. first flush + a larger storm + several random, first flush + several random, vs. all random) were evaluated. From the analysis it appears that scenarios that include first flush and one of the largest storms of the year provide more robust loads estimates than random sampling alone.
- Power for detecting trends appeared to be possible with just 10 samples collected per year, based on a preliminary scenario in which the samples were randomly selected and did not confirm to any of the tested sampling designs

While the optimization assessment focused on PCBs and mercury, the findings should be generally applicable to other sediment-associated pollutants and probably more than adequate for dissolved constituents since dissolved concentrations generally vary much less with flow. They may not be as relevant for methylmercury since the intent of the permit is to investigate a representative set of drainages and obtain seasonal information and to assess the magnitude and spatial/temporal patterns of methylmercury concentrations. It may also not be particularly good for water toxicity since toxicity response is a function of both concentration and cumulative duration of exposure.

Taking into consideration recent automated sampling experiences at other Bay Area sites, the final sampling design for WY 2012 was modified to include manual grabs for mercury and methylmercury, and both discrete and composite samples using autosamplers as shown in Table 10. Discrete samples collected with a D94 or DH84 FISP sampler were depth-integrated. Samples collected using ISCOs are considered mid depth relative to flow, and samples collected using hand dipping methods (Marsh Creek only) will be reported as collected 25 cm below water surface. This hybrid approach was estimated to be roughly equivalent or slightly lower in cost compared to using autosamplers for all samples; other advantages include reducing the likelihood of false starts and more flexibility in sampler configuration.

The STLS Work Group decided that all sites would use a new high-range model of turbidity probe based on turbidities observed during the WY 2011 characterization study. However delays in delivery of the probes caused a delay in completing the site set-up. At Guadalupe River, logistical problems prevented completion of composite sampler installation prior to the WY 2012 sampling season so monitoring during WY 2012 is being conducted using manual grabs (a D95 FISP) water quality sampler and 4-wheel boom-truck assembly.

Categories of watersheds

From its early days, the SPLWG has recommended stratifying the numerous watersheds of Bay Area small tributaries into general categories to provide a rationale for systematic sampling of a subset of watersheds in selected categories (Davis et al., 2000). These categories are needed to answer two key questions for the design of the STLS MYP watershed monitoring:

1. How many types of watersheds occur in the region and,
2. How many watersheds should be studied to answer key management questions, and how should they be distributed among the identified types?

To address the first question, SFEI conducted a preliminary characterization study using ordination and cluster analysis, exploratory statistical techniques designed to visualize patterns on complex multivariate data sets (see background in Appendix C preliminary discussion "Categorization of watersheds for potential stormwater monitoring in San Francisco Bay"). The study aimed for an initial classification of Bay Area small tributary watersheds into a small number (<10) of classes, relevant for loads monitoring and Bay margin impacts. Statistics were generated for 18 attributes on each of the watersheds to form the basis for analyses. Table 3 summarizes a scheme consisting of eight clusters or classes which appeared robust and meaningful for the STLS purposes.

The descriptions in Table 3 include those attributes that seemed most influential in discriminating among the clusters (all attributes were assigned equal weight in the analyses). Clusters 1, 2, and 3 are similar to each other in all having relatively high residential, commercial, and industrial land cover and consequently, high surface imperviousness. Combined, these clusters include 119 watersheds, and could therefore be described as typical watersheds for the study area. These clusters generally include densely populated, low-lying areas that drain into South Bay and Central Bay
In the remaining groupings, Cluster 6 watersheds are distinguished by their large size while the rest seem to fall into smaller, more specialized clusters.

Table 3. Description of eight preliminary watershed clusters generated using Bray-Curtis distance with Ward's linkage method.

Cluster No.	Number of watersheds	Description
1	41	High commercial and residential land cover and imperviousness. High historic industry and railroads. No PG&E facilities. Moderate area.
2	43	High commercial and residential land cover and imperviousness. High historic industry and railroads. One to four PG&E facilities. Large area.
3	35	High commercial and residential land cover and imperviousness. Low historic industry or railroads. Smaller area.
4	11	Small, sparsely populated, predominantly industrial, highest historic industrial and imperviousness. Located around San Francisco Airport and Brisbane.
5	11	Sparsely populated, low development, high open land cover, no railroads, "green space." Located adjacent to Bay or in undeveloped uplands.
6	22	Largest watersheds, with moderate population density, high open

		land cover, and low imperviousness.
7	17	High agricultural land cover, lower rainfall, draining to Carquinez Strait and Suisun Bay.
8	5	Small, sparsely populated, predominantly open, containing historic railroad, and draining to Carquinez Strait.

Design of characterization study

After reviewing the preliminary watershed classification the STLS agreed that further information was needed to select watersheds for future STLS monitoring. RMP resources for WY 2011 monitoring were redirected to a characterization study consisting of storm water grab samples from 16 of the candidate watersheds for which there were little or no existing PCB or mercury concentration data[11].

Table 4 shows the watersheds selected for the characterization study, along with a summary of some of their key attributes. Criteria for the composition of the sampling list included the following:

- Multiple representatives of the most common small to medium sized watershed classes 1-3, distributed throughout the four counties (Contra Costa, Alameda, Santa Clara, and San Mateo) where loads monitoring is required by the MRP.
- A few representatives of the medium to large watershed classes.
- Smaller catchments, generally heavily urban with industrial land uses, where stormwater programs are planning enhanced management actions to reduce PCB and mercury discharges.
- Other watersheds with distinctive histories of mercury or PCB occurrence, or related management concerns.

Figure 3 shows the general locations of the study watersheds and the drainage areas above the initially selected monitoring locations. Some of the monitoring station locations were adjusted after field reconnaissance. Table 5 lists watersheds considered but not selected for the study, and also watersheds excluded from the study because of the availability of significant amounts of previously collected PCB and mercury data. Appendix E provides details of the study design, methods and preliminary results, which will be updated with a more complete analysis later in 2013.

In June 2011 the STLS Work Group reviewed the results of the WY 2012 sampling. Analytes measured at each sampling site varied depending on budget and Water Board management questions (Table 6). Between 4-7 PCB, total mercury, SSC and organic carbon samples were collected at each site. PBDE and PAHs were collected at a subset of sites chosen based on logistics (essentially randomly from a water quality perspective). Selenium data were only measured at Contra Costa sampling locations.

[11] This redirection was allowed by MRP Provision C.8.a, which indicates that initiation of the required POC loads monitoring can be deferred to October 2011 if the stormwater Permittees are participating in a regional collaborative process to plan and conduct the monitoring.

Table 4. Watersheds sampled during reconnaissance characterization study of Water Year 2011.

Watershed/ station	Area (km^2)	Prelim, Cluster No.	Percent Impervious	Percent Old Industrial	Reconnaissance Feasibility/ Safety	PCB-Hg attributes
Ettie Street Pump Station	4.0	1*	73.4**	28.60**	Good/Good	PCB P13 Cluster, CW4CB pilot watershed
Pulgas Creek	7.1	2	28.2		Good/Good	CW4CB pilot watershed
Sunnyvale East Channel	18.0	2	59.7	3.47	Good/Good	PCB P13 Cluster
Santa Fe Channel	2.64	2	70.3	3.6	Poor-Medium/ Good	Confirm proposed station vs. locations of CW4CB pilot watersheds
Lower San Leandro Creek	8.9	2	37.5	2.96	Good/Good	PCB spill into creek in 1995
Stevens Creek	73.7	6	15.8	0.24	Good/Good	Within airshed of Lehigh-Hanson Cement Manufacturer
Zone 5 Line M	8.1	*	33.5	3.15	Good/Good	Hg P13 Cluster
Lower Marsh Creek	97.5	?	14.7		Good/Good	Drains historic Hg mine
San Lorenzo Creek	124.8	6	13.2	0.50	Medium/Good	
Walnut Creek	318.7	7	16.6	0.72	Good/Good	
Lower Penitencia Creek	12.0	*	67.1	7.14	Good/Good	
Belmont Creek	7.2	2	27.4	0.00	Medium/Good	
Borel Creek	3.2	2	31.4	1.57	Medium/Good	
Calabazas Creek	52.9	1	45.6	0.44	Good/Good	
Glen Echo Creek	5.4	3	39.3	0.80	Good/Good	Hg P13 Cluster
San Tomas Creek	114.1	1	34.4	0.35	Good/Good	

* Catchment does not correspond to a polygon used in cluster analyses

** Estimated for larger polygon used in cluster analyses

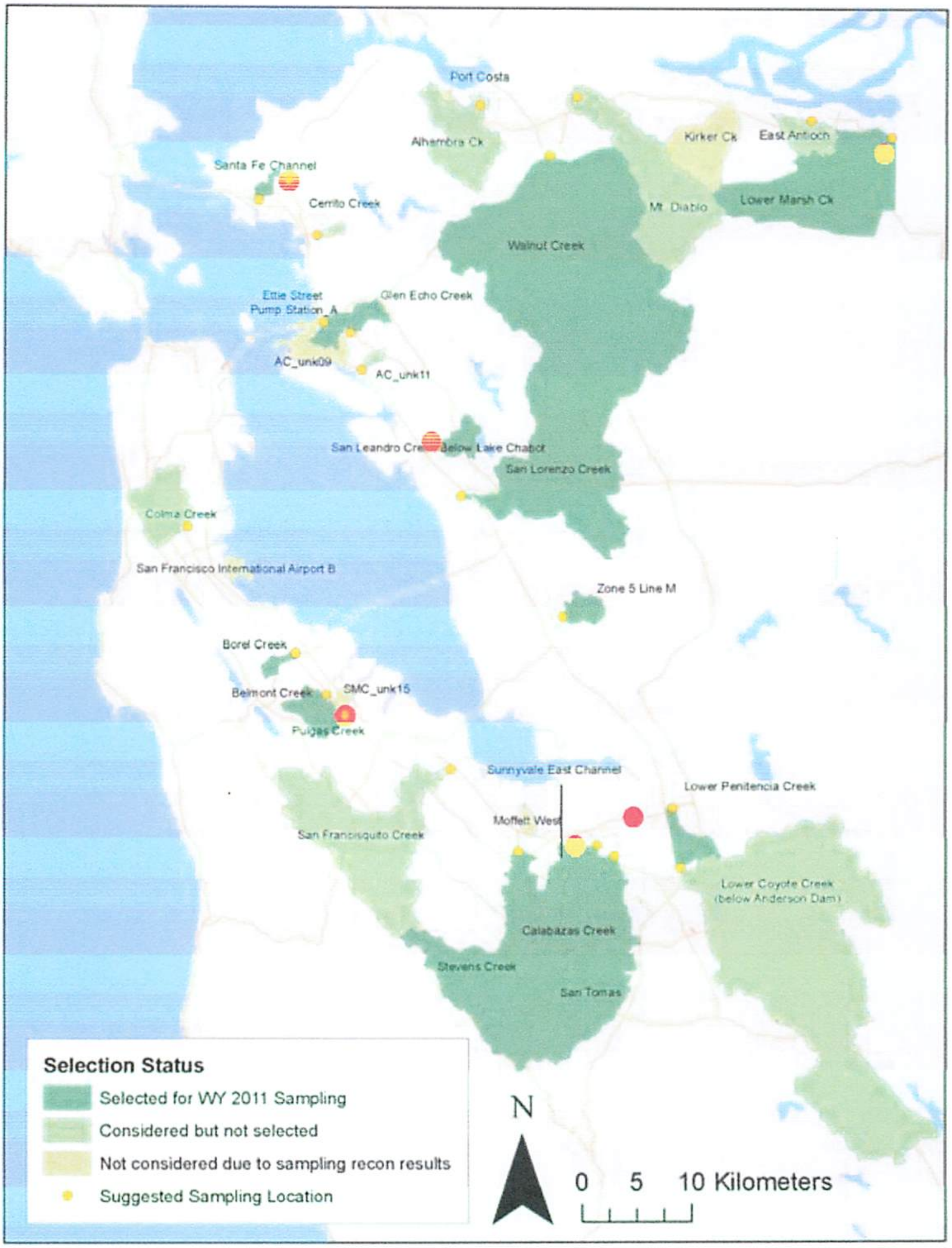

Figure 4. Watersheds sampled in Water Year 2011 reconnaissance characterization study. Red circles indicate approximate locations of six watershed monitoring stations for WY 2013.

Table 5. Potential candidate watersheds, not selected for reconnaissance characterization sampling during WY 2011.

County	Watershed	Area (km^2)	Prelim, Cluster No.	Percent Impervious	Percent Old Industrial	PCB-Hg attributes
San Mateo	Colma Creek	28.0	2	37.5	2.18	PCB P13 Cluster, CW4CB pilot watershed
Contra Costa	Alhambra Creek	41.0	6	6.0	0.01	
Alameda & Contra Costa	Cerrito Creek	1.9	2	35.8		
Contra Costa	East Antioch	14.4	7	41.4	1.31	
Contra Costa	Mt Diablo Creek	80.2	6	10.5		
Alameda	Oakland, East of Lake Merritt	2.1	2	67.3	6.18	PCB P13 Cluster
Alameda	Zone 4 Line A	8.78*	1	67.6	10.1	
Santa Clara	Lower Coyote Creek (below Anderson Dam)	318.6	6	21.1	0.38	PCB P13 Cluster
Santa Clara	Guadalupe River	226	6	32.5	2.7	Hg TMDL
San Mateo & Santa Clara	San Francisquito	111.8	6	7.3	0.27	

Table 6. Summary of analytes collected during the water year 2011 reconnaissance characterization study.

Analyte	MRP Category	Number of Samples
PCB	Category 1	91
Total Mercury	Category 1	91
SSC	Category 1	91
Total Organic Carbon	Category 1	91
PBDE	Category 2	22
PAH	Category 2	22
Total Selenium	Category 2	30
Dissolved Selenium	Category 2	30

Table 7 shows that while maximum concentrations of total mercury varied from 19-1740 ng/L (about 100x) between sites in relation to suspended sediment concentration and watershed characteristics, maximum PCB concentrations varied from 1,851 - 467,696 pg/L a variation of about 250x. Methylmercury did not relate directly to maximum total mercury observed at each site. Normalizing mercury and PCB data to SSC and turbidity respectively (see Appendix E for discussion) resulted in a different pattern and rankings of the sampled watersheds, as shown in Table 8.

Table 7. Maximum concentrations of mercury and PCBs for the Water Year 2011 reconnaissance characterization study.

Watershed	Max HgT (ng/L)	Max. PCBs (pg/L)
Belmont Creek	59	4,909
Borel Creek	74	8,671
Calabazas Creek	89	24,765
Ettie Street Pump Station	73	68,996
Glen Echo Creek	179	85,815
Lower Marsh Creek	200	4,136
Lower Penetencia Creek	19	1,851
Pulgas Creek Pump Station - North	27	84,490
Pulgas Creek Pump Station - South	28	53,894
San Leandro Creek	477	31,336
San Lorenzo Creek	77	20,421
San Tomas Creek	129	4,372
Santa Fe Channel	217	467,696
Stevens Creek	121	22,554
Sunnyvale East Channel	151	67,462
Walnut Creek	181	24,396
Zone 5 Line M	1740	25,091

Table 8. Summary of PCB and Hg results in relation to suspended sediment or turbidity and organized by PCB/SSC ratio.

Watershed	PCB/SSC Avg Ratio (pg/mg)	THg/SSC Avg Ratio (ng/mg)	PCB Rank	Hg Rank	Rank Sum	Comment
Santa Fe Channel	1401	0.68	1	4	5	Tidal
Pulgas Creek Pump Station - North	1048	0.47	2	5	7	Extremely flashy
Pulgas Creek Pump Station - South	905	0.83	3	1	4	Extremely flashy
Ettie Street Pump Station	741	0.78	4	3	7	Access time restricted
San Lorenzo Creek	114	0.21	5	12	17	
Glen Echo Creek	86	0.42	6	6	12	Underground downstream
San Leandro Creek	86	0.80	7	2	9	
Sunnyvale Channel	59	0.35	8	8	16	
Zone 5 Line M	48	0.40	9	7	16	SSC >1800 mg/L
Calabassas Creek	41	0.16	10	16	26	
Stevens Creek	35	0.26	11	10	21	
San Tomas Creek	23	0.27	12	9	21	
Walnut Creek	19	0.09	13	17	30	SSC > 1800 mg/L, 12-24 hour hydrograph - sample preservation
Lower Penitencia Creek	17	0.16	14	15	29	
Belmont Creek	14	0.25	15	11	26	
Borel Creek	13	0.17	16	14	30	
Lower Marsh Creek	3	0.20	17	13	30	SSC > 1800 mg/L, Remote, access by Hwy 4, sample preservation

For the most part, sampling logistics at these sites were taken into account as part of the decisions made prior to the reconnaissance study. However, there were some additional lessons learned during the reconnaissance study about feasibility and potential sampling constraints that are worth noting in Table 8. The tidal nature of the Santa Fe channel, although it was sampled during low tide, will challenge the measurement of discharge if loads at this site are desired in the future; acoustic Doppler technology at a greater cost would be needed. Three locations (Zone 5 Line M, Walnut and Lower Marsh) had observed turbidities that exceed the use of the DTS12 turbidity sensors employed previously at Guadalupe and Zone 4 Line A; sensor technology that ranges to 4000 NTU is available but with some loss of sensitivity at the lower end of the range (<50 NTU).

The narrow sampling platform at Sunnyvale East Channel adds challenges for manual sampling equipment and safety due to lack of space. Sampling locations at the base of large watersheds such as Walnut Creek and Guadalupe River, with storm hydrographs that can span a day or more, may add sample preservation challenges if ice melts before samples can be retrieved following storm events. Lower Marsh Creek is a challenging location due to travel time to the site and the same kinds of preservation challenges.

Criteria for selection of watersheds for monitoring

In June 2011 the STLS WG reviewed characteristics of the candidate watersheds that it considered as priorities for the watershed monitoring:

- **Representative** for purposes of long-term trends monitoring. Watersheds selected have a station near the bottom of the watershed, and include a range of sizes and land uses, ranging from already urban to those expected to undergo significant additional urbanization over the next 20 -30 years.
- Containing **Management** opportunities for TMDL load reductions, especially of PCBs and mercury, that are likely to be explored through pilot projects or other targeted stormwater program activities during the next 5-10 years (see Appendix A). Since the first round of pilot management activities will be limited to a few local catchments, the STLS Work Group decided to focus the watershed selection for Phase 1 (WY 2012) on representative sites and defer potential selection of this category of watersheds until later planning for Phase 2.
- Named as a monitoring location for specific NPDES **Permit** requirements affecting Bay Area stormwater programs. This includes Lower Marsh Creek which is named in a parallel C.8.e provision in the municipal stormwater permit for eastern Contra Costa County. The Guadalupe River site previously monitored by the RMP is one of the 8 stations identified as default locations for POC Loads Monitoring in the MRP, and continued monitoring at this site is also required by a permit supporting the implementation of the mercury TMDL for that watershed.[12]
- **Feasibility** of monitoring for the desired Management Question. For example, many catchments with planned or potential management activities are heavily culverted and located in low-lying Bayside areas, so that monitoring stations downstream of the management areas are often subject to tidal inflow or inaccessible due to private property boundaries.

The four stations selected for Phase 1 start-up (See Table 2 for funding sources) were:

- Lower Marsh Creek (Contra Costa County)
- Lower San Leandro Creek (Alameda County)
- Sunnyvale East Channel (Santa Clara County)
- Guadalupe River (Santa Clara County)

[12] Both of these permits specify additional monitoring requirements which are not included in the scope of this STLS MYP, i.e. additional parameters for Lower Marsh Creek and additional sites and periodic intensified monitoring in the Guadalupe River watershed.

In March 2012 the STLS Work Group discussed criteria for selecting two additional stations to be initiated in 2012 for Phase 2. Priority attributes identified for these additional watersheds included:

- High percentage of impervious area to help fill gaps in available hydrological data for calibrating the RWSM
- Significant proportion of older industrial land uses which are more likely to have higher PCB concentrations. Such catchments are also more likely to be priorities for future management actions to reduce PCBs in runoff.

Most watersheds meeting the above criteria present logistical challenges for runoff monitoring, since most older industrial areas are located close to the Bay within the zone of tidal influence and often have completely culverted storm drain systems, For these reasons both Phase 2 sites were selected at existing pump stations.

Analytes and Data Quality Objectives

Where applicable, the MRP specifies that default standards for monitoring data quality be consistent with the latest version of the Quality Assurance Program Plan (QAPrP; SWAMP 2008) adopted by the Surface Water Ambient Monitoring Program (SWAMP). The QAPrP adopts a performance-based approach with target Reporting Limits (RL) for a large list of analytes in water and sediment.

The RMP has not specified target Reporting Limits for most analytes; for the SPLWG monitoring studies SFEI has utilized laboratory services that provide much lower method detection limits (MDL) for some analytes than those that would be associated with the SWAMP Target RLs.

Table 9 summarizes the results of a review of detection frequency at Zone 4 Line A, indicating that the RMP's laboratories have obtained much higher frequencies of detection with much lower detection levels for the organic compounds (see Appendix F).

MDLs are variable depending on the concentrations of the target analyte and similar compounds as well as potential interference from other constituents in the sampling matrix. While quality assurance considerations should be used in interpreting data near the MDL, accurate quantitative results at low range are important for developing load estimates.

For WYs 2012 and 2013, analyses were performed by the laboratories listed in Table 10[13]. Laboratory contracting and Quality Assurance procedures for laboratory data are being performed by SFEI for all STLS stations, through funding provided by both the RMP and BASMAA.

[13] The STLS MYP does not include other analytes for which occasional sampling at some or all of the STLS watershed monitoring stations may occur, such as monitoring required by the municipal stormwater permit for eastern Contra Costa County issued by the Central Valley Regional Water Quality Control Board, or sampling for special studies initiated through other RMP strategy workgroups (e.g. nutrients and dioxins) that take advantage of the existing infrastructure for STLS monitoring stations while covering all incremental costs for sampling those analytes.

Table 9. Comparison of detection rates for selected analytes using SWAMP Reporting Limits vs. RMP-contracted lab results for storm water samples at Zone 4 Line A; see Appendix F for additional notes.

Analyte	SWAMP Target RL	Z4LA data, fraction > SWAMP RL	Actual RL	Z4LA % detection	Sample Volume, Liters
Category 1					
Copper (Total)	0.01 µg/L	45/45	0.03-0.1 µg/L	100%	0.12
Copper (Dissolved)	0.01 µg/L	11/11	0.1 µg/L	100%	
Mercury (Total)	0.0002 µg/L	112/112	0.0002 µg/L	100%	0.25
Methylmercury	0.00005 µg/L	55/56	0.00002 µg/L	99%	0.25
PCB congeners	0.02 µg/L	20/77	NA	(98%)	2.5
SSC	0.5 mg/L	392/392	0.6 mg/L	99%	0.25
TOC	0.6 mg/L	40/40	0.3-2.4 mg/L	100%	.25
Nitrate as N	0.01 mg/L	10/12	NA	(NA)	(0.15)
Hardness (as CaCO3)	1 mg/L	NA	NA	NA	NA
Category 2					
Selenium (Total) [e]	0.30 µg/L	15/30	0.045-1 µg/L	36%	0.5
Selenium (Dissolved)	0.30 µg/L	0/5	0.045-0.053 µg/L	66%	
PBDEs	NL - assume 0.02 µg/L	18/36	NA	(75%)	2.5
PAHs [g]	10 µg/L	3/21	NA	(99%)	2.5
DDTs	0.002 µg/L [h]	14/20	NA	(100%)	
Chlordane [i]	0.002 µg/L	13/20	NA	(100%)	
Dieldrin [i]	0.002 µg/L	3/20	NA	(100%)	
Pyrethroids [j]	NL	NA	NA	NA?	4
• Bifenthrin		–	NA		
• Delta/Trihalomethrin		–	NA		
• Permethrin, total		–	NA		
Carbaryl	NL	NA	NA	NA	NA
Fipronil	NL	NA	NA	NA	NA
Phosphorus (Total)	NL	NA	NA	NA	(with N)
Phosphorus (Diss.)	NL	NA	NA	NA	(0.17)

Table 10. Final list of STLS watershed monitoing analytes and associated analytical laboratories, methods and sample holding times.

Analyte	Hold Time	Laboratory WY2012	Laboratory WY2013	Method
Copper (Total) Selenium (Total)	180 days	BRL	Caltest	EPA 1638
Copper (Dissolved) Selenium (Dissolved)	48 hours	BRL	Caltest	EPA 1638
Mercury (Total)	90 days	MLML	Caltest	EPA 1631
Methylmercury	90 days		Caltest	EPA 1630
PCB congeners	One year	AXYS	AXYS	AXYS MLA-010 Rev 1
SSC	7 days	EBMUD	Caltest	ASTM D3977-97B
TOC	28 days	Delta	Caltest	SM20 5310B
Nitrate as N	28 days	EBMUD	Caltest	EPA 353.2
Hardness (as CaCO3)	180 days	BRL	Caltest	EPA 1638
PBDEs	One year	AXYS	AXYS	AXYS MLA-033 Rev 0
PAHs[g]	7 days	AXYS	AXYS	AXYS MLA-021 Rev 1
Pyrethroids[j]	3 days	AXYS	Caltest	EPA 8270 mod
Carbaryl	7 days	DFG - WPCL	DFG - WPCL	EPA 632 Mod / CDFA Mod
Fipronil	7 days	DFG - WPCL	DFG - WPCL	EPA 632 Mod / CDFA Mod
Phosphorus (Total)	28 days	EBMUD	Caltest	SM20 4500—P E
Dissolved Orthophosphate	48 hours	EBMUD	Caltest	SM20 4500—P E

Laboratory name abbreviations: AXYS - AXYS Analytical Services; MLML - Moss Landing Marine Laboratory; BRL – Brooks Rand Labs; Caltest – Caltest Analytical Laboratory; EBMUD – East Bay Municipal Utility District; Delta – Delta Environmental Laboratories; PER – Pacific EcoRisk; DFG – WPCL – California Department of Fish and Game Water Pollution Control Laboratory.

Watershed Monitoring Approach

The MRP requires POC loads monitoring effort that is equivalent to conventional flow weighted composite sampling at eight sites, with an annual average of four events sampled for Category 1 analytes and one event for Category 2. The MRP allows phased implementation: Phase 1 monitoring of at least four stations, or roughly half of the effort, must be initiated by October 2011 and Phase 2 monitoring of the remaining stations must start by October 2012.

After discussion of assumptions for the MRP default plan compared with alternative scenarios incorporating the recommendations for sampling frequency and laboratory data quality described above, the STLS work group agreed to pursue a watershed monitoring plan that approximates the MRP cost benchmark and includes:

- A total of six watershed monitoring stations, with four to be deployed in Phase 1 (WY 2012) and an additional two stations in Phase 2 (WY 2013).
- Continuous turbidity monitoring (not included in the MRP) at all stations to enable turbidity surrogate regression estimation of seasonal loads of particulate associated POCs and allow for the future inclusion of other analytes and the back calculation of loads using turbidity records.
- For best load estimation of mercury, PCBs and sediment at least 16 samples should be collected in a season; for planning purposes, this would be a minimum of 4 events with an average of 4 samples per event. Sampled events should target a first flush event and at least one of the larger storms of the year.
- Samples would not be analyzed for organochlorine pesticides.
- Sample analyses for all stations would be performed by specific laboratories recommended on the basis of previous performance and reliability in achieving low MDLs for each parameter.

In March 2011 Water Board staff indicated that this STLS program with annual cost similar to the MRP benchmark of $800,000-$1,000,000[14] would meet the MRP requirement for an alternative monitoring approach that addresses the priority Management Questions, with the assumption that at least 2/3 of this cost would be supported by the storm water programs (see work plan below). At the SPLWG meeting on October 25, 2011, Water Board staff confirmed that the mobilization then in progress for Phase 1 watershed monitoring stations was in compliance with the MRP.

In July 2011 the STLS Work Group determined that all monitoring stations should use the same sampling methods for each parameter, and began developing a plan using automated sampling equipment (Model 6712 full size by Teledyne ISCO, hereafter "ISCO") for all parameters except methyl mercury. After further evaluation this was changed to a hybrid of several sampling methods as described above. Modifications were also made to the sampling plan to permit efficient use of ISCOs for composite sampling and to reflect evolving regulatory priorities for data on particular analytes. The revised STLS Work Group consensus plan for sampler configuration is shown in Table 11. Annual number of samples per site is equal to or greater than the average annual frequency specified in the MRP for all analytes except organochlorine pesticides, for which recent data have suggested a reduced regulatory priority. Due a very dry WY 2012 rainy season, fewer than the planned number of storm events were sampled at 3 of the first 4 stations. With concurrence of Water Board staff, The STLS Work Group agreed that additional samples would be added to sampling plans in the next two Water Years so that over a 3- year period, a total of 12 representative storm events will be sampled at each site.

[14] Benchmark cost for default MRP monitoring (including ongoing project administration but excluding data management and reporting and contingency for false starts) was established as a range to express variation in labor costs among the participating agencies. Benchmark calculations distributed one-time start-up costs over 3 years of operation, although this assumption has limited value for actual project planning. No site-specific cost variations were assumed other than stage-discharge monitoring and calibration for sites not served by an existing USGS gauging station.

In June 2012 the STLS Work Group also discussed potential improvements to monitoring procedures for WY 2013 including:

- Collecting composite samples on a time-interval rather than flow-weighted basis.
- Re-evaluating guidelines for number of composite aliquots per storm event to balance needs for storm representation against variability in pumping capabilities of the auto samplers.
- Changing contract laboratories for some analytes (pyrethroids, SSC, TOC) to improve turnaround times, quality control and costs. These changes are noted in Table 10.

Further adaptations are required for monitoring in the pump stations, which typically have little to no dry weather flow. Updated methods will be finalized in 2013 and incorporated in the Quality Assurance Project Plan and Field Manual as described below.

Table 11. Sample type and target frequency of STLS sampling by analyte.

MRP Category	Parameter	No. of Storms / year	No. of Samples/ storm	Frequency change from MRP	Sample Type
1	PCBs (40 congener)	4	4	400%	Discrete
1	Total Mercury	4	4	400%	Grab
1	Total methyl mercury	2[15]	4	400%	Grab
1	Dissolved Cu	4	1	0%	Composite
1	Total Cu	4	1	0%	Composite
1	Hardness	4	1	0%	Composite
1	SSC (GMA)	4	8	800%	Discrete
1	Nitrate as N and Total Phosphorous	4	4	400%	Discrete
2	Dissolved phosphorus	4	4	400%	Discrete
1	Total Organic Carbon	4	2.5	250%	Discrete
1	Toxicity – water column (3 species + *Hyalella azteca*)	4	1	0%	Composite
2	Pyrethroids	4	4	1600%	Composite
2	Carbaryl	4	4	1600%	Composite
2	Fipronil	4	4	1600%	Discrete
2	Chlordane, DDTs, Dieldrin	0	0	-100%	N/A
2	Dissolved Se (collect with Dissolved Cu)	4	1	400%	Composite
2	Total Se (collect with Total Cu)	4	1	400%	Composite
2	PBDE	2	1	200%	Discrete
2	PAH	2	1	200%	Discrete

Watershed Monitoring Plan

This section contains recommendations in two categories. The core plan is the minimum recommendation to meet the requirements for an alternative equivalent approach to the POC Loads Monitoring in the MRP. Additional plan options may be considered subject to the availability of additional resources, either for the current participants or by leveraging resources of additional programs or partners in the future.

[15] Two additional dry weather methyl mercury grab sampling events, required by the MRP, will generally soccur during station set-up in September and shutdown in April or May.

The core plan comprises six sites as shown in Table 2, using the sampling frequencies and methods in Table 11.
In January 2012, STLS Work Group members noted that initiating field sampling for EMC development seemed premature during the discovery phase of final model structures for the initial group of POCs, and evaluating GIS data quality in relation to pollutant specific land use/ source areas and the usefulness of existing data sets for back-calculation of EMCs. After further discussion, the STLS Work Group agreed on the RWSM workplan assuming initial model runs would use EMCs derived from available data. Should model runs indicate weaknesses, field data many be collected during subsequent wet seasons to provide improved input data for later model versions.

The Quality Assurance Project Plan and Field Manual with Standard Operation Procedures will document details of equipment and methods, to be summarized in a future revision of Appendix F. The updates will include modifications made during the first two years of monitoring along with guidelines for additional quality assurance/quality control procedures.

Should additional resources become available, plan options could include:

- Accelerating Core Plan activities on an earlier schedule.
- Adding other analytes where compatible with the STLS autosampler configuration and grab sampling logistics described in the Field Manual and summarized in Table 10. MYP updates would not necessarily include short-term examples such as the RMP nutrient and dioxins strategies' separately funded studies involving supplemental nutrient and dioxins sampling and analysis at the two STLS sites operated by the RMP.

The STLS Work Group will not produce a detailed written interpretive report of WY 2012 results, but will provide a limited summary of the monitoring activities for purposes of the RMP and MRP. SFEI presented a preliminary review of the first year's data for discussion at STLS and SPLWG meetings in the second half of 2012. An integrative two-year report will be prepared in late 2013 updating loads estimates for WY 2012 with improved information and interpretation and providing loads estimates for WY 2013. This information will be incorporated in BASMAA's Integrated Monitoring Report to fulfill MRP reporting requirements.

Source Area Runoff Monitoring

The RWSM literature review identified several gaps in available information about EMCs. As an alternative to starting reconnaissance for source area monitoring sites, SFEI began exploratory work with an approach suggested at the May 2011 SPLWG meeting that uses available data from sediment samples collected in storm drain conveyances to back-calculate EMCs for the input side of the RWSM. After initial explorations several refinements pursued as described above for the RWSM and in Appendix B. Further results and potential implications for source area runoff monitoring will be provided in future updates of the MYP and its Appendix G.

Adaptive Updates

This MYP is a working document and will require revisions as new information and data are reviewed for POCs on the existing priority list, or new pollutants are identified as regional priorities. Updated working versions of the MYP will be incorporated in BASMAA Urban Creeks Monitoring Reports related to MRP requirements. Future versions may incorporate added or updated materials listed below:

- Updated Appendix F with details of watershed monitoring sampling procedures, & QA, with reference to QAPP, field Manual, and field training materials; also documentation of procedures for coordinating management, QA/QC of watershed monitoring data,
- Review priorities for watershed monitoring data vs. EMC studies, document potential scenarios for future allocations of STLS effort,
- Draft planning timeline for future data reviews (e.g. trends analyses, integration with spreadsheet modeling),
- Updates on potential coordination with RMP Modeling Strategy, as applicable
- Updates on Regional Watershed Spreadsheet Model development and load estimates for additional POCs,
- Updates to work plan and descriptions of future planned studies,
- Recommendations for EMC development studies,
- Coordination with other RMP strategies, as applicable, and
- Timeframe for future MYP version(s) and adaptive updates.

As the primary stakeholder forum, the STLS Work Group will track these various needs and set priorities for further MYP updates. The SPLWG will review these updates, at least annually but ideally several times per year, to track progress according to the RMP Multi-Year Plan, or at milestones such as the following:

- Trends power analysis, after accumulation of appropriate minimum number of samples. Revisions of the MYP in 2012 will develop a provisions timeframe for trends analyses over the next 3-5 years, and
- Bay Modeling milestones as they become established through Modeling Strategy.

Workplan and Detailed RMP Task Descriptions

This section outlines the 5-year STLS workplan for both the RMP and stormwater programs acting collaboratively through the Bay Area Stormwater Management Agencies Association (BASMAA) (see Table 12), and presents capsule summaries of RMP workplan tasks for the same time period as guided by the RMP Multi-Year Plan which has committed approximately $400,000 annually during 2012-2014[16]. The budgets and scopes shown below are updated as of RMP adoption of its 2013 budget for Pilot Studies/Special Studies. Detailed task scopes for future years will be prepared as part of the annual planning process with STLS and SPLWG oversight.

1A) Regional Watershed Spreadsheet Model Development and Support.

Objective: Develop and use GIS-based spreadsheet model for regional load estimation.

Deliverables: Load estimates for priority pollutants of concern and sediment; see 2012 study proposal in Appendix B for more details on near-term activities.

Milestones and Linkages to other Projects: see workplan in Appendix B.

Project Participants: RMP

Due Date: ongoing; see schedule in Appendix B

RMP Contributions and Years: 2011 approved $20,000; 2012 approved $20,000; 2013 approved $25,000; 2014 planned $25,000; -2015 TBD .

BASMAA funding for sediment load estimation (Phase I, estimated) 2012: $33,000; 2013: $12,000; 2014 TBD. PBDE, chlordane, dieldrin, DDT (Phase II) 2012 $35,000; 2013 $14,000; 2014 TBD.

Total Cost: TBD,

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[16] RMP Master Planning Workshop, February 7. 2011

Table 12. 2013 update of five-year STLS workplan. Numbers indicate budget allocations or planning projections in $1000s. Stormwater programs budgets interpolated from BASMAA Fiscal Year budgets (regional reporting budgets not shown). Budget numbers shown in parentheses for later years are projected, subject to annual authorization processes of the RMP and BASMAA.

Task ID	Funding Agency	Task Description	2011	2012	2013	2014	2015
0	RMP	**Coordination and Management**			20		
1		**Watershed and Associated Bay Modeling**					
1A		Regional Watershed Spreadsheet Model					
1A.1	RMP	Phase I – Water, Sediment, PCBs and Mercury	20	20	25	25	
1A.1	BASMAA	Phase I – Sediment		33	12	TBD	
1A. 2	RMP	Phase II – Other Pollutants of Concern				TBD	
1A.2	BASMAA	Phase II– PBDE, DDT, chlordane, dieldrin		35	14	TBD	
1A.3	RMP	Phase III – Periodic Updates				TBD	TBD
1B	RMP	Coordination with Bay Margins Modeling				TBD	
1C	TBD	HSPF dynamic modeling					TBD
2	RMP	**Source Area Monitoring / EMC Development**	20	80	80	TBD	TBD
3		**Small Tributaries Monitoring**					
3.1	BASMAA	Multi-Year Plan Development	15				
3.2	BASMAA	Standard Operating and Quality Assurance Procedures	55		5		
3A	RMP	Monitor Two Representative Small Tributaries[a]	300	328	343	300	TBD
3AB.1	BASMAA	Monitor Two to Four Representative Small Tributaries or Sites Downstream of Management Actions	255	468	440	(500)	TBD
3AB.2	BASMAA	Lab analyses, Quality Assurance, Data Management	183	377	375	(375)	TBD
4	RMP	**Reporting, Stakeholder Administration and Adaptive Updates**	41		50	TBD	
	BASMAA	**Data Analysis, Communications, Administration**	45	94	115	(100 est)	TBD
RMP Total		[a]includes lab analyses, QA, Data Management	**381**	**428**	**518**	**TBD**	**TBD**
BASMAA Total		**Task 1**		**68**	**26**	**TBD**	
		Tasks 2-4	**553**	**939**	**935**	**TBD**	**TBD**
Total			**934**	**1,435**	**1,479**	**TBD**	**TBD**

1B) Coordinate STLS with Bay Margins Modeling.

Objective: Identification of high-leverage watersheds contributing to POC impairment in S.F. Bay.

Deliverables: Timely coordination and exchange of information between STLS and Bay Margins modeling Work Groups.

Milestones and Linkages to other Projects: Depends on Modeling Strategy

Project Participants: RMP

Due Date: Depends on Modeling Strategy

RMP Contributions and Years: 2014-2015 TBD?

Total Cost: TBD

2) Land Use/Source Area Specific EMC Development and Monitoring.

Objective: Calibrate RWSM loading estimates to Bay Area specific conditions and POCs.

Deliverables: Refined EMCs or other modeling coefficients for RWSM; see 2012 study proposal for more details on near-term activities.

Milestones and Linkages to other Projects: Coordinate with 1A, RWSM Development.

Project Participants: RMP

Due Date: TBD

RMP Contributions and Years: 2011 approved $20,000; 2012 approved $80,000; 2013 approved $80,000; 2014-2015 TBD.

Total Cost: TBD

3.1) Development of STLS Multi-Year Plan

Objective: Develop alternative monitoring approach to POC Loads Monitoring that meets objectives of STLS and MRP; facilitate consistent implementation

Deliverables: Consensus STLS MYP document for timely implementation of required stormwater monitoring.

Milestones and Linkages to other Projects: To be coordinated with RMP 3A and MRP reporting requirements (initial Phase 1 results in late.2012)

Project Participants: BASMAA

Due Date: Selection of monitoring methods and Phase 1 sites by July 2011; sites for Phase 2 monitoring by January 2012

RMP Contributions and Years: (review using 2010 available funds).
BASMAA funding 2011: $15,000

Total Cost: BASMAA $15,000 one-time

3.2) Stormwater Programs - Monitoring, Standard Operating and Quality Assurance Procedures.

Objectives: Ensure that alternative monitoring methods in STLS meet MRP requirements for SWAMP comparability and reporting formats; provide documentation and facilitate consistent implementation

Deliverables: Quality Assurance Project Plan, Standard Operating Procedures

Milestones and Linkages to other Projects: To be coordinated with RMP 3A and MRP reporting requirements (initial Phase 1 results in late.2012)

Project Participants: BASMAA

Due Date: July 2012

RMP Contributions and Years: RMP N/A;
BASMAA funding 2011: $55,000; 2013 $5,000

Total Cost: BASMAA $60,000 one-time

3A) Monitor Representative Small Tributaries.

Objective: Collect POC stormwater data to be used for tracking long-term trends in loading to S.F. Bay

Deliverables: small tributaries monitoring data

Milestones and Linkages to other Projects:

Project Participants: RMP, BASMAA[17]

Due Date: Exploratory watershed characterization results by June 2011; Phase 1 monitoring begins October 2011; Phase 2 monitoring begins October 2012

RMP Contributions and Years: 2011 approved $300,000; 2012 approved $328,000; 2013 approved $343,000; 2014 planned $300,000.
BASMAA funding $2011: 255,000, see 3A/B.1 below for 2012-2015

Total Cost: RMP: [$300,000/year projected in RMP Multi-Year Plan?]

3A/B.1) Monitor Sites Downstream of Management Actions.

Objectives: Collect POC stormwater data to be used for tracking potential load reductions downstream of Management Actions.

Deliverables: Monitoring data.

Milestones and Linkages to other Projects:

Project Participants: BASMAA

Due Date: Phase 2 monitoring begins October 2012

RMP Contributions and Years: N/A.
BASMAA funding $468,000 for monitoring field operations including 3A and setup in 2012; budgeted $440,000 in 2013[18]; budgeted $500 in 2014; -2015 TBD.

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[17] RMP budgets include all field operations, project management, laboratory analyses and data management and Quality Assurance, while BASMAA scopes and regional budgets for laboratory analyses, data management/QA and a portion of management and coordination costs are shown under Task 3A/B.2 and a portion of Task 4.2. Additional cozts to individual BASMAA stormwater programs of managing and coordinating watershed monitoring stations not included.
[18] After subtracting estimated cost-sharing contribution from another SMCWPPP project to WY2013 monitoring at the Pulgas Creek Pump station

Total Cost: TBD.

3A/B.2) Stormwater Programs ongoing Quality Assurance and Data Management.

Objective: implement and document QA procedures and reporting for SWAMP comparability.

Deliverables: QA review and data management on laboratory results, consistent with those for RMP-operated stations.

Milestones and Linkages to other Projects: To be coordinated with Task 3A/B.1 and MRP reporting requirements.

Project Participants: BASMAA

Due Date: Ongoing Quality Assurance and Data Management; BASMAA funding

RMP Contributions and Years: N/A;
BASMAA funding 2011: $183,000, 2012: $377,000, 2013: $375,000 budgeted; 2014: 375,000 estimated; 2015 TBD

Total Cost: TBD.

4) Reporting, Stakeholder Administration and Adaptive Updates.

Objectives: Report results at agreed-upon intervals; support future STLS decision-making through facilitation of stakeholder processes and timely updates to STLS MYP.

Deliverables

Milestones and Linkages to other Projects

Project Participants: BASMAA (initial MYP draft); RMP (ongoing)

Due Date: WY 2012 Watershed Monitoring Plan complete by July 2011; other due dates TBD.

RMP Contributions and Years: 2011 special allocation approved: $41,000; 2012: $0; 2013 approved $50,000. ; 2014-2015 TBD.
BASMAA funding 2011: $45,000; 2012: $94,000; 2013 $115,000 budgeted; 2014-2015 TBD.

Total Cost: TBD.

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Appendix A – References and Resources for PCBs and Mercury-related Activities by the Regional Monitoring Program and BASMAA.
(provided with Version 2011, BASMAA Monitoring Status Report Appendix B2a http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/MRP/2011_AR/BASMAA/B2a_2010-11_MRP_AR.pdf).

Appendix B – Regional Watershed Spreadsheet Model Construction and Calibration
(provided with Version 2012B, BASMAA Monitoring Status Report Appendix B4b
http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/MRP/2012_AR/BASMAA/BASMAA_2011-12_MRP_AR_POC_APPENDIX_B4b.pdf)

Appendix C - Optimizing Sampling Methods for Pollutant Loads and Trends in San Francisco Bay Urban Stormwater Monitoring.
(provided with Version 2011, BASMAA Monitoring Status Report Appendix B2c http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/MRP/2011_AR/BASMAA/B2c_2010-11_MRP_AR.pdf)

Appendix D - Exploratory Categorization of Watersheds for Potential Stormwater Monitoring in San Francisco Bay.
(provided with Version 2011, BASMAA Monitoring Status Report Appendix B2d http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/MRP/2011_AR/BASMAA/B2d_2010-11_MRP_AR.pdf)

Appendix E - Watershed Characterization Field Study.
(preliminary summary provided with Version 2011, BASMAA Monitoring Status Report Appendix B2e
http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/MRP/2011_AR/BASMAA/B2e_2010-11_MRP_AR.pdf)

Appendix F – Sampling and Analysis: Quality Assurance.
(provided with Version 2011, BASMAA Monitoring Status Report Appendix B2f http://www.waterboards.ca.gov/sanfranciscobay/water_issues/programs/stormwater/MRP/2011_AR/BASMAA/B2f_2010-11_MRP_AR.pdf)

Appendix G – EMC Development and Source Area monitoring
(to be included in future version as applicable)

Development of Regional Suspended Sediment and Pollutant Load Estimates for San Francisco Bay Area Tributaries using the Regional Watershed Spreadsheet Model (RWSM): Year 2 Progress Report

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Introduction, context and objectives

The RMP is providing direct support for answering specific Management Questions through multi-year Strategies consisting of coordinated activities centered on particular pollutants of concern (POCs) or processes. The Small Tributaries Loading Strategy (STLS, SFEI, 2009) presented an initial outline of the general strategy and activities to address four key Management Questions:

1. Which Bay tributaries (including stormwater conveyances) contribute most to Bay impairment from POCs;
2. What are the annual loads or concentrations of POCs from tributaries to the Bay;
3. What are the decadal-scale loading or concentration trends of POCs from small tributaries to the Bay; and,
4. What are the projected impacts of management actions (including control measures) on tributaries and where should these management actions be implemented to have the greatest beneficial impact.

Since then, a Multi-Year-Plan (MYP) (STLS, 2011) has been written that provides a more comprehensive description of activities that will be included in the STLS over the next 5-10 years in order to provide information in compliance with the municipal regional stormwater permit (MRP; Water Board 2009). The MYP provides detailed rationale for the methods and locations of proposed activities, including loads monitoring of local tributaries. The MYP, which will be updated at least once a year to reflect evolving information, recommended the development of the Regional Watershed Spreadsheet Model (RWSM) as a tool for estimating regional loads. Point-source loads, though covered in TMDLs or other potential regulatory activities, are not included in this model.

The first phase of the project (Year 1) served to develop a GIS-based regional rainfall-runoff model, calibrate the hydrology, collate land use / source specific concentration data for pollutants of interest, and perform initial forays into sediment and pollutant models (Lent and McKee, 2011). The RWSM Year 1 report concluded that there were concerns with the hydrologic calibration data set and with the underlying land use data set, and that the immediate next steps should be to refine hydrology model by:

- Adding several calibration watersheds to ensure watershed characteristics spanned a wider range of imperviousness including more of the higher %IC character
- Removing any gage records incongruent with land use / impervious data
- Refining land use categories and re-calibrating model

This write-up serves to document these model refinements performed during year 2 of the RWSM development. At the end of year 2, no further hydrologic model refinement was recommended as a priority in year 3; focus should now shift to the sediment and contaminant models. However, development and calibration of a selection of water quality models in year 3 may highlight weaknesses in the hydrological model that may need to be addressed in year 4 in concert with other priorities identified at that time.

Improved calibration data set

The original calibration data set used in the RWSM Y1 model (Lent and McKee, 2011) lacked representation at the high end of the imperviousness range. This was was problematic because highly impervious areas contribute disproportionately to runoff and because San Francisco Bay is ringed by highly developed flatlands. Only one of the original watersheds had greater than 50% impervious surface (Figure 1). To better represent the range of development conditions present in the Bay Area, we added three high imperviousness watersheds to the calibration data set: Ettie Street Pump Station (79% impervious), Victor-Nelo Pump Station (88%) and Laurelwood Pump Station (74%) (Figure 1, right side). In keeping with Bay Area development patterns, all of the high imperviousness watersheds added were in the highly developed lowlands. Additionally, the sites added were all pump stations due to the lack of flow monitoring in highly urban watersheds. The added advantage of including these watersheds is they might also include some of the source areas proposed for structuring the PCB and Hg model components.

The data sets for all of the pump stations were derived from pump run logs, which were converted to estimated flow using the maximum pump capacity for each station. This assumption of instantaneous pump "run-up" and maximum rated capacity introduces errors, but they are likely small relative to the overall magnitude of flow volume passed by the pumps. To check if the pump data logs seemed reasonable, we plotted monthly rainfall versus estimated flow volume using the 5 months of data available for each station (Figure 2). The pump data showed a good correlation with rainfall for the two South Bay pump stations. Based on 41 months of data, Ettie Street pump station records exhibited a strong relationship with rainfall as well (R^2 = 0.98, data not shown).

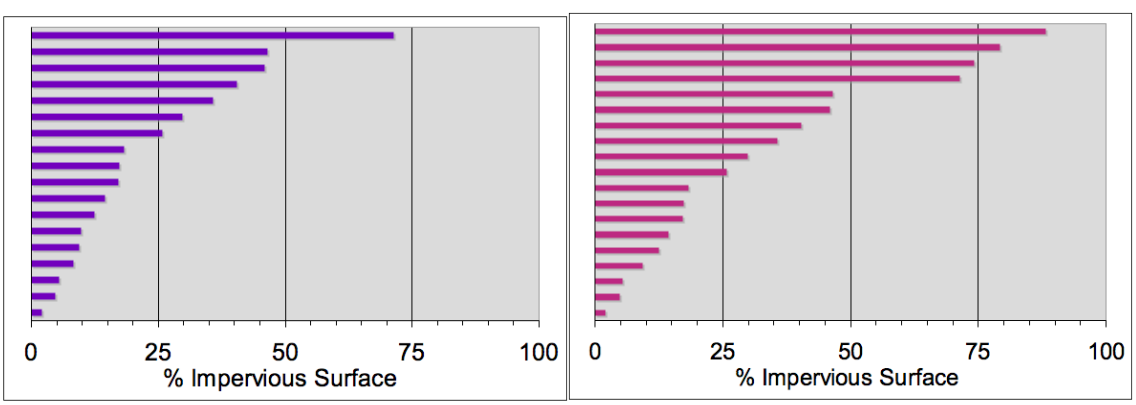

Figure 1 - Percent imperviousness in the original (Left) and updated (Right) calibration watershed data set. The left panel shows the RWSM Y1 calibration data with only one watershed with >50% impervious surface.

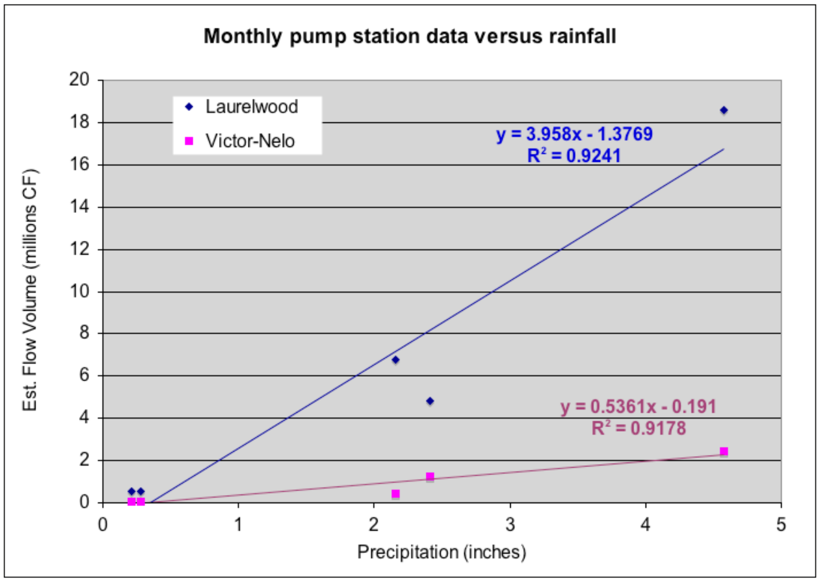

Figure 2 - Correlation between flow obtained by conversion of the pump data logs (using assumptions about pump capacity) and rainfall.

Aside from the lack of representation at the high end of the imperviousness range in the original calibration data set, we were also concerned about potential incongruence between disparate non stationary data that represents differing time periods. Given that we were using a land use and impervious surface data set from the 1990-2000s to estimate runoff coefficients, some of the older gage records potentially were not representative of more recent hydrological behavior in some of the calibration watersheds, especially if significant development had occurred in the watershed between the start of the gage data record and the 1990s. We checked the older (pre-1990s) gage records for watersheds with ≥5% built impervious surface for changes in runoff behavior over time. In some watersheds, a distinct development signal was shown by the increase in runoff coefficient by decade; a prime example is Colma Creek, which underwent massive development over the period of flow monitoring (Figure 3). As a result of this analysis, we removed earlier portions of several gage records (Colma Creek, Matadero Creek, and Walnut Creek). Additionally we completely removed two records which ended too early to properly evaluate hydrologic changes relative to more recent conditions: Arroyo Corte Madera (1966-1986) and Wildcat Creek at Richmond (1965-1975).

Watersheds in our calibration data set span the entire spatial geography of the Bay Area and incorporate watersheds that represent a wide range of imperviousness (Table 1). A flow record actually exists for Sunnyvale East Channel, but unfortunately it is of poor quality (pers. comm., Ken Stumpf, SCVWD), which was apparent when the record was regressed against rainfall (R^2 = 0.58). Upon further analysis, based on regression with rainfall data, data quality was found to be good before 2001. This subset of data was initially used in the calibration but Sunnyvale Creek was found to be the worst performer in the model amongst all the calibration watersheds again casting dispersion on data quality. We decided to reject incorporating it at this time but may include it in the future once data generated by SFEI monitoring efforts can be used to verify quality. Our basic check of data quality revealed very

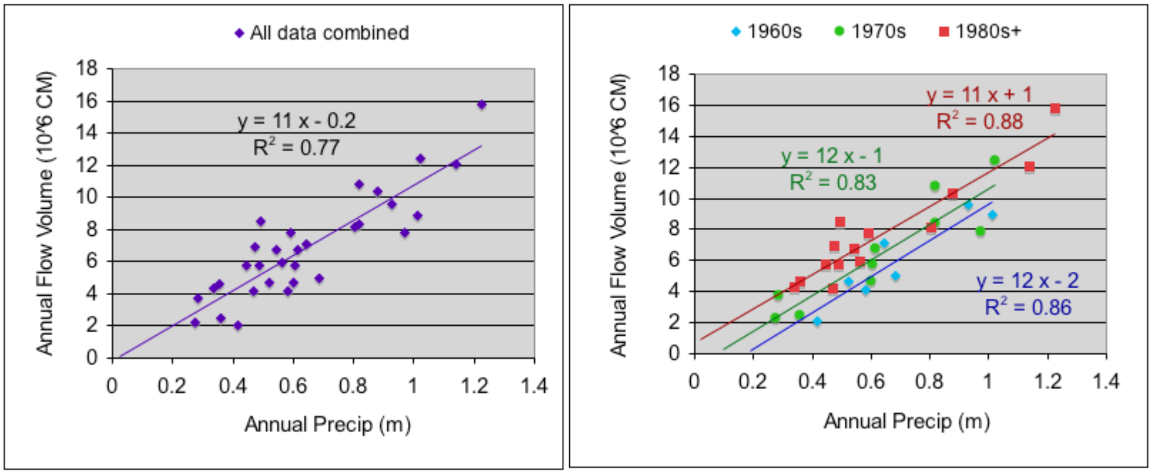

Figure 3 - Colma Creek rainfall-runoff relationship changing over time.

Table 1 - Updated calibration watershed set.

Watershed	County	Agency / Gage ID	Gage Record Used	% Built Imp. c.2000
Canoas Creek	Santa Clara	SCVWD 1485	1995-2007	46
Castro Valley Creek	Alameda	USGS 11181008	1972-2009	46
Colma Creek	San Mateo	USGS 11162720	(REVISED) 1981-1994	38
Dry Creek	Napa	USGS 11458500	1952-1966	0.1
Matadero Creek	Santa Clara	USGS 11166000	(REVISED) 1981-2009	17
Novato Creek	Marin	USGS 11459500	1947-2009	3
Pinole Creek	Contra Costa	USGS 11182100	1940-1977	0.3
Corte Madera Creek	Marin	USGS 11460000	1952-1993	5
Ross Creek	Santa Clara	SCVWD 2058	1995-2007	36
San Ramon Creek	Contra Costa	USGS 11182500	1953-2009	3
San Tomas Creek	Santa Clara	SCVWD 2050	1973-2009	30
Sonoma Creek	Sonoma	USGS 11458500	1956-1981; 2002-2009	2
Upper Napa River	Napa	USGS 11456000	1940-1995; 2001-2009	2
Walnut Creek	Contra Costa	USGS 11183600	(REVISED) 1981--1992	13
Wildcat Creek - Vale	Contra Costa	USGS 11181390	1976-1995	4
Zone 4 Line A Channel	Alameda	SFEI (no ID)	2007-2010	71
San Leandro Creek	Alameda	SFEI (no ID)	To be monitored WY2012	38
Sunnyvale East Channel	Santa Clara	SFEI (no ID)	To be monitored WY2012	59
Victor-Nelo Pump Station	Santa Clara	City of Santa Clara	2009-2010	88
Laurelwood Pump Station	Santa Clara	City of Santa Clara	2009-2010	74
Ettie St. Pump Station	Alameda	ACFCD	2005-2008	79

strong relationships between a local representative rainfall data set and the annual runoff ranging between r^2=0.78 to r^2=0.98 (Table 2).

The model was rerun using the reevaluated watershed calibration data sets that included dropping some watersheds and picking up others (Table 3). Unfortunately, the model performance worsened with the updated calibration data set. The two worst performers in the revised data set were the South Bay pump stations: Laurelwood being under-simulated by 95% and Victor-Nelo being over-simulated by 60%. This may reflect the very short records and the conversion of pump logs to estimated flow not providing an accurate target volume for calibration. But this poor performance may also reflect the model being over-calibrated to the new calibration data set being skewed towards less impervious areas. Without longer, higher quality flow records in highly impervious watersheds, it's hard to know. Ettie Street Pump Station has a longer record (albeit with the pump log-to-flow conversion issues), and is also one of the worst performers (under-simulated by 86%), suggesting that at least part of the problem is over-calibration to a data set lacking representation of high impervious areas.

Table 2 - Rainfall-runoff regression equations for updated calibration set.

Watershed	PRISM Annual Prec. (m)	Rainfall gage	Scale rainfall?	Regression			Est. Annual Volume (10^6 CM)
				Slope	Y-int.	R^2	
Canoas Creek	0.48	Alamitos	No	17	-1.8	0.87	6.6
Castro Valley Creek	0.58	Upper San Leandro	Yes	7.8	-1.4	0.93	3.2
Colma Creek (REVISED time period: WY1981-1994)	0.66	SFO Airport	Yes	11	+0.73	0.88	7.9
Dry Creek	1.05	St. Helena	Yes	34	-19	0.94	17
Matadero Creek (REVISED time period: WY1981-2009)	0.55	Palo Alto	Yes	9.6	-2.2	0.85	3.2
Novato Creek	1.04	Petaluma	Yes	28	-16	0.88	11
Pinole Creek	0.63	Berkeley	Yes	16	-5.7	0.88	4.1
Corte Madera Creek	1.08	San Rafael	Yes	36	-16	0.86	55
Ross Creek	0.59	Johnson Ranch	No	7.5	-0.98	0.87	3.4
San Ramon Creek	0.67	Berkeley	Yes	10	-3.9	0.86	2.9
San Tomas Creek	0.62	Palo Alto	Yes	19	-5.5	0.78	6.4
Sonoma Creek	1.08	Sonoma	Yes	111	-45	0.86	75
Upper Napa River	1.05	St. Helena	Yes	143	-69	0.95	81
Walnut Creek (REVISED time period: WY1981-1992)	0.60	Berkeley	Yes	155	-43	0.94	50
Wildcat Creek - Vale	0.66	Richmond	Yes	13	-3.9	0.92	5.0
Zone 4 Line A Channel	0.49	Hayward 541A	No	1.8	-0.013	0.93	0.86
Victor-Nelo Pump Station	0.38	San Jose	Yes	0.59	-0.0054	0.92	0.22
Laurelwood Pump Station	0.39	San Jose	Yes	4.3	-0.039	0.92	1.6
Ettie St. Pump Station	0.54	Oakland Museum	Yes	10	0.070	0.98	5.7

Table 3 - Model performance (% difference between simulated and observed values).

Calibration set	Mean	Median	Minimum	Maximum
Original	+2%	+3%	-42%	+46%
Updated	+1%	+9%	-95%	+60%

Another possibility is the assumption of linearity in the relationship between imperviousness and the resulting runoff coefficient. For example, in the LA region (even more arid than the Bay Area), a curvilinear function has been applied (Figure 4) (Peter Mangarella, GeoSyntec Consultants, Oakland, personal communication, February 2012). In addition another problem with runoff coefficient modeling method is that contribution from both impervious and pervious areas can vary depending on storm size and season (soil moisture content and evapotranspiration). This has been discussed extensively in science literature and was documented by M.I Budyko in 1974. The "Budyko curve", as it came to be referred to, describes the relationship between climate, evapotranspiration and runoff (Donohue et al., 2006; Gerrits et al., 2009). The explicit outcome of the curve is that watersheds of differing rainfall and heat should have differing inter-annual rainfall -runoff functions. Thus, the centrality of the medium or mean relative to the runoff extremes in reaction to rainfall extremes will be a function of aridity. This is presently not incorporated into the year 2 version of the RWSM but could be in future versions. This appears consistent with experience in Wisconsin, where runoff coefficients have been defined as a function of both land use and percent connected imperviousness and rainfall depth (Roger Bannerman, personal communication, December 2011).

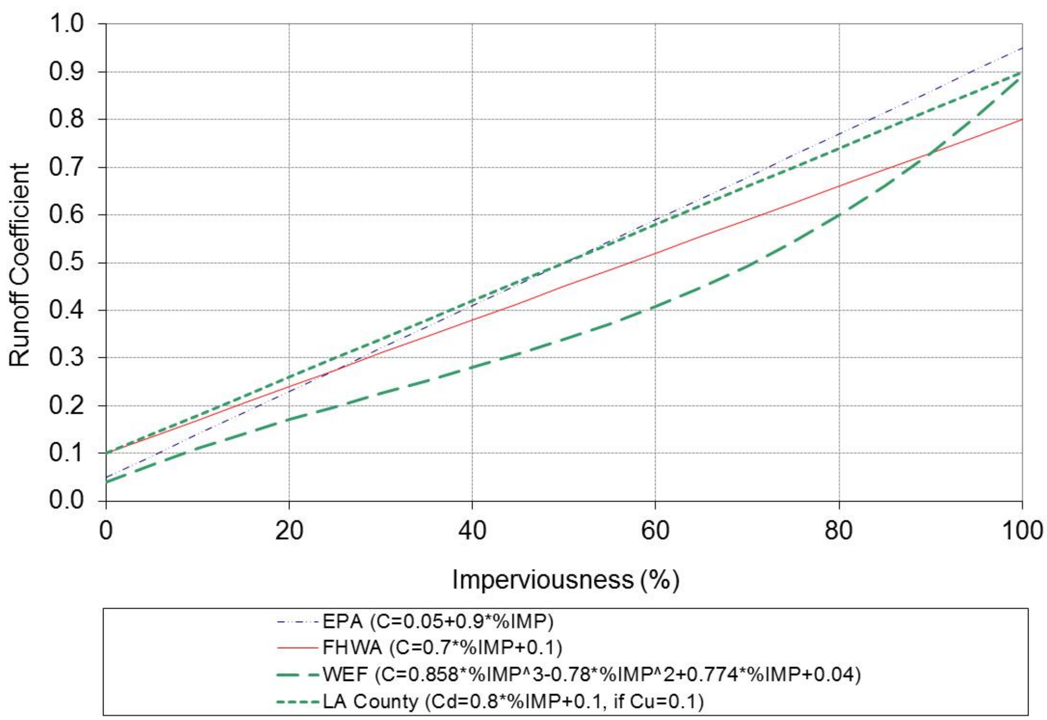

Figure 4. Runoff coefficients as a function of imperviousness. Source: Peter Mangarella, GeoSyntec Consultants, Oakland.

Refined land use input data

During development of the base hydrology model, we noticed that the land use layer (ABAG 2000) contained discrepancies related to transportation land use. Specifically, for Alameda and Santa Clara counties, local roads were not broken out into their own category (Figure 5) as they had been for the other Bay Area counties. Upon close inspection, it was noted that the land use resolution varied dramatically between counties (Figure 6). These discrepancies were corrected in the updated land use layer (ABAG 2005). Accordingly the model was re-developed using the improved ABAG 2005 land use data set.

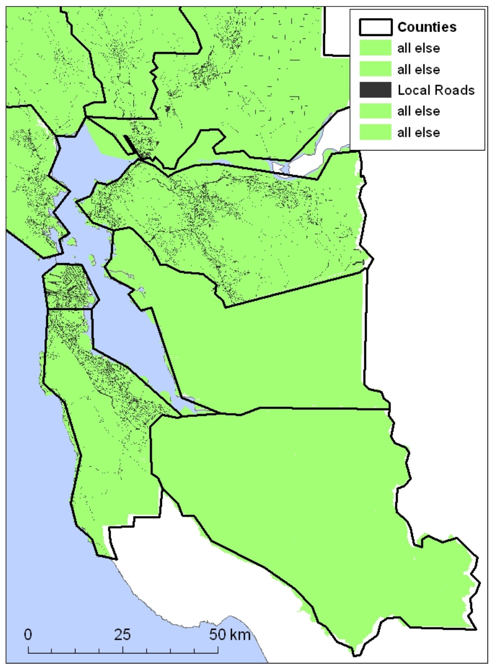

Figure 5 - Discrepancies in ABAG 2000 data set for transportation land use.

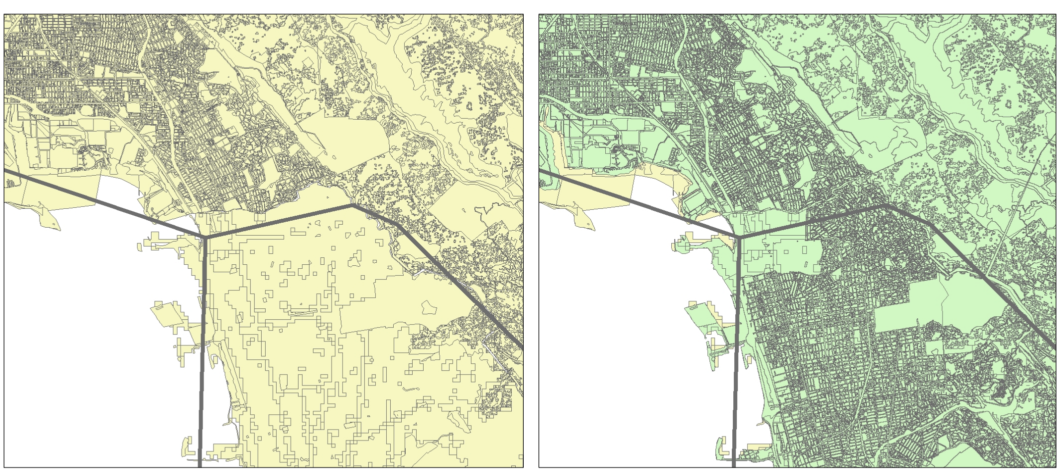

Figure 6 – ABAG 2000 versus ABAG 2005 (zoomed to border of Contra Costa and Alameda Counties).

The revised treatment of transportation land use in Alameda and Santa Clara counties between ABAG 2000 and ABAG 2005 (Figure 7) resulted in more area being assigned very high runoff coefficients (since transportation RC = 0.8). As a result, the modeled runoff increased fairly dramatically and the overall performance shifted towards over-simulation (Table 4). This performance change adds further support to the hypothesis that the previous version of the model was over-calibrated to previous input parameters.

For the development of the base hydrology model, most land use categories were treated as a single land category (as in Davis et al., 2000). However, land use categories can encompass a large range of runoff behavior, either through variable imperviousness or dirt compaction. To improve the treatment of runoff, we used the imperviousness underlying the different land use categories to reclassify some of the land use descriptions and to create higher resolution categories (Figure 8; Table 5). For the example shown in Figure 8, approximately 40 land use descriptions that make up the commercial land use category (e.g., Offices, Hospitals, etc) were reclassified into “High density commercial” and “Low density commercial” based on their average percent imperviousness.

The open land use category was split into two categories based on expected hydrologic behavior. Areas such as forests and rangelands were assigned to the “Infiltrative open” category and areas such as golf courses and cemeteries were assigned to “Compacted open” since we expect a greater fraction of rainfall will runoff compacted ground compared to less disturbed soil.

The revised land use categories were applied to the model (Figure 9) and we re-calibrated the runoff coefficients. The results of the re-calibration (Table 6) do not look as good as version 1 of the model, but we have reduced bias in the calibration data set. Unfortunately, while reducing bias through introducing the high impervious pump station watersheds, we probably have increased the errors associated with the target calibration volumes by using short records with known flaws. To do a better job of calibrating the high imperviousness areas we need high quality, multi-year flow records from highly developed watersheds. Without this type of data, we are limited in our ability to calibrate this portion of the model.

Conclusion

The tasks performed in year 2 of the Regional Watershed Spreadsheet Model (RWSM) served to correct or reduce errors and biases in the hydrological model that were noted in the year 1 report. The hydrologic model will need to be re-visited, for example, in the context of calibrating the sediment model (the development of which is one of the next steps) or the contaminant models. When the hydrologic model is next re-calibrated, to reduce the possibility of over-calibration, the calibration watershed data set should be split into two sets and calibrate to one set and then verify the calibration on the other (Mike Strenstrom, personal communication, October, 2011). In addition next versions of the hydrologic portions of the model may be improved by incorporating runoff coefficients that have either a curvilinear function with imperiousness alone (Peter Mangarella, GeoSyntec Consultants, Oakland, personal communication, February 2012 or runoff coefficients defined as a function of both land use and percent connected imperviousness and rainfall depth (Roger Bannerman, personal communication, December 2011).

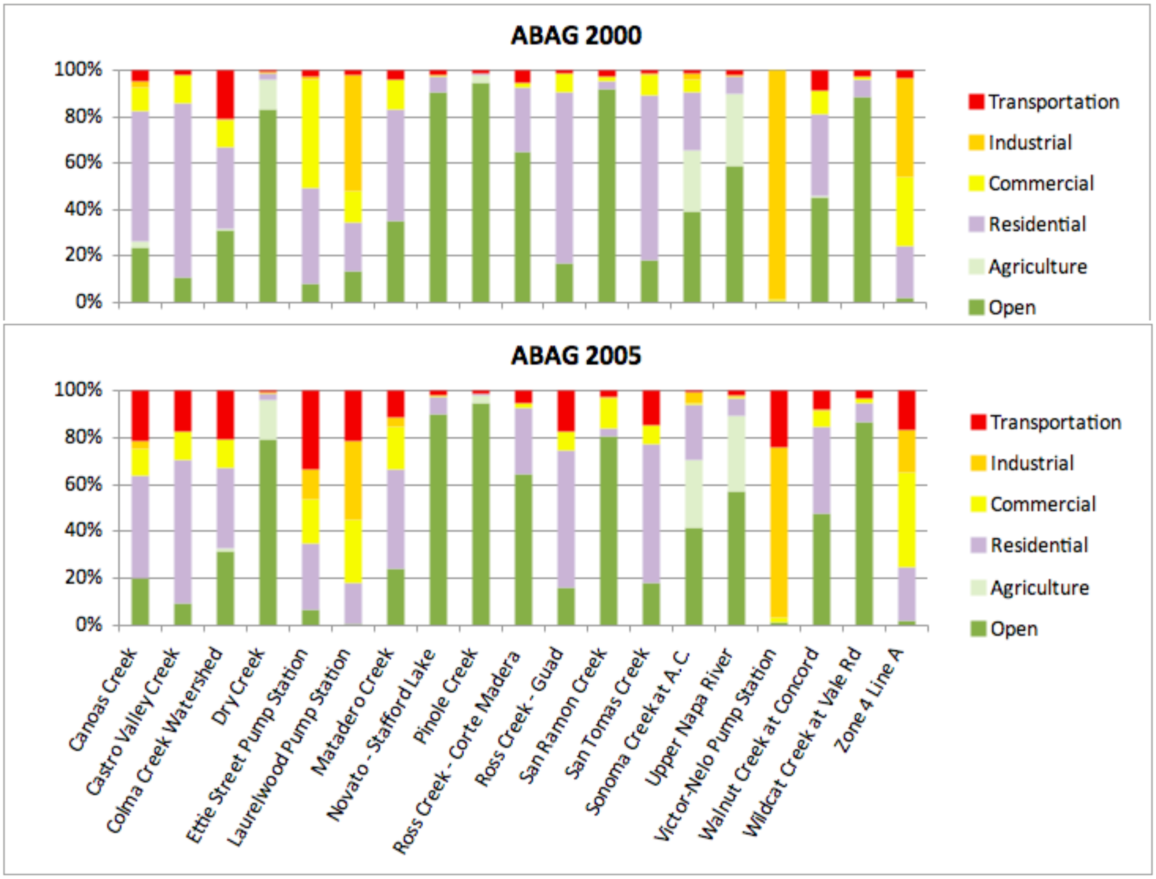

Figure 7 - Changes in land use classification from ABAG 2000 to ABAG 2005 for calibration watersheds.

Table 4 - Model performance for different land use data sets (using updated watershed set).

Land use data set	Mean	Median	Minimum	Maximum
ABAG 2000	+1%	+9%	-95%	+60%
ABAG 2005	+13%	+17%	-78%	+79%

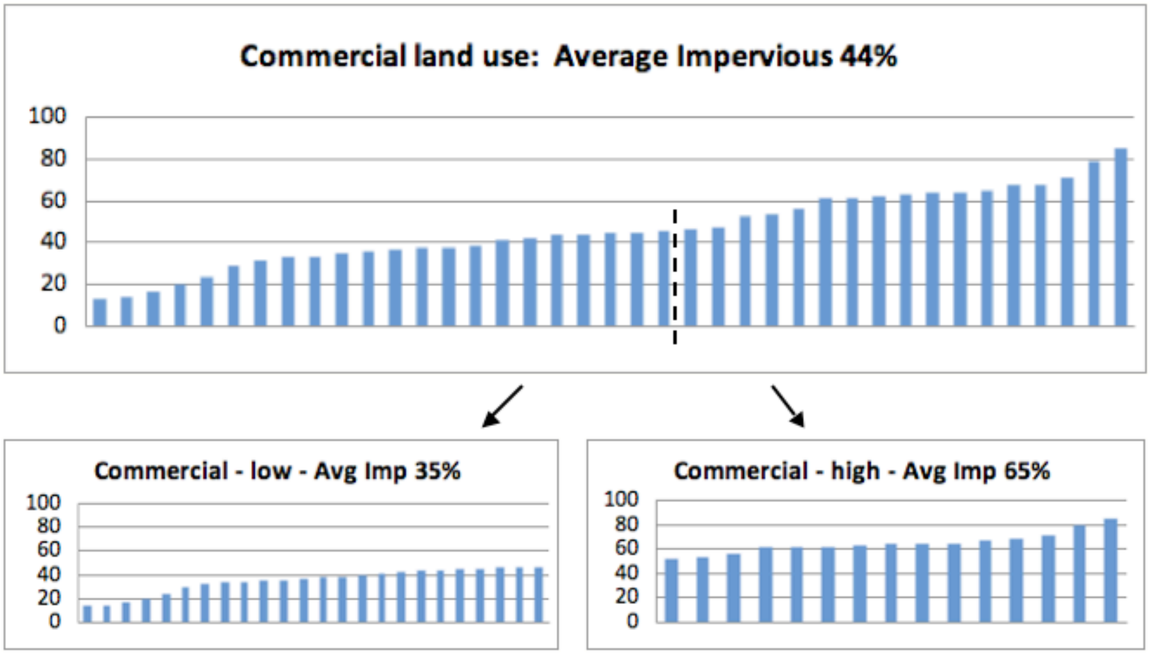

Figure 8 – An example of using imperviousness to reclassify land use descriptions into categories that more accurately group runoff behavior

Table 5 – Revised higher resolution categories for assignment of runoff coefficients. Note the full listing of land use descriptions with assigned categories and average percent impervious is presented in the Appendix.

Original Categories	Revised Categories
Agriculture	Agriculture
Open	Open
	Open – compacted
Residential	Residential – rural
	Residential – low
	Residential – med
	Residential – high
Commercial	Commercial – low
	Commercial – high
Industrial	Industrial
Transportation	Transportation
Water	Water
	Water – runoff

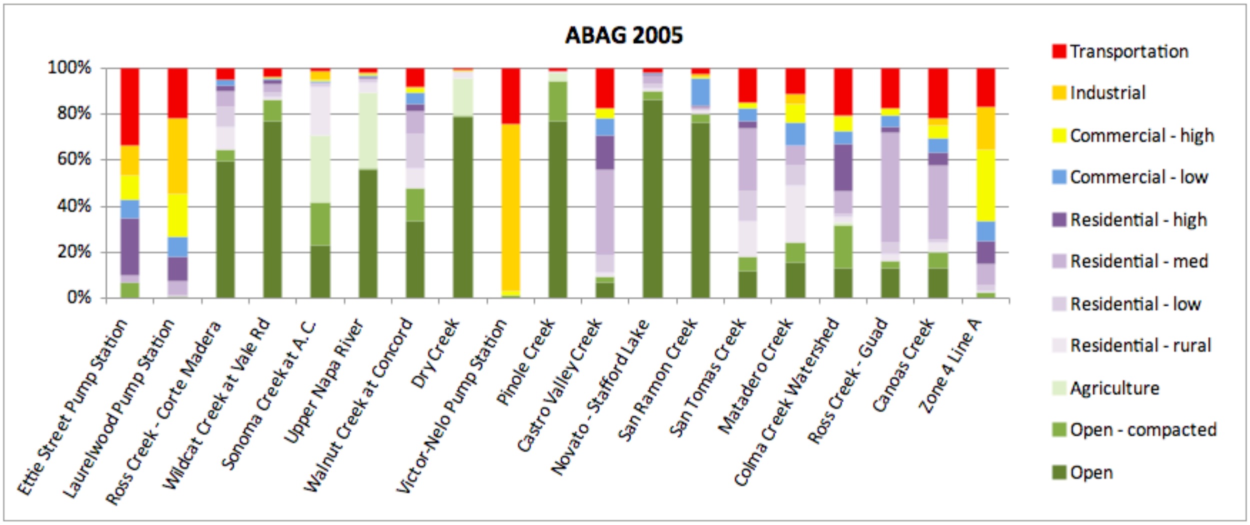

Figure 9 - Distribution of revised land use categories in calibration watershed set.

Table 6 - Model performance.

Model	Mean	Median	Minimum	Maximum
Uncalibrated ABAG 2005	+13%	+17%	-78%	+79%
Calibrated ABAG 2005 (rev. cat.)	+1%	+3%	-75%	+70%

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Appendix - Revised land use classification for runoff coefficients.

Land Use Description	Original Reclassification	New Reclassification	Mean % Imp.
Cropland & Pasture	Agriculture	Agriculture	1
Cropland	Agriculture	Agriculture	1
Confined Feeding (Including Feed Lots)	Agriculture	Agriculture	3
Small Grains	Agriculture	Agriculture	3
Pasture	Agriculture	Agriculture	4
Orchards, Groves, Vineyards, And Nurseries	Agriculture	Agriculture	6
Row Crops	Agriculture	Agriculture	6
Vineyards And Kiwi Fruit	Agriculture	Agriculture	11
Farmsteads And Agricultural Buildings	Agriculture	Agriculture	13
Orchards Or Groves	Agriculture	Agriculture	13
Military Installations	Commercial	Commercial - low	13
Military Hospital	Commercial	Commercial - low	14
Transitional Or Mixed Use Of Land Areas	Commercial	Commercial - low	17
Medical Clinics	Commercial	Commercial - low	20
Colleges & Universities	Commercial	Commercial - low	24
Greenhouses And Floriculture	Agriculture	Commercial - low	29
Stadiums	Commercial	Commercial - low	32
Local Gov't Jails And Rehab Centers	Commercial	Commercial - low	33
Extensive Recreation	Open	Commercial - low	33
State Prisons	Commercial	Commercial - low	35
Medical Long-Term Care Facilities	Commercial	Commercial - low	36
Transitional Areas	Open	Commercial - low	37
City Halls & Co., State, Fed. Govt. Facilities	Commercial	Commercial - low	38
Education	Commercial	Commercial - low	38
Elementary & Secondary Schools	Commercial	Commercial - low	39
Mixed Commercial & Industrial Complexes	Commercial	Commercial - low	41
Other Transitional	Open	Commercial - low	42
Commercial Or Services Vacant	Open	Commercial - low	44
Museums And Libraries	Commercial	Commercial - low	44
Commercial	Commercial	Commercial - low	45
Closed Military Facilities	Commercial	Commercial - low	45
Communications Facilities	Commercial	Commercial - low	46
Local Government And Other Public Facilities	Commercial	Commercial - low	47
Churches, Synagogues, And Mosques	Commercial	Commercial - low	47
Community Hospitals	Commercial	Commercial - high	52
Convention Centers	Commercial	Commercial - high	54
Daycare Facilities	Commercial	Commercial - high	56
Hospitals, Rehab, Health, & State Prisons	Commercial	Commercial - high	61
Hotels And Motels	Commercial	Commercial - high	62
Stadium	Commercial	Commercial - high	62
Research Centers	Commercial	Commercial - high	64
Offices	Commercial	Commercial - high	64
Hosptals - Designated Trauma Centers	Commercial	Commercial - high	64
Fire Station	Commercial	Commercial - high	65
Mixed Use In Buildings	Commercial	Commercial - high	67
Retail And Wholesale	Commercial	Commercial - high	68
Police Station	Commercial	Commercial - high	71
Warehousing	Commercial	Commercial - high	79
Out-Patient Surgery Centers	Commercial	Commercial - high	85
Strip Mines & Quarries, Commercial Opera	Industrial	Industrial	23
Water Storage (Covered)	Industrial	Industrial	26

Land Use Description	Original Reclassification	New Reclassification	Mean % Imp.
Food Processing	Industrial	Industrial	26
Municipal Water Supply Facilities	Industrial	Industrial	32
Wastewater Treatment Plant	Industrial	Industrial	34
Water Treatment (Filtration) Plant	Industrial	Industrial	35
Earth Works Not Part Of Commercial Extra	Open	Industrial	36
Industrial Vacant	Open	Industrial	39
Electric, Other	Industrial	Industrial	40
Electric Substation	Industrial	Industrial	47
Heavy Industrial	Industrial	Industrial	52
Wastewater Storage	Industrial	Industrial	54
Light Industrial	Industrial	Industrial	55
Wastewater Pumping Station	Industrial	Industrial	57
Industrial	Industrial	Industrial	69
Electric Power Plant	Industrial	Industrial	72
Media Broadcast Towers And Facilities	Industrial	Industrial	84
State Psychiatric Facilities	Commercial	Open - Compacted	0
Camps And Campgrounds	Open	Open - Compacted	1
State Mental Health And Devel. Disabled	Commercial	Open - Compacted	2
Military Open Areas	Open	Open - Compacted	4
Golf Courses	Open	Open - Compacted	7
Military - General Use	Commercial	Open - Compacted	9
Urban Open Space - Slated For Redevelopment	Open	Open - Compacted	10
Racetracks	Open	Open - Compacted	11
Bare Exposed Rock	Open	Open - Compacted	14
Cemeteries	Open	Open - Compacted	14
Residential Vacant	Open	Open - Compacted	14
Urban Parks	Open	Open - Compacted	17
Commonly Owned Residential, No Du	Residential	Open - Compacted	18
Other Urban And Built-Up Land	Open	Open - Compacted	20
Sanitary Landfills	Open	Open - Compacted	23
Commercial Intensive Outdoor Recreation	Open	Open - Compacted	24
Urban Vacant Undeveloped Land	Open	Open - Compacted	25
Nonforested Wetlands	Open	Open	2
Mixed Forest - Protected As Park	Open	Open	3
Evergreen Forest - Protected As Park	Open	Open	3
Salt Evaporation Ponds	Open	Open	4
Shrubland - Protected As Park	Open	Open	6
Herbaceous Rangeland - Protected As Park	Open	Open	6
Beaches	Open	Open	7
Herbaceous Rangeland	Open	Open	7
Mixed Forest	Open	Open	8
Mixed Rangeland	Open	Open	9
Mixed Rangeland - Protected As Park	Open	Open	10
Forested Wetlands	Open	Open	11
Deciduous Forest - Protected As Park	Open	Open	11
Sedimentation Ponds	Open	Open	12
Land On Usgs Topo Maps, Water On Other Maps	Open	Open	13
Deciduous Forest	Open	Open	14
Evergreen Forest	Open	Open	14
Mixed Sparsely Vegetated Land	Open	Open	17
Quarries, Strip Mines, And Gravel Pits	Open	Open	19
Shrub And Brush Rangeland	Open	Open	21

Land Use Description	Original Reclassification	New Reclassification	Mean % Imp.
Dune Or Other Sand (Not Beaches)	Open	Open	54
Very Low Density: < 1 & >= 0.2 Du Per Acre	Resid-rural/low	Resid-rural	11
Residential	Residential	Resid-low	16
Low Density: >= 1 Du/Acre And <3 Du/Acre	Resid-rural/low	Resid-low	22
Military Residential	Residential	Resid-med	33
University Housing	Commercial	Resid-med	35
Medium Density: >= 3 Du/Acre And <8 Du/Acre	Resid-low/med	Resid-med	42
Mixed Residential & Commercial Use	Residential	Resid-high	49
Group Quarters Residential	Residential	Resid-high	52
Mobile Homes And Mobile Home Parks	Residential	Resid-high	55
High Density: >= 8 Du/ Acre	Resid-med/high	Resid-high	57
Road Transportation Facilities	Transportation	Transportation	12
Inspection And Weighing Stations	Transportation	Transportation	14
Transportation, Communication, And Utilities	Transportation	Transportation	25
Rail Transportation Facilities	Transportation	Transportation	29
Private Airfield	Transportation	Transportation	30
Military Airport	Transportation	Transportation	33
General Aviation (Public) Airfield	Transportation	Transportation	37
Airports	Transportation	Transportation	42
Truck Or Bus Maintenance Yards	Transportation	Transportation	49
Highways And Interchanges	Transportation	Transportation	50
Local Roads And Streets	Transportation	Transportation	50
Marina	Transportation	Transportation	55
Commercial Port Passenger Terminal	Transportation	Transportation	62
Park And Ride Lots	Transportation	Transportation	63
Commercial Port Other Terminals and Ship	Transportation	Transportation	63
Parking Garages	Transportation	Transportation	63
Rail Yards	Transportation	Transportation	65
Commercial Port Oil & Liquid Bulk Terminal	Transportation	Transportation	65
Commercial Airport Runway	Transportation	Transportation	66
Commercial Airport - General Facilities	Transportation	Transportation	69
Rail Passenger Stations	Transportation	Transportation	70
City, County Or Utility Corporation Yard	Transportation	Transportation	71
Ferry Terminal	Transportation	Transportation	74
Marine Transportation Facilities	Transportation	Transportation	75
Commercial Port Storage & Warehousing	Transportation	Transportation	80
Tow Boat (Tug) Facility	Transportation	Transportation	80
Commercial Port Container Terminal	Transportation	Transportation	85
Military Port	Transportation	Transportation	87
Commercial Airport Passenger Terminal	Transportation	Transportation	90
Commercial Airport Airline Maintenance	Transportation	Transportation	92
Commercial Airport Utilities	Transportation	Transportation	93
Commercial Airport Air Cargo Facility	Transportation	Transportation	96
Bays & Estuaries	Water	Water	5
Lakes	Water	Water	9
Reservoirs	Water	Water	9
Unclassified Water	Water	Water	6
Water - Industrial Ports And Piers Over	Water	Water	67
Water - Residential (Arks) Over Water	Water	Water	38
Water On Usgs Topo Maps, Land On Other Maps	Water	Water	52
Water Storage (Open)	Water	Water	27

Appendix E

Status Report - Sediment Delivery Estimate/Budget (Provision C.8.e.vi)

Sediment Delivery Estimate/Budget:

Status Review and Proposed Modifications

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And

Regional Monitoring Program for Water Quality in San Francisco Bay (RMP)
Sources Pathways and Loadings Workgroup (SPLWG)
Small Tributaries Loading Strategy (STLS)

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1. Introduction

San Francisco Bay is impaired by mercury and PCBs (SFRWRCB 2006; SFRWRCB, 2008) and urban runoff from local watersheds has been identified as a significant pathway for these and many pollutants of concern (POC) (Municipal Regional Stormwater Permit (MRP); SFRWRCB, 2009). The permit contains several provisions that require management actions and studies to address information gaps for mercury, PCBs, legacy pesticides, PBDEs, and selenium (portions of provisions C.8, C.11, C.12, and C.14). Provision C.8.e requires permitees to, among other things, determine which Bay tributaries (including stormwater conveyances) contribute most to Bay impairment from POCs and to provide improved estimates of annual average loads or concentrations of POCs from tributaries to the Bay. To address these and other requirements, a Multi-Year-Plan (MYP) has been written and updated (STLS, 2011; STLS, 2012). Included in the MYP are rationale for modeling using the regional watershed spreadsheet model (RWSM) to estimate regional scale loads (Lent and McKee, 2011; Lent et al., 2012; Gilbreath et al., in preparation).

Fine suspended sediments (functionally defined as <0.0625mm), eroded from industrial areas and other components of the urban environment, are known to be enriched with these hydrophobic pollutants (Lent and McKee, 2011). During rainstorms, pollutant-enriched fine sediments are easily entrained into sheet flow and find their way into the stormwater collection systems where they are quickly conveyed to the Bay. Given this, hydrophobic POCs may be best modeled using hybrid RWSM modeling structures that include the ability for the user to select water or sediment transport processes as the basis for each land use or source area (Lent and McKee, 2011). Consistent with this premise, MRP Provision C.8.e(vi) requires permittees to design a robust sediment delivery estimate/sediment budget for local tributaries and urban drainages.

The objective of this short report is to briefly review and critically evaluate previous regional estimates of fine suspended sediment loads to the Bay and to highlight weaknesses in relation to POC loads modeling and any other proposed information uses. Modifications are proposed to address weaknesses, task priorities are proposed, and next steps are generally identified.

2. Status review

2.1. History of estimates

The first estimates of suspended sediment loads entering the Bay from local tributaries within the nine-county Bay Area were based on field measurements made by the USGS in a few larger watersheds (Napa, Sonoma, San Francisquito, Guadalupe, and Alameda) during three water years (1957-1959) (Krone, 1979). These were later modified by Porterfield (1980), who included a longer time period of 10 water years in some of the watersheds (1957-1965) and an additional two watersheds (Walnut Creek and Colma Creek). To estimate regional sediment load, both authors scaled the measured sediment loads for the measured watershed areas by an area ratio although the estimate by Porterfield (1980) applied a slightly more sophisticated technique that took into account a recognition of "areas of negligible contribution" that were unlikely to functionally supply sediment through rainfall run-off induced fluvial processes. These estimates remained the best estimates until the Regional Monitoring

Program for Water Quality in San Francisco Bay (RMP) provided funding in 2000-2002 to review existing sediment loads estimates in relation to supply of pollutants to the Bay from the Central Valley via the Sacramento – San Joaquin River Delta (McKee et al 2002), and from local small tributaries in the nine County Bay Area (McKee et al 2003). The estimates by McKee et al (2003) followed the same methodology as Krone (1979) and Porterfield (1980) with the following improvements:

1) Data on suspended sediment concentrations and loads was compiled up to and including the year 2000 thus incorporating data from a much greater number of watersheds (21) and covering wider climatic variability,
2) The data were climatically averaged by applying a flow weighted mean concentration (FWMC) for each measured watershed by estimates of annual average flow (based only on available data) for each watershed to estimate an annual average suspended sediment load.

However, despite these improvements, it was recognized that the existing USGS data sets were lacking information on sediment loads in urban areas, the simple area interpolation methodology did not take into account storage variations between basins of varying size (conceptually modeled as a delivery ratio that relates decreasing sediment yield (mass per unit area) to increasing basin area), and better spatial definition and regional loads estimates would provide an improved dataset for estimating: pollutant loads to the Bay; modeling pollutant processes in the Bay; and possibly uptake into the Bay food web. As such, the RMP funded another effort in 2008 to make improved regional sediment loads estimates. The following improvements were described in the resulting RMP technical report (Lewicki and McKee, 2009):

1) Data on suspended sediment concentrations and loads was compiled up to and including the year 2007 thus incorporating data from a yet greater number of watersheds (29) and covering wider climatic variability than McKee et al. (2003),
2) Loads for watersheds that directly drain the Bay where empirical measurements were made were climatically weighted for a 50-year period,
3) For other agriculturally dominated large watersheds, sediment loads were estimated using measured flow or estimates of flow over a 50 year period (using Alameda and Napa as the index watersheds) combined with sediment rating relationships specific to 3 sub-regions (North Bay, East Bay, and peninsular/South Bay),
4) Sediment loads from urban areas were estimated using the methods used in the HSPF model (unit area sediment erosion in relation to land use) taking into account delivery ratio (NRSC),
5) Sediment loads were estimated for 482 individual watersheds based on improved urban storm drain mapping, Contra Costa Creek and watershed maps, and a 10 m digital elevation model (DEM) before being summed to subregional scale estimates for each RMP Bay segment.

2.2. Likely uses of improved sediment loads information

The RWSM contains structural elements and equations that allow computation of POC loads based on:

1) spatial data for watershed boundaries, imperviousness, land use, and source areas, slope or flow accumulation,

2) estimates of annual average rainfall,
3) imperviousness, land use, or source area-based run-off coefficients (the proportion of rainfall that is converted to run-off), and
4) land use, or source area based pollutant concentrations (annually averaged event mean concentrations (EMCs)).

Depending upon the properties of the pollutant, POC could be modeled primarily as a function of hydrology, primarily as a function of sediment erosion and transport, or perhaps ideally as a hybrid where some land uses or source areas would be modeled using hydrology and others using sediment transport. The primary use of an improved robust sediment delivery estimate/sediment budget for local tributaries and urban drainages called for in MRP Provision C.8.e(vi) is to provide an improved basis for POC loads estimates. Secondary uses include the provision of improved sediment load estimates for modeling pollutant processes on the Bay margin in the context of the RMP modeling strategy, and information to support permitee questions in relation to creek beneficial uses (e.g. supporting anadromous fish populations). There are many tertiary uses of improved sediment loading that involve third parties using the data for management goals in relation to flood control, navigation in the Bay, and wetland restoration. However, these will not be discussed further here nor are driving factors for improved information.

2.3. Weaknesses in current estimates in relation to likely priority uses and proposed modification methods

Although considerable improvements were made over the last decade primarily through RMP efforts, given the objectives have been primarily focused on subregional and regional sediment loads estimates (McKee et al., 2003; Lewicki and McKee (2009)), there remain a few important weaknesses in the current suspended sediment loads estimates that are particularly pertinent to the proposed priority uses in relation to the MRP. A summary of proposed modification methods and a suggested priority in relation to weaknesses is provided (Table 1). This tabular summary is intended to be the basis for a suspended sediment RWSM workplan to assist BASMAA to address MRP Provision C.8.e(vi). Since all of the weaknesses are important in relation to the likely priority uses, once ratified by the Small Tributaries Loading Strategy (STLS) team, we propose to implement improvements to the model focusing on the highest priority aspects first and work down the table as far as budget allows.

A. Larger and agriculturally dominated watersheds are modeled as a single entity (lumped). The effort by Lewicki and McKee (2009) provided very robust estimates for 12 watersheds with empirical flow and suspended sediment measurements covering 56% of the nine-county Bay Area, and moderately robust estimates for a further 11 watersheds using empirically-based flow information and regional sediment rating curves. This lumped approach is inconsistent with the RWSM structure, and presently necessitates modeling POC loads from these large agricultural watersheds based on a watershed wide averaged particle concentration (mass of POC per mass of sediment, functionally ng/mg equivalent to grams/metric tonne). The objective is the proposed improvement is to split these watersheds into individual land use based components (see B for method) and incorporate calibration using a subset of watersheds.

B. Smaller and urban land use dominated watersheds are not modeled using locally derived coefficients and equations. The effort by Lewicki and McKee (2009) provided much less robust estimates for the remaining 459 watersheds based on combining the typical erosion rates described by Donigian and Love (2003) and the HSPF manual (EPA, 2008) to compute gross sediment erosion. A sediment delivery ratio equation described by the NRCS, (1983) was then used to estimate the fraction of gross sediment erosion occurring in a land-use segment that reaches the channel ("edge of stream" inputs). The governing equation was:

$$Watershed\ Load = \sum_{1}^{n}(LU_n * A_n) * DR$$

Based on the commentary in the NRCS report, though there was a wide scatter, the data did show "some similarity in sediment delivery ratios throughout the country". "Rough estimates of the sediment delivery ratio can be made..., but any such estimate should be tempered with judgment, and other factors such as texture, relief, type of erosion, sediment transport system, and areas of deposition within the drainage area should be considered. For example, if the texture of the upland soils is mostly silt or clay, the sediment delivery ratio will be higher than if the texture is sand." Given the tectonically active geology, Mediterranean climate, unique history of land use and water management, and the clay loam soils that prevail in the Bay Area, it seems likely that the coefficients and equations developed in other parts of the US may not be entirely applicable to:

i. the low land dominantly urban portions of Bay Area watersheds, or
ii. the steeper dominantly agricultural or open space dominated upland portions of our smaller and dominantly urban land use watersheds where processes such as landslides, gully formation, and bed incision and bank erosion are known to occur.

We are now aware of a greater amount of local data on urban suspended sediment loads collected by Balance Hydrologics Inc. on behalf of local public agency clients that can be incorporated with geologically based erosion coefficients to create locally derived model parameters. In addition, ongoing advancements in regional digital elevation models make it now possible to generate accurate slope and convergence metrics for our less steep and urban watersheds, and improved digital landslide maps are now available. The objective of the improvement would be to develop and apply a new model that incorporates land use, new local geological factors (GF), perhaps a watershed slope/convergence factor (SCF), and perhaps an improved delivery ratio equation:

$$Watershed\ Load = \sum_{1}^{n}(LU_n * GF_n * A_n) * DR_{Local} * SFC$$

C. Suspended sediment estimation methods developed previously are not currently incorporated into the RWSM. Since the RWSM was developed during 2010-2012, and is based on hydrology, the sediment erosion coefficients and equations that comprise the spreadsheet model developed by Lewicki and McKee (2009) are not yet incorporated into the RWSM. Therefore, presently it is not possible to develop POC models based on either suspended sediment or a hybrid of suspended sediment and water flow using the RWSM geoprocessing tool.

D. Water reservoirs in smaller and urban land use dominated watersheds are modeled assuming no fine sediment retention. Sediment storage and larger reservoirs in larger and agriculturally dominated watersheds of the nine-county Bay Area was taken into account through the use of empirical flow and suspended sediment concentration data in 12 watersheds. In contrast, the computations completed by Lewicki and McKee (2009) who focused on subregional and regional scale loads, did not need to account for sediment storage (the assumed 100% transmission) in reservoirs in the remaining 44% of the Bay Area drainage. As such, loads estimates for the watersheds of Walnut Creek, San Leandro Creek, San Pablo Creek, San Mateo Creek, Corte Madera Creek, Stevens Creek and Novato Creek need to be revisited.

E. All watersheds are presently modeled assuming zero storage in flood control infrastructure. The computations completed by Lewicki and McKee (2009) did not take into account sediment storage in flood control channels and sediment detention basins. Some of our larger flood control channels are known to trap sediment of mixed grain size including some sediment finer than 0.0625 mm (Collins, 2006).

3. Next steps

1. The Small Tributaries Loading Strategy local team reviews and ratifies the proposed steps,

2. SFEI RMP STLS staff contact a small group of local experts for input on geologically based erosion/gradient coefficients[1],

3. SFEI RMP STLS staff implement steps in order of priority providing regular updates to the STLS local team,

4. SFEI RMP STLS staff complete model documentation (<10 page memo on methods and results), including a discussion of uncertainty and data limitations and recommendations regarding potential improvements and/or data collection, and relevance to potential use scenarios by Water Board or BASMAA.

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[1] There are conceptually several types of sediment production in relation to the episodic nature of landslide and the underlying geology:
1. Sediment production chronically based on landuse/geology/vegetation
2. Sediment production based on landslides/episodic events that supply pulses of sediment to a given system
3. Active gullying/bank erosion of streams
It may be possible to separate out hillslope erosion from fluvial erosion or we could use a slope and convergence type model for routing hillslope sediment though stream networks (e.g. Benda et al., 2007) based on just slope, convergence, and flow accumulation through the drainage network. Another idea is to make an "episodic index" for watersheds based on landsliding rates and geologic formations (Franciscan gets highest etc), and then a "chronic index" based on land use, vegetation, geology, and slope. The result would be two coefficients and use the chronic one for most of the time and the episodic one for very wet years.

Table 1. Model weaknesses, proposed modification steps, and proposed priorities for designing a robust sediment delivery estimate/sediment budget in local tributaries and urban drainages in relation to MRP Provision C.8.e(vi) through the Regional Watershed Spreadsheet Model (RWSM) and associated user interface.

Model weaknesses addressed	Proposed modification steps		Priority
	Step	Description	
A. Larger and agriculturally dominated watersheds are modeled as a single entity (lumped); and B. Smaller and urban land use dominated watersheds are not modeled using locally derived coefficients and equations	1.	Enhance existing watershed sediment loads database (currently 38 watersheds) with data collected by Balance Hydrologics Inc. on behalf of local public agency clients.	High
	2.	Climatically average the sediment loads estimates at each location to a consistent climatic period.	
	3.	Compile watershed boundary information, land use, slope and other physical factors specific to the sampling locations of each suspended sediment loads dataset.	
	4.	Compile geologic and landslide maps at the appropriate scale taking into account geologic formations occurring in reasonable proportions (>5%) of > 10 watersheds in the sediment loads database.	
	5.	Develop locally applicable geologic erosion coefficients based on previous studies by SFEI and others in addition to local expert judgment.	
	6.	Check the validity of the "national" NRCS (1983) sediment delivery equation using local data and possibly develop a local equation.	
	7.	Apply parameter estimation (also known as inverse optimization) methods to derive local land use/geology erosion coefficients and test.	
	8.	Model loads by applying new coefficients and equations to all watersheds in the Bay Area using a subset of watersheds from the suspended sediment loads database (for example the downstream locations in some of the watersheds with nested data) and/or from recent STLS POC loads monitoring sites for verification.	
C. Suspended sediment estimation methods developed previously are not currently incorporated into the RWSM	9.	Develop a new RWSM geoprocessing tool for the robust sediment delivery estimate/sediment budget model structure and parameterization (locally derived land use/geological sediment erosion coefficients and equations)	High
D. Water reservoirs in smaller and urban land use dominated watersheds are modeled assuming no fine sediment retention	10.	Develop a watershed boundary layer for all reservoirs in the Bay Area that are included in the Department of water resources, division of safety of dams database (DWR, 2012). Assume all sediment upstream from dams is trapped.	Medium
	11.	Research trapping capacity of reservoirs by speaking to state and local experts. Possibly incorporate the commonly used trapping equation (Brune, 1953; White, 1990; Verstraeten and Poesen, 2000; Jothiprakash and Garg, 2008) into the suspended sediment RWSM allowing the user to select this option through the user interface.	Medium
E. All watersheds are presently modeled assuming zero storage in flood control infrastructure	12.	Complete EPA grant awarded to SFEI in partnership with SFEP, BCDC, and SFBJV working with BAFPAA agencies. Possibly incorporate sediment trapping coefficients specific to each Bay Area flood control channel derived from the database developed as part of this grant into the suspended sediment RWSM allowing the user to select this option through the user interface.	Low

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