Regional Watershed Spreadsheet Model

Appendix B to Small Tributaries Loading Strategy Multi-Year Plan

Version 2012B PROGRESS

The Small Tributaries Loading Strategy's element for a Regional Watershed Spreadsheet Model (RWSM) was recommended as the primary tool for estimating regional scale loads to San Francisco Bay. Initial activities in 2010 included setup of the base hydrology model and initial contaminant models for testing. Details of the model construction and results of initial hydrologic calibrations are described in the Year 1 Progress Report recently finalized to incorporate review comments by the Sources Pathways Loadings Work Group move (SPLWG)[1]. The Year 1 progress report also discusses the concepts of varying sub-model architectures adapted to the properties of each contaminant, and the characterization of the distributions of various pollutants. This conceptual framework was applied in Year 1 to PCBs, mercury and copper, and will be extended to other contaminants or analytes in Years 3and 4.

This Appendix to the STLS MYP is a working update, composed of the following stand-alone documents:

- Workplan to "Develop and Update EMC Data and Spreadsheet Model – Year 3", including proposed Five-Year Plan for the RWSM, as provided for review to the STLS Work Group in February 2012. The planning matrix and task list show both RMP and BASMAA-funded tasks; the latter are based on the Workplan's "Appendix A" which has been updated provisionally as of August 2012.
- RWSM Year 2 Progress Report discussing improvements in the hydrology model and model documentation. This document is also available at http://www.sfei.org/sites/default/files/RWSM_EMC_Year2_report_FINAL.pdf

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[1] Lent, M.A. and McKee, L.J., 2011. Development of regional suspended sediment and pollutant load estimates for San Francisco Bay Area tributaries using the Regional Watershed Spreadsheet Model RWSM): Year 1 progress report. A technical report for the Regional Monitoring Program for Water Quality, Small Tributaries Loading Strategy. Contribution No. 666. San Francisco Estuary Institute, Richmond, CA. Available at http://www.sfei.org/sites/default/files/RWSM_EMC_Year1_report_FINAL.pdf

DEVELOP AND UPDATE EMC DATA AND SPREADSHEET MODEL – YEAR 3

BACKGROUND

Planning level watershed loading estimates were provided in the TMDLs for Hg and PCBs, however, the Water Board called for improvements of regional scale loads and for determining how these could be reduced. These needs are reflected in the municipal stormwater permit (MRP) (SFRWQCB, 2009), in the 2nd and 4th questions of the RMP Small Tributaries Loading Strategy (STLS), and refined more recently in the Multi-Year-Plan (MYP) version 2011 submitted to the Water Board last July (STLS, 2011). The strategy team recommended the use of a "Regional Watershed Spreadsheet Model" (RWSM) for estimating regional scale loads (STLS, 2011). Originally developed in MS Excel in the 80s with simple statistical input from land use and water quality data bases, these models are now commonly used for estimating contaminant loads from specific regions and for testing the potential improvement of management scenarios on hydro-modification and water quality. These models still use annual average runoff estimates as an algebraic function of rainfall and land characteristics (imperviousness and land use) as their basis, but now, within the GIS platform rather than in a spreadsheet, sophistication has increased to include generation of hydrology and water quality components with independent calibration in separate "layers" of the model, more sophisticated calibration and optimization procedures, and a separate land use / source area basis for each contaminant (especially important for our priority pollutants). The strategy group recommended that the hydrology model be developed first followed by sediment, PCBs, and Hg and then other contaminants as outlined in the MRP or by the dioxins or nutrients strategy teams.

FIVE-YEAR PLAN FOR THE SPREADSHEET MODEL

Developing a spreadsheet model for multiple analytes with a myriad of sources and/or land use relations is not a simple task. Beyond the development and calibration of the hydrology model (the basis for loading estimates for all pollutants), there are a number of steps that need to be taken for each analyte (Table 1). Here we briefly outline the overall plan in a step by step fashion but anticipate slight modifications each year hence as lessons are learned or if proposed uses are expanded.

Step 1: Develop factsheet/methodology: The first step for each analyte is to review what is known locally or internationally about the sources or use characteristics and processes of release and transport of the constituent of interest. This information is then put together with what is known about available GIS layers on the proposed most important sources and a model structure and generalized work plan is recommended. In the case of the hydrology model, much work had already been done on this topic and a model structure was available to adapt for our uses. For suspended sediment, similarly, several modeling efforts have already been completed for the Bay Area largely negating the need for developing a factsheet as the technical basis for the model structure and methodology.

Step 2: Develop GIS layers: Once the model structure has been identified (Step 1), the next step is to collate the appropriate spatial data bases of source areas and land uses specific to the constituent to be modeled. In the case of our test case model (copper) or some of the other conventional urban pollutants such as PAHs, these may be the conventional land use classes (open space, agriculture, low density urban, high density urban, commercial, light industrial, heavy industrial and transportation), but even for these conventional classifications, pollutant specific decisions have to be made on how to group the several hundred land use categories that are typical in city and county land use data bases. In addition, since transportation land use is usually a mixture of lines and polygons in raw GIS data bases, pollutant specific decisions have to be made on the buffer width and on what to include with regards to transportation categories (roads, airports, etc.).

Table 1. Long term work plan for developing and completing the Regional Watershed Spreadsheet model for each pollutant.

		Loads calculation analytes									
Step	**Description**	**Flow**	**SS**	**PCBs**	**Hg**	**Cu**	**Se**	**PBDE**	**OC pest**	**Dioxins**	**Nutrients**
1	Develop fact sheet / methodology	②									
1a	Collate local data	③	①	③	③	③	③	B-2012	B-2012	③	2014?
1b	Collate data from review of the world literature	③	①	③	③	③	③	B-2012	B-2012	③	2014?
1c	Develep source area / land use categorization conceptual model	③	①	③	③	③	③	B-2012	B-2012	③	2014?
2	Develop GIS layers	③	①	③	③	RMP-RWSM-2012	2013?	2013?	2013?	2014?	2014?
3	Collate input data and calibration data	③	①	③ ④	③ ④	③	2013?	2013?	2013?	2014?	2014?
4	Run version 1 model and compare with calibration data	③	① ③	WG presentation only		RMP-RWSM-2012	2013?	2013?	2013?	2014?	2014?
5	Improve input data and/ or model structure										
5a	Back-calculate RCs / EMCs / EFs from local or world data	④	B-2012	③ 2011 attempt not sucessful; RMP-EMC-2012	③ 2011 attempt not sucessful; RMP-EMC-2012	RMP-EMC-2012	2013?				
5b	Improve GIS layers	④	B-2012*	RMP-EMC-2012	RMP-EMC-2012	RMP-EMC-2012	2013?	PCB/Hg level of effort may not be needed depending on the level of accuracy needed for the watershed specific and regional loading estimates			
6	Run version 2 model and compare with calibration data	④	B-2012	RMP-EMC-2012	RMP-EMC-2012	RMP-EMC-2012	2013?				
7	Complete FINAL input data set										
7a	Further refine GIS layers if needed	RMP-RWSM-2013	-	RMP-EMC-2012?	RMP-EMC-2012?	RMP-EMC-2012?	2013?				2015?
7b	Further refine back-calculations if needed	-	-	RMP-EMC-2012?	RMP-EMC-2012?	RMP-EMC-2012?	2013?				2015?
7c	Perform wet weather field sampling if needed			RMP-EMC-WY 2013	RMP-EMC-WY 2013	RMP-EMC-WY 2013 TBT	RMP-EMC-WY 2013 TBT	RMP-EMC-WY 2013 TBT	RMP-EMC-WY 2013 TBT	RMP-EMC-WY 2013 TBT	2015?
8	Run version 3 (FINAL) model and complete calibration / varification	RMP-RWSM-2014	RMP-RWSM-2014	RMP-RWSM-2014	RMP-RWSM-2014	RMP-RWSM-2014	RMP-RWSM-2014	RMP-RWSM-2014	RMP-RWSM-2014	RMP-RWSM-2014	2016?
9	Complete model packaging and user manual	RMP-EMC-2012	RMP-EMC-2012	2013?	2013?	RMP-EMC-2012	2014?	2014?	2014?	2014?	2016?

	References
①	Lewicki, M., and McKee, L.J, 2009. Watershed specific and regional scale suspended sediment loads for Bay Area small tributaries. A technical report for the Sources Pathways and Loading Workgroup of the Regional Monitoring Program for Water Quality: SFEI Contribution #566. San Francisco Estuary Institute, Oakland, CA. 28 pp + Appendices
②	Ha, S.J., and Stenstrom, M.K., 2008. Predictive Modeling of storm-water runoff quantity and quality for a large urban watershed. Journal of Environmental Engineering 134, 703-711
③	Lent, M.A. and McKee, L.J., 2011. Development of regional contaminant load estimates for San Francisco Bay Area tributaries based on annual scale rainfall-runoff and volume-concentration models: Year 1 results. A technical report for the Regional Monitoring Program for Water Quality. San Francisco Estuary Institute, Oakland, CA
④	Lent et al 2012 RWSM y2 documentation memo
B	Funding from BASMAA via a contract with ACCWP
B	Funding from BASMAA via a contract with ACCWP
*	Note - the model resolution for sediment will vary from place to place given the need to use measured data where it exists and modeled data where it does not exist
RMP-RWSM	RMP funding ($20k/year) allocated to regional watershed spreadsheet model (RWSM) general development
RMP-EMC	RMP funding ($80k/year) allocated to EMC development + depending on modeling outcomes perhaps a further $80-100k

Step 3: Collate input data and calibration data: In the case of the rainfall-runoff model, this included rainfall data, land use specific runoff coefficients, soils and slope data, and runoff data for 18+ calibration watersheds. In the case of the sediment model, since we are modifying an existing model to address known weaknesses, this will only need to include local geology, classification, and relative erosion rates for each class or erosional province. Depending on the recommended model structure outlined in the fact sheet (Step 1) and the availability of spatial data sets (Step 2), for each of the pollutants, data on land use or source area specific event mean concentrations (EMCs) or soil concentrations would be collated along with available "bottom of the watershed" loadings information that has been collected in the past from Bay Area watersheds.

Step 4: Run version 1 of the model: Using the information and data developed in Steps 1, 2, and 3, the model will be run and compared to existing knowledge of loads from watersheds. This first run will be largely "proof of concept". Various forms of a sensitivity analysis can be run on v1 help to determine weaknesses in model structure, input and calibration data sets so that recommendations can be developed to guide future model versions.

Step 5: Improve model structure and/ or input data: Based on constituent specific recommendations from step 4, further spatial data base development could occur or exploration of other sources of coefficients or land use classifications. In addition, in this task more effort can be put into developing EMC data for model input including EMC back-calculations upon either water concentration or sediment concentration data or combinations of both data types either locally available or from elsewhere.

Step 6: Run version 2 of the model: Using the information and data developed in Steps 1, 2, 3, 4, and 5, the model will be run and compared to existing knowledge of loads from watersheds. This second run will necessarily incorporate a detailed sensitivity analysis and or/ Monte Carlo techniques to determine weaknesses in model structure, input and calibration data sets. Very specific recommendations will be developed to prepare for decisions on further GIS layer development or consolidation, back-calculation techniques, or a need for specific field data collections to support model improvements.

Step 7: Complete FINAL input data set: Based on constituent specific recommendations and decisions from step 6, further spatial data base development could occur or exploration of other sources of coefficients or land use classifications. In addition, more effort can be put into back-calculation techniques. Pollutant specific EMC data or reconnaissance bottom of the watershed data in combination with back-calculation techniques may be collected in the field or specific watersheds may be targeted for bottom of the watershed loads data to be used for model calibration.

Step 8: Run version 3 (likely FINAL) of the model: Using the information and data developed this in Steps 1, 2, 3, 4, 5, 6, and 7, the model will be run and compared to existing knowledge of loads from watersheds. This "FINAL" version will include documentation of model weaknesses for specific land uses or source areas. In addition, the model accuracy and precision will be analyzed for each constituent at scales of specific watersheds, Bay margin segments, and the Bay as a whole.

Step 9: Complete model packaging and user manual: Model packaging and documentation will be completed to ensure complete transparency between the model development group (SFEI staff, STLS team) and information users, and that the model results are repeatable, the model is expandable as appropriate, and that the model is not used for purposes it is not designed for. Such an open source model will mean that those who are not the originators of the model can run the model, however an open source model will require that, from 2012 forward, appropriate model structure and suitable user documentation is considered at each step of model development.

PROGRESS TO-DATE

During the RMP 2010 calendar year (year 1 of this project), version 1 of the hydrology component of the regional watershed spreadsheet model (RWSM) was developed. Two base hydrology model approaches were investigated: one using runoff coefficients based on land use and the other based on impervious cover. Initial versions of each model were calibrated to local hydrology data from 18 local watersheds with a wide variety of imperviousness, soil, and slope. Recommendations were made to address hydrology model weaknesses. The year 1 report also presented a review of land use and source areas in relation to PCBs, Hg, dioxins, Cu, and Se and provided recommendations for steps to develop event mean concentration (EMC) data to support the input side of the model. The report recommended the model structure for each pollutant, methods to fill data gaps, and priorities (Lent and McKee 2011).

During RMP 2011 calendar year (year 2 of this project), version 2 of the GIS-based model was developed following Y1 recommendations. In v2, several more calibration watersheds were added to increase the range of watershed characteristics including %imperviousness character. In addition, gauge records with incongruent land use / impervious data were removed and land use categories were refined. For Y3, a focus on the sediment and pollutant models was recommended (Lent et al., 2012).

In parallel, the BASMAA Monitoring / Pollutants of Concern (POC) Committee has been discussing and prioritizing work products in relation to the MRP. During 2011, project profiles were developed for addressing MRP provisions C.8.e.vi (sediment delivery estimate / budget) and C.14 (PBDEs and OC pesticides). Subsequently, BASMAA has asked SFEI to complete work outlined in these project profiles. Since all these tasks are components of what is envisioned to be a single model developed over three years and final report in 2014, this work plan reflects all recommendations and BASMAA work requests in relation to the RWSM that can be accurately budgeted at this time. However, we are careful to explicitly describe products and deliverables in relation to the specific resources allocated by either the RMP or BASMAA.

OBJECTIVES FOR YEAR 3

Step*	Task	Objective	Funding source
2, 3, 4	Cu-2 Cu-3 Cu-4 Cu-9	Complete a copper RWSM as a test case for calibration procedures and to set reasonable expectations for other contaminants and document outcomes and recommendations	RMP 2012 RWSM base model funds
5, 6	SS-5 SS-6 SS-9	Complete an updated version of the sediment RWSM (hybrid), refinement of the existing model (Lewicki and McKee, 2009) per BASMAA sediment project profile and document outcomes and recommendations	BASMAA funds via ACCWP contract
2	PCB-2 Hg-2	Complete GIS layer development for PCBs and Hg per recommendations from the Y1 report (Lent and McKee 2011) including meta data documentation	RMP 2012 EMC development funds
5	PCB-5 Hg-5	Complete back-calculations of PCB and Hg EMC data using available local (focus where possible) and literature data per recommendations from the Y1 report (Lent and McKee 2011) and document outcomes and recommendations	RMP 2012 EMC development funds
6	PCB-6 Hg-6 PCB-9 Hg-9	Complete next versions of the PCB and Hg RWSMs and document outcomes and recommendations	RMP 2012 AND 2013 RWSM base funds; RMP 2012 EMC development funds
1	PBDE-1 OCPest-1	Complete contaminant profiles and model workplan recommendations for PBDE, PBDE, DDT, chlordane, dieldrin per BASMAA project profile	BASMAA funds via ACCWP contract
0	Mgmt-0	STLS EMC spreadsheet model communication and coordination	RMP 2012 EMC development funds and BASMAA POC Monitoring Contract

***Refers to steps in Table 1**

WORK PLAN FOR YEAR 3

Develop Copper test case Model for RWSM: Copper represents a data rich urban contaminant that follows classical source, build-up, and wash off processes in relation to urban land uses in a similar fashion to PAHs and pesticides and parts of the mercury model process. It therefore represents an ideal test case as a step toward model development for other contaminants that are of more interest. There is abundant local land use specific data on copper EMCs (BASMAA, 1995) and abundant bottom of the watershed calibration data (BASMAA, 1995; RMP loading studies, recent BASMAA/ BACWA studies; other SFEI studies). In addition, there is SPLWG experience and published papers from SoCal (Stenstrom, Stein and coauthors).

Task Cu-2 Refine GIS data to include transportation land uses.
Deliverable: Transportation GIS data layer

Task Cu-3 Compile EMC data with a focus on local data sets, filling in any data gaps firstly from SoCal data (compiled by Stein and Stenstrom and coauthors) and lastly by world data (should not be needed). Budget assumes BASMAA data base is “model ready”.
Deliverable: Copper EMC Database

Task Cu-4a Complete RWSM v1 and refine based on a sensitivity analysis to each of the input parameters (land use choices, lumping v splitting land uses, upper and lower bounds of EMC etc.), Calibration with local bottom-of-the-watershed data including Guadalupe River, Zone 4 Line A, and possibly Ettie St and Cerrito Creek and BASMAA 1995 data sets. Comparison of model output to results of Brake Pad Partnership.
Deliverable: Model calibration and output

Task Cu-4b Complete a short concise report section outlining methods, results and recommendations briefly (5 pages total). Develop framework for documentation of hydrology model, document data inventory and metadata for hydrology model. Example questions to be explored:

- Are the data available from 4 watersheds enough for model calibration?
- Are the appropriate land uses represented in the calibration watersheds?
- Was input data representative of land uses/source areas?

Deliverable: Short technical memo – 5 pages

Task Cu-9 Develop and package a user manual for the Cu model with documentation for external users of the model including assumptions and recommended uses. Not budgeted.

Estimated cost: $12,200

Update version of the suspended sediment RWSM: Suspended sediment (SS) is an important vector for many pollutants. In 2008/09 the RMP completed a detailed analysis of SS flowing to SF Bay from local tributaries in the 9-counties adjacent to the Bay (Lewicki and McKee, 2009). During 2011, the first versions of the SS RWSM was developed using local land use based SSC EMC data (BASMAA, 1995). The results were questionable but informative. The outcomes of the SS RWSM differed substantially and non-systematically from Lewicki and McKee (2009) leading us to recommend improving the Lewicki and McKee (2009) model as the best path. Weakness in the Lewicki and McKee (2009) analysis included the treatment of urban upland land use categories without regard for base geology (known to have highly variable erosivity in the Bay Area). SFEI and many Bay Area consulting firms have completed geomorphic studies that describe either quantitatively or qualitatively landscape erosion in relation to land use and geology/soils.

Task SS-5a Complete a status review (of previous Bay Area sediment estimates) and provide rationale for improvements or modifications to RWSM in a 1-2 page memo to BASMAA (will become the introduction section in the documented outcomes)
Deliverable: 1 page memo on recommended RWSM improvements, proposed tasks budgets and schedules (Appendix A; S1)

Task SS-5b Compile local geology GIS layers, literature and reports, and professional judgments/ opinions on geological / terrain classes / erosional provinces, and relative erosion rates. Interpret and complete a classification scheme for Bay Area urban uplands (values/ ranges/ distributions of sediment-related coefficients) and route to local professionals for review and input (about 3 local erosion experts)
Deliverable: Erosion rates classification scheme (Appendix A; S2)

Task SS-6a Migration of Lewicki and McKee (2009) model into compatible format with RWSM. Complete sediment RWSM v2 testing and calibration, sensitivity analysis and make any obvious or within budget improvements (Appendix A; S2)
Deliverable: Model calibration and output

Task SS-6b 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
Deliverable: 10 page technical memo including methods, results and any recommended phase II improvements (Appendix A; S2)

Task SS-7, 8 PHASE II model improvements and final technical memo for inclusion into MYP v2013. Scope and budget TBD. (Appendix A; S3)

Task SS-9 Develop and package a user manual for the sediment portion of the model with documentation for external users of the model including assumptions and recommended uses. Not budgeted.

Estimated cost: labor $29,250; sub-contracts: $3,000 “data input/ review” from local erosion experts

<u>GIS layer development for PCBs and Hg:</u> Although Hg and PCB concentrations and loads in urban landscapes do correlate positively increasing urban land use density/intensity, this is less likely due to rainfall-wash off processes of pollutant behavior (like Cu or Zn for instance), but rather due to a greater density of polluted source areas in relation to land use intensification. A better model for Hg and PCBs is a combination of land use and source areas emission factors (Lent and McKee, 2011). Based on the review of local and international information, PCBs and Hg are likely associated with the manufacture, repair, testing, storage, and use of electrical transformer and capacitor equipment, military areas, drum, metals, and auto recycling yards, oil refineries and petrochemical industrial areas, manufacture of steel or metals, and transport including rail and shipping. In addition, Hg is also associated with cement production and cremation. This task will generate the basal land use and source area geospatial data set to support the Hg and PCB RWSM. There are a range

of challenges including lack of existing published data on some of the proposed layers and the conversion of line data for form transportation and other land use / source area categories in to shape files.

Task PCB&Hg-2a Coordinate with BASMAA by holding 3-3 hour in person meetings to plan scope of task, level of effort for each land use, and align this effort with other BASMAA work, prep, and follow-up to meetings. Compile or generate GIS shape files (polygon or point depending on source type) and associated metadata in the following order of importance (through a lens of sensible level of effort):

1. Electrical transformer / capacitor (manufacture/repair/testing/storage/use)
2. Military = Recycling (drum)
3. Cement production
4. Cremation
5. Oil refineries / petrochemicals = Manufacture (steel or metals)
6. Transport (rail) = Transport (ship)
7. Recycling (metals) = Recycling (auto)

Deliverable: GIS data layers (prioritized by STLS)

Task PCB&Hg-2b Devise a QA method, apply it across the layers, and revise / complete meta data.

Deliverable: Develop QA Methodology and Meta-Data

Task PCB&Hg-2c Prepare a short documentation memo (5 pages) that briefly discusses data sources, data quality, and potential for improvements. Present results to SPLWG (1 meeting) and STLS (monthly phone calls during development and face-to-face).

Deliverable: 5 page technical memo

Estimated cost: $25,850

<u>Back-calculations of PCB and Hg EMC data:</u> During 2011, an unsuccessful attempt was made to back-calculate EMC data for Hg and PCBs in relation to basic land use categories using data generated from the 16-watershed reconnaissance loadings study. Success was limited by too few concentration data in relation to the number of land uses, a situation that may be rectified through further reconnaissance. In the meantime, Lent and McKee (2011) recommended the exploration of EMC back-calculation using a number of other data sets including land use specific ranges indicated by local data (preferably) augmented with data from published literature on water and soil concentrations for water. They proposed a number of methods (which might require further discussion and refinement) which generally use combinations of either soils or water data or both to either use matrix algebra or statistical distribution to determine reasonable ranges in concentration associated with land uses and source areas. The challenge with methods using soils data is the potential for underestimation due to a lack of knowledge about concentration factors between in-situ soil concentrations and those found in stormwater.

Task PCB&Hg-5a Compile local and international data on soils and water concentrations in relation to land use and source areas for Hg and PCBs (from task 3) ensuring the resulting data base is well documented

Deliverable: PCB and Mercury EMC database and documentation

Task PCB&Hg-5b Research various back-calculation methods, including inverse optimization methods.
Deliverable: Methods for calculating EMCs

Task PCB&Hg-5c Provide regular updates and feedback opportunities to STLS, including discussion of proposed back-calculation methods.
Deliverable: Project updates at up to 3 STLS meetings

Task PCB&Hg-5d Complete back-calculations, perform sensitivity analysis, and develop error bars around results (or professional judgment to assign errors or ranges)
Deliverable: EMC back calculation results

Task PCB&Hg-5e Prepare a short (<5 page) summary of methods and results for inclusion in the model documentation.

Deliverable: 5 page technical memo summarizing methods and results
Estimated cost: $19,500

<u>PCB and Hg Regional Watershed Spreadsheet models (RWSMs):</u> During 2011, the first versions of the Hg and PCB RWSMs were developed using combinations of SoCal EMC data (Hg only) and world soils data (Hg and PCBs) combined with local SSC EMC data (BASMAA, 1995). The Hg load results were consistent with existing estimates at a regional scale but questionable at the scale of individual land uses. For PCBs, the loads were 20x higher than expected on a regional scale and, relatively from one land use to another, in the right order.

Task PCB&Hg-6a Review modeling options (more or less land use / source area classes, hybrid sediment/water based models) and prepare a short memo (will be a component of the methods section of the Y3 documentation) that provides the rationale for each model structure - present model options to STLS.
Deliverable: Short memo of possible modeling options

Task PCB&Hg-6b Refine RWSM to incorporate spatial data created in Task 3 and back calculations completed in Task 4 into the input data sets. Revise and complete Hg and PCB RWSM v2 testing and calibration. This will include re-tooling the model, for speed in use and efficiency in structure, and build a tool interface in Arc-GIS that can handle both iterative (loop over multiple watersheds) and single inputs. Evaluate model weaknesses through a sensitivity analysis (combinations of more and less source area classes and reasonable ranges of EMCs for each source class, hybrid models) and make any obvious or within budget improvements. Assumption: The model and documentation will not be developed for external users. Such documentation may be a prioritized further step.
Deliverable: Model calibration and output

Task PCB&Hg-6c Complete model documentation (10 page report section 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.
Deliverable: 10 page technical memo

Task PCB&Hg-9 Develop and package a user manual with documentation for external users of the PCB and Hg models including assumptions and recommended uses. Not budgeted.

Estimated cost: $43,000

Contaminant profiles and model workplan recommendations for PBDE, DDT, chlordane, and dieldrin: During 2010 and 2011, SFEI completed contaminant profiles and model workplan recommendations for PCBs, Hg, Dioxins, Cu, and Se (Lent and McKee, 2011). Five components went into developing each profile: 1. A review of known uses for each substance (Hg, PCBs, Cu, Dioxins, and Se), 2. a review of regulatory data bases on contaminated sites/ spills (Hg, PCBs, and Cu), 3. a review of local and world soils literature (Hg, PCBs, Se), 4. A review of concentrations in stormwater (Hg, PCBs, Cu, Dioxins, and Se), and 5. A general commentary on presently known GIS layers in relation to the recommended land use / source area categories resulting from the first four components. The outcome of this task will be contaminant profiles and model workplan recommendations for PBDE, DDT, chlordane, and dieldrin based on a selection of these steps.

Task PBDE/OCP-1a Review existing contaminant profile structures for Hg, PCBs, Cu, Dioxins, and Se (Lent and McKee, 2011) and the CMIA reports for PBDEs (Werme et al., 2007) and OC Pesticides (Connor et al., 2004). Prepare a short (<3 page) memo (note, will become the introduction sections in the contaminant profiles for each POC) outlining known uses for each substance (note, we would lump the OC pesticides to reduce the level of text redundancy), knowledge gaps in previous CMIA reports in relation to RWSM development, and propose/estimate level of detail for PBDE, DDT, chlordane, and dieldrin contaminant profiles. Present proposal to STLS for discussion and decisions.
Deliverable: 3 page technical memo (Appendix A; P1)

Task PBDE/OCP-1b Prepare contaminant profiles and model workplan recommendations for PBDE, DDT, chlordane, and dieldrin. Base the recommendations on information gaps or uncertainties for each POC and clarifications from WB staff regarding potential/desired uses and data quality needs. Document the outcomes in a short concise technical memo (subsuming the previous effort for Se (Lent and McKee, 2011)) that addresses the following questions:

1. Is the POC present in urban runoff?
2. Is the POC distributed fairly uniformly in urban areas?
3. Are storm drain systems a generalized source or are there specific source locations or types?

Present findings and work plan rationale to the STLS for discussion and decisions on next steps.
Deliverable: Contaminant profiles for PBDEs and OC pesticides (Appendix A; P2)
Estimated cost (6a-6b): $35,000

Task PBDE/OCP-2a If needed, generate GIS layers to support the RWSM structure for each POC.
Deliverable: GIS layers for PBDEs and OC pesticides
Estimated cost: Not Budgeted – Year 4 (Appendix A; P3)

Task PBDE/OCP-2b Perform preliminary setup of RWSM to estimate annual loads of PBDE, DDT, chlordane, dieldrin. Perform preliminary model runs for selected POCs, depending on available resources and WB interest. Document findings (<5 pages) with a focus on recommendations that result from initial model runs appending the previous memo.

Deliverable: 5 page technical memo on model results
Estimated cost: Not Budgeted – Year 4 (Appendix A; P3)

STLS EMC spreadsheet model communication and coordination: In previous years, the RMP provided separate budget for maintaining communications between STLS team members. In 2012, budget for communications is assumed to be a component of the RMP STLS projects.

Task Mgmt-0 Conduct up to 8 STLS phone conferences to update STLS members on progress, coordinate tasks, solicit feedback and direction, and present findings. Hold 4 quarterly in-person meetings for discussion and decision making on WY 2013 additional monitoring activities and review of WY 2012 monitoring activities. Review Multiyear Plan and QAPP draft documents.

Estimated cost: $24,000

PROJECT BUDGET AND SCHEDULE

The estimated budget (Table 2) is a not-to-exceed amount based on the anticipated time and materials needed by SFEI to complete the project tasks described in the previous section. The completion of some of the tasks within the preliminary schedule provided in Table 2 is dependent upon the timely discussion and agreements by the Water Board and BASMAA.

Table 2. Cost estimates and schedule for completing RWSM components as described in the workplan above.

Old Task No	**New Task No**	**Description**	**RMP base model funds**		**BASMAA sediment funds via ACCWP contract**		**BASMAA PBDE/ OC pest funds via ACCWP contract**		**RMP EMC development funds**		**BASMAA POC Monitoring via ACCWP contract**	**Estimated Completion Date**
			2012	2013	2012	2013	2012	2013	2012	2013	2012	
1	Cu-2, 3, 4	Copper test case RWSM	$9,700						$2,500			March-July 2012
2	SS-5, 6	Updated version of the suspended sediment RWSM			$32,250							April-November 2012
3	PCB-2 Hg-2	GIS layer development for PCBs and Hg							$25,850			March-July 2012
4	PCB-5 Hg-5	Back-calculations of PCB and Hg EMC data							$19,500			July-September 2012
5	PCB-6 Hg-6	PCB and Hg Regional Watershed Spreadsheet models (RWSMs):	$10,300	$20,000					$12,700			March-July 2013
6	PBDE-1 OCPest-1	Contaminant profiles and model workplan recommendations for PBDEs, DDT, chlordane, and dieldrin					$35,000					OC Pest March-September 2012; PBDE September-December 2012
7	Mgmt-0	STLS EMC spreadsheet model communication and coordination:							$17,200		$6,800	Ongoing
		Total Cost	**$20,000**	**$20,000**	**$32,250**		**$35,000**		**$77,750**		**$6,800**	
		Funds Available	**$20,000**	**$20,000**	**?**	**?**	**?**	**?**	**$80,000**	**$80,000**	**$6,800**	

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Appendix A

Sediment and MRP C.14 Contaminants Regional Loads Estimation: Revised August 2012
Multi-year Deliverables List

The table below lists the key SFEI deliverables for Sediment Estimate (S prefix) and Permit-specific Contaminants (P prefix) regional projects to be implemented through ACCWP Action Plans starting with C14-1-12. The right hand column describes, for planning purposes, assumed interim steps or products that will inform or be incorporated into each deliverable. There can be some flexibility in the alignment of these interim steps with key deliverable dates, e.g. degree of finalization of individual contaminant profiles for Deliverable P-2.

The ACCWP Action Plans will be based on the S and P workplans which should be integrated with each other and also with updates to the STLS and Regional Watershed Spreadsheet Model Multi-year Plans. It is assumed that SPLWG review or comment will be solicited and incorporated at each stage, especially for sediment deliverables. The Sediment and Permit-specific Contaminants interim schedules should be coordinated with other scheduling considerations for SPLWG but preference is for early review or feedback on presentation of interim results/products rather than commenting on draft final deliverables.

Item	Target	Deliverable	Interim steps or products
S-1	Final draft for MPC 2/9/12 Final 3/1/12	Workplan, detailed through 2012 and draft through 2013 (add text, tables to STLS MYP V2012A, or else reference as stand-alone appendix to STLS MYP and BASMAA Monitoring Status Report)	• Status review (vs. previous Bay Area estimates) • Rationale for improvements or modifications to RWSM • Proposed tasks, budget and schedule through 2013
S-2	Final draft for MPC 11/2/12	Status memo for update to STLS Work Group	• Propose modifications to RWSM • Develop values/ranges/distributions of sediment-related coefficients • Clarification from WB staff re potential/desired uses for estimates, e.g. data quality needs, for which other contaminants is sediment likely to be used as a surrogate?
S-3	Final draft for MPC 1/2/ Final 1/25/13	Summary memo on initial sediment estimates, with appended “sediment profile” (incorporate as stand-alone appendix in STLS MYP V2013, and in BASMAA Urban Creeks Monitoring Report)	• Model testing, calibration • Coordination with RMP-funded POC model testing (i.e. PCBs) • Model refinements, testing, (limited?) sensitivity analysis • discussion of uncertainty and data limitations • recommendations re potential improvements and/or data collection, and relevance to potential use scenarios by WB or BASMAA

Appendix A continued

Sediment and MRP C.14 Contaminants Regional Loads Estimation: Revised August 2012
Multi-year Deliverables List

P-1	Final draft for MPC 2/9/12 Final 3/1/12	Workplan, detailed through 2012 and draft through 2013 (add text, tables to STLS MYP V2012A, or else reference as stand-alone appendix to STLS MYP and BASMAA Monitoring Status Report)	• Reference previous CMIA reports by CEP, other potential info sources • Reference RMP-funded RWSM contaminant profile & modeling workplan for Se • Propose/estimate level of detail to be used in contaminant profiles for PBDE, DDT, chlordane, dieldrin
P-2	Final draft for MPC 11/20/12 Final 1/25/13	Memo on characterization of PBDEs, legacy pesticides and Se addressing MRP questions: • Is it present in urban runoff? • Is it distributed fairly uniformly in urban areas? • Are storm drain systems a generalized source or are there specific source locations or types?	• Working, draft or final draft Contaminant profiles for PBDE, DDT, chlordane, dieldrin (BASMAA funded) and Se (RMP funded) • Evaluate information gaps or uncertainties for each POC • Clarification from WB staff re potential/desired uses and DQ needs for estimating loads of each POC
P-3	Final draft for MPC 5/31/13 Final 7/26/13	Report with information required to compute regional loads to SF Bay from urban runoff conveyance systems	• Contaminant profiles for PBDE, DDT, chlordane, dieldrin (BASMAA funded) and Se (RMP funded) • Preliminary setup of RWSM to estimate annual loads of PBDE, DDT, chlordane, dieldrin • (Preliminary model runs for selected POCs may be added, depending on available resources and WB interest)
P-4	Workplan Oct 2012 Final draft May 2013	Review and comment on report identifying control measures and/or management practices	(workplan, reports by others)

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

Prepared by

Michelle A. Lent

Alicia N. Gilbreath

Lester J. McKee

San Francisco Estuary Institute

For

The Regional Monitoring Program for Water Quality in San Francisco Bay (RMP)

Small Tributaries Loading Strategy (STLS)

CONTRIBUTION NO. 667

MAY 2012

SAN FRANCISCO ESTUARY INSTITUTE

4911 Central Avenue, Richmond, CA 94804

p: 510-746-7334 (SFEI), f: 510-746-7300,

www.sfei.org

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This progress report can be cited as:

Lent, M., Gilbreath, A., and McKee, L., 2012. 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. A technical progress report prepared for the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP), Small Tributaries Loading Strategy (STLS). Contribution No. 667. San Francisco Estuary Institute, Richmond, California.

Table of Contents

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).

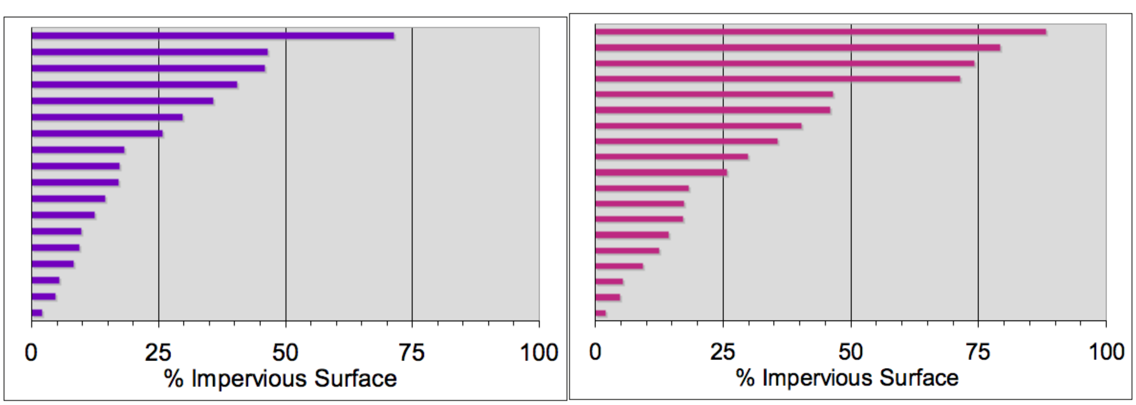

Figure 1 - Percent imperviousness in the original (Left) and updated (Right) calibration watershed data set. The left panel shows the RWSM Y1 calibration data with only one watershed with >50% impervious surface.

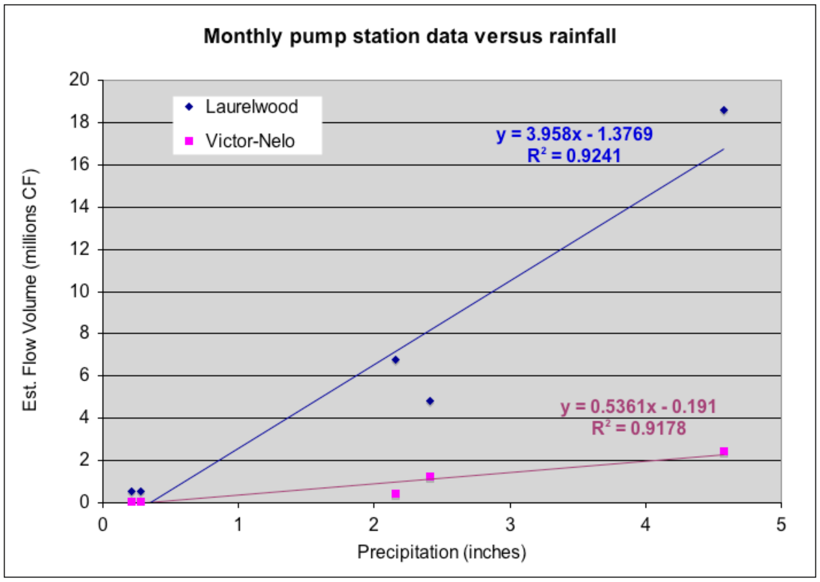

Figure 2 - Correlation between flow obtained by conversion of the pump data logs (using assumptions about pump capacity) and rainfall.

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

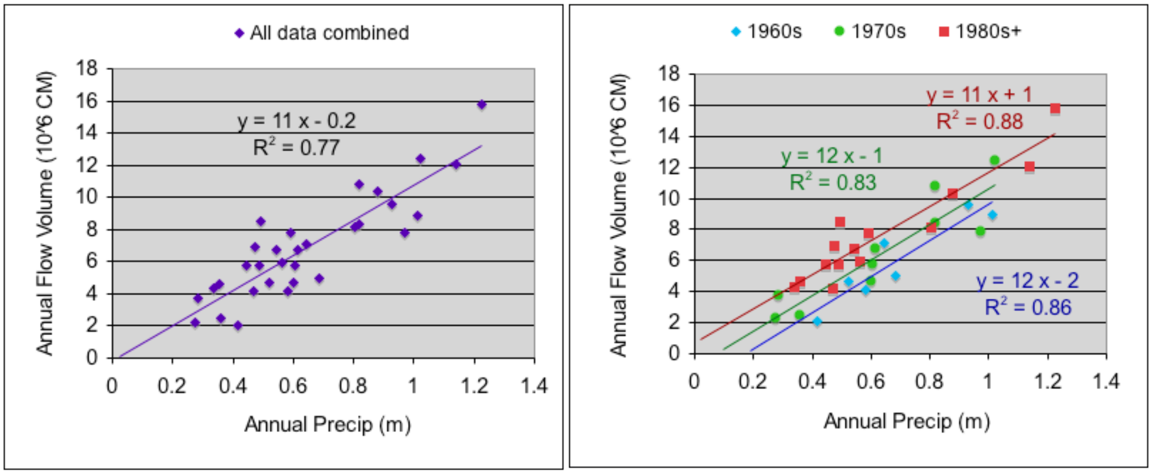

Figure 3 - Colma Creek rainfall-runoff relationship changing over time.

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).

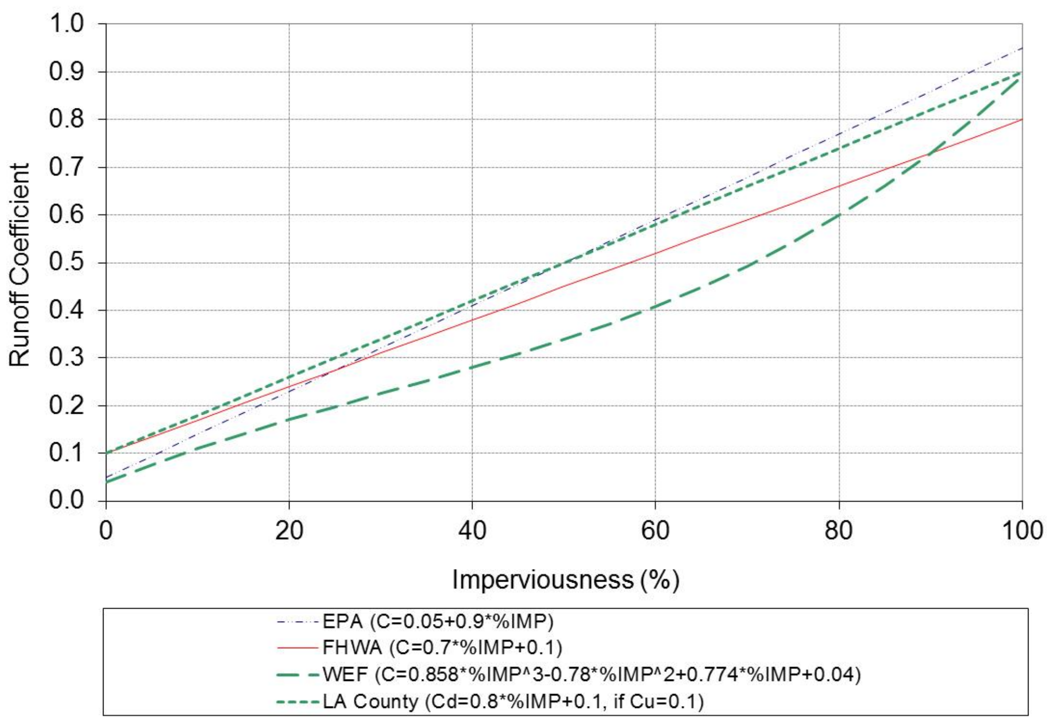

Figure 4. Runoff coefficients as a function of imperviousness. Source: Peter Mangarella, GeoSyntec Consultants, Oakland.

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.

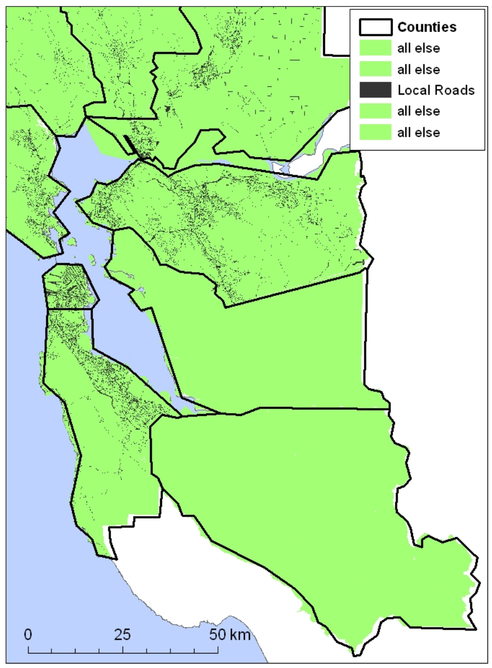

Figure 5 - Discrepancies in ABAG 2000 data set for transportation land use.

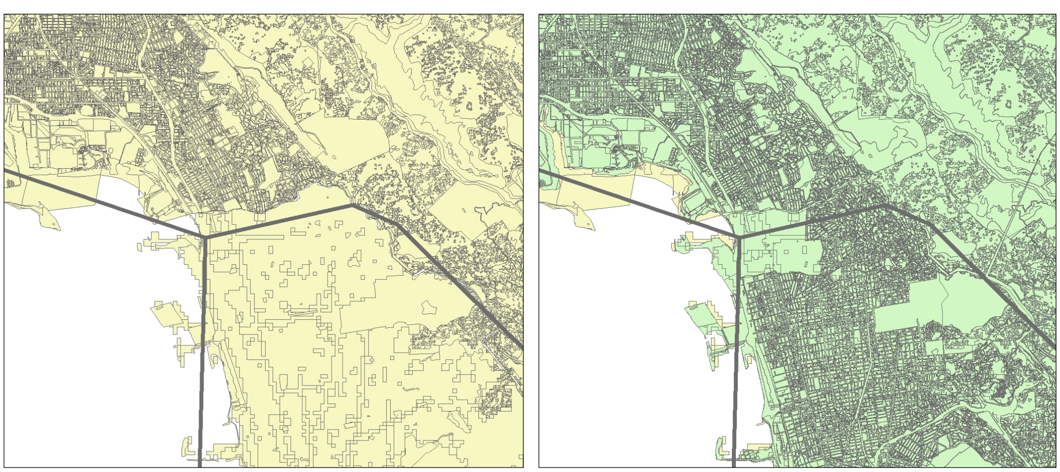

Figure 6 – ABAG 2000 versus ABAG 2005 (zoomed to border of Contra Costa and Alameda Counties).

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).

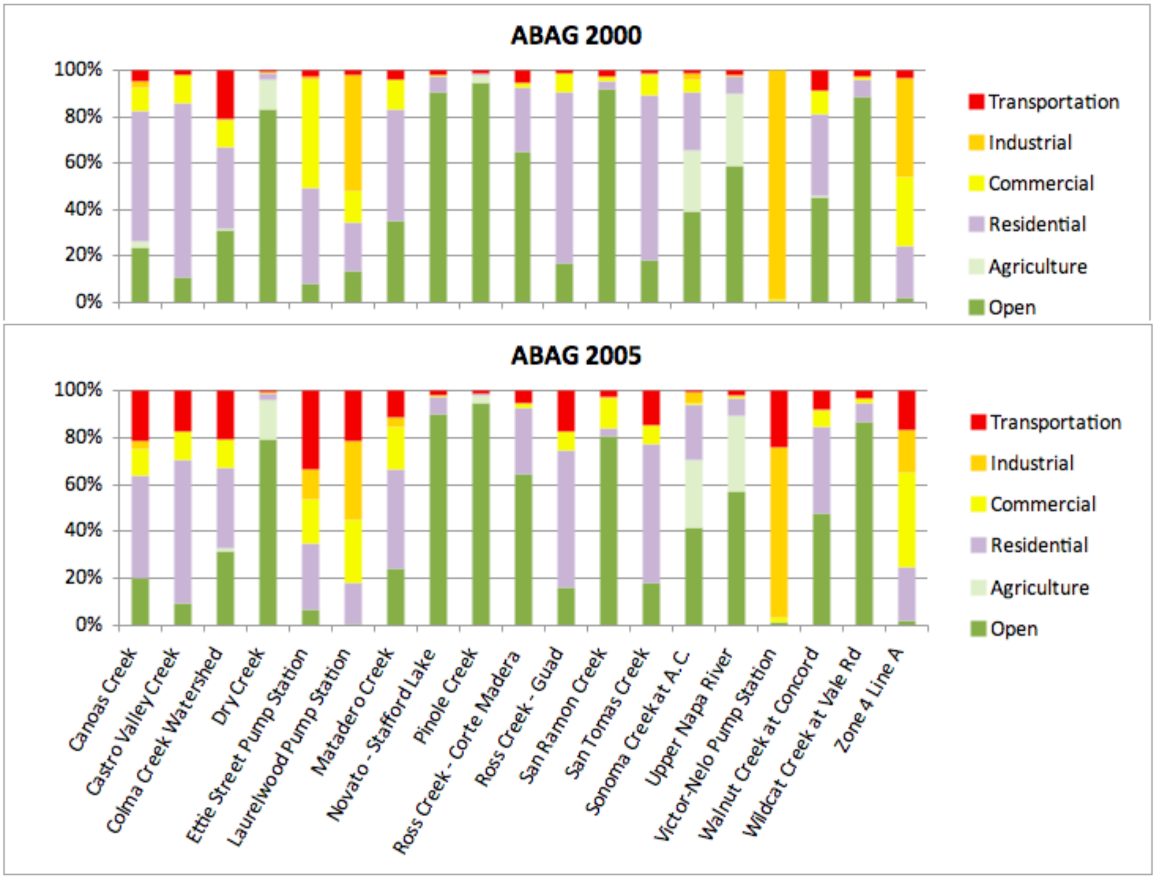

Figure 7 - Changes in land use classification from ABAG 2000 to ABAG 2005 for calibration watersheds.

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%

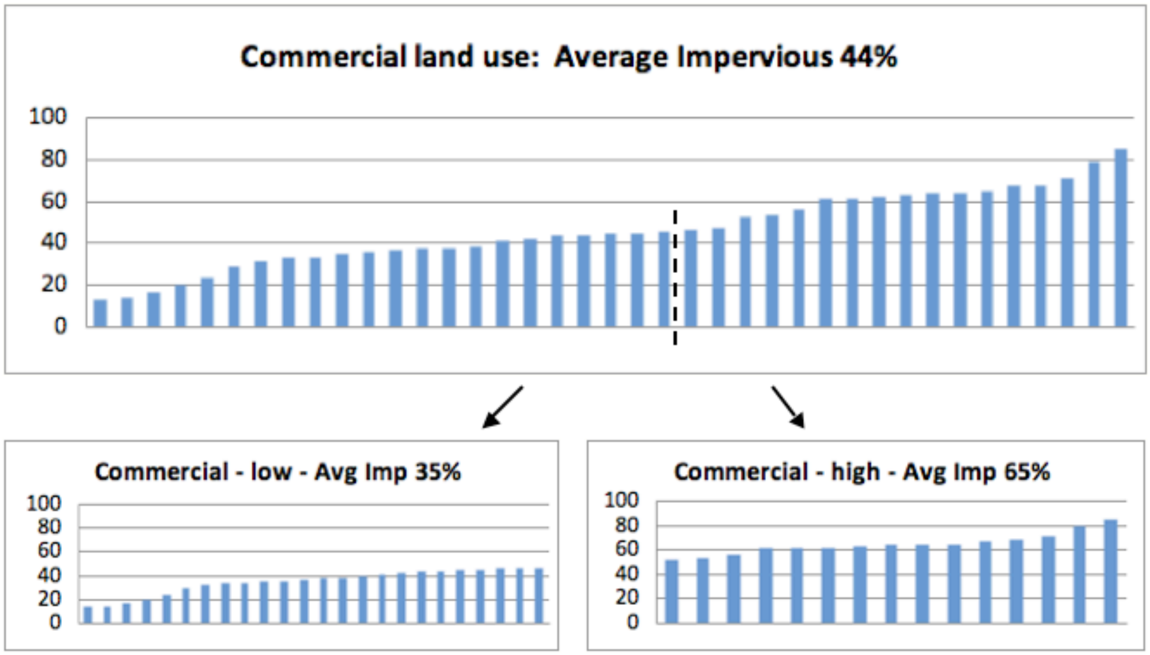

Figure 8 – An example of using imperviousness to reclassify land use descriptions into categories that more accurately group runoff behavior

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

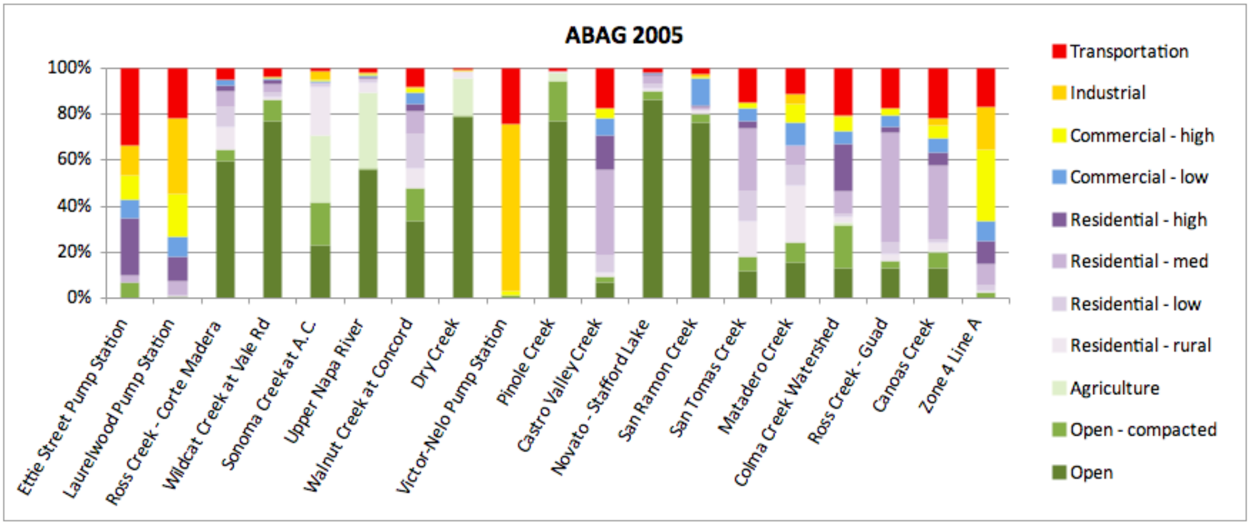

Figure 9 - Distribution of revised land use categories in calibration watershed set.

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