SUBJECT: Amendment No. 1 to Request for Proposal No. 13-006

DATE OF AMENDMENT: November 2, 2012

DATE OF RFP RELEASE: October 11, 2012

PROPOSAL DEADLINE: November 16, 2012 @ 5:00 PM

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The following shall be a part of RFP No. 13-006 for Lake Clarity Crediting Program Stormwater Tools Improvement Project. If an Applicant has already returned a proposal and any of the information provided below changes that proposal, please submit the changes along with this amendment. You need not re-submit an entire proposal prior to the proposal deadline.

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1. Is it possible to get some documentation for the tools listed under B. Lake Clarity Crediting Program #1 through #5 ? Manuals etc. to better acquaint us with what you are looking for?

   Section II. Part B. (Lake Clarity Crediting Program heading) contains web links for each of the Crediting Program stormwater tools. The documentation for each tool can be found by clicking on the respective links.

2. Is the use of the awarded contract fees limited to only the applicant's included partners, or can additional subconsultants be added by the prime as a result of stakeholder input on needed tool improvements or other project related recommendations?

   Applicant's should identify all anticipated subcontractors and describe their roles, responsibilities and all work to be performed in the proposal. However, if necessary and with NDEP approval, additional subcontractor(s) not identified in the proposal may be added after a contract has been established.

3. Page eleven (11) of the RFP states that "applicants are encouraged to submit Attachment C" for all references. However, page 32 of the RFP states that "the proposing applicant is required to send the following reference form to each business reference listed". Is the form required from each reference or is it optional?

Submitting up to five (5) references is optional, however only the reference form contained in RFP Attachment C will be accepted and distributed to the Evaluation Committee.

4. Should we include a references section in the proposal AND have our references submit Attachment C? Or does the NDEP prefer that we only submit reference forms?

   Only the reference forms in RFP Attachment C will be accepted and distributed to the Evaluation Committee.

5. Page eleven (11) of the RFP states that "up to five references…may be provided". Is this the combined maximum for the prime and all subcontractors, or is it the maximum for each organization on the team?

   Up to five (5) reference forms may be submitted for the prime; up to five (5) additional reference forms per subcontractor may be submitted.

6. It is clear that the electronic copy of the proposal must be submitted to the NDEP by the proposal deadline. Can you please clarify whether the proposal hardcopies have to be postmarked by the deadline or delivered by then?

   Proposal hardcopies must be received, checked and stamped by NDEP by the deadline.

7. Is the Applicant Information Sheet required by subcontractors or just the prime contractor?

   Submit the Applicant Information Sheet only for the prime contractor.

8. Can the Statement of Qualifications, References, Disclosures and all required forms be included as attachments in the proposal? Or should they be submitted separately?

   The Statement of Qualifications, References, Disclosures and all required forms may be submitted as attachments to the proposal or as a separate document.

9. Does NDEP have a general target schedule regarding deliverables?

   A schedule was not included in the RFP in order to give the Applicant the freedom to lay out a timeline they deem would be realistically achievable. The proposed timeline will be reviewed by the Evaluation Committee and may be negotiated with the selected contractor.

10. What is the final completion target date for all deliverables in the work scope?

    A specific project completion date for the project has not been determined. However, applicants should be aware of the 12/31/15 grant award termination date.

11. Are there any material assumptions that we should make regarding significant milestones?

Milestones were not specified in the RFP in order to give the Applicant freedom to lay them out as they deem appropriate.

12. How many meetings are anticipated under item 2 of the "Work to be Performed"?

    Number of meetings has been left to the discretion of the Applicant. This item will be evaluated by the Evaluation Committee and may be negotiated with the selected contractor.

13. Who are the anticipated members of the PAC?

    The composition of the Project Advisory Committee (PAC) was not specified in the RFP in order to give the Applicant freedom to propose a composition that they deem appropriate. Minimally, it should include staff from NDEP and the Lahontan Water Board. This item will be evaluated by the Evaluation Committee and may be negotiated with the selected contractor.

14. Who is the NDEP Project Manager for this work?

    The NDEP Project Manager is anticipated to be Jason Kuchnicki, Lake Tahoe Watershed Program Manager.

15. Who is the Agency Executive for this work?

    NDEP's executive representative is anticipated to be David Gaskin, Deputy Administrator. The Lahontan Water Board executive representative is anticipated to be Patty Kouyoumdijan. Inclusion, roles and responsibilities of other appropriate agency executive representatives is left to the discretion of the Applicant.

16. Under item 3a and 3b of "Work to be Performed" - can you provide access to past research projects and improvement recommendations or post on the web site or email?

    The following sources may contain relevant information for the development of proposals:
    1. **Respective stormwater tools documentation (links contained in the RFP Section II.B.).**
    2. ***List of Potential PLRM Improvements* (June 2010) document included as Attachment A to this Amendment;**
    3. ***Focused Stormwater Monitoring to Validate Water Quality Source Control and Treatment Assumptions* (June 2010) final technical report included as Attachment B to this amendment;**
    4. ***Focused Stormwater Quality Monitoring to Inform Assumptions & Evaluate Predictive Capabilities of Existing Tools* (June 2012) final technical report included as Attachment C to this amendment;**
    5. ***Pilot Catchment Validation Study: Lake Tahoe Basin* (June 2012) final technical report included as Attachment D to this amendment;**

6. ***Crediting Program Support Services – Recommendations Memorandum and Project Report* (December 2011) included as Attachment E to this amendment;**
7. **Lake Tahoe Stormwater Tools Improvement nomination included as Attachment F to this amendment.**

It is important to note that the sources contained in Attachments A thru E to this amendment are those that could be readily identified and may not represent the only sources of relevant information. A comprehensive list of past research project and improvement recommendations does not exist at this time. Thus, compiling a comprehensive list of past research project and improvement recommendations is a work task identified in the RFP. The NDEP Project Manager and PAC members will work with the successful contractor to identify and evaluate other sources of information relevant to the update of stormwater tools.

Additionally, useful and related information for the development of proposals may be available at the following websites:

1. **NDEP Lake Tahoe Watershed Program: http://ndep.nv.gov/bwqp/tahoe.HTM;**
2. **Lahontan Water Board: http://www.waterboards.ca.gov/rwqcb6/water_issues/programs/tmdl/lake_tahoe/index.shtml;**
3. **USDA Forest Service Pacific Southwest Research Station Southern Nevada Public Management Act (SNPLMA) Tahoe Science Projects: http://www.fs.fed.us/psw/partnerships/tahoescience/.**

17. How many training sessions do you anticipate will be required under item 4. of "Work to be Performed"? Will an allowance for this training work scope be considered?

The number of training sessions was not specified in order to give the Applicant the freedom to lay out an appropriate associated workplan task. This item will be evaluated by the Evaluation Committee and may be negotiated with the selected contractor.

ALL ELSE REMAINS THE SAME.

Applicants must sign and return this amendment with proposal submitted.

NAME OF APPLICANT_____

AUTHORIZED SIGNATURE _____

TITLE _____ DATE _____

This document must be submitted in the "State Documents" section/tab of the applicants technical proposal

Attachment A

List of Potential PLRM Improvements (June 2010)

List of Potential PLRM Improvements
Project: PLRM Training Assistance
Prepared for: USACE Sacramento District
Prepared by: northwest hydraulic consultants
June 2010

This document summarizes 15 potential improvements to Version 1 of the Pollutant Load Reduction Model (PLRM). The list of potential improvements has been prioritized based on input received from attendees of the first PLRM training sessions, which were conducted for implementing agencies associated with the Lake Tahoe Basin Storm Water Quality Improvement Committee (SWQIC).

The improvements listed in this document are technical improvements to the model structure and algorithms that can be completed using existing information or ongoing research. Improvements to the PLRM that would require new research are not listed, but could be recommended through another forum, such as the Lake Tahoe Regional Storm Water Monitoring Program (RSWMP). Improvements listed are considered feasible with funding within the range of $5,000-$75,000 for each improvement. Improvements that would require long-term model development, or would require more significant budgets to complete are not listed.

Notes on the Table Below

1. The column "*Rank*" prioritizes the potential improvements based on input received from the SWQIC participants of the first PLRM training sessions.

2. The column "*What Improvement Would Provide*" categorizes the benefit of each improvement into three areas:
    a. Better User Experience: reduces model bugs, improves the flexibility of the model, or increases document guidance
    b. Development as a TMDL Tool: advances the PLRM structure and supporting documentation to better support the TMDL and Crediting Programs
    c. More Robust Computations: improves technical algorithms or incorporates ongoing research to improve, develop, or enhance model calculations

3. The column "*Level of Effort and Summary of Work*" estimates the level of effort to complete the improvement using a ballpark estimate of total staff hours divided into the following categories.
    a. Minor: less than 60 total hours to compete
    b. Low: ranging between 60 – 160 total hours to complete
    c. Moderate: ranging between 160 – 320 total hours to complete
    d. High: ranging between 320 – 600 total hours to complete

Rank	Improvement Reference	Summary of Need	What Improvement Would Provide	Level of Effort and Summary of Work
1	Fix Miscellaneous Bugs	Initial use of the PLRM has identified various bugs that don't necessarily effect results but are frustrating to users.	Better User Experience Decrease the number of model bugs.	Moderate 1. Fix various bugs through code modifications
2	Pollutant Generation Output by Urban Land Use	Pollutant generation by urban land use is not currently reported. This limits the ability for a user to assess the significance of pollutant sources in their model.	Development to Support TMDL Improved PLRM functionality for planning efforts, including better estimates of jurisdictional baseline loading and the formulation of strategies to achieve TMDL allocations	Low 1. Develop code to indentify pollutant loading generated by urban land use 2. Revise format of output reporting and test
3	Increase PLRM Stability	The PLRM programming code needs additional development to reduce access violations caused when both the PLRM and SWMM5 try to access the same Windows program. The errors result in PLRM program crashes.	Better User Experience Increased PLRM stability resulting in less program crashes	Moderate 1. Continue testing PLRM to identify actions that cause access violations 2. Develop rules and code to eliminate access violations
4	Integrate Road RAM into PLRM	The Road RAM is currently under development by 2NDNATURE. Research collected in support of the Road RAM has shown that the current structure of the PLRM Road Shoulder Conditions form and supporting algorithms could be improved to better integrate with the Road RAM and future validations through monitoring.	More Robust Computations Create better linkage of PLRM defined actions, Road RAM observations, and validations through monitoring	Moderate 1. Incorporate Road RAM research and approach into PLRM algorithms 2. Re-organize Road Shoulder Conditions Form in PLRM 3. Test PLRM and update documentation
5	Update Characteristic Effluent Concentrations (CECs)	Current research led by 2NDNATURE is investigating the performance of various SWTs for fine sediment particle removal. Results of this research are intended to be incorporated into PLRM.	More Robust Computations Refine CEC defaults in PLRM for FSP based on results of ongoing research	Minor 1. Revise PLRM database where applicable for SWT CECs 2. Update PLRM documentation

Rank	Improvement Reference	Summary of Need	What Improvement Would Provide	Level of Effort and Summary of Work
6	Augment Applications Guide	Current guidance in the applications guide provides limited examples, which could be expanded to help user's with anticipated applications of the PLRM.	Better User Experience and Development as a TMDL Tool Provide examples of how to apply PLRM for: 1) baseline load estimates for the TMDL; 2) as a Crediting tool; 3) and detailed alternative analysis.	High 1. Coordinate example development with TMDL and Crediting Programs 2. Draft examples and update documentation 3. Develop supporting PLRM models
7	Improve Road Shoulder Infiltration Algorithms and Guidance	The current algorithms may not provide adequate default values to represent infiltration for urban land uses (in particular for compacted road shoulders). Research will begin in the Summer of 2010 to field test road shoulder infiltration and compare to PLRM estimates.	More Robust Computations Improved algorithms and guidance to better estimate infiltration on pervious road shoulders	Likely Low 1. Effort dependent upon research findings and algorithms developed from research 2. Modify GUI to include new algorithms 3. Update documentation
8	Develop a Crediting Version of PLRM Database	The PLRM database contains all default values necessary to run a continuous simulation but it is open to the user and can be modified. A consistent set of assumptions (i.e. modeled effectiveness of street sweeping) is needed across jurisdictions for the PLRM Database if the PLRM is to be used as a Crediting tool.	Development as a TMDL Tool Develop consensus on default parameters used for PLRM simulations among Tahoe Basin urban jurisdictions.	High 1. Educate users on PLRM default values 2. Develop consensus among urban jurisdictions on appropriate PLRM defaults 3. Produce a PLRM Version that requires the Crediting version of the database to run 4. Improve Recommended Range Report for review purposes focused on Crediting Program

Rank	Improvement Reference	Summary of Need	What Improvement Would Provide	Level of Effort and Summary of Work
9	Improve ICIA Representation	Current algorithms don't provide flexibility to define routing characteristics for indirectly connected impervious area (ICIA). In certain cases, runoff from impervious areas may be distributed over too large a pervious area, which will result in an under-prediction of surface runoff	More Robust Computations Provide more flexibility to better define and estimate routing and infiltration from ICIA.	Moderate 1. Rebuild internal algorithms to allow for variable routing of impervious runoff 2. Revise PLRM forms to incorporate user inputs for this functionality 3. Test PLRM and update documentation
10	Provide Source Code Guidance	While PLRM source code is publicly available, general guidance within the code to interpret the code is not provided.	Better User Experience Would assist other software developers (other than PLRM developers) to efficiently interpret and modify PLRM source code.	Low 1. Clean up source code (old code no longer in use) 2. Provide guidance within code on general architecture, linkages, and function 3. Produce mapping document of code
11	Incorporate Cut Slope Erosion Algorithms	There is no direct method to represent cut slope erosion in the PLRM. Research led by IERS may provide data and methods to estimate pollutant loads from cut slope erosion.	More Robust Computations Provide specific methods to estimate pollutants loads from cut slope erosion	Moderate 1. Develop and modify PLRM forms to accept user input for new algorithms 2. Develop program code to integrate into output reporting 3. Test PLRM and update documentation
12	Rebuild Flexible Volume-Discharge Relationships for SWTs	Flexible volume-discharge relationships allow for better simulation of the performance of SWTs, but these methods were removed from PLRM Version 1 because they produced a circular reference that could potentially create erroneous results.	More Robust Computations Better flexibility to simulate the performance of an SWT relative to actual design for treatment rates and infiltration.	Low 1. Rebuild all SWT forms in PLRM 2. Test forms and the code transfer to SWMM5 3. Update documentation

Rank	Improvement Reference	Summary of Need	What Improvement Would Provide	Level of Effort and Summary of Work
13	Omit SWT Treatment Vault Option	Initial use of Treatment Vault SWT options has raised concerns that performance may be over predicted for this SWT, especially for FSP removal.	More Robust Computations Eliminate the Treatment Vault options and require justification of CECs for a User-Defined SWT (which can be a Treatment Vault) to reduce the chances that treatment performance is over-predicted.	Minor 1. Modify GUI and require CECs to be confirmed by user. 2. Flag CECs regardless of values in Recommended Range Report as a warning (requires justification to use) 3. Update documentation
14	Improve File Management	Current file management from the PLRM interface is limited. (A user has to manually delete files, install the PLRM to a specific directory, and manually adjust names of folders when importing projects).	Better User Experience Allow the PLRM to be installed in user-specified location. Allow all file management activities to occur from the PLRM interface.	Moderate 1. Augment PLRM code 2. Test PLRM file management 3. Update documentation
15	Improved Computations of Loads Infiltrated to Groundwater	The PLRM estimates pollutant loads that are infiltrated but does not attempt to estimate loads reaching groundwater. TRPA and the Water Board have just initiated a project to assess water quality impacts to groundwater associated with infiltration of urban storm water.	More Robust Computations Incorporate the findings of ongoing research to better estimate pollutant loads from infiltrated storm water that reach groundwater.	Likely Low 1. Effort dependent upon research findings and algorithms developed from research 2. Incorporate algorithms to estimate loading to groundwater 3. Update output report to include this calculation

Attachment B

Focused Stormwater Monitoring to Validate Water Quality Source Control and Treatment Assumptions (June 2010)

PLRM V.1

Focused Stormwater Monitoring to Validate Water Quality Source Control and Treatment Assumptions

FINAL

March 2010

SOURCE CONTROL & TREATMENT

2NDNATURE
ecosystem science + design

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LIST OF ACRONYMS

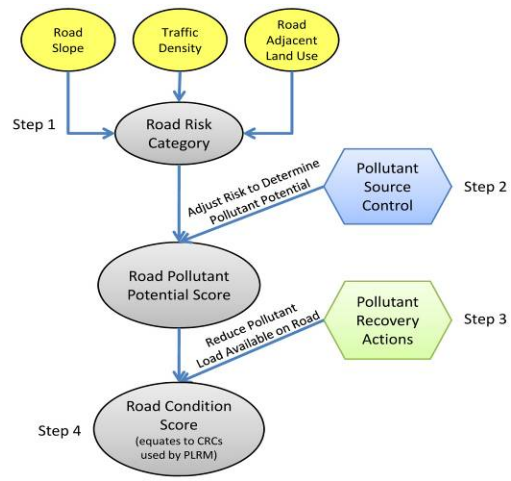
BMP	Best Management Practice
BMP RAM	Best Management Practice Maintenance Rapid Assessment Methodology
CEC	Characteristic Effluent Concentration
Clarity Program	Lake Tahoe Clarity Crediting Program
CRC	Characteristic Runoff Concentration
DIN	Dissolved Inorganic Nitrogen
FSP	Fine Sediment Particles; sediment particles defined as <16µm
PHR	Primary High Risk Road
PLR	Primary Low Risk Road
PMR	Primary Moderate Risk Road
PLRM	Pollutant Load Reduction Model
RAM	Rapid Assessment Methodology
Road RAM	Road Rapid Assessment Methodology
SHR	Secondary High Risk Road
SLR	Secondary Low Risk Road
SMR	Secondary Moderate Risk Road
SRP	Soluble Reactive Phosphorous
SWT	Stormwater Treatment BMP
TMDL	Total Maximum Daily Load
TP	Total Phosphorous
TSS	Total Suspended Sediment
TN	Total Nitrogen

EXECUTIVE SUMMARY

2NDNATURE was contracted by the US Army Corps of Engineers (ACOE) to develop a data collection strategy to improve the scientific basis of the water quality algorithms used in the initial version of the Pollutant Load Reduction Model (PLRM v1, nhc et al. 2009). The PLRM provides Lake Tahoe resource managers with a tool to compare urban stormwater quality improvement alternatives in an urban catchment based on the predicted pollutant load reductions. The objective of this Phase I of PLRM v1 Database Refinement monitoring is to develop a better understanding of the generation, fate and transport for fine sediment particles (FSP, <16µm), particularly from urban roads, and the treatment performance of stormwater treatment BMPs (SWTs). The datasets generated are also intended to inform two rapid assessment tools (RAMs) developed to support the PLRM estimates (Best Management Practice Maintenance RAM: BMP RAM and Road RAM) and the overall Lake Clarity Crediting Program. The ACOE contract (Phase I) included the development of a detailed data collection monitoring plan, implementation of the monitoring plan for 6 months during WY2009, and a detailed data analysis technical report summarizing the findings of the effort. Since the award of this ACOE contract, the 2NDNATURE team has been awarded a SNPLMA Round 9 research grant to continue the stormwater research initiated under this ACOE contract as Phase II of PLRM v1 Database Refinement monitoring through WY2011.

URBAN ROAD MONITORING

The PLRM quantifies pollutant generation from a catchment based on land uses (single family residential, commercial, primary roads, etc.) and the associated land use condition. Condition is defined as the existing state of a land use relative to the pollutant generation risk during a subsequent storm. In the PLRM, the condition of an urban land use is correlated to a Characteristic Runoff Concentration (CRC), which is a representative concentration for a pollutant of concern in stormwater runoff from a specific urban land use and its associated condition. CRCs are combined with continuous runoff hydrology from the PLRM to provide a representative estimate of average annual pollutant loading for specific land use conditions. PLRM v1 assumes that significant pollutant load reduction opportunities exist by improving the condition of an urban road to protect water quality. The PLRM Road Methodology (Appendix B) integrates physiographic characteristics, pollutant source control efforts, and pollutant recovery efficiency to predict likely road condition and associated CRCs from urban roadways.



Simplified schematic illustrating PLRM Road Methodology approach.

To address the current water quality data gaps for urban roads 2NDNATURE designed and implemented the following stormwater data collection strategy. Thirty-two (32) urban road and 2 impervious commercial land use segments were selected within the Lake Tahoe Basin that represented a range of the 6 road risk categories as defined by PLRM Road Methodology. Each road segment was initially characterized to document key factors in accordance with PLRM assumptions and monthly road sampling was conducted at each road segment, including:

- Rapid visual observations and dry material sampling to estimate the relative amount and distribution of total suspended sediment (TSS) and fine sediment particles (FSP)on the road segment available for mobilization and transport during a subsequent runoff event.

- Controlled experiments using a portable simulator to obtain representative water quality data from urban roads and improve our empirical understanding between observed road segment condition and expected CRCs for TSS and FSP.

The key findings, results and recommendations of the Phase I Urban Road Monitoring are:

- The Phase I dataset is temporally limited. PLRM estimates are on average annual time scales and the road results obtained from March to July 2009 equate to only a fraction of the annual conditions for one distinct water year.

- Road condition was observed to improve seasonally, with the maximum and the variability of TSS and FSP concentrations significantly decreasing each month (see Figure 4.5) likely due to the combination of (1) warmer climatic conditions increasing the duration since the last road abrasive application, (2) increased time since last winter storm increasing the # of sweeps since last road abrasive application, and (3) the occurrence of late spring/summer rain events mobilizing sediment accumulated on the road surface and virtually rinsing the road of pollutants.

- The range of PLRM urban road CRCs for TSS (60 to 1398 mg/L) and FSP (22 to 1014 mg/L) appear to be representative of measured road conditions in Lake Tahoe (see Table 4.4). Continued controlled urban road monitoring will improve our confidence in and refine the PLRM urban road CRC values.

- PLRM estimates the maximum reduction in TSS and FSP CRCs for high frequency sweeping practices using a high efficiency regenerative air sweeper to be 38.1% and 26.7%, respectively. Preliminary findings based on this very limited dataset suggest that sweeping practices may strongly influence TSS and FSP concentrations on urban roads, and that further monitoring and analysis should focus on appropriate variability in PLRM CRCs to account for sweeping practices.

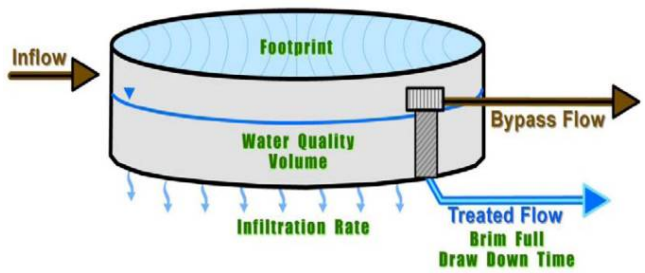
- Particularly with respect to load reductions of FSP, source control strategies that prevent the accumulation and subsequent transport are likely more consistently reliable than the stormwater capture and subsequent passive water quality treatment processes, such as particle settling, nutrient cycling, infiltration and/or media filtration, relied upon by typical SWTs in the Lake Tahoe Basin.

- A number of visual and rapid proxies appear to be promising predictors for TSS and FSP concentrations measured on urban road surfaces using the portable simulator. The road sampling dataset will continue to be used to test, develop and validate the primary observations, integration methods and scoring approach of the Road RAM in the following months.

- Additional data and continued analytical strategy development is needed to appropriately identify reliable temporal and spatial integration of discrete observed data into long-term annual average simulations.

- A lesson learned from this effort is the need to continue to improve the accuracy and communication of jurisdictional records on 1) abrasive application frequencies and magnitudes, and 2) respective sweeping practices to continue to inform estimates of the potential benefits of road maintenance practices on water quality. Coordination and collaboration with other researchers addressing urban road sweeping practices and water quality is encouraged.

SWT MONITORING



PLRM Dry Basin schematic illustrating bypass flow through the bypass outlet structure and treated flow through the treatment outlet. PLRM design parameters vary for each SWT type. See PLRM (nhc et al. 2009) for complete discussion and definition of terms.

The PLRM provides a function to estimate the performance of a stormwater treatment BMP (SWT) by assigning a Characteristic Effluent Concentration (CEC) depending on the type of SWT and fundamental design parameters. An SWT is defined as a Treatment BMP that reduces pollutants of concern from a concentrated stormwater flow path and PLRM estimates the CEC from six specific SWT types: dry basin, infiltration basin, wet basin, treatment vault, cartridge filter, and bed filter. The PLRM estimates pollutant load reductions achieved by an SWT facility using basic design information and a long-term simulation of hydrology to continuously compute hydraulic capture for the SWT. Runoff captured by the SWT is considered "treated", and is assigned a CEC for pollutants of concern that is specific to each SWT facility. Runoff that is not captured by the SWT is considered untreated or bypassed, and is assigned an effluent concentration equaling the influent concentration to the SWT. Reasonable maintenance by the jurisdictions to ensure acceptable water quality treatment function of each SWT is assumed in PLRM estimates.

In order to build the initial SWT water quality dataset to improve the Lake Tahoe urban stormwater management tools, 2NDNATURE obtained the following data from 4 SWTs (Osgood Basin, Park Avenue Upper and Lower Basins, and Stormfilter® Vault): (1) Treatment BMP condition using BMP RAM protocols, (2) continuous surface water hydrology of the SWTs to develop a comprehensive surface water budget and cost-effectively estimate event volumes and hydrograph characteristics, and (3) event-based surface water sampling using automated and passive techniques to determine inlet and outlet TSS and FSP concentrations and inform PLRM CEC estimates by SWT type.

The key findings, results and recommendations of the Phase I SWT Monitoring are:

- The Phase I PLRM database refinement monitoring has made great strides toward developing standardized and consistent protocols to collect, manage and analyze data to inform and test the assumptions underlying PLRM v1 CEC estimates. The Phase I dataset is temporally limited. PLRM estimates are on average annual time scales and the 4 stormwater runoff events monitored represent only a limited fraction of one distinct water year. Phase II of the PLRM v1 Database Refinement monitoring includes the instrumentation of additional SWTs along with the 4 sites described above to expand the current dataset through 2011 and to continue the sampling efforts initiated by this Phase I contract.

- The Phase I sampling configuration failed to capture the water quality treatment volumes outflowing from the Osgood Basin because the effluent passive samplers were all placed at or above the bypass outlet elevation. Modifications to the site sampling configuration were made in the fall of 2009 to rectify this issue as monitoring continues at this site through WY2011 using SNPLMA Round 9 funds. The sampling configuration at Park Avenue Upper Basin (PA1) and the Stormfilter® Vault did include representative outflow sampling of the water quality treatment volumes. Park Avenue Lower Basin (PA2) did not have any treated outflow occur during the Phase I sampling. Familiarity of SWT configuration and the continued knowledge gained regarding idiosyncratic site conditions is essential to ensure effective site instrumentation and sampling techniques of SWTs.

- Of the 21 inlet and outlet passive sample pairs collected at Osgood and PA1 wet basins, 86% indicated an FSP concentration reduction. This finding is consistent with the limited inlet and outlet sampling of FSP at PA1 by 2NDNATURE (2008) and supports the ability of wet basins to provide some FSP load reductions that are not solely due to volume reductions within the SWT.

- While the absolute magnitude of FSP mass reductions varied per event, consistent load reductions were observed and are measureable on an event time scale. Additional data collection will be key in the continued investigation of the seasonal and average annual water quality treatment performance of SWTs to inform PLRM with respect to fine sediment particle removal in urban stormwater.

- SWT inlet sampling results were consistent with previous knowledge indicating the higher-intensity, short-duration summer thunderstorm and rain events have a greater transport capability than the winter/spring rain, rain on snow, and snowmelt runoff events. While the Summer/Fall concentrations are typically higher, only 21% of the annual surface water volume delivered to Lake Tahoe occurs from June to November, with the remaining 79% occurring from December through May.

- While the existing data is limited and will not be used to recommend changes to PLRM v1 CECs at this time, three potential SWT data analysis approaches are presented to apply temporally and spatially specific data to PLRM average annual CECs for each SWT type and pollutant of interest.

- Additional next step priorities beyond the currently funded Phase II efforts include catchment-scale integration and testing of site-specific, cost-effective monitoring techniques, RAM tool observations, and PLRM predictions. Once our datasets and knowledge of specific monitoring and evaluation techniques to inform the PLRM CRC and CEC database are improved, the imperative next step of integrating all of these tools is a complete and detailed urban catchment evaluation that includes the initiation and completion of all of the recommended Lake Tahoe stormwater tools intended to support the Lake Clarity Crediting Program (LRWQCB and NDEP 2009). The 2NDNATURE team has submitted a SNPLMA Round 10 research proposal to undertake this critical next step in tool integration and testing.

CHAPTER 1 - STUDY INTRODUCTION

1.1 PROBLEM STATEMENT

A significant decline in Lake Tahoe's famed clarity has been observed over the last several decades. Secchi disk readings have decreased from 90 feet in the 1970s to less than 70 feet in 2008 and annual primary production is now greater than 200 grams of carbon per square meter per year (g C m^{-2} y^{-1}) compared to peaks below 60 g C m^{-2} y^{-1} four decades earlier (LRWQCB and NDEP 2007). Lake Tahoe Basin scientific research has identified three primary pollutants of concern: fine sediment particles, phosphorous species, and nitrogen species. Fine sediment particles (FSP, <16µm) have residence times in the water column of many years, and increased nutrient delivery, particularly phosphorous, stimulate primary production rates. On-going research indicates that reductions in the pollutant loading to the lake of these three pollutants can restore Lake Tahoe clarity to pre-1970 Secchi depths. The Lake Tahoe TMDL has established a lake clarity standard of 29.7 meters (97.4ft) and an interim Clarity Challenge milestone at 24 meters (78.7ft). Direct stormwater runoff originating in urban areas is estimated to contribute 72% of the total FSP, 38% of the total phosphorous, and 16% of the total nitrogen annual loading to the lake (LRWQB and NDEP 2007). To meet the standards set by the TMDL, large reductions in the FSP and nutrient loading from urban lands need to be achieved and sustained.

Numerous urban stormwater management tools have been, or are in the process of being, developed to estimate and track achievements toward the Lake Tahoe TMDL goals of reducing pollutant loading to Lake Tahoe. The Lake Clarity Crediting Program (Clarity Program) Handbook (LRWQCB and NDEP 2009) provides guidance to estimate and track pollutant load reductions within the context of the Lake Tahoe TMDL. The Clarity Program recommends the use of the Pollutant Load Reduction Model (PLRM; nhc et al. 2009), Road Rapid Assessment Methodology (Road RAM; CTC and NDEP 2010) and Best Management Practices Maintenance Rapid Assessment Methodology (BMP RAM; 2NDNATURE 2009) by local jurisdictions and regulators to estimate and track urban load reductions over time. The Clarity Program directs urban jurisdictions to estimate annual load reductions using distinct urban catchments to preserve the physical mass balance concept that annual pollutant loading to Lake Tahoe is the sum of distinct input points (i.e., urban catchment outlets). PLRM is the Clarity Program's recommended model for jurisdictions to estimate catchment load reductions on an average annual basis. Water quality algorithms in the PLRM are empirical. The Urban RAM tools (Road RAM and BMP RAM) are also recommended to validate model assumptions and to track and validate the condition with respect to water quality of urban land uses and Treatment BMPs over time. The initial versions of all three of these stormwater tools have been informed by limited existing data on the generation, fate and transport of FSP in urban catchments. It is clear that continued urban stormwater and Lake Tahoe Treatment BMP research is necessary to improve our empirical understanding of fine sediment particle (FSP <16µm) and nutrient generation, fate and transport from urban land uses (particularly roadways) and the ability of stormwater treatment BMPs to retain and remove these pollutants.

RESEARCH OVERVIEW

2NDNATURE was contracted by the US Army Corps of Engineers (ACOE) to develop a data collection strategy to improve the scientific basis of the water quality algorithms used in the initial version of the Pollutant Load Reduction Model (PLRM) (nhc et al. 2009). The objective of this Phase I of PLRM v1 Database Refinement monitoring is to develop a better understanding of the generation, fate and transport for fine sediment particles, particularly from urban roads, and the treatment performance of SWTs. Increased accuracy and reliability of PLRM load estimates will depend on focused and defensible data collection and analysis specifically designed to better inform key model assumptions and input parameters.

The primary data sources that inform water quality algorithms in PLRM v1 are Lake Tahoe stormwater quality monitoring datasets compiled and integrated from a variety of sources. The available Lake Tahoe stormwater data was collected to meet a myriad of data collection goals and objectives, and therefore does not perfectly align with the goals and objectives of the PLRM. This research was initiated to directly inform the PLRM v1 assumptions and algorithms, particularly with respect to FSP, to continue to improve the predictive power of the PLRM.

The ACOE contract (Phase I) included the development of a detailed data collection monitoring plan, implementation of the monitoring plan for 6 months during WY2009, and a detailed data analysis technical report summarizing the findings of the effort. The final Lake Tahoe PLRM Database Refinement Monitoring Plan details the research approach, field methods, and protocols and is attached as Appendix A. This document is the technical final report for the ACOE Phase I effort. Since the award of this ACOE contract, the 2NDNATURE team has been awarded a SNPLMA Round 9 research grant to continue the stormwater research initiated under this ACOE contract as Phase II of PLRM v1 Database Refinement Monitoring. The data collection and data analysis methods presented herein will be continued and augmented using the SNPLMA resources through WY2011.

RESEARCH APPROACH

The initial version of the Pollutant Load Reduction Model (PLRM v1) was released in October 2009 by Northwest Hydraulic Consultants (nhc), 2NDNATURE, and Geosyntec Consultants through grants provided by the US Army Corps of Engineers (ACOE) and the Southern Nevada Public Land Management Act (SNPLMA) (nhc et al. 2009). The PLRM provides Lake Tahoe resource managers with a tool to compare urban stormwater quality improvement alternatives in an urban catchment based on the predicted pollutant load reductions. The PLRM estimates pollutant concentrations in urban catchments using two primary water quality algorithms: Characteristic Runoff Concentrations (CRCs) and Characteristic Effluent Concentrations (CECs).

CRC (Characteristic Runoff Concentrations)

The PLRM quantifies pollutant generation from a land use and the associated land use condition. Land use types include single family residential, commercial, primary roads, etc. Condition is defined as the existing state of a land use relative to the pollutant generation risk during a subsequent storm. PLRM attempts to estimate the average likely condition of specific urban land use types within a catchment over the long-term. A wide range of pollutant source controls are implemented on urban land uses with the intention of improving condition and reducing the pollutant generation risk. In the PLRM, the condition of an urban land use is correlated to a CRC, which is a representative concentration for a pollutant of concern in stormwater runoff from a specific urban land use and its associated condition. CRCs are combined with continuous runoff hydrology from the PLRM to provide a representative estimate of average annual pollutant loading for specific land use conditions. CRCs represent the average annual pollutant load divided by the average annual runoff volume, and vary according to PLRM inputs for land use and land use condition. CRCs thus differ from individual concentration measurements or shorter term composite variables reported in the literature as Event Mean Concentrations (EMCs). PLRM v1 assumes that significant pollutant load reduction opportunities exist by improving the condition of an urban road to protect water quality. The PLRM Road Methodology (Appendix B) integrates physiographic characteristics, pollutant source control efforts, and pollutant recovery efficiency to predict likely road condition and associated CRCs from urban roadways.

The research presented in this report has developed specific data collection and data analysis techniques to test, validate and continue to improve the PLRM urban roadway CRCs. In an effort to inform the Road RAM tool, the

collected water quality data from this study is coupled with visual observations and simple measurements to improve our ability to estimate roadway condition using the Road RAM tool.

CEC (Characteristic Effluent Concentrations)

The PLRM provides a function to estimate the performance of a stormwater treatment BMP (SWT) by assigning a characteristic effluent concentration (CEC) depending on the type of SWT and fundamental design parameters. An SWT is defined as a Treatment BMP that reduces pollutants of concern from a concentrated stormwater flow path and PLRM estimates the CEC from six specific SWT types: dry basin, infiltration basin, wet basin, treatment vault, cartridge filter, and bed filter. When combined with continuous runoff hydrology from the PLRM, CECs provide a representative estimate of average annual pollutant loading at the outlet of a SWT. CECs represent the average annual pollutant load divided by the average annual runoff volume at the SWT outlet, and thus differ from individual concentration measurements or shorter term composite variables reported in the literature as Event Mean Concentrations (EMCs). Reasonable maintenance by the jurisdictions to ensure acceptable water quality treatment function of each SWT is assumed in PLRM estimates.

This research has developed specific data collection and data analysis techniques to test, validate and continue to improve PLRM CEC values for SWTs. The continued implementation of these sampling techniques by other funding sources, coupled with evaluations of SWT condition (using the BMP RAM), will continue to broaden our quantitative understanding and inform PLRM CECs.

1.2 POLLUTANTS OF CONCERN

Fine sediment particles (FSP <16µm), total suspended sediment (TSS), soluble reactive phosphorous (SRP), total phosphorous (TP), dissolved inorganic nitrogen (DIN) and total nitrogen (TN) are the primary pollutants of concern affecting Lake Tahoe clarity, and catchment loading is estimated for each of these pollutants of concern by PLRM. Research for the Tahoe TMDL (LRWQCB and NDEP 2007) suggests nearly two-thirds of the total annual contribution of fine sediment particles to the lake is generated from urban stormwater runoff and that these particles are the primary cause of the clarity decline of Lake Tahoe (Swift et al. 2006). Fine sediment is generated on urban land uses and then is mobilized into the stormwater system during direct runoff events. Treatment BMPs are assumed to retain fine sediment particles through infiltration, particle capture, vegetation interactions and/or media filtration that physically trap and remove FSP from stormwater volumes, though the actual performance of FSP load reductions by these water quality treatment processes is not well understood.

The Lake Tahoe TMDL program is tracking FSP by number of particles <16µm. TSS is expressed as the mass of sediment per liter of water (mg/L). A particle size distribution analysis conducted on a TSS sample can be analyzed to yield the number of individual particles within each size fraction, including FSP (<16µm). The cost and complexity of quantifying the number of particles <16µm for each sample was impractical for the purposes of this research, and thus FSP concentrations are determined as the percent of the TSS by mass that is <16µm. The percent of the TSS sample <16µm by mass (%) is multiplied by the TSS concentration (mg/L) for the respective sample to obtain the FSP concentration (mg/L). Linear relationships have been developed and are continuing to be refined by local academic institutions to convert the mass of FSP to # of particles using a simple particle conversion factor to allow Basin research to maintain consistency with the Lake Tahoe TMDL program. At the time of this report, the current particle converter indicates 1kg of FSP = 1.12×10^{14} particles <16µm (UC Davis 2007). In terms of improving Lake Tahoe clarity, it is the reduction of FSP loads that is of utmost importance.

CHAPTER 2 - DATA COLLECTION OBJECTIVES

The dataset presented herein is based on a relatively brief monitoring duration, extending from December 2008 through July 2009. This single winter monitoring effort is a limited dataset that cannot account for inter-annual climatic and hydrologic variability. However, this Phase I data collection effort does provide initial datasets with which we can develop data collection, management and analysis techniques and begin to address the priority data gaps within the suite of urban stormwater management tools (e.g., PLRM, Road RAM, BMP RAM, etc.). SNPLMA Round 9 funded research (Phase II) will continue and expand this dataset towards improving PLRM and associated tools.

The specific data collection objectives of the monitoring were:

- *Develop cost-effective, scientifically defensible data collection techniques that can be implemented at a wide range of urban roadway and SWT sites.*
  The 2NDNATURE research team developed and tested a number of new data collection techniques to generate standardized, measurable results that directly address the water quality effects of condition and design characteristics and address the current urban roadway and SWT data gaps. These protocols have been detailed in the final Lake Tahoe PLRM Database Refinement Monitoring Plan (Appendix A) and can be implemented throughout the Lake Tahoe Basin.
- *Begin initial dataset collection at urban roadways that represent a range of road factors, risk, and condition as defined in PLRM Road Methodology.*
  The 2NDNATURE research team combined documentation of key road segment factors as defined in the PLRM, observations of relative road condition and cost-effective road sampling techniques over a range of urban road conditions that exist in Lake Tahoe Basin. These urban road sample collection efforts significantly increased the current dataset and improve our understanding of fine sediment particles (FSP) fate and transport on this critical urban land use. Urban road sampling consisted of controlled experiments of urban Lake Tahoe roads. The contributing roadway condition was evaluated and documented prior to each controlled experiment. The field verification of urban road condition and subsequent standardized sampling of the associated road water quality provides valuable qualitative and quantitative data to (1) inform the PLRM Road Methodology (provided in Appendix B of this document) and (2) test initial Road RAM concepts. 2NDNATURE has been funded through SNPLMA to continue urban road monitoring through WY2011 and build upon this initial dataset.
- *Begin initial dataset collection at a range of SWT types to assess the influent and effluent concentrations and collect continuous surface water hydrology.*
  The 2NDNATURE research team instrumented 4 SWTs to collect continuous surface water hydrology time series data and sample influent and effluent water quality conditions during significant stormwater runoff events. These data collection efforts significantly increased the current dataset and the understanding of water quality treatment performance with respect to FSP for 3 SWT types: dry basins, wet basins, and cartridge filters. SWT instrumentation included in-basin depth transducers and inlet and outlet passive sampler pairs to standardize sampling by basin water surface elevation and event hydrograph location. 2NDNATURE has been funded through SNPLMA Round 9 to expand SWT monitoring through WY2011 and include an additional 5-7 SWTs to build upon this initial dataset.

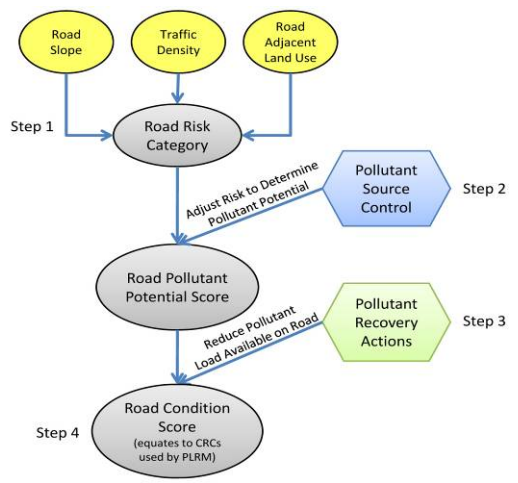
CHAPTER 3 - METHODS

2NDNATURE developed a complete data collection strategy, including monitoring goals and objectives, site selection justification, detailed instrumentation and field monitoring protocols, sample QA/QC requirements, and data management specifications. The Final Monitoring Plan was produced in July 2009 and is included as Appendix A. A general discussion of the methods is provided below; however for specific sampling technique rationale and detailed protocols, please consult Appendix A.

3.1 URBAN ROAD MONITORING

This urban road research integrated concepts from the PLRM Road Methodology (Appendix B) with innovative field data collection protocols to build the initial urban road water quality dataset and begin analysis to address current priority data gaps and test assumptions within the suite of Lake Tahoe urban stormwater management tools.

The PLRM Road Methodology predicts the likely long-term average urban road condition through the step-wise integration of road risk, pollutant source control efforts, and pollutant recovery actions (i.e., sweeping practices). The schematic at right provides a simple graphic illustrating how these factors are integrated to arrive at a likely road condition and associated TSS and FSP CRC for each road risk category. The road risk category is based on key physiographic and anthropogenic characteristics that are assumed to influence the relative stormwater quality downslope in the absence of pollutant source controls or actions. There are 6 road risk categories, combining road land use designations and road risk: primary high risk (PHR), primary moderate risk (PMR), primary low risk (PLR), secondary high risk (SHR), secondary moderate risk (SMR), and secondary low risk (SLR). The road pollutant potential integrates the road risk category with pollutant source control efforts, including road shoulder protection and/or stabilization and road abrasive application reduction strategies. Pollutant recovery actions include sweeping and are used in the final step to predict likely PLRM road condition scores and CRCs. Based on the integration of the road risk category and pollutant control measures, the PLRM Road Methodology estimates the likely long-term average CRC for TSS, FSP and nutrients for each road risk category. Given resource limitations of this data collection effort, only TSS and FSP were evaluated.



Simplified schematic illustrating PLRM Road Methodology approach.

To address the current water quality data gaps for urban roads 2NDNATURE designed and implemented the following stormwater data collection strategy:

- Selection of 32 urban road segments within the Lake Tahoe Basin that represented a range of the 6 road risk categories as defined by PLRM Road Methodology (Appendix B), as well as 2 impervious commercial land use segments.
- Initial characterization of each road segment to document key factors in accordance with PLRM assumptions.

- Monthly road sampling conducted at each road segment, including:
    - Rapid visual observations and dry material sampling to estimate the relative amount and distribution of total and fine sediment on the road segment available for mobilization and transport during a subsequent runoff event.
    - Controlled experiments using a portable simulator to obtain representative water quality data from urban roads and improve our empirical understanding between observed road segment condition and expected CRCs for TSS and FSP.

Figure 3.1 provides a visual orientation to summarize the temporal frequency and spatial distribution of the complete suite of data collected from the urban road segments monitored during Phase I.

ROAD SEGMENT SELECTION

Thirty-four (34) road segments, including thirty-two (32) roads and two (2) commercial parking lots (Table 3.1, Figures 3.2-3.3), were selected to represent a range of:

- road type (primary and secondary),
- road risk (high, moderate, and low), and
- jurisdictions in charge of maintenance.

The combination of roads selected, based on the above characteristics were expected to also represent a range of road conditions, consistent with the PLRM Road Methodology assumptions.

ROAD SEGMENT CHARACTERIZATION

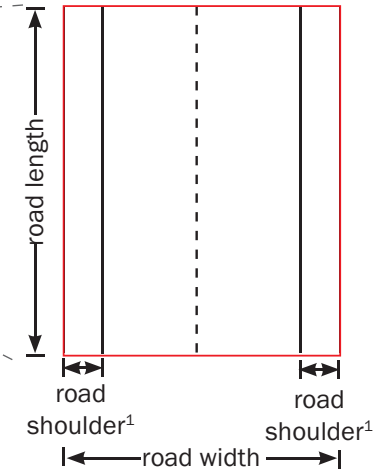
An initial road segment characterization was performed the first time field personnel visited each site (March or April 2009, depending on the site). Each road was divided into reaches that visually appeared to be of similar condition and the observation area was standardized to 1,000m^2 across all sites by adjusting segment length relative to road segment widths (i.e., narrower roads have a longer segment length). For the purposes of this research, a road segment is defined to include only impervious surfaces. PLRM includes the pervious area of the right-of-way in its definition of a road shoulder; however, due to sampling constraints, the pervious area is not included in these data collection and analysis efforts. Specific road segment characteristics documented were based on the PLRM Road Methodology and included: slope, cross-slope, aspect, surface integrity and % distress, and right and left road shoulder condition (protection, stabilization, and flow path erosion severity). Field personnel completed detailed field data sheets during the initial site visit and verified the information during each subsequent visit. Photos were taken during each sampling effort at each road segment and cataloged. The top half of Figure 3.1 presents the spatial distribution of data collected during the road segment characterization.

Following the field characterizations, the average annual predicted condition scores, TSS CRCs and FSP CRCs were predicted for each road segment using the PLRM Road Methodology (Appendix B) and the results are shown in Figure 3.4. The segments are ordered by increasing predicted road condition from left to right, and display a range of predicted condition across the road segments. The PLRM inputs for each road segment are provided in Appendix C.

ONCE EVERY 3-5 YEARS

Lake Tahoe Basin

Road Segment (1000m²)

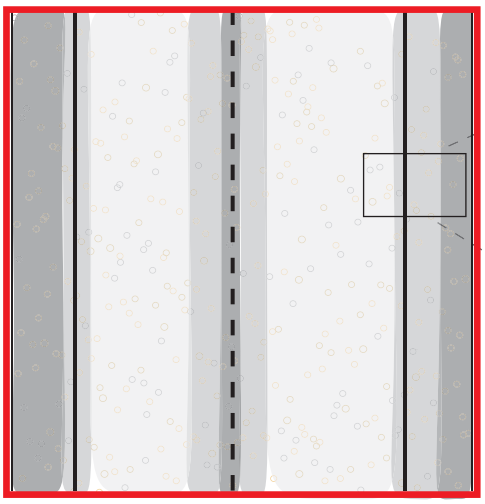


GIS analysis of:
- Road Risk Category
  - [PHR, PMR, SHR, PLR, SMR, SLR]
- Jurisdiction

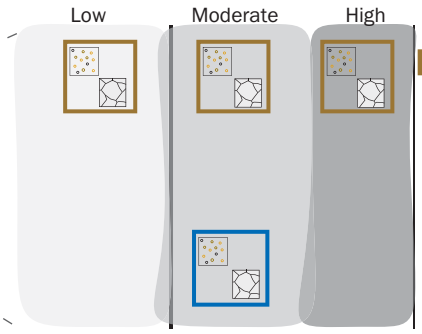
Characterized by:
- Right and Left Road Shoulder[1] Condition
  - [1, 3, 4, 5]
- Road Surface Integrity
  - [H, M, L]

EACH MONITORING EFFORT

Road Segment (1000m²)



1'x1' squares within Material Accumulation Category



Dry Material Sampling from all 3 categories:
- Volume/Mass [ml, mg]
- Particle Size Distribution
  - [% of mass <16μm]
  - (limited)
- Degree of Fines [H, M, L]
- Road Surface Integrity
  - [H, M, L]

Controlled Experiments obtain wet sample from 1 material accumulation category:
- TSS and FSP Concentrations [mg/L]
- Turbidity [ntu]
- Particle Size Distribution [% of TSS]
- Degree of Fines [H, M, L]
- Road Surface Integrity [H, M, L]

Visual observations of:
- Material Accumulation Category
  - % distribution of:
    - High
    - Moderate
    - Low
- Degree of Fines within each H, M, L area
  - [H, M, L]

[1] PLRM defines the road shoulder to include the pervious area of the right-of-way. For the purposes of this monitoring, only the impervious portion of the road shoulder is considered to be part of the road segment.

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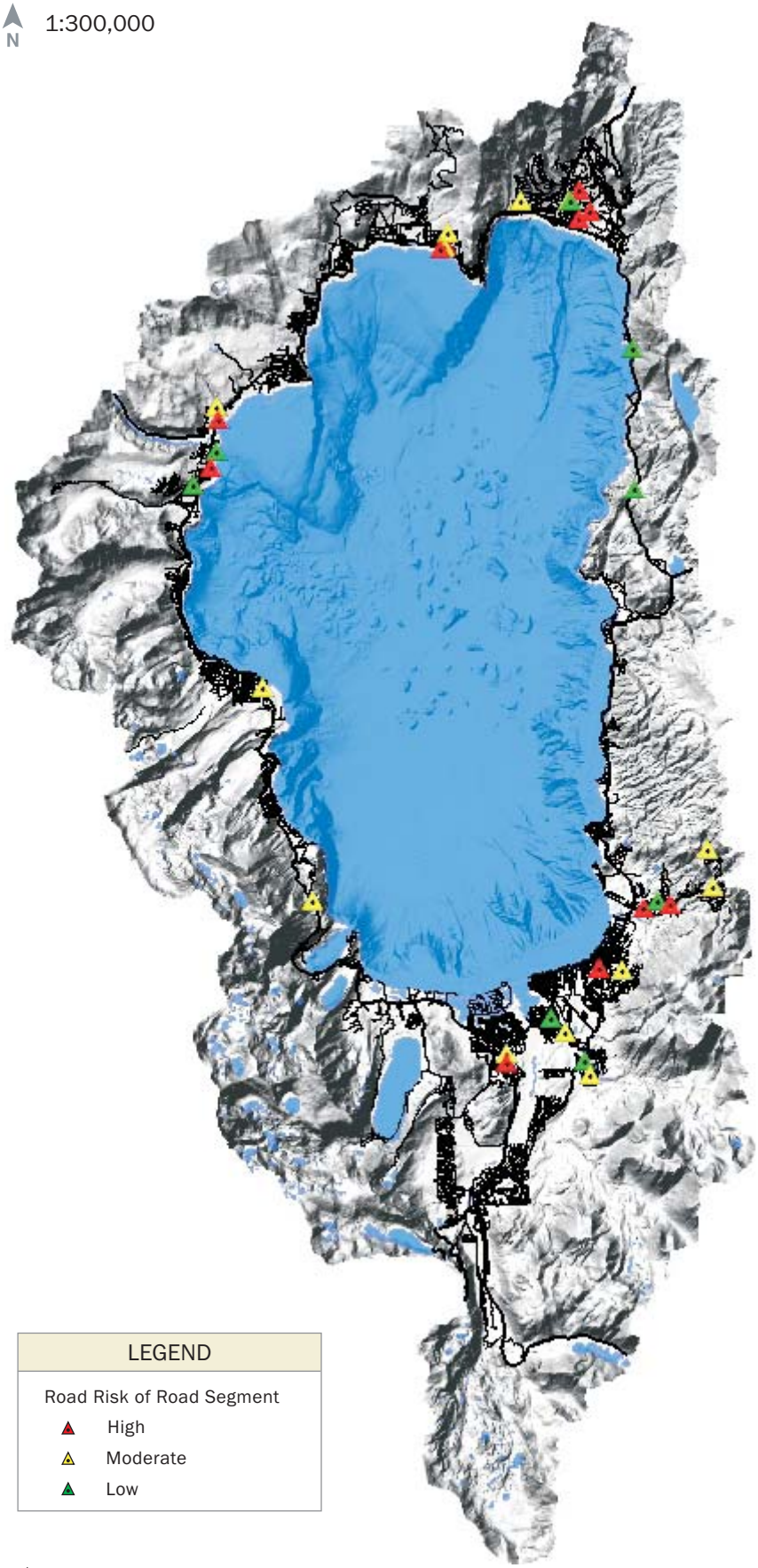
URBAN ROAD MONITORING DATA COLLECTION SCHEMATIC

FIGURE 3.1

Table 3.1. Urban Road Monitoring Road Segments

Road Type	Road Segment ID	Street Name	Jurisdiction Responsible for Road Maintenance	Road Risk (estimate September 2009)
Primary	EI	Highway 50	CalTrans	High
	H281	Highway 28	CalTrans	High
	H28TC	Highway 28	CalTrans	High
	H89S	Highway 89	CalTrans	High
	EB1	Highway 89	CalTrans	Moderate
	SPP1	Highway 89	CalTrans	Moderate
	HM2	Pioneer Trail	El Dorado County	Low
	KG1	Kingsbury Grade	NDOT (Douglas County)	High
	KG2	Kingsbury Grade	NDOT (Douglas County)	High
	H28C	Highway 28 (Tahoe Blvd)	NDOT (Washoe County)	High
	H28A	Highway 28	NDOT	Low
	H28B	Highway 28	NDOT	Low
Secondary	SR1	Ski Run Boulevard	CSLT	High
	BO1	Bonanza Avenue	CSLT	Moderate
	KC3	Keller Road	CSLT	High
	EW1	Elwood Drive	CSLT	Low
	KG3	North Benjamin Drive	Douglas County	Moderate
	KG4	Andria Drive	Douglas County	Moderate
	KG5	Juniper Drive	Douglas County	Low
	HM3	High Meadow Trail	El Dorado County	Low
	MA1	Martin Avenue	El Dorado County	High
	TR1	Trout Avenue	Placer County	Moderate
	CO1	Coon Street	Placer County	High
	JP	Red Cedar Street	Placer County	Moderate
	KB1	Cut Throat Avenue	Placer County	Moderate
	PINE	Pine Avenue	Placer County	High
	BURL	Olympic Drive	Placer County	Moderate
	VIL1	Village Boulevard	Washoe County	High
	VIL2	Village Boulevard	Washoe County	High
	DD	Dale Drive	Washoe County	Moderate
	KMAC	McDonald Drive	Washoe County	Moderate
	JEN	Jensen Circle	Washoe County	Low
Commercial	RSLT	Raley's- South Lake Tahoe	Private	High
	RIV	Raley's Incline Village	Private	High

N 1:300,000



LEGEND

Road Risk of Road Segment

- High
- Moderate
- Low

Road Segment Sampling Sites by Jurisdiction and Primary and Secondary Road Risk (as calculated September 2009).[1]

Jurisdiction	# High Risk		# Mod Risk		# Low Risk	
Road Type[2]	*P*	*S*	*P*	*S*	*P*	*S*
CalTrans	4		2			
City of South Lake Tahoe		2		1		1
Douglas County				2		1
El Dorado County		1			1	1
NDOT	3				2	
Placer County		2		4		
Washoe County		2		2		1

[1] Table does not include the 2 commercial parking lot sites under private jurisdiction.

[2] P= Primary Road; S = Secondary Road

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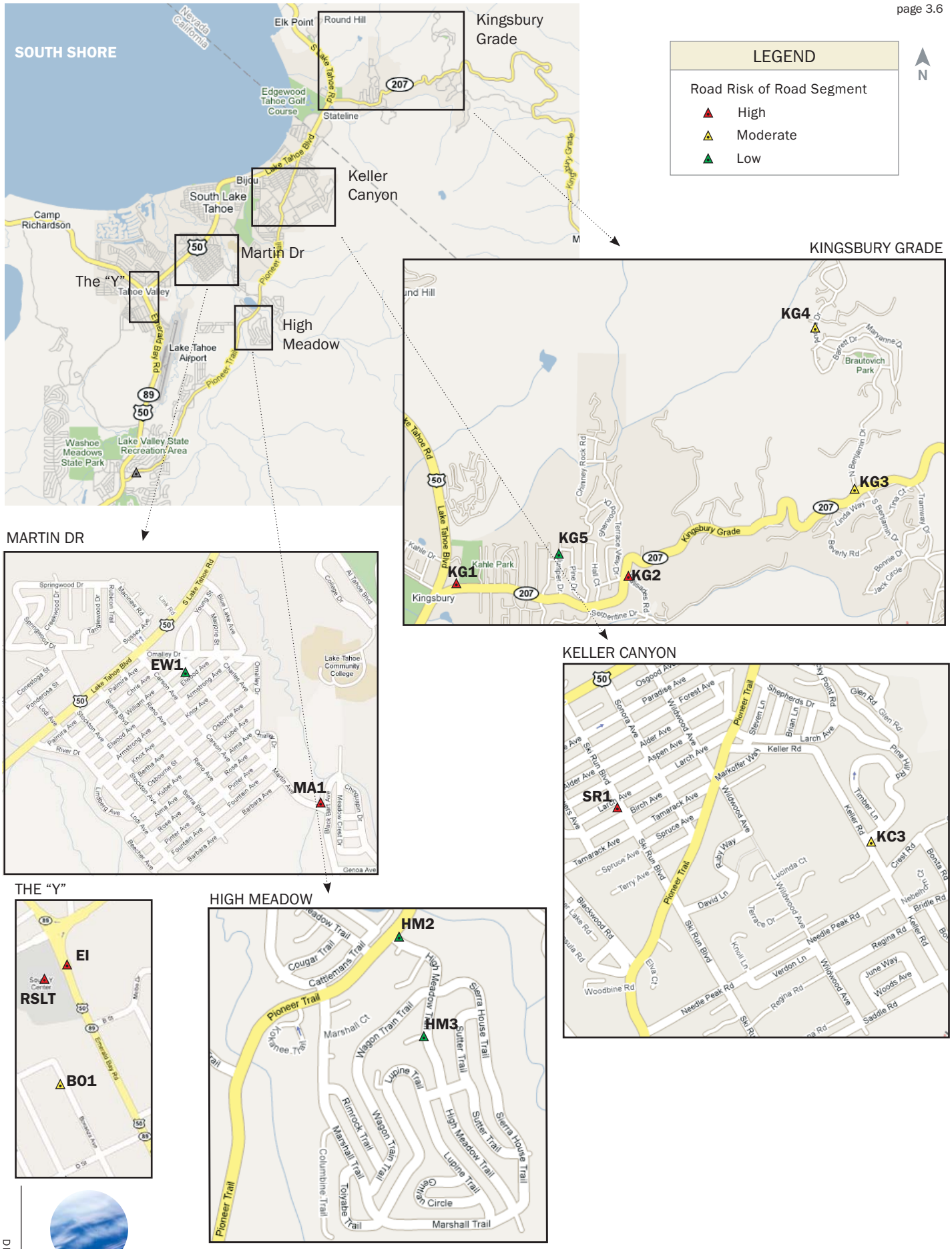
URBAN ROAD MONITORING ROAD SEGMENTS - OVERVIEW

FIGURE 3.2



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URBAN ROAD SEGMENTS - SOUTH SHORE

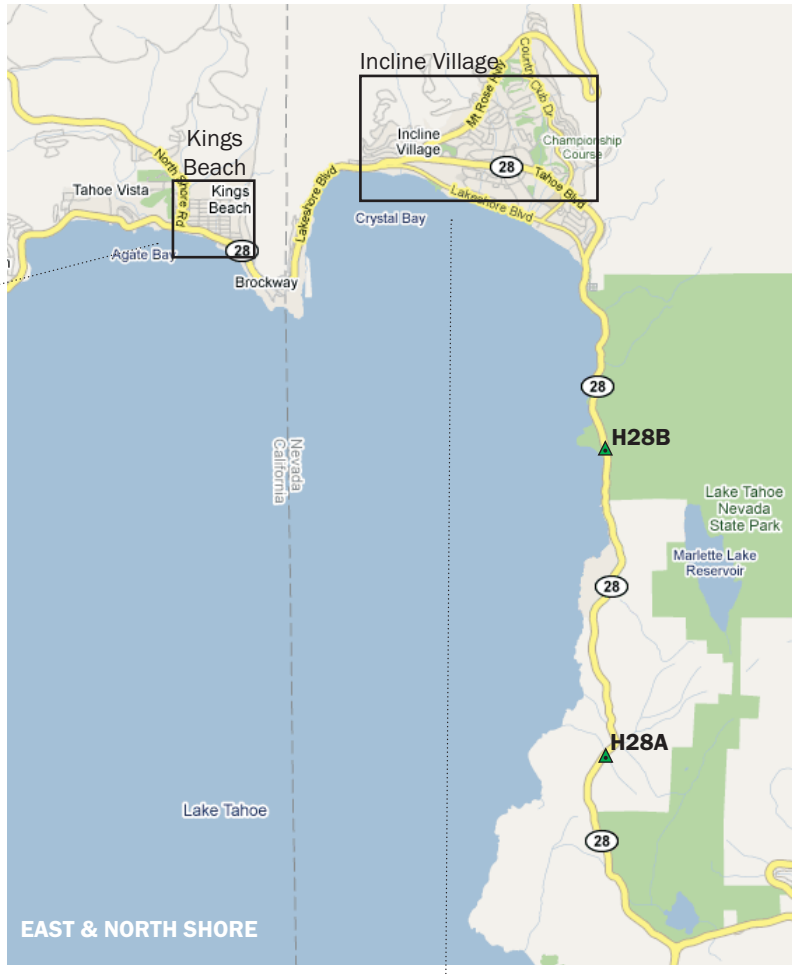
FIGURE 3.3A

N

LEGEND

Road Risk of Road Segment

- High
- Moderate
- Low



KINGS BEACH

INCLINE VILLAGE

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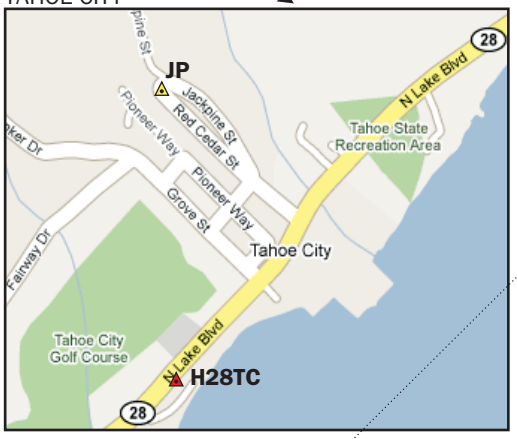
URBAN ROAD SEGMENTS - EAST & NORTH SHORE

FIGURE 3.3B

N

TAHOE CITY



GRANLIBAKKEN

SUNNYSIDE

LEGEND
Road Risk of Road Segment
High
Moderate
Low

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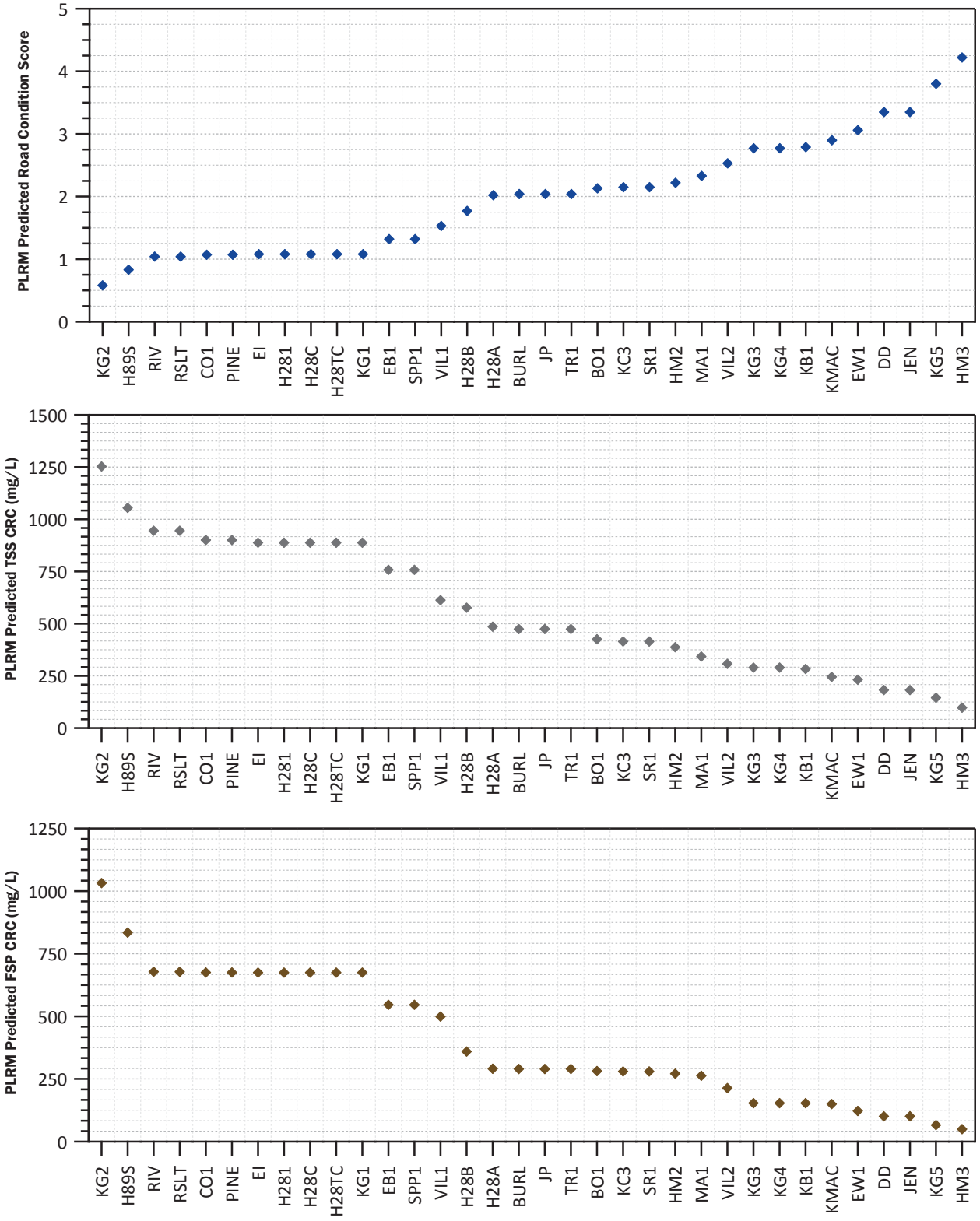
URBAN ROAD SEGMENTS - WEST SHORE

FIGURE 3.3C



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PLRM ROAD METHODOLOGY PREDICTIONS BY ROAD SEGMENT

FIGURE 3.4

PHASE I URBAN ROAD DATA COLLECTION

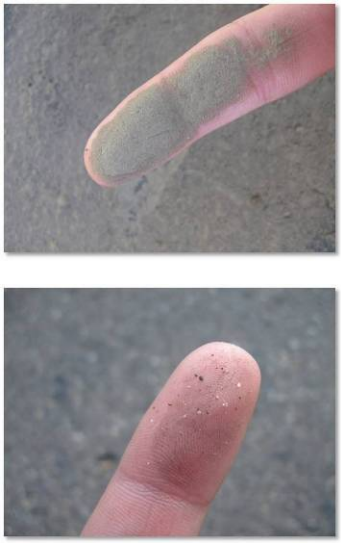
Road sampling consisted of a collection of visual observations as well as dry material and wet sediment sampling at each site with typically the collection of 3 dry material samples and 1 wet sediment sample at each road segment. Road sampling was conducted four times (March 16-18, April 13-15, May 11-12, and July 7-9). All 34 road segments were sampled over 3 continuous sampling days (termed a sampling period) to reduce weather and hydrologic variability to the extent possible. A total of 122 data collection efforts were conducted on the 34 road segments during Phase I. The bottom half of Figure 3.1 presents the spatial distribution of data collected during every sampling period at each urban road segment.

Visual Observations

Field personnel conducted visual observations according to the protocols established in the Monitoring Plan (Appendix A) and recorded all data on field datasheets. Visual observations of the entire 1,000m^2 road segment included:

- percent distribution of each material accumulation category (heavy, moderate, and light),
- degree (high, moderate, low) of fine material within each accumulation category, as determined by a finger test,
- general road segment dustiness (high, moderate, low),
- evidence of recent road abrasive application (Y/N), and
- evidence of recent sweeping activity (Y/N).

Material accumulation categories were characterized relative to the specific road segment evaluated and not relative to all road segments during the sampling period. The heavy and light accumulation categories of the specific road segment at the time of observation set the bookend scales of the existing condition for these factors, and then % distribution of each category was estimated and confirmed by all field personnel. The finger test provides a quick, relative estimate of the percentage of fine material within the sediment accumulated on the road surface. The road surface is wiped with a wet finger and the residual material on the finger is ranked based on finger color and sensation when fingers are rubbed together: high (black color, little to no grit), moderate (light grey or brown, some grit), or low (clean finger, very gritty).



Examples of high (top) and low (bottom) degree of fines using finger test.

Dry Material Sampling

Field personnel collect dry material samples.

Dry material samples were collected from the heavy, moderate and light material accumulation areas to represent the entire road segment. Dry material samples were collected using a hand broom from a 1ft by 1ft road surface area to measure the volume of material potentially available for subsequent transport. Volume was measured by immediate

transfer into a graduated cylinder and field personnel entered the measurements on pre-printed field datasheets or directly into Palm Pilots. 2NDNATURE staff developed measured volume to dry mass relationships for 25 urban road dry material samples and calculated an average density of 1.7 g/ml. All dry material samples were converted to mass using this measured density value. Two hundred ninety-eight (298) dry material samples were collected; most were immediately discarded after measurements were recorded. Forty-nine (49) samples were saved and submitted to Cooper Testing Laboratory following the handling protocols outlined in the Sample Plan (see Appendix D of that document).

Controlled Urban Road Experiments

2NDNATURE designed and fabricated a portable wet sample simulator that applies a standardized volume of water at a constant intensity over a controlled area of an urban road surface (Figure 3.5). The controlled wet sediment sampling was designed to be cost-effective, repeatable, and allow a large number of water samples to be obtained across a range of Lake Tahoe urban road conditions. This need requires that the portable simulator be run at an estimated intensity of 5 in/hr. While this intensity is higher than most rain events in Lake Tahoe, this increased rate is necessary to minimize the sampling duration and remain cost-effective. The relatively high intensity of simulated rainfall, to some degree, compensates for the lack of material transport downslope by flowing stormwater over the road surface that occurs during actual stormwater runoff events on impervious surfaces.

A water volume of 750ml is applied by the simulator and field personnel monitored both water pressure and application time to maintain consistency across sampling. Following completion of the simulation, which takes approximately 2.5 minutes, an additional 250ml of water is applied using a squirt bottle to rinse the collection pan and capture all material transported from the road to the collection pan into the sample. A total of 145 wet sediment samples were collected from March to July 2009 and submitted to WETLAB.

Due to field personnel safety and resource limitations, only one wet sample was obtained from each road segment during each sampling period, unless field triplicates were performed for QA/QC procedures. Wet samples were typically collected on the shoulder margin of the drive lane and sites were selected to be visually representative of the condition of that location over the entire road segment. Typically an area of moderate material accumulation was selected to reduce sampling variability across sites and sampling periods. Personal safety and actual road condition occasionally required field personnel to select a location in a different accumulation category. The material accumulation category of the wet sample location was noted and all visual observations were conducted in an adjacent 1ft by 1ft square that was visually representative of the wet sampling site. This approach provides the dataset and information necessary to:

- test and refine the predictive capability of rapid observations to predict the TSS and FSP concentrations obtained from a wet sample for the road segment, and
- allow the extrapolation of the TSS and FSP concentration values obtained from a discrete location on an urban roadway to represent the complete road segment.

SIMULATOR IN ACTION IN THE FIELD

site set-up

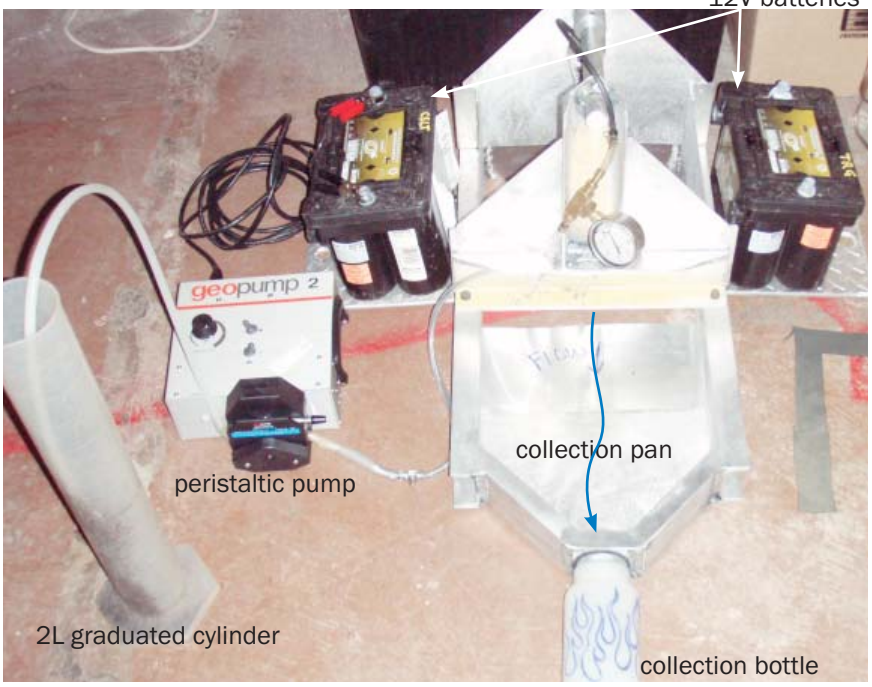
simulation

sample collection

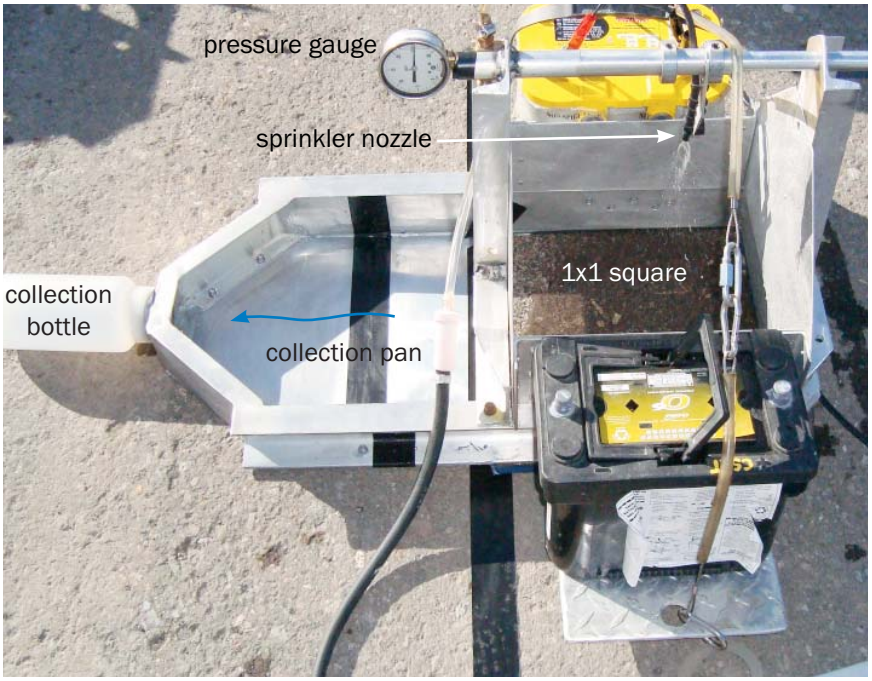
transfer to collection bottle

collection pan rinse

PORTABLE SIMULATOR - FRONT VIEW



PORTABLE SIMULATOR - TOP VIEW



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PORTABLE SIMULATOR USED IN CONTROLLED URBAN ROAD EXPERIMENTS

FIGURE 3.5

3.2 SWT MONITORING

To build an initial stormwater treatment BMP (SWT) dataset to address the current data gaps within the Lake Tahoe urban stormwater management tools, 2NDNATURE designed and implemented stormwater monitoring at three typical Lake Tahoe SWT types: dry basins, wet basins, and cartridge filters. In an effort to minimize the instrumentation complexity and cost of typical detailed SWT water quality sampling, 2NDNATURE developed cost-effective protocols that maintain the quality of the hydrologic and chemical datasets, but minimize the need for high resolution water quality instrumentation. The primary components of the 2NDNATURE monitoring include:

- Continuous surface water hydrology to develop a comprehensive surface water budget and cost-effectively estimate event inflow, treatment, and bypass volumes and SWT hydraulic characteristics.
- Event-based surface water sampling using passive samplers to determine the inlet and outlet TSS and FSP concentrations.
- Treatment BMP condition evaluations using BMP RAM protocols (http://www.swrcb.ca.gov/rwqcb6/water_issues/programs/tmdl/lake_tahoe/index.shtml).

SWT SITE SELECTION

2NDNATURE developed a prioritization matrix (Table 3.2) to assist with the selection of the monitoring sites for SWT data collection. Existing wet basins, dry basins, cartridge filters, and treatment vaults were considered for site selection, given the existing need to expand water quality datasets for a range of SWT types. Sites were prioritized based on cost-effectiveness during this short-term study. High priority was placed on sites that have been previously instrumented and monitored to limit the need for extensive site reconnaissance prior to instrumentation, improve data collection and analysis efficiency by building upon previous knowledge, and provide cost sharing opportunities with other monitoring agencies.

Sites selected for monitoring are highlighted in grey in Table 3.2. Two wet basins (Osgood and Upper Park Avenue Basins), one dry basin (Lower Park Avenue Basin) and one cartridge filter (Stormfilter Vault®) (Figure 3.6) were selected based on the above factors. Their close proximity to each other reduces travel time by field personnel during data collection efforts, which was also a factor influencing selection.

PHASE I SWT DATA COLLECTION

Table 3.3 summarizes the hydrologic and water quality instruments at each SWT.

Surface Water Hydrology Monitoring

An In-Situ LevelTroll 500 pressure transducer and staff plate were installed within Park Avenue Upper Basin (PA1), Park Avenue Lower Basin (PA2) and Osgood Basin in December 2008 to record basin water depth on 15-minute intervals. The LevelTrolls at the Park Avenue Basins were installed within pre-existing infrastructure that had been constructed in September 2005 for the Park Avenue Basins Water Quality Performance Evaluation conducted for CSLT (2NDNATURE 2008). The instrument housings and staff plates were inspected by field personnel prior to gage installation and found to be in good condition. New housing and a staff plate were installed in Osgood Basin within the primary flow path through the basin.

The LevelTroll 500s are unvented and corrected for barometric pressure changes using an In-Situ BaroTroll maintained at the office of Environmental Incentives in South Lake Tahoe, CA on the same 15-minute intervals. All

Table 3.2. SWT Monitoring Site Selection Matrix

SWT Name	Location	SWT Type	Key Design Characteristics	Previously Monitored for WQ? Instrumented?	Data Available (Data Quality Ranking[1])	Prioritization Ranking (1-5)[2]
Osgood Basin	South Lake Tahoe, CA	Wet Basin	Low HRT Forebay Settling Basin	Yes (CSLT) Yes (CSLT)	Sfc Hydrology, Sediment, Nutrients (3.5)	5
Park Avenue Basins (Upper and Lower)	South Lake Tahoe, CA	1 Wet Basin, 1 Dry Basin	Treatment Train 2 basins in sequence Both Basins: Low SA:V Ratio Max Depth ~ 1.7'	Yes (2N) Yes (2N)	Sfc Hydrology, Groundwater, Sediment, Nutrients (4.5)	5
Stormfilter Vault®	South Lake Tahoe, CA	Cartridge Filter	Proprietary Vault Active Media Filtration	Yes (2N) Yes (2N)	Sfc Hydrology, Sediment, Nutrients (2.5)	5
Eloise Basin	South Lake Tahoe, CA	Dry Basin	Low SA:V Ratio Max Depth = 3.2'	Yes (SHG, 2N) Yes (SHG, 2N)	Sfc Hydrology, Groundwater, Sediment, Nutrients (4)	4
Industrial Basin	South Lake Tahoe, CA	Dry Basin	High SA:V Ratio Max Depth = 0.5'	Yes (SHG, 2N) Yes (SHG, 2N)	Sfc Hydrology, Groundwater, Nutrients (3.5)	4
Northwood Basin	Incline Village, NV	Dry Basin	Low SA:V Ratio Max Depth = 3.1'	Yes (SHG, 2N) Yes (SHG, 2N)	Sfc Hydrology, Sediment, Nutrients (3.5)	3.5
Cattleman's Basin	South Lake Tahoe, CA	Dry Basin	High SA:V Ratio Max Depth = 3.2'	Yes (USGS) No	Groundwater, Nutrients (3)	3.5
Roundhill Vaults (CDS, Vortechnics, and Jensen)	Zephyr Cove, NV	3 Treatment Vaults	3 Proprietary Vaults Flow Separation to Trap Sediment and Debris	Yes (DRI, TERC) Yes (DRI, TERC)	Sfc Hydrology, Groundwater, Sediment, Nutrients (2.5)	3.5
Coon Street	Kings Beach, CA	Dry Basin	Low SA:V Ratio Max Depth = 3.0'	Yes (TERC) Yes (TERC)	Sfc Hydrology, Sediment, Nutrients (2.5)	3

[1]Quality of data is ranked 1-5 (1 is low, 5 is high) based on data format (preferably Excel and/or Access), usability (raw data available for subsequent analysis), completeness (lack of substantial data gaps), and level of QA/QC (data collected, analyzed and summarized to event mean concentrations in manner consistent with Appendix A). Data Collection Quality Evaluation Scores designated in Appendix B of Lake Tahoe BMP Monitoring Evaluation Process: Synthesis of Existing Research (2NDNATURE 2006) incorporated into site selection analysis.
[2]Sites are ranked from 1-5 (1 is low priority, 5 is high) based on meeting the site selection criteria described above. Sites recommended for monitoring are highlighted in grey in Table 3.2. Two wet basins (Osgood Basin and Upper Park Avenue Basin), 1 dry basin (Lower Park Avenue Basin) and one cartridge filter (Stormfilter Vault®) have been instrumented for detailed monitoring.

LEGEND

- Major Roads
- Minor Roads
- SWT
- Catchment

LAKE TAHOE

Park Avenue Basins

StormFilter Vault®

Osgood Basin

Pioneer Trail

Ski Run Blvd

50

Park Avenue

Rocky Point

Bijou Park

Keller Canyon

N

1:6,000

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SWT MONITORING SITE LOCATION MAP

FIGURE 3.6

Table 3.3. SWT Site Instrumentation, including previously existing and newly installed monitoring instrumentation at each SWT monitoring site. See Figures 4.21 and 4.23 for site-specific instrumentation locations.

Treatment BMP	Instrument Site	Data Collection Type	Installation Date	Elevation (ft)
Osgood	OS_LT	Surface Hydrology - Stage	12/18/09	99.43
	OGIN_ASC	Surface Hydrology - Flow Meter/ Sample Collection - Auto Sampler	11/2007	*n/a*
	OGOUT_ASC	Surface Hydrology - Flow Meter/ Sample Collection - Auto Sampler	11/2007	*n/a*
	OGIN_PS1	Sample Collection - Passive Sampler	1/19/09	103.00
	OGIN_PS2	Sample Collection - Passive Sampler	1/19/09	103.30
	OGIN_PS3	Sample Collection - Passive Sampler	1/19/09	103.64
	OGOUT_PS1	Sample Collection - Passive Sampler	1/19/09	102.11
	OGOUT_PS2	Sample Collection - Passive Sampler	1/19/09	102.38
PA1	PA1_LT	Surface Hydrology - Stage	9/29/09	6234.38
	PA1IN_PS1	Sample Collection - Passive Sampler	1/19/09	6235.53
	PA1IN_PS2	Sample Collection - Passive Sampler	1/19/09	6236.06
	PA1OUT_PS1	Sample Collection - Passive Sampler	1/19/09	6235.37
	PA1OUT_PS2	Sample Collection - Passive Sampler	1/19/09	6235.79
PA2	PA2_LT	Surface Hydrology - Stage	10/1/05	6233.15
	PA2IN_PS1	Sample Collection - Passive Sampler	1/19/09	6232.23
	PA2IN_PS2	Sample Collection - Passive Sampler	1/19/09	6233.55
	PA2OUT_PS1	Sample Collection - Passive Sampler	1/19/09	6232.86
	PA2OUT_PS2	Sample Collection - Passive Sampler	1/19/09	6233.78
	PA2OUT_PS3	Sample Collection - Passive Sampler	1/19/09	6234.95
StormFilter	SF_LT	Surface Hydrology - Stage	8/2/09	*n/a*
	SF_IN	Surface Hydrology - Flow Meter/ Sample Collection - Auto Sampler	3/1/09	*n/a*
	SF_OUT	Surface Hydrology - Flow Meter/ Sample Collection - Auto Sampler	3/1/09	*n/a*

gages were downloaded and maintained regularly during site visits and the staff plates were used to visually verify instrument performance and perform data QA/QC. The accuracy of the water level recorders is ±0.05 ft, as documented in the manufacturer's specifications.

The Park Avenue Basins and Osgood Basin were surveyed to obtained detailed topography. Basin topographic data was tied to the continuous stage data to create a basin stage to volume rating curve, facilitating the creation of a continuous basin water volume time series and detailed water budget, from which inflow and outflow rates for discrete runoff events can be estimated (2NDNATURE 2008), as well as treatment and bypass flows as defined by PLRM (nhc et al. 2009). To remain cost-effective, existing 2005 Park Avenue Basin topographic data was used. Osgood Basin was surveyed in July 2009, including both basin topography and the specific elevations of critical basin features (inlet, outlet, stage recorder, staff plate, etc.).

Sigma 950 Flow Meters record continuous flow measurements (cfs) on 10-minute intervals were installed at both the inlet and outlet of Osgood Basin and the Stormfilter® Vault. CSLT has maintained the Osgood Basin equipment since November 2007 and the Stormfilter® Vault was instrumented in March 2009. Due to backwatering issues at both the inlet and outlet of the Stormfilter® Vault, data was not consistently collected at this SWT. An In-Situ LevelTroll 500 was installed within the outlet in August 2009 to improve our understanding of the SWT surface water hydrology.

Water Quality Sample Collection

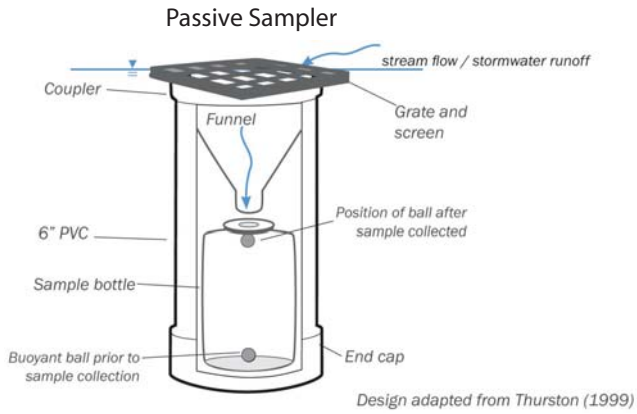
Passive samplers (Nalgene® Stormwater Samplers) were installed in December 2008 to characterize the inlet and outlet water quality of Osgood and Park Avenue Basins. Passive samplers are a low-cost method to collect water samples associated with a specific basin water surface elevation. Samplers collect the rising limb of the hydrograph (standardizing sample collection across all sites) and are self-sealing to preserve the sample until field personnel can safely visit the site (top half of Figure 3.7). In some instances, water samples collected from passive samplers may be slightly higher than event mean concentrations (EMCs) because they sample the rising limb and do not represent the entire hydrograph. However, the reduced cost of passive sampler installation and lower data management complexity compared to flow-weighted automated samplers allow for a significant increase in the number of sites monitored and samples collected.

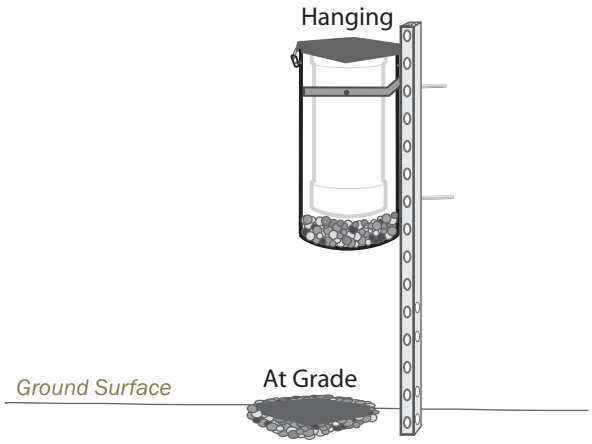
Two to three passive samplers were installed at both the inlet and outlet of each basin (bottom half of Figure 3.7) and sample collection is standardized based on relative basin stage. Inlet/outlet pairs were installed at near equivalent water surface elevations to ensure collection of samples occurs at a similar location on the storm hydrograph and the difference pollutant concentrations between the inlet and outlet pair can be attributed to the water quality treatment as a result of flow through and interaction with the Treatment BMP. Sampler elevations are determined relative to the treatment and bypass outlet elevations of the SWT, in order to compare treated and bypass flow, as defined by PLRM.

The passive sampling techniques are not feasible to sample stormwater from the Stormfilter®. Therefore, Sigma 900 series automated samplers were installed at the inlet and outlet of the Stormfilter® Vault in March 2009, adjacent to the Sigma flow meters. The sampler is equipped with 24 1-liter bottles and is programmed to collect flow-weighted samples throughout a storm runoff event. Similar Sigma 900 series automated samplers, originally installed by CSLT in November 2007 for other monitoring needs, were maintained at the inlet and outlet of Osgood Basin.

A total of 46 samples were collected from all of the inlets and outlet passive samplers and auto samplers and submitted to Western Environmental Testing Laboratory (WETLAB).

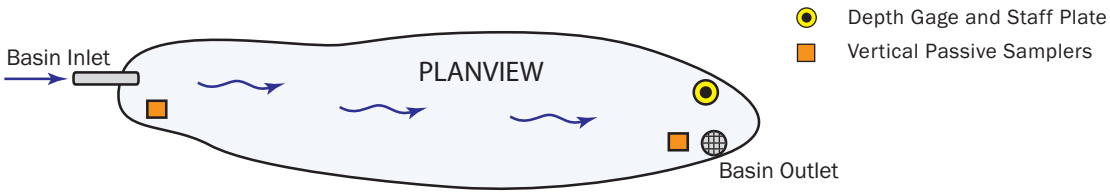
BASIN SWT PASSIVE SAMPLER DESIGN

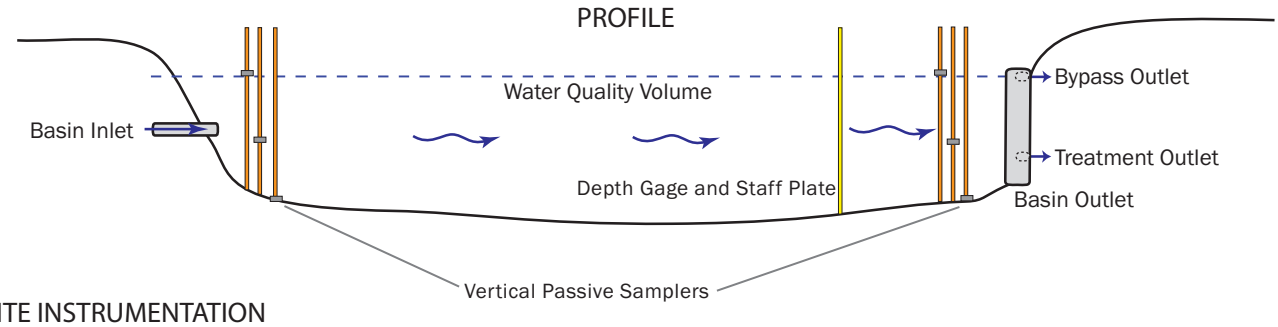




- Passive samplers can be custom fabricated to meet site-specific needs, but typically are Nalgene Stormwater Samplers®.
- Passive samplers can be (1) buried in the flow path to collect sample at grade or (2) secured to vertical sign post to collect a sample at a targeted stage elevation (i.e., hanging).
- Sample is collected when water surface exceeds elevation of top of sampler. Sample flows over grate, through funnel and into bottle. As bottle fills with water during the event, the ping pong ball floats to the top and plugs the hole in the lid and seals the sample until it is collected by field personnel.

BASIN SWT





SITE INSTRUMENTATION

- Depth Gage installed in basin to record water depth continuously on 15-minute intervals and create surface water hydrology time series.
- Staff Plate is installed to QA/QC depth data.
- 4 - 8 Basin Passive Samplers are installed within basin (2-4 at inlet and 2-4 at outlet, depending on basin depth at invert of bypass outlet).
  - Samplers are installed to collect samples at various water surface elevations to standardize sampling based on relative basin stage.
  - Inlet and outlet sampler elevations are matched as closely as possible to create inlet/outlet sample pairs. This technique assumes that at the same basin stage, the inlet/outlet sampler pairs are collecting samples at a similar location on the storm hydrograph and observed water quality differences between the samples is the result of flow through and interaction with the SWT.

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SWT SAMPLING SCHEMATIC

FIGURE 3.7

SWT Condition Assessment

2NDNATURE field personnel performed the field observations (STEP 4) of the Best Management Practices Maintenance Rapid Assessment Methodology (BMP RAM) at each SWT per the detailed protocols found in the BMP RAM User Manual v.1 (2NDNATURE 2009). Observations were conducted in September 2009 to evaluate the existing condition of each Treatment BMP; however, benchmark and threshold values (STEP 3) require jurisdictional input and consideration and thus BMP RAM Scores for each BMP were not obtained at this time.

3.3 ANALYTICAL LAB PROCEDURES

All water samples collected during this study were submitted to WETLAB and analyzed for total suspended solids (TSS; mg/L) and particle size distribution (PSD; % by mass) for the following size breaks: <1µm, <10 µm, <16 µm, <20 µm, <63 µm, <100 µm, and <1,000 µm. Samples were transferred to 1,000ml pre-cleaned HDPE bottles in the field, labeled, placed on ice, and submitted with proper chain of custody forms to WETLAB. TSS and turbidity analyses were performed by WETLAB (see Appendix D for lab standard operating procedures); PSD analysis was subcontracted to Desert Research Institute (DRI) and conducted using the laser optical backscatter (Saturn Digisizer 5200). (No laboratory QA/QC documentation was available from the DRI laboratory.) A fraction of the CRC dry material samples were submitted to Cooper Testing Laboratory for particle grain size distribution analysis (see Appendix E for lab standard operating procedures and ASTM Standard D422).

All road wet sediment samples were analyzed for turbidity in the field using a Hach 2100P portable turbidimeter. Prior to sample analysis, field blanks and standards were used to calibrate the meter. Samples that registered field turbidity readings >1,000ntu (the maximum range of the turbidimeter) were submitted to WETLAB for turbidity (>1,000ntu) analysis.

Table 3.4 presents the details of sample analyses for each constituent, including the frequency of analysis for the two sampling methods, analytical method, and respective detection limits. Field quality control samples included field blanks and triplicates. Lab quality control samples included method blanks, matrix spikes, laboratory duplicates and external standards. Table 3.5 presents the results of field and analytical precision calculations and field and method blank analysis.

Table 3.4. Frequency of pollutant constituent analysis in Urban Road and SWT samples.

Constituent	Analytical Method	Frequency of Analysis in Urban Road Samples	Frequency of Analysis in SWT Samples	Detection Limit
Total Suspended Sediment-Wet (TSS)	SM 2540D	100%	100%	1 mg/L
Particle Size Distribution-Wet (PSD)	Saturn Digitizer 5200	97.9%	100%	1 mg/L
Particle Size Distribution-Dry (PSD)	ASTM D422	16.4	n/a	n/a
Turbidity >1,000ntu (lab)[1]	EPA 180.1	13.8%	0%	5.0 ntu
Turbidity (field)	Hach 2100P Turbidimeter	91.7%	0%	0.1 ntu

[1] Wet sediment samples that exceeded the maximum range of the field turbidimeter (1,000ntu) were submitted to the analytical lab for analysis.

Table 3.5. Field and laboratory QA/QC results. Pollutant field and analytical precision expressed as percent error. (Number of samples used in calculation noted in parentheses.)

Type	Analysis	TSS (mg/l)	FSP (mg/l)[1]	Field Turbidity (ntu)	Lab Turbidity (ntu)
Replicates	Field	20.7% (27[2])	11.2% (27[2])	5.0% (27[2])	n/a
	Lab	3.2% (12)	n/a	n/a	2.1% (3)
Blanks	Field	1.0 (3)	100% (2)	1.0 (2)	0.1 (1)
	Lab	1.7 (8)	n/a	n/a	0.1 (4)

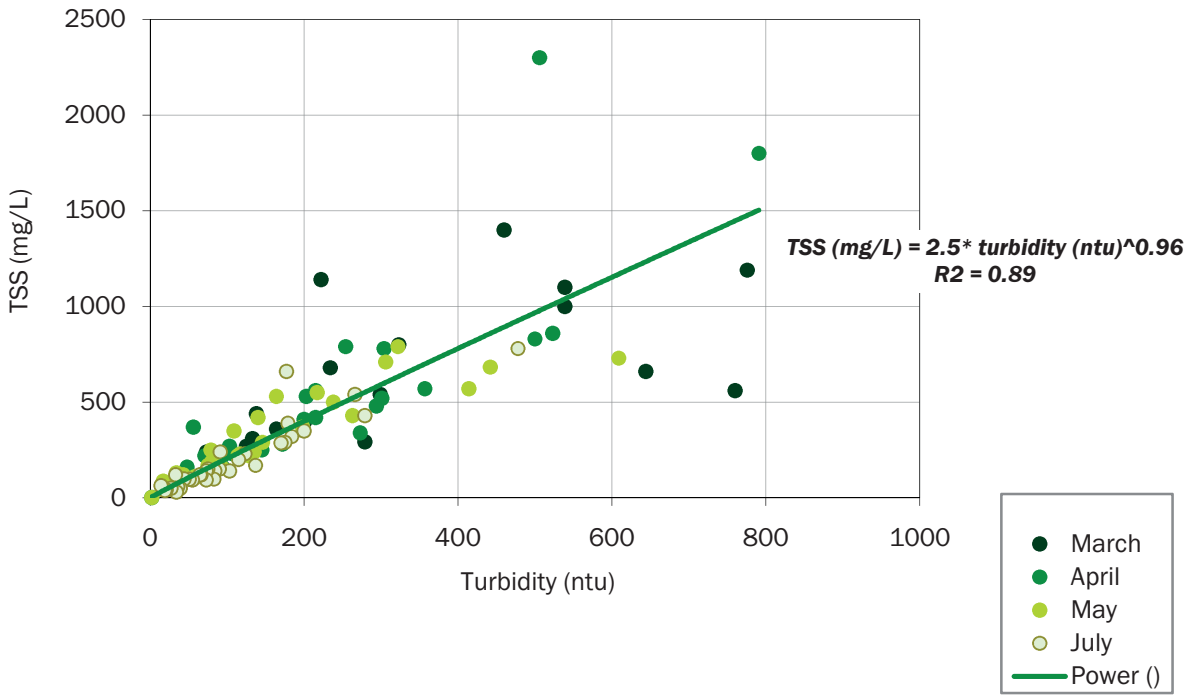
[1] Samples were submitted to laboratory for TSS concentration and particle size distribution. FSP concentration (mg/L) is calculated as TSS (mg/L) * % of TSS <16µm.
[2] Twenty-seven (27) samples represent field triplicates collected at 9 road segments throughout the course of monitoring.

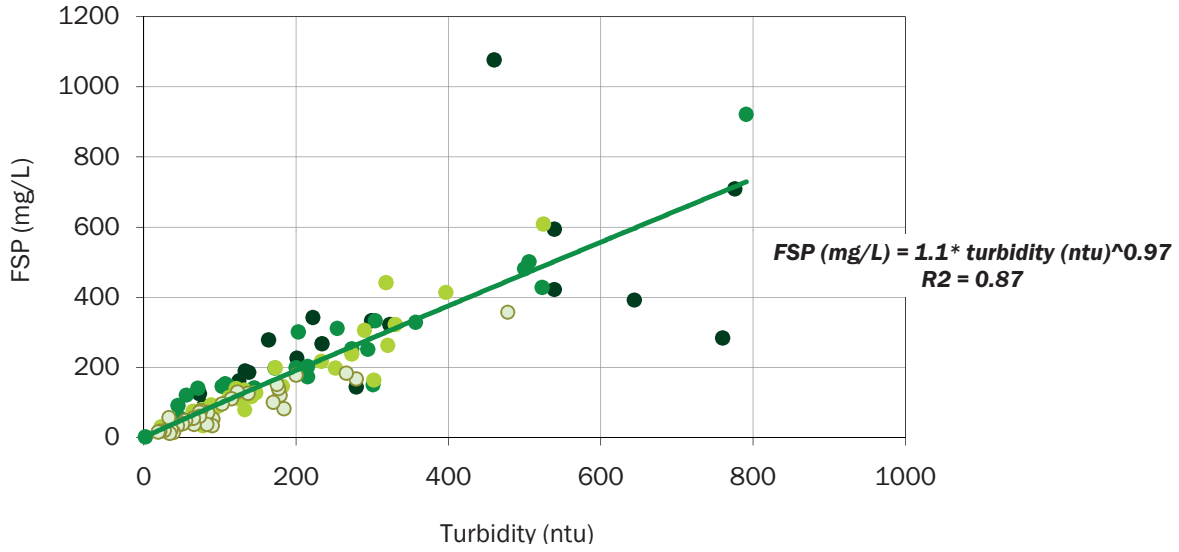
TURBIDITY AS A PROXY FOR TSS AND FSP

Turbidity, TSS and FSP were measured in all wet samples collected by the portable simulator. Turbidity is a cost-effective measurement in the field and results are obtained within minutes. TSS and FSP analyses require sample submission to an analytical lab, cost approximately $100/sample, and take weeks to obtain results. Therefore, a preliminary evaluation with existing data was conducted to determine if turbidity measurements have promise to be a reasonable proxy for TSS and FSP concentrations measured in the same sample. Figure 3.8 shows correlation plots (i.e., rating curves) for turbidity v. TSS and turbidity v. FSP. The r^2 values for each exceed 0.85 and show strong power function correlations. The ANCOVA analysis (described in Section 4.1) also identified that turbidity strongly covaries with both TSS and FSP. The field turbidity probe (HACH 2100P portable turbidimeter) upper limit is 1,000 ntu, but accuracy of the instrument declines above 800 ntu. Therefore all samples with turbidity values > 800 ntu were eliminated from Figure 3.8. Based on the Phase I sampling, turbidity appears to have potential to be a reliable and consistent proxy for TSS and FSP as long as turbidity values do not exceed 800 ntu. Continued road sampling efforts through WY2011 will expand this dataset and further validate this finding.

3.4 DATA MANAGEMENT

All data and observations collected during the study were managed in a digital Microsoft (MS) Access database: PLRMRefinement.accdb. Figure 3.9 provides a visual representation of the organizational structure of the database. In the field site observations were recorded on pre-printed data sheets or entered directly into a Palm Pilot during sampling and instrument maintenance activities. Upon return to the office, all data was QA/QC'd for accuracy and completeness and then integrated into PLRMRefinement.accdb. Instrument downloads were corrected for barometric pressure as necessary, checked for inaccuracies, and calibrated to the relevant spot measurement prior to database entry. Results of lab analyses were transmitted electronically by the laboratories, checked for data quality and completeness, verified against the chain of custody record, and entered into the study database. FSP concentrations were calculated for each sample using the TSS and particle size distribution results. FSP (mg/L) equals TSS (mg/L) * % of TSS <16µm.





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TURBIDITY V. TSS AND TURBIDITY V. FSP CORRELATION PLOTS

FIGURE 3.8

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PLRM V1 DATABASE REFINEMENT MONITORING
DATABASE STRUCTURE

FIGURE 3.9

CHAPTER 4 - PHASE I DATA ANALYSIS

The Lake Tahoe PLRM Database Refinement Study was primarily designed to develop data collection techniques and build initial water quality datasets for urban roads and SWTs within the Lake Tahoe Basin.

- Road factors, roadway condition and water quality samples collected using a portable simulator were evaluated at 34 road segments during 4 controlled sampling periods from March to July 2009 to measure TSS and FSP water quality concentrations emanating from a range of Lake Tahoe urban roads. The road data obtained from this research improves our quantitative understanding between observable urban road condition and pollutant loading potential and provides extremely valuable data to inform the development of Road RAM, currently being formulated in conjunction with the California Tahoe Conservancy (CTC) and Nevada Division of Environmental Protection (NDEP) by the 2NDNATURE team.
- Continuous surface water hydrology and event-based influent and effluent water sample collection was conducted at 4 individual SWTs to improve our understanding of TSS and FSP treatment performance by wet basins, dry basins and cartridge filters. This hydrologic and water quality dataset both informs priority data gaps within PLRM and tests assumptions within PLRM and BMP RAM.

WEATHER

Figure 4.1 presents the relevant precipitation and air temperature data from the City of South Lake Tahoe City Lab weather station over the duration of the data collection to provide the climatic context for the urban road and Treatment BMP monitoring that occurred from December 2008 through July 2009. The City Lab weather station is located on Lake Tahoe Boulevard and D Street, near the "Y" in South Lake Tahoe and is assumed to be relatively representative of the general winter and spring weather conditions within the Lake Tahoe Basin and adequate for the purposes of this study.

4.1 URBAN ROAD MONITORING

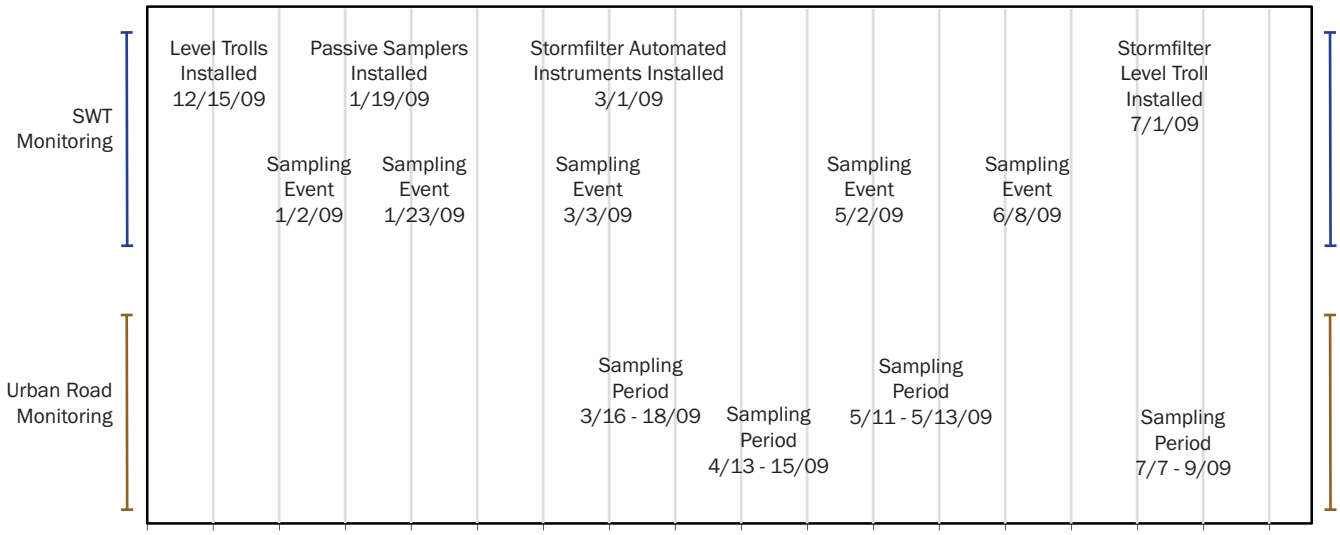
This research sought to build the initial urban road water quality dataset to begin to address four priority data collection goals for the current suite of Lake Tahoe urban stormwater management tools:

(1) Test and refine the PLRM Road Methodology assumptions regarding the role urban road factors may have on urban roadway water quality condition,
(2) Inform PLRM estimates of the total (TSS) and fine sediment particles (FSP; TSS<16µm) characteristic runoff concentrations (CRCs) from roads varying in condition,
(3) Improve the breadth and quality of urban stormwater data on the generation, fate and transport of fine sediment particles (FSP), and
(4) Collect focused and controlled data from urban roads to inform and improve the Road RAM tool.

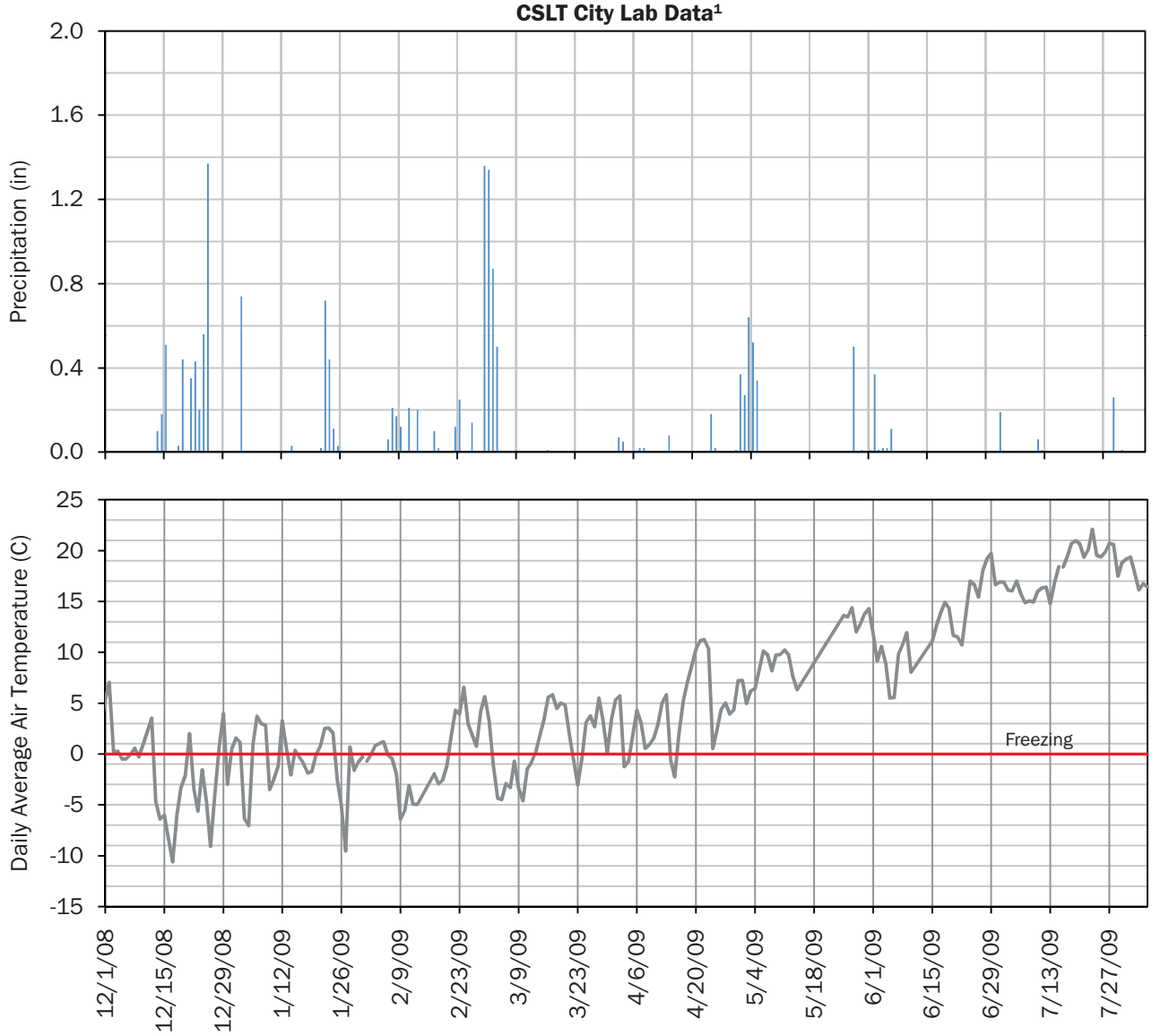
PLRM ROAD METHODOLOGY: TERMS AND FACTORS

The PLRM Road Methodology (Appendix B) was developed to be a flexible, yet robust approach to integrate physiographic characteristics, source control efforts and pollutant recovery efficiency to predict the likely road condition and associated CRCs for pollutants of concern to lake clarity. A CRC represents average concentrations in runoff for pollutants of concern and are used with a long-term hydrologic simulation of stormwater runoff to estimate average annual loads. Pollutants of concern modeled in the PLRM include Total Suspended Sediment

Instrumentation & Monitoring Summary



CSLT City Lab Data[1]



[1]CSLT City Lab weather station is located at Lake Tahoe Blvd and D Street.

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PHASE I MONITORING + WEATHER SUMMARY

FIGURE 4.1

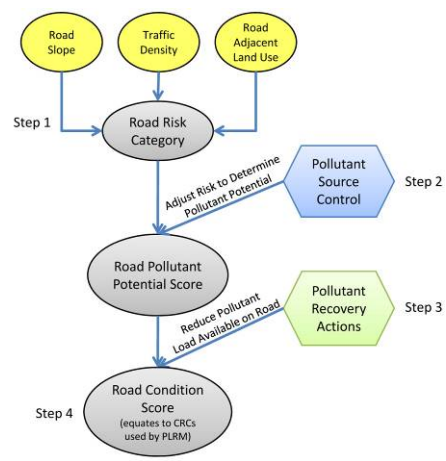
(TSS); Fine Sediment Particles (FSP) – defined as the fraction of TSS particles < 16 microns in diameter; Total Phosphorus (TP); Soluble Reactive Phosphorus (SRP); Total Nitrogen (TN); and Dissolved Inorganic Nitrogen (DIN).

Note that due to resource limitations, this monitoring study focuses only on validating and refining TSS and FSP algorithms used in the PLRM Road Methodology. Based on observations of previously monitored catchments, interviews with road maintenance personnel, and analyses of existing stormwater quality data from the Tahoe Basin, there is clear evidence to suggest that road condition varies dramatically within the urban areas of Lake Tahoe and likely plays a critical role in driving the pollutant loads emanating from urban catchments. For the purpose of this document, road condition is defined as the relative risk to downslope water quality as a result of both pollutant generation and transport from a specific land use. Condition of a land use is variable over short time periods based on the balance of the pollutant sources and sinks. PLRM estimates the likely average annual road condition over the 18 yr simulation, based on general physiographic, car and human disturbance and road management practices. The PLRM Road Methodology assumes road condition can be expressed on a relative continuum, using a scale of 0 to 5, where 5 is the best road condition and represents minimal potential water quality impacts downslope during a subsequent runoff event.

The two central hypotheses to the PLRM Road Methodology (Appendix B) are:

1. The relative condition of urban roads is predictable based on the integration of physiographic characteristics, the distribution of pollutant source controls, road abrasive application practices, and pollutant recovery actions (i.e., sweeping practices).
2. This relative condition of an urban road can be correlated to predictable characteristic runoff concentrations (CRCs) for pollutants of concern within the PLRM framework.

The PLRM Road Methodology categorizes Lake Tahoe urban roads using road type (primary or secondary) and road risk (high, moderate, low), which is based on traffic density, human density and slope, resulting in 6 distinct road risk categories. The schematic in the margin at right summarizes how these factors are integrated in the PLRM Road Methodology to arrive at a likely road condition and associated CRC for each road risk category. The three primary sources of pollutants of concern generated from urban roads are assumed to be road abrasive application, road degradation and road shoulder erosion either by stormwater runoff or via vehicle and human tracking of material onto the adjacent road. Factors that may reduce these overall pollutant sources include source control efforts, such as abrasive application reduction strategies, road shoulder protection, road shoulder stabilization, and/or pollutant recovery actions.



Simplified schematic illustrating PLRM Road Methodology approach.

Road condition predictions in PLRM combine static road factors to estimate CRCs. In reality, road condition varies temporally on any specific urban road as a result of the balance of pollutant inputs and pollutant outputs. Inputs can include road abrasive applications and erosion of native material. Human and car traffic may pulverize this material, which could increase the contribution of sediment that is <16µm. Outputs include sweeping, wind and/or traffic that transport the sediment pollutants from the road surface. Precipitation events can serve as an output, mobilizing pollutants into stormwater and essentially cleaning the road surface. The pollutant inputs and outputs are dynamic over time and isolating the significance of any one factor on the observed condition is a difficult task.

The urban road water quality dataset generated during the Phase I monitoring effort included the collection of temporally and spatially discrete data points from specific locations on the road segment at a specific point in time. Two goals of this data collection were to begin to understand (1) the role of certain road factors on road condition and (2) how measured TSS and FSP concentrations vary with road condition. Confidence in the sensitivity of these factors and the water quality concentrations will greatly increase as more data and observations are obtained. The expanded dataset will also allow for the future spatial and temporal integration of these discrete data points to better inform and validate the PLRM CRC estimates for TSS and FSP.

Each road factor assumed to affect roadway condition is defined below and the rationale on the resulting effects on TSS and FSP water quality concentrations are presented. For a complete discussion on the underlying assumptions in PLRM, see the PLRM Road Methodology (Appendix B).

- **Road Type** (Primary, Secondary): Road type is based on land use designations. Primary roads include all state and U.S. roads, as well as major arterial roads in the Basin. Secondary roads are all other publicly maintained, paved roads within the Basin.
- **Road Risk** (High, Moderate, Low): A default road risk layer has been created for the Lake Tahoe Basin and used in PLRM (nhc et al. 2009). Road risk incorporates characteristics assumed to impact the relative risk of pollutant generation and transport downslope. Risk is based on 3 physiographic characteristics (slope, traffic density, and adjacent land use) that are thought to influence the road's potential sources and transport capacity. Road risk is determined slightly differently for primary and secondary roads but in general:
    - Steeper sloped roads have more road abrasive applications per year to protect driver safety.
    - Steeper roads convey stormwater at higher velocities, increasing scour and pollutant transport.
    - Higher trafficked roads receive more road abrasive applications per year to protect driver safety.
    - Land use types with higher human density increase the disturbance by human and car traffic, increasing the amount of road shoulder disturbance; leading to increased road shoulder erosion.
    - Higher trafficked roads will have a higher risk of elevated FSP concentrations due to increased pulverization of sediment on the roadway surface by automobiles.
- **Road Risk Category**: Road risk category combines the 2 road land uses (primary and secondary roads) with the 3 risk categories (high, moderate, low) to create six categories representing the theoretical risk of pollutant supply and transport downslope of the roadway. The presumed order of risk, from highest to lowest, is: primary high risk (PHR), primary moderate risk (PMR), secondary high risk (SHR), primary low risk (PLR), secondary moderate risk (SMR), and secondary low risk (SLR). Table 4.1 illustrates the characteristics used to define default road risk category for each Lake Tahoe urban road.

Table 4.1. Default Lake Tahoe Urban Road Risk Categories.

Primary Roads			
Primary Road Average Annual Daily Traffic (AADT)	**Low Slope (<3%)**	**Moderate Slope (3% - 7%)**	**High Slope (>7%)**
Low Average Annual Daily Traffic (<10,000 AADT)	Low Risk Primary	Moderate Risk Primary	High Risk Primary
High Average Annual Daily Traffic (>=10,000 AADT)	High Risk Primary	High Risk Primary	High Risk Primary
Secondary Roads			
Dominant Land Use Adjacent to the Secondary Road	**Low Slope (<3%)**	**Moderate Slope (3% - 7%)**	**High Slope (>7%)**
Non-Urban	Low Risk Secondary	Moderate Risk Secondary	High Risk Secondary
Residential - Single family	Low Risk Secondary	Moderate Risk Secondary	High Risk Secondary
Residential - Multi-family	Moderate Risk Secondary	High Risk Secondary	High Risk Secondary

- **Road Shoulder Condition** (1-5): The PLRM Road Methodology defines a road shoulder condition score to characterize the source control efforts to reduce road shoulder and primary flow path erosion along the side of the roadway. The score is calculated as follows: 1=Erodible; 3= Protected; 4=Stable; 5=Stable and Protected. The following are the presumed effects of road shoulder protection and stabilization:
  - *Protected* – The road shoulders have physical features (e.g., structures, vegetation, etc.) or policies (parking ordinances) that discourage or minimize disturbance by automobiles and snow plows. Defining a road shoulder as protected means that the majority of the pervious portion of road shoulder within the public right-of-way will remain undisturbed under typical conditions.
  - *Stable* – The road shoulders have physical improvements or other elements that either: 1) promote sheet flow and avoid concentration of stormwater and conveyance along the road shoulder; or 2) stabilize the conveyance of stormwater and inhibit erosion along the road shoulder. Physical improvements are actions that stabilize a road shoulder (e.g., curb and gutter, rock-lined channel, etc.). Other elements can include vegetation that stabilizes a road shoulder, or topography that promotes sheet flow and avoids concentration and conveyance of stormwater in the road shoulder.

Photos illustrating unprotected (top), unstable (middle) and protected and stable (bottom) road shoulders.

- **Sweeping:** Road sweeping physically removes the pollutants of concern from the road surface prior to a subsequent runoff event. The water quality benefit of sweeping in PLRM is estimated on an annual average basis based on general sweeping practices employed on the road risk category, including sweeping frequency and sweeper type. Within each jurisdiction, sweeping frequency is variable by roads based on priority, available resources and on-the-ground conditions. Increased sweeping frequency is assumed to improve average road conditions and reduce the average annual CRCs. Sweeper type is also a key factor in reducing urban road CRCs; mechanical broom sweepers

are assumed to be significantly less efficient at reducing TSS and FSP CRCs compared to high efficiency vacuum assisted sweepers. PLRM v1 estimates of TSS and FSP CRC reductions as a result of sweeping practices are based on available literature and research conducted outside of Lake Tahoe (Appendix B).

- **Abrasive Application Strategy:** The PLRM Road Methodology assumes that jurisdictions apply road abrasives during conditions when snow and ice may affect traffic safety, and at varying frequencies and levels that are related to road risk categories. The initial PLRM road risk categorization integrates basic assumptions on the magnitude and frequency of road abrasive application into the road risk assessment. PLRM allows for adjustment to the rate of road abrasive applications using three tiers of application strategies: minimal controls (95-100% road cinder or sanding material), moderate controls (some deicing strategies), and advanced controls (road temperature monitoring and deicing strategies).
- **Road Surface Integrity** (Low, Moderate, High): Road surface integrity is currently not a factor included in the PLRM v1, but urban road monitoring during Phase I suggest road surface integrity may have a measurable influence on TSS and FSP concentrations and downslope water quality risk. The integrity of the pavement appears to influence the retention of material on the road surface. Cracks and pocked pavement can trap and store sediment within the road surface. This material is often difficult for road sweepers to remove; yet stormwater runoff will mine the cracks for material and transport the pollutants downslope.

Photos illustrating low (left) and high (right) road surface integrity.

PHASE I URBAN ROAD MONITORING

Data Collection Summary

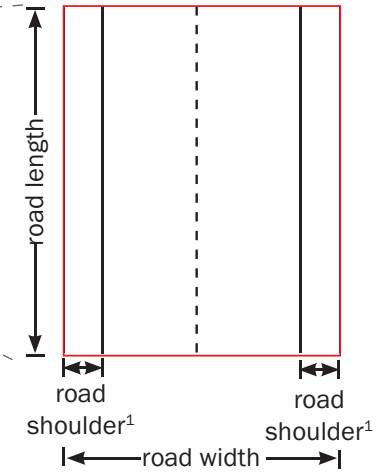
Thirty-four road segments (see Table 3.1, Figures 3.2-3.3) were chosen to represent a range of road risk categories and conditions. Data collection included one-time road segment characterizations, as well as monthly sampling efforts that included visual observations, dry material sampling, and controlled experiments. Figure 4.2 visually summarizes the temporal frequency and spatial distribution of the complete suite of data collected from the urban road segments monitored during Phase I.

Road segment characterizations (upper half of Figure 4.2) were performed using both GIS analysis prior to monitoring and field observations. Field personnel conducted the characterizations during the initial sampling effort at each road segment and this data was verified during each subsequent sampling effort. Road segments include only the impervious road surface and are standardized to an area of 1,000m^2. While PLRM includes the pervious area of the right-of-way in its definition of a road shoulder, sampling constraints associated with this research precluded the inclusion of the pervious area in these data collection and analysis efforts. Based on the characterization, the 34 road segments were designated as follows:

ONCE EVERY 3-5 YEARS

Lake Tahoe Basin

Road Segment (1000m²)

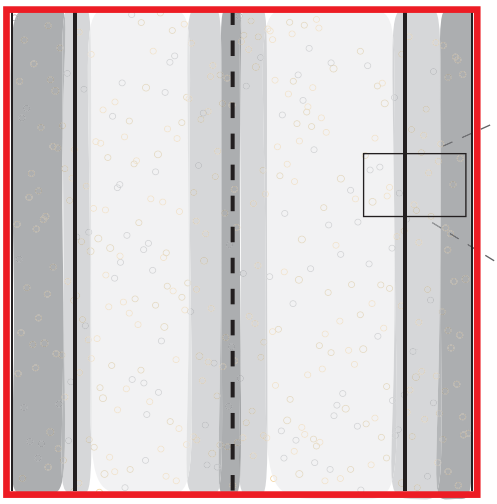


GIS analysis of:
- Road Risk Category
  - [PHR, PMR, SHR, PLR, SMR, SLR]
- Jurisdiction

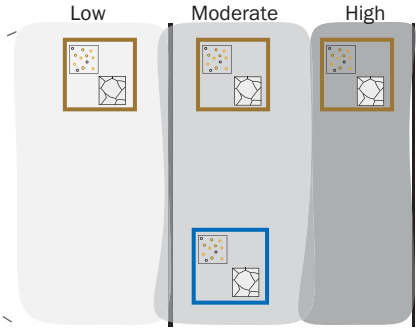
Characterized by:
- Right and Left Road Shoulder[1] Condition
  - [1, 3, 4, 5]
- Road Surface Integrity
  - [H, M, L]

EACH MONITORING EFFORT

Road Segment (1000m²)



1'x1' squares within Material Accumulation Category



Dry Material Sampling from all 3 categories:
- Volume/Mass [ml, mg]
- Particle Size Distribution
  - [% of mass <16μm]
  - (limited)
- Degree of Fines [H, M, L]
- Road Surface Integrity
  - [H, M, L]

Controlled Experiments obtain wet sample from 1 material accumulation category:
- TSS and FSP Concentrations [mg/L]
- Turbidity [ntu]
- Particle Size Distribution [% of TSS]
- Degree of Fines [H, M, L]
- Road Surface Integrity [H, M, L]

Visual observations of:
- Material Accumulation Category
  - % distribution of:
    - High
    - Moderate
    - Low
- Degree of Fines within each H, M, L area
  - [H, M, L]

[1] PLRM defines the road shoulder to include the pervious area of the right-of-way. For the purposes of this monitoring, only the impervious portion of the road shoulder is considered part of the road segment.

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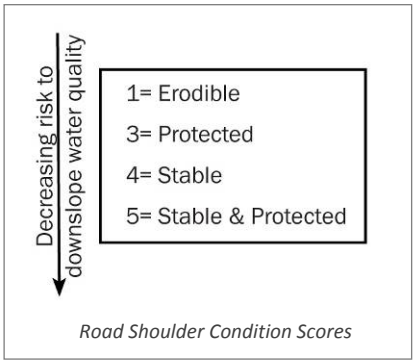
URBAN ROAD MONITORING DATA COLLECTION SCHEMATIC

FIGURE 4.2

- **Road Type**: 14 primary roads and 20 secondary roads based on GIS land use analysis;
- **Road Risk**: 16 high risk roads, 11 moderate risk roads, and 7 low risk roads based on the default PLRM road risk GIS layer;
- **Road Risk Category**: 9 PHR, 2 PMR, 7 SHR, 3 PLR, 9 SMR, and 4 SLR based on the identified road types and risks;
- **Road Shoulder Condition**: 10 Erodible, 5 Protected, 3 Stable, and 16 Stable and Protected road segments. Initial site characterizations included the designation of road shoulder condition scores for both the left and right road shoulders. For the purpose of data analysis, the road shoulder condition score for the side of the road where controlled urban road experiments were conducted is used.



- **Sweeping and Abrasive Application**: These practices are assumed to vary by jurisdiction and risk. There is a current assumption that roads within the same road risk category in the same jurisdiction are subjected to similar management practices: 6 Caltrans, 4 City of South Lake Tahoe (CSLT), 3 Douglas County, 3 El Dorado County, 5 Nevada Department of Transportation (NDOT), 6 Placer County, 5 Washoe County, and 2 private jurisdictions. The road maintenance practices during the study period were provided by jurisdiction personnel.
- **Road Surface Integrity**: 7 low, 15 moderate, and 12 high road surface integrity road segments based on initial road segment characterization.

Table 4.2 summarizes the complete urban road monitoring efforts conducted at all 34 road segments by road type, jurisdiction in charge of road maintenance, and month. A total of 122 monitoring efforts were conducted from March to July 2009. Due to road resurfacing on Highway 28, road segments H28A and H28B were only monitored twice. Additionally a snow storm occurred during the April 2009 monitoring; the wet road surface prohibited full sample collection at 5 road segments. Urban road monitoring included visual observations, dry material sampling, and controlled urban road experiments (lower half in Figure 4.2):

- **Visual Observations:** Visual observations of the entire 1,000m^2 road segment include the percent distribution of material accumulation categories (H, M, L) and the degree of fine material (H, M, L) within each accumulation category. Material accumulation categories are characterized relative to the specific road segment evaluated and not relative to all road segments during the sampling period. This relative % distribution allows the extrapolation of the wet sample results from one accumulation category to the entire road segment in future data analysis. An estimate of the general road segment dustiness (H, M, L) and any evidence of recent road abrasive application or sweeping were noted by field personnel.
- **Dry Material Samples**: Dry samples are collected from each area of accumulation (H, M, L) and the following data is recorded:
  - Volume – Dry volume (ml) of sediment is measured for each sample collected and converted to mass (mg) using a standard density (1.7 g/mL) for all samples. A total of 298 dry material samples, including field triplicates, were collected; most were immediately discarded, but a subset of samples was kept for later analysis.
  - Particle Grain Size Analysis – Forty-nine (49) samples were submitted to an analytical laboratory for particle grain size analysis and dry FSP mass (mg) was calculated.
  - Road surface integrity at the location of all dry material samples was noted to evaluate the effects of pavement condition on the dry material measurements.
- **Controlled Experiments:** The controlled experiments on road segments yielded wet samples for water quality analyses. Due to field personnel safety concerns and resource limitations, the collection of wet

sediment samples was restricted to one sample collected from the road shoulder – typically in the area of moderate accumulation on each road segment.

- The wet sediment samples obtained using the portable simulator were analyzed for turbidity (ntu), TSS concentration (mg/L) and grain size distribution. The % of TSS <16µm and TSS concentrations were used to calculate FSP concentration (mg/L). Due to cost and field personnel safety, fewer wet samples were collected using controlled experiments than dry samples; 145 wet sediment samples, including field triplicates and blanks, were analyzed during Phase I monitoring.
- Road surface integrity at the location of the controlled experiment was noted to evaluate the effects of pavement condition on the observed measurements.

Table 4.2. Phase I Urban Road Monitoring Sample Summary

Road Type	Jurisdiction	March	April	May	July	Jurisdiction	Road Type
Primary	CalTrans, CA	4	6	6	6	22	**46**
	CSLT, CA	0	0	0	0	0	
	Douglas County, NV	0	0	0	0	0	
	El Dorado County, CA	0	1	1	1	3	
	NDOT, NV	4	4	3	4	11	
	Placer County, CA	0	0	0	0	0	
	Private	0	2	2	2	6	
	Washoe County, NV	0	0	0	0	4	
Secondary	CalTrans, CA	0	0	0	0	0	**76**
	CSLT, CA	4	4	4	4	8	
	Douglas County, NV	1	3	3	3	10	
	El Dorado County, CA	2	2	2	2	16	
	NDOT, NV	0	0	0	0	0	
	Placer County, CA	5	6	6	6	23	
	Private	0	0	0	0	0	
	Washoe County, NV	4	5	5	5	19	
	Monthly Totals	**24**	**33**	**32**	**33**	**122**	**122**

Portable Wet Sample Simulator Field Precision

A portable wet sampler was developed to provide a consistent, repeatable, rapid and cost-effective technique to sample the TSS and FSP concentrations emanating from urban road pavements. The field precision of the portable simulator was calculated by performing field triplicates at 9 road segments over the winter of 2009 (see Table 3.5). The road segments represented a range of conditions and road risk categories. The average field precision is 20.7% for TSS concentration (mg/L) and 11.2% for FSP concentration (mg/L). The primary sources of sampling error appear to occur when the amount of material on the road is high or when road surface integrity is poor.

- When sampling road surfaces with a high mass of material, the sampling technique is not consistently able to transport the entire fraction of material on the road surface into the simulator collection pan. It appears wet sampling precision declines when the mass of dry material on the road surface exceeds 50mL of material from the 1ft x 1ft square. In these instances, the portable sampler is underestimating the TSS and FSP concentrations from the road segments in the poorest condition.
- In areas with low road surface integrity, the cracks and surface irregularity add significant variability on how material is transported into the sampler collection pan. If cracks are perpendicular to the water flow path, the cracks trap sediment; if they are parallel, the simulated runoff can mine and transport stored sediment. In both cases, the precision of the portable simulator on roads with low surface integrity is reduced.

Even with the observed sampling variability, the temporal variability of TSS and FSP concentrations and other wet sample parameters observed from specific roads over the course of data collection do significantly exceed the calculated precision of the portable sampler. The additional observed variability suggests that there are other factors influencing the measured TSS and FSP concentrations over time and across road segments. Future refinements to the sampler will be made and the field precision will continue to be calculated.

Road Maintenance Practices

The observed condition of each urban road is assumed to be the integrated signal of pollutant inputs (sources) and outputs (sinks). The maintenance practices of each road segment by the responsible jurisdiction are assumed to greatly influence the observed road condition throughout the year. The primary practices on short-time scales are road abrasive application and sweeping, and these two practices can vary widely by jurisdiction, road priority, and weather conditions. Ideally, the specific chronology of these actions on each road segment sampled for this study would be documented, including dates and amount per unit area of abrasive applications and dates and sweeper type used during pollutant recovery actions. Coordination with the local jurisdictions produced Table 4.3 based on available records and assumptions. Future road sampling will hopefully include increased coordination with jurisdictions to develop better data management and communication to improve the accuracy and completeness of this critical information and improve our ability to evaluate the factors influencing road condition in Lake Tahoe.

For the purposes of this study, proxies were used to approximate sweeping activity and abrasive application data. Specific sweeping history for each road segment was provided by each jurisdiction; however, the accuracy of this information is limited because (1) jurisdictions were not specifically tracking their efforts with respect to each 2NDNATURE urban road monitoring location and (2) jurisdictions vary widely in their data management approaches. In many instances, gross estimates on the number of sweeps at any particular road segment were necessary and specific sweeper type data was limited. In the case of road abrasive application, current data management practices preclude the use of jurisdiction data. The current information is too general in terms of both location and application magnitudes to allow for proper analysis with the Phase I urban road monitoring dataset. Instead antecedent weather conditions, described below, and visual records from local partners were used to estimate dates of likely road abrasive application during Phase I monitoring.

Weather Conditions

Figure 4.3 provides the weather conditions preceding each urban road monitoring period. The timeline indicates significant precipitation events and freezing temperatures (daily average air temperature below 32°F). It is important to note that the climate data presented herein is collected from a weather station located in South Lake

Jurisdiction		CSLT				Douglas County			El Dorado County			NDOT				
Time Period	Details (# of Sweeps and Sweeper Type)	KC3	SR1	BO1	EW1	KG4	KG3	KG5	HM2	MA1	HM3	KG2	H28C	KG1	H28B	H28A
Feb 18th to Mar 18th	# of Sweeps	0	0	0	0	0	0	0	13	0	1	9	4	8	5	6
	Sweeper Type	-	-	-	-	-	-	-	Reg	-	Reg	Reg	Reg	Reg	Reg	Reg
Mar 18th to Apr 13th	# of Sweeps	0	0	0	0	0	0	0	9.5	1	0	4	3	2	1	2
	Sweeper Type	-	-	-	-	-	-	-	Reg	Reg	Reg	Reg	Reg	Reg	Reg	Reg
Apr 15th to May 11th	# of Sweeps	0	0	1	1	0	0	0	6.5	1	0	2	0	2	0	0
	Sweeper Type	-	-	Mech	Mech	-	-	-	Reg	Reg	-	Reg	-	Reg	-	-
May 13th to July 7th	# of Sweeps	2	2	1	1	0	0	0	7	0	3	0	2	0	0	1
	Sweeper Type	Mech	Mech	Mech	Mech	-	-	-	Reg	-	Reg	-	Reg	-	-	Reg

Jurisdiction		Placer County						CALTRANS						Washoe County				
Time Period	Details (# of Sweeps and Sweeper Type)	CO1	Pine	BURL	JP	TR1	KB1	H89S	EI	H281	H28TC	SPP1	EB1	VIL1	VIL2	KMAC	DD	JEN
Feb 18th to Mar 18th	# of Sweeps	0	0	0	0	0	0							3	1	1	1	1
	Sweeper Type	-	-	-	-	-	-							High	High	High	High	High
Mar 18th to Apr 13th	# of Sweeps	0	1	1.5	2.5	0	0							3	0	2	1	1
	Sweeper Type	-	Mech	Mech	Mech	-	-							High	High	High	High	High
Apr 15th to May 11th	# of Sweeps	4	0	0	1	3	3							3	2	1	1	1
	Sweeper Type	Mech	-	-	Mech	Mech	Mech							High	High	High	High	High
May 13th to July 7th	# of Sweeps	0	0	3	2	2	2							2	4	1	1	1
	Sweeper Type	-	-	Mech	Mech	Mech	Mech							High	High	High	High	High

High= High-efficiency vacuum-assisted (dustless)
Reg= Regenerative air (dustless)
Mech= Tandem operation (mechanical + vacuum sweeper)
Brm= Mechanical broom (1988 model or newer)

PHASE I SWEEPING SUMMARY AT URBAN ROAD SEGMENTS

TABLE 4.3

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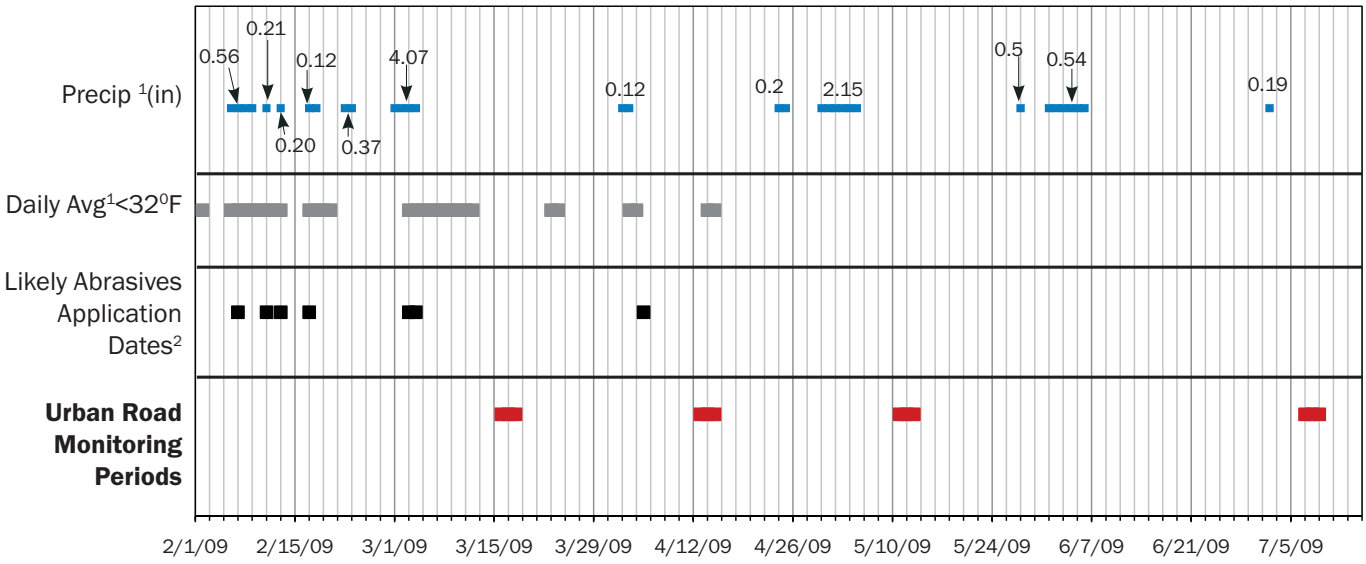

[1.] Weather data is recorded by the CSLT City Lab weather station located at the intersection of Lake Tahoe Blvd and D Street in South Lake Tahoe, Ca.
[2.] Likely abrasive application dates are estimated based on concurrent instances of precipitation and freezing temperatures.

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PHASE I URBAN ROAD MONITORING + WEATHER SUMMARY

FIGURE 4.3

Tahoe, CA and is provided to give a general context for the likely weather conditions. This data is not assumed to represent exact conditions within the entire Basin.

The precipitation and daily average temperature metrics in Figure 4.3 were integrated to estimate periods of likely road abrasive application, given the likelihood of icy road conditions necessitating abrasives to improve traffic safety[1]. Phase I urban road monitoring efforts are shown to indicate sampling timing relative to the climatic conditions and probable road maintenance activities.

The climatic conditions leading up to each urban road monitoring effort are summarized below:

- **March**: In the month prior to the March sampling period, there were multiple winter snow storms and instances of winter road abrasive applications. The most recent was 14 days prior to monitoring.
- **April:** Prior to April monitoring, climatic conditions and local records suggest only one major winter storm occurred. During the April urban road monitoring a minor rain/snow event fell on the North Shore and eliminated the sampling of certain North Shore sites in April. However, field personnel did not observe active abrasive application during this event.
- **May**: Warmer temperatures in late April/early May eliminate the need for abrasive applications, and it is estimated that no abrasives were applied between the April and May monitoring. A rain event that exceeded 2 inches occurred in early May, prior to the mid-May monitoring. Rain events when temperatures are above freezing likely transport sediment accumulated on the road surface downslope, thereby improving the road conditions observed following spring rains.
- **July**: A few summer thunderstorm events occurred in June, again likely improving road conditions due to wash off of material from the roadways. The July monitoring event occurred over 3 months following the last winter storm when road abrasives were applied to select urban roads.

REFINEMENT AND VALIDATION OF PLRM ROAD METHODOLOGY

The urban road CRC values in the initial version of PLRM (Appendix B) are based on limited Lake Tahoe urban stormwater monitoring datasets. The primary data sources used to inform the PLRM urban road CRCs include previous Lake Tahoe stormwater quality monitoring datasets compiled and integrated from a variety of sources, including UC Davis, Desert Research Institute, 2NDNATURE, Nevada Department of Transportation, California Department of Transportation, El Dorado County, and others (nhc et al. 2009). This synthesized data was originally collected by a variety of researchers to meet a myriad of goals and objectives, and therefore did not perfectly align with the goals and objectives of the PLRM urban road CRC determination. The limitations of the data used to inform PLRM road CRCs include: (1) stormwater sampling of urban catchments containing a mixture of land uses, (2) a lack of documentation of land use condition in conjunction with water quality data collection, and (3) few samples were analyzed for fine sediment particles (FSP, <16µm). The PLRM Road Methodology development team made a number of assumptions when integrating the available dataset to define the PLRM urban road TSS and FSP CRCs. Results from Phase I 2NDNATURE urban road monitoring were used for comparison against the urban road CRC estimates in the initial version of PLRM. The Phase I controlled road sampling dataset is temporally limited and only includes 4 temporally representative observations from March to July during 2009. However, some initial evaluations of the PLRM CRC assumptions are made below with the newly obtained dataset. The controlled road sampling data collection approach will continue to be implemented through WY2011 by 2NDNATURE under a currently funded Round 9 SNPLMA grant (Phase II) and will further refine the observations below.

[1] Future urban road sampling needs to better coordinate with local road managers to track when abrasives applications occurred to each urban road sampling segment; however at this time, these records are not available and general climatic conditions are used to estimate when abrasives may have been applied.

PLRM v1 Bookend Values

The Phase I wet sample results are used to evaluate if the PLRM estimated bookend TSS and FSP CRCs and % FSP are representative of observed conditions. During PLRM development the minimum and maximum CRCs were carefully selected to define the range of values that can be expected from urban road surfaces on an average annual basis. Table 4.4 compares these PLRM estimates to the values measured during urban road sampling for TSS and FSP concentrations. In making these comparisons, it is important to remember that PLRM estimates average annual loads, while the Phase I TSS and FSP concentrations represent discrete measurements at a specific location at a specific point in time. In addition, PLRM CRCs are intended to represent the entire pavement and shoulder area included in the road land use category, and the wet samples represent only the paved area.

PLRM uses a maximum TSS CRC of 1398 mg/L and FSP of 1014 mg/L from the urban roads with the poorest condition (0.5). The maximum Phase I observed concentrations were 6000 mg/L TSS and 3468 mg/L FSP, but the PLRM predictions were only exceeded by 12% and 8% of the total samples for TSS and FSP, respectively, suggesting the high bookend PLRM CRC are within reason. The minimum TSS and FSP concentrations observed during sampling were 30 mg/L and 12 mg/L, respectively, compared to the PLRM estimations of 63 mg/L and 22 mg/L. Six percent of the TSS samples and 7% of the FSP samples were observed to be below the PLRM minimum values, confirming that the PLRM minimum CRCs are achievable. Based on the limited data obtained from March – July 2009, PLRM TSS and FSP CRCs appear to be representative of the observed range in road conditions in Lake Tahoe. Continued controlled urban road monitoring will improve our confidence in these findings.

Table 4.4. Comparison of PLRM CRC Estimates to Phase I Measured Concentrations

	TSS (mg/L)	FSP (mg/L)
PLRM Maximum	1398	1014
Phase I Measured Maximum (n)	6000 (124)	3468 (122)
Frequency Measured Maximum exceeded PLRM Maximum (n)	12% (15)	8% (10)
PLRM Minimum	63	22
Phase I Measured Minimum (n)	30 (124)	12 (122)
Frequency Measured Minimum below PLRM Minimum (n)	6% (8)	7% (8)

Predicted TSS/FSP CRCs versus Measured Concentrations

Data from the initial road segment characterizations at each of the 34 road segments was input into the PLRM Road Methodology model to predict the average annual condition score, TSS CRCs and FSP CRCs for each road segment. Figure 3.4 in Section 3.1 illustrates that the selection of 34 urban road sites for 2009 sampling represent a range of expected road condition based on PLRM. The PLRM predicted TSS and FSP CRCs are compared to the Phase I measured wet sample TSS and FSP concentrations to begin to validate a number of PLRM assumptions and estimates. The quantitative comparison between PLRM average annual estimates and discrete observations that only represent urban road conditions for 4 months of 1 single year must be interpreted cautiously, but do provide

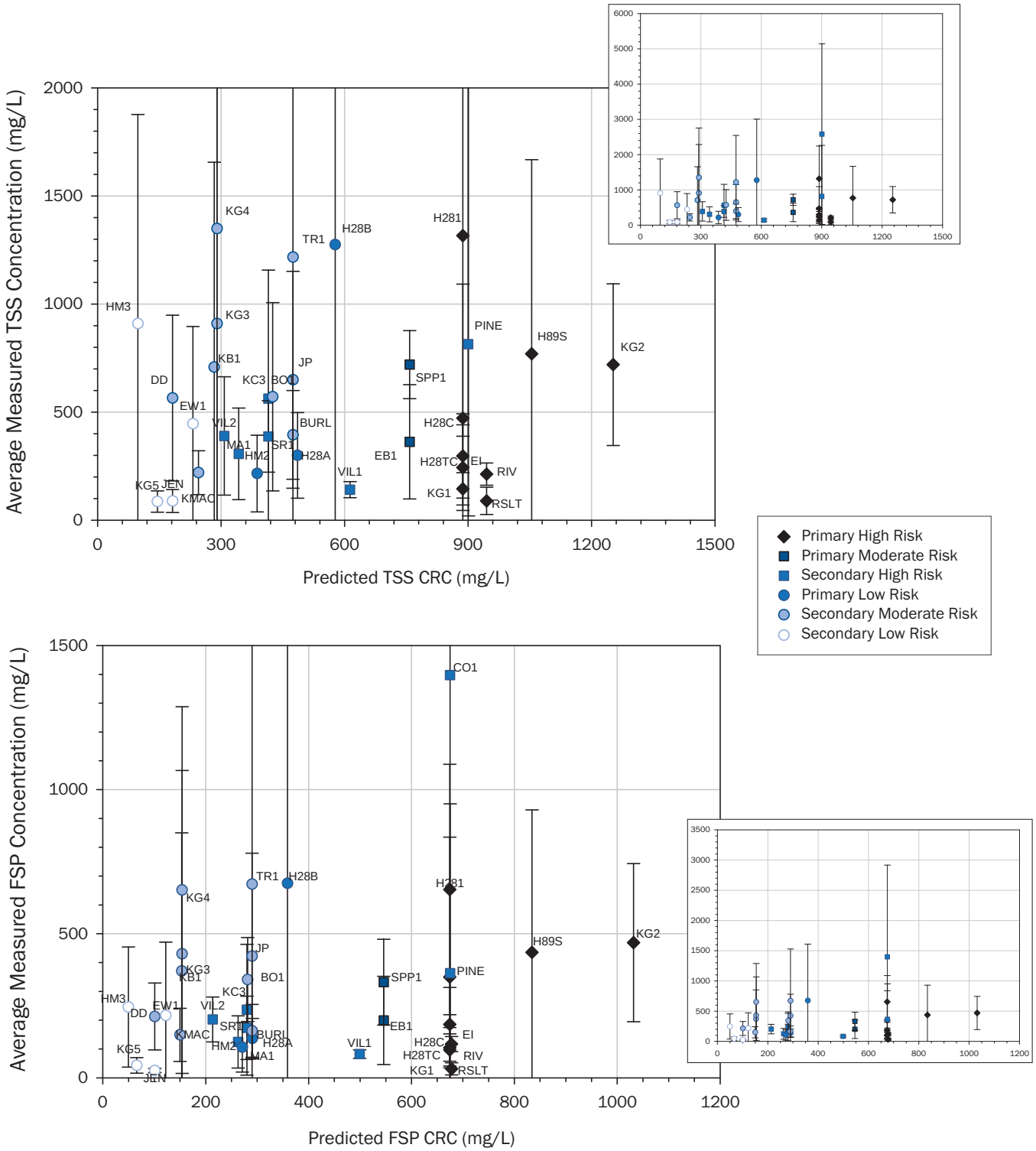
insight. A continued and pressing question of the Lake Clarity Crediting Program (LRWQCB and NDEP 2009) is how to integrate discrete observations in time and space to inform long-term average annual estimations, such as those generated from PLRM.

Figure 4.4 plots the predicted CRC values against the measured average +/- standard deviation for each road segment using unique data symbols for each road risk category. The PLRM predicted values (x-axis) show a range and generally follow the assumed order of risk to downslope water quality by road risk category. The figure illustrates the high temporal variability of the measured water quality concentrations during the 5-month monitoring period. The variability in observed road condition is expected and likely due to the integration of continued sources and sinks of material on the road surface.

The poor comparison between this initial limited dataset and the average annual PLRM estimates are expected, and lead us to investigate which factors influence the observed urban road condition on short time scales. The PLRM estimates the likely long-term average road condition over an 18-year time period, using static road characteristics such as slope, traffic density, and road shoulder condition. The factors used by PLRM do not change between sampling periods and therefore we would not expect the model to accurately predict the highly variable seasonal differences in urban road condition. The final predicted TSS and FSP CRC values from PLRM can be significantly influenced by sweeping strategies and abrasive applications on an average annual basis. One limitation of the predicted PLRM CRCs for each road segment in this study is the vague understanding of each jurisdiction's road management practices on each road sampled by 2NDNATURE. As the controlled road sampling data collection continues under Round 9 SNPLMA funding, the subsequent dataset will document condition of the selected road sites for two complete water years. Once a full annual distribution of road condition observations and wet sample data is available, informed recommendations to improve the PLRM estimates to predict urban road CRCs will be warranted.

Seasonal Influence on Road Condition

As expected, many road segments were observed to have a fairly large seasonal variability in measured road water quality concentrations from March to July (see Figure 4.4). Using the limited 4-month dataset, the detailed statistical analysis (discussed below) indicates that month is a consistent predictor variable of road condition and simple time series plots of the water quality observations support this finding. Figure 4.5 summarizes the wet sample results by month to provide a quick overview of the seasonal variation within the sampling. Box and whisker plots are presented for each of the four sampling periods (March, April, May and July) and the results are shown for TSS and FSP concentrations (mg/L). These graphics indicate road condition as determined by controlled wet sampling improved seasonally, with the maximum and the variability of TSS and FSP concentrations significantly decreasing each month. These findings are likely the result of (1) warmer climatic conditions reducing the need for road abrasive application, (2) jurisdictions having more time to sweep since the most recent winter storm, and (3) late spring/summer rain events mobilizing and removing sediment accumulated on the road surface and thereby reducing the TSS and FSP concentrations observed on the road surface. There were some urban road segments where FSP concentrations were consistently measured below 200 mg/L for all sampling efforts. The factors of these road segments are of particular interest to improve our understanding of how to maintain very low FSP and TSS concentrations throughout the winter and spring. The factors potentially influencing the seasonal and spatial differences observed across sites are explored below.



Error bars show standard deviation of Phase I measurements for each road segment.

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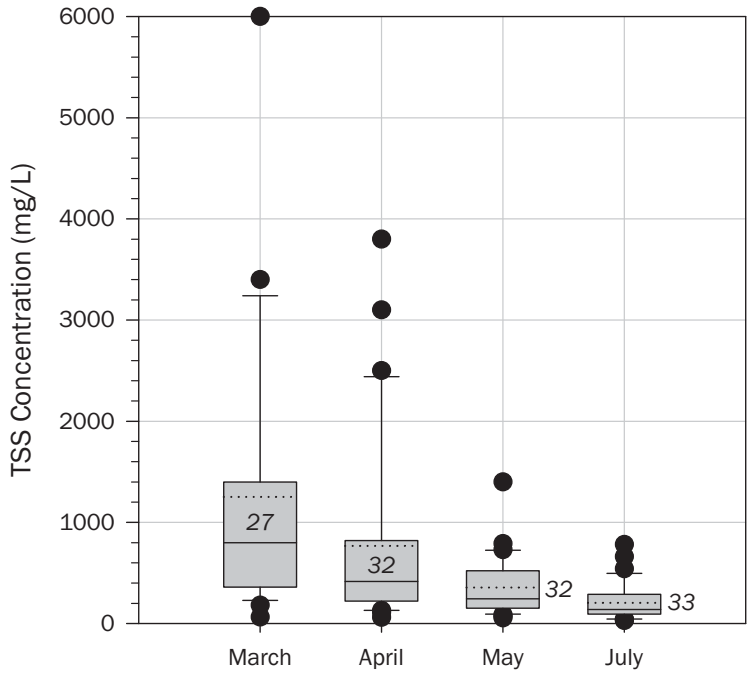
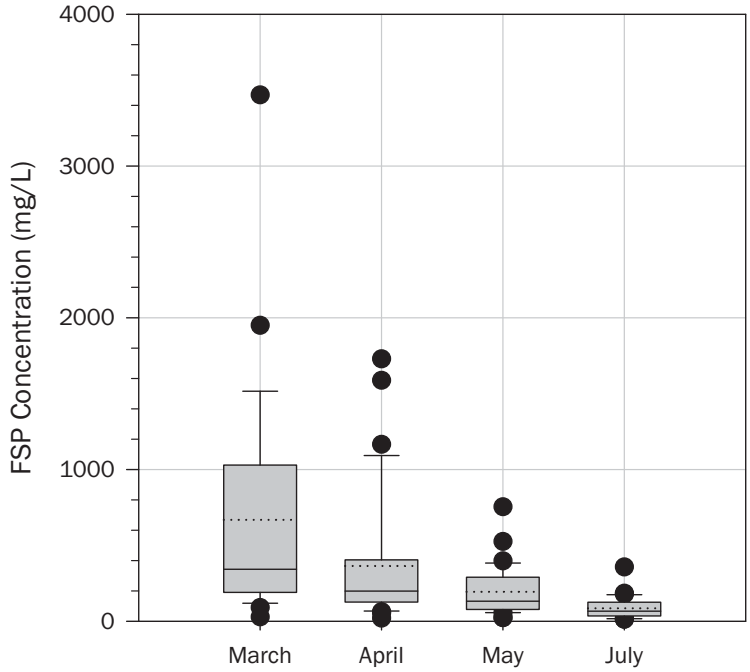
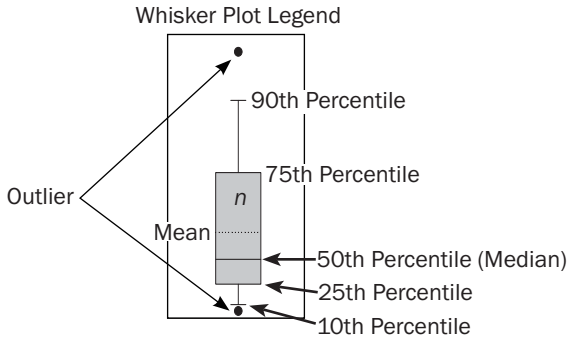
PLRM PREDICTED VERSUS PHASE I MEASURED VALUES:
AVERAGE ± STANDARD DEVIATIONS

FIGURE 4.4







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PHASE I MEASURED TSS + FSP CONCENTRATIONS BY SAMPLING PERIOD

FIGURE 4.5

Road Risk Category

The Phase I data does not show any correlation of maximums, averages, or variability of road condition to current default road risk designations for each road segment. The initial PLRM road risk GIS layer is based solely on physiographic characteristics, including slope, traffic density, and adjacent land use. Future refinements may be necessary to adjust for anthropogenic factors that likely increase the application of road abrasives due to traffic safety concerns (e.g., school bus routes, ski resort access, etc.) and the subsequent sweeping recovery actions. The current road risk categorization may not be a predictive factor for observed condition and water quality concentrations, because there are many other roadway factors that can influence condition during any one sampling effort and the current default road risk layer may not, in isolation, account for jurisdiction-specific road management practices.

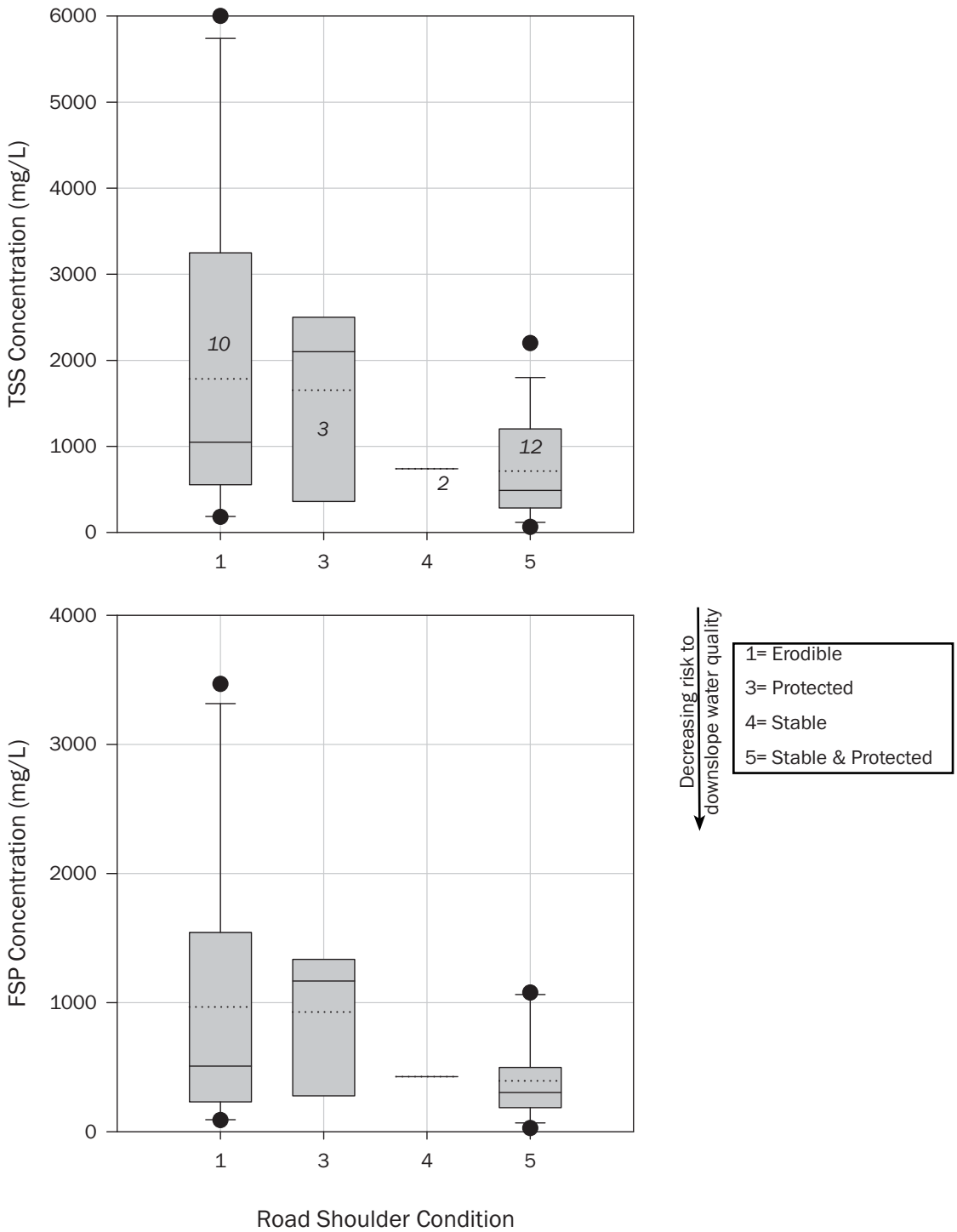
Road Shoulder Condition

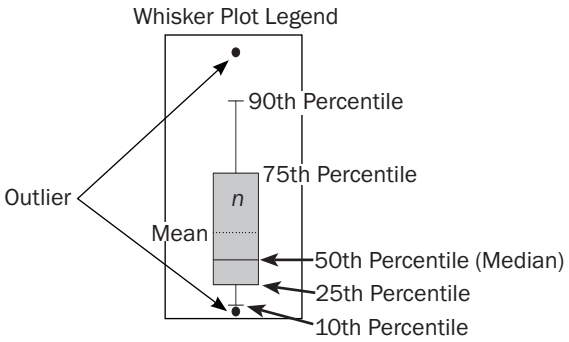
Based on PLRM assumptions, poor road shoulder condition is expected to increase the relative risk to downslope water quality. An unprotected road shoulder is expected to increase the potential source of material and pollutants due to car, snow plow and human disturbance. An unstable road shoulder will have a relatively higher erosive risk. The portable wet sampling methodology focuses data collection on runoff from the paved surface and therefore does not directly sample the effects of road shoulder stabilization on water quality measurements. The pollutant loading contribution from native erosion from pervious surfaces beyond the sampled road right of way are not included in the sample collected using the portable sampler.

With an understanding of the sampling limitations stated above, the March 2009 data is grouped by road shoulder condition score and presented in Figure 4.6. While limited, the data does show a slight response in the maximum concentrations and variability when comparing the erodible (score = 1) road segments to those that are protected and stable (score = 5). These limited findings tend to support the PLRM hypotheses that road shoulder stabilization and protection are able to reduce the magnitude of available pollutant loads generated from a specific road segment.

A comparison of water quality results from road segments KG1 and KG2 during the April 2009 sampling period provide anecdotal support that road shoulder condition can influence TSS and FSP concentrations. Both road segments are primary high risk roads within NDOT's jurisdiction and are in close proximity to one another. It is reasonable to assume that the abrasive application and pollutant recovery actions on KG1 and KG2 are similar. In fact, as shown in Table 4.3, KG2 was swept slightly more often than KG1. KG1 is protected and stable, while KG2 is erodible. In April 2009, TSS and FSP concentrations at the 2 road segments varied considerably; KG1 measured 230 mg/L and 155 mg/L for TSS and FSP, respectively, while results at KG2 were 1200 mg/L and 810 mg/L. By constraining road risk category, jurisdiction, and sampling period, it can be assumed that observed water quality conditions may be influenced, to some degree, by the differences in road shoulder condition.

Photos comparing KG1 (on left) to KG2 (on right). KG1 is protected and stable with a road shoulder condition score of 5: KG2 is erodible has a road shoulder condition score = 1.





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MARCH 2009 MEASURED TSS + FSP CONCENTRATIONS BY ROAD SHOULDER CONDITION

FIGURE 4.6

Road Surface Integrity

Urban road observations and sampling results suggest that road surface integrity can influence downslope water quality. Wet sampling on urban roads with low road surface integrity displayed large sampling variability, some of which was likely due to sampling error as water volume losses may occur under the sampler when it is placed on highly cracked pavement. The direction and magnitude of the surface cracks also appears to influence precision. Cracks that aligned parallel with the flow of water from the sampler into the sampling bottle would be mined by the simulated runoff and material was transported into the sample. Cracks perpendicular to the flow would trap some fraction of the sediment, and thus would potentially decrease the wet sampling water quality results. Thus, cracks parallel to the road slope will be mined by stormwater sheet flow more effectively during runoff events than fissures aligned perpendicular to the road slope.

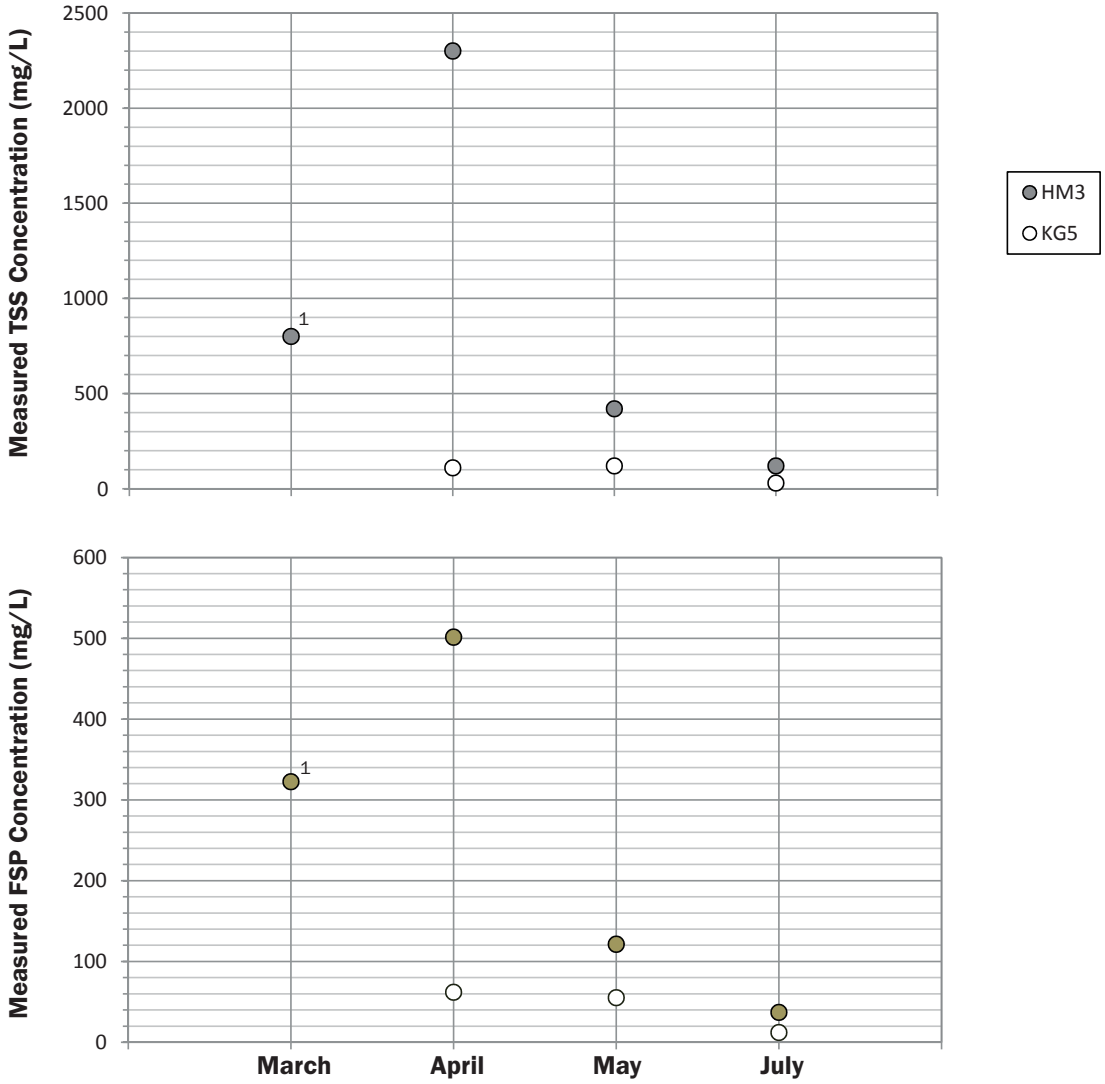
Figure 4.7 compares the water quality concentrations from HM3 and KG5, two secondary low risk roads with stable road shoulders. In April 2009, the TSS concentration at HM3 (2300 mg/L) is over 20 times greater than the concentration measured at KG5 (110 mg/L), and the FSP concentration is 8 times greater (501 mg/L compared to 61.9 mg/L). According to sweeping data provided by the jurisdictions (El Dorado County and Douglas County, respectively), neither road had been swept in the month leading up to the sampling. The primary visual difference between the road segments is the road surface integrity, shown in Figure 4.7. HM3 is highly cracked, providing storage of sediment and fine sediment particles on the road surface. KG5, on the other hand, has a very smooth surface with little to no storage capacity to store debris. In fact, the lowest observed TSS concentration at HM3 (120 mg/L in July) is equal to the greatest observed concentration at KG5.

This preliminary data suggests that road surface integrity has some effect on the maximum values and sampling variability of TSS and FSP concentrations observed at a specific road segment. Road surface integrity is expected to influence pollutant loads primarily by increasing the effectiveness of road abrasive recovery and sweeping efforts. Where these types of source controls are not practiced, road surface integrity may affect temporal variability of concentrations more than long-term loads. The influence of road surface integrity will continue to be evaluated as a factor in road condition and the potential water quality risk to downslope resources.

Jurisdictions and Road Maintenance Practices

The jurisdictions managing urban roads within Lake Tahoe practice a range of road maintenance strategies as a result of resources, priorities and other constraints. This range of practices provides an opportunity to improve our understanding of how various strategies may relate to the relative condition of urban roads in Lake Tahoe. The 2009 road maintenance practices and record keeping vary greatly throughout the Basin jurisdictions. Table 4.3 summarizes the February through July 2009 pollutant recovery actions at each road segment by jurisdiction, as provided by jurisdiction personnel based on available records. Table 4.3 and urban road sampling observations over the Phase I suggest sweeping practices are highly variable on Lake Tahoe urban roads (frequency and spatial variability) and that sweeping can have a significant influence on the observed road condition and measured water quality concentrations over time. At this time abrasive application magnitudes and frequency per urban road segment are unknown. Current jurisdictional road abrasive data management strategies are highly variable and overly generalized, which precluded the use of the data in the Phase I analyses.

The comparison to measured TSS and FSP concentrations are made based on information provided by each of the jurisdictions on their general road sweeping practices and estimated abrasive application using weather data. More consistent road maintenance data collection and management by the jurisdictions in the future will improve our understanding of the effects sweeping and abrasive application may have on loading from Lake Tahoe Basin



[1]KG5 was not sampled in March 2009

HM3 Road Segment March 2009

KG5 Road Segment May 2009

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ROAD SEGMENT COMPARISON: ROAD SURFACE INTEGRITY

FIGURE 4.7

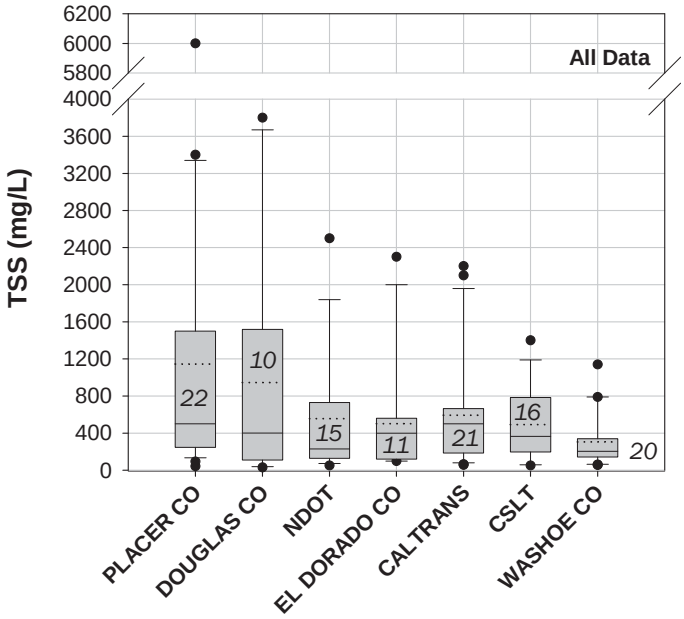
urban roads. The wet sample data is presented by jurisdiction for the purposes of constraining this one road factor variable, since it is likely (and the intent of the road risk layer) that roads of similar risk within the same jurisdiction are subjected to similar practices. The purpose of the jurisdiction comparison is not to identify failure or poor road management practices, but rather to improve our understanding of how road management strategies relate to observed water quality during the winter of 2009.

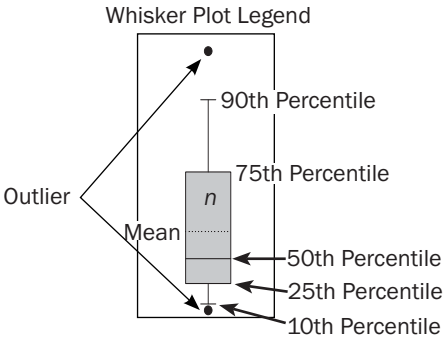
The measured water quality concentrations for each jurisdiction are presented by individual road segment and sampling period and also as box and whisker plots for all roads within each jurisdiction. The results of the wet sampling are integrated for all roads by jurisdiction in Figures 4.8 and 4.9. The top graphic in Figures 4.10-4.16 is a series of box and whisker plots displaying the wet sample results for all samples collected within each jurisdiction, and then below are the jurisdiction results by each discrete sampling month. The jurisdictions are presented from left to right in decreasing order of maximum observed value for the respective constituent (TSS or FSP). The top graphic in both Figure 4.8 and 4.9 displays a decreasing trend in the maximum observed value, mean and the seasonal range of data from left to right.

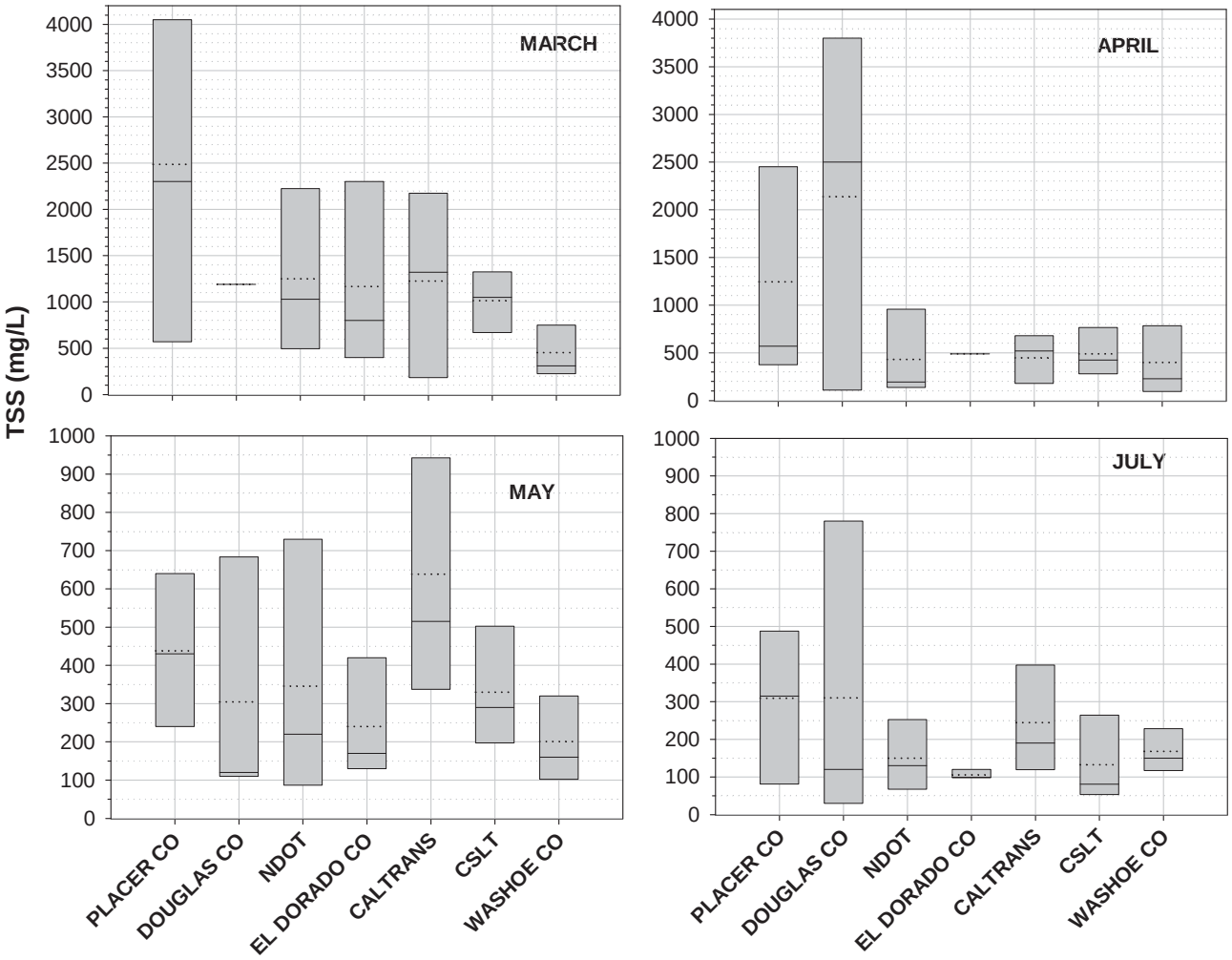
The wet sample TSS (mg/L), FSP (mg/L) and turbidity (ntu) values observed for each road segment by jurisdiction are plotted in Figures 4.10-4.16. In Figures 4.10-4.16, road segments within each jurisdiction are presented from left to right based on expected relative condition based on the road risk category and road characteristics. For each road segment the road risk category, road shoulder condition score, road surface integrity, and the total number of times swept during the study period are provided. The measured value for each sampling effort is plotted, and changes in water quality values between some sampling dates are called out. Below we provide a general discussion of the jurisdiction's road maintenance practices based on information provided by the jurisdictions and the observed wet sample results from the respective roads.

- **Placer County** (Figure 4.10):
  - The urban road sampling included 6 roads within the Placer County jurisdiction, which is on the upper end of the number of roads included in the study by jurisdiction.
  - On average, Placer County swept their urban road segments 4 times from late March to July using a mechanical broom sweeper.
  - Over the 2009 winter, Placer County displayed relatively high maximum, average and median TSS and FSP concentrations (Figure 4.8 and 4.9) in comparison to the other jurisdictions.
  - There was a significant variability of Placer County road conditions for the 4 SMR roads sampled, with 2 of interest being BURL and TR1. During the March 2009 road sampling effort, FSP concentrations were 7 times higher at TR1 compared to BURL (1950 mg/L to 267 mg/L). According to Placer County data, neither site had been swept in the month leading up to the sampling. Without detailed road abrasive application history at the two road segments, definitive conclusions cannot be drawn; however, these limited results do suggest the difference in road condition is in part due to road surface integrity. TR1 has a densely cracked surface, likely capable of storing a considerable volume of sediment, while BURL shows high road surface integrity. Obviously, the application of abrasives that are subsequently not recovered will decrease road condition, regardless of the road integrity.

Photos comparing the road surface integrity of BURL (top) to TR1 (bottom).







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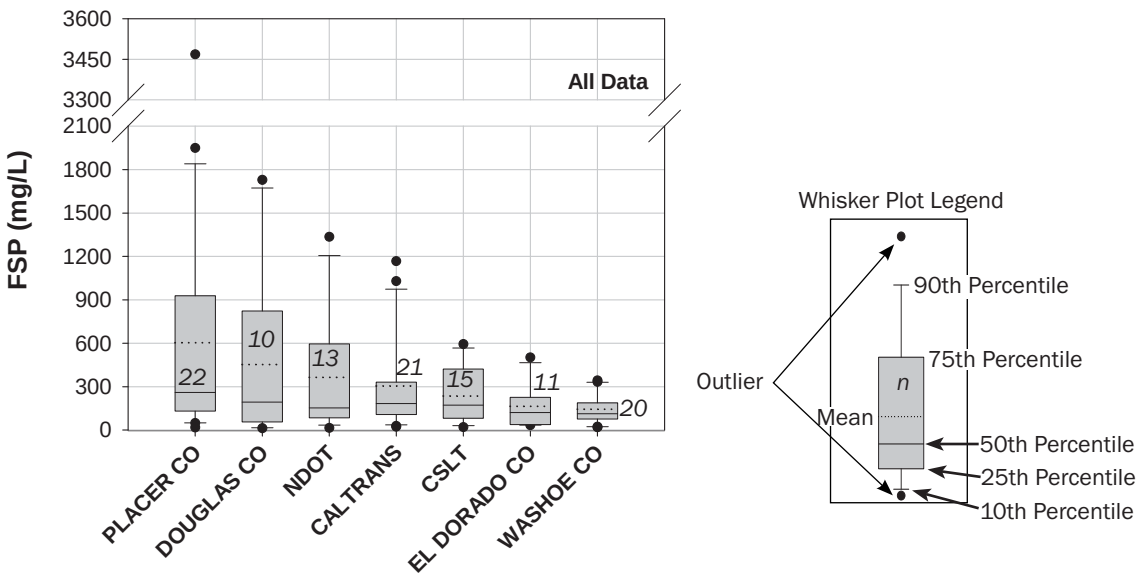
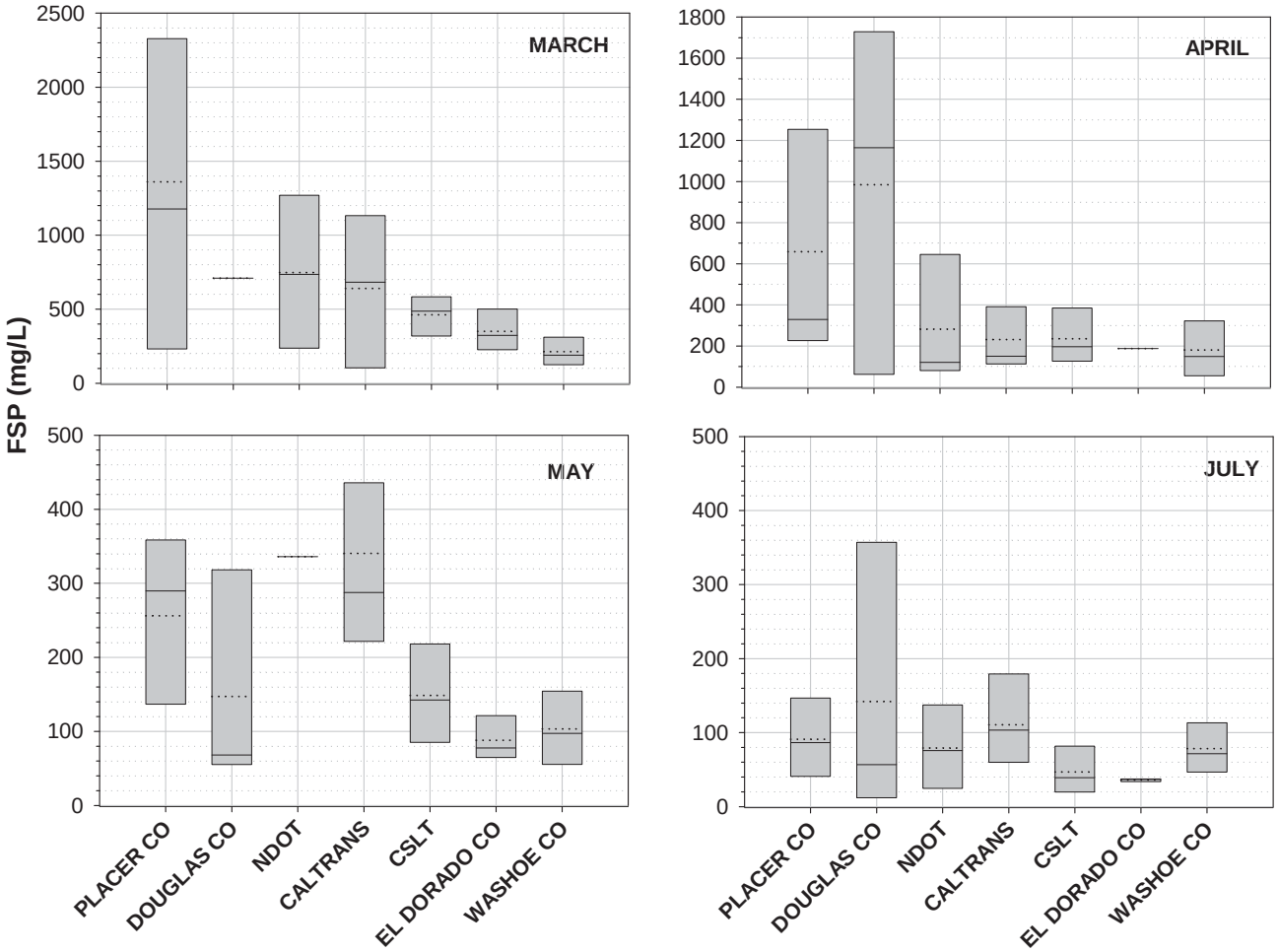
PHASE I MEASURED TSS CONCENTRATION BY JURISDICTION

FIGURE 4.8





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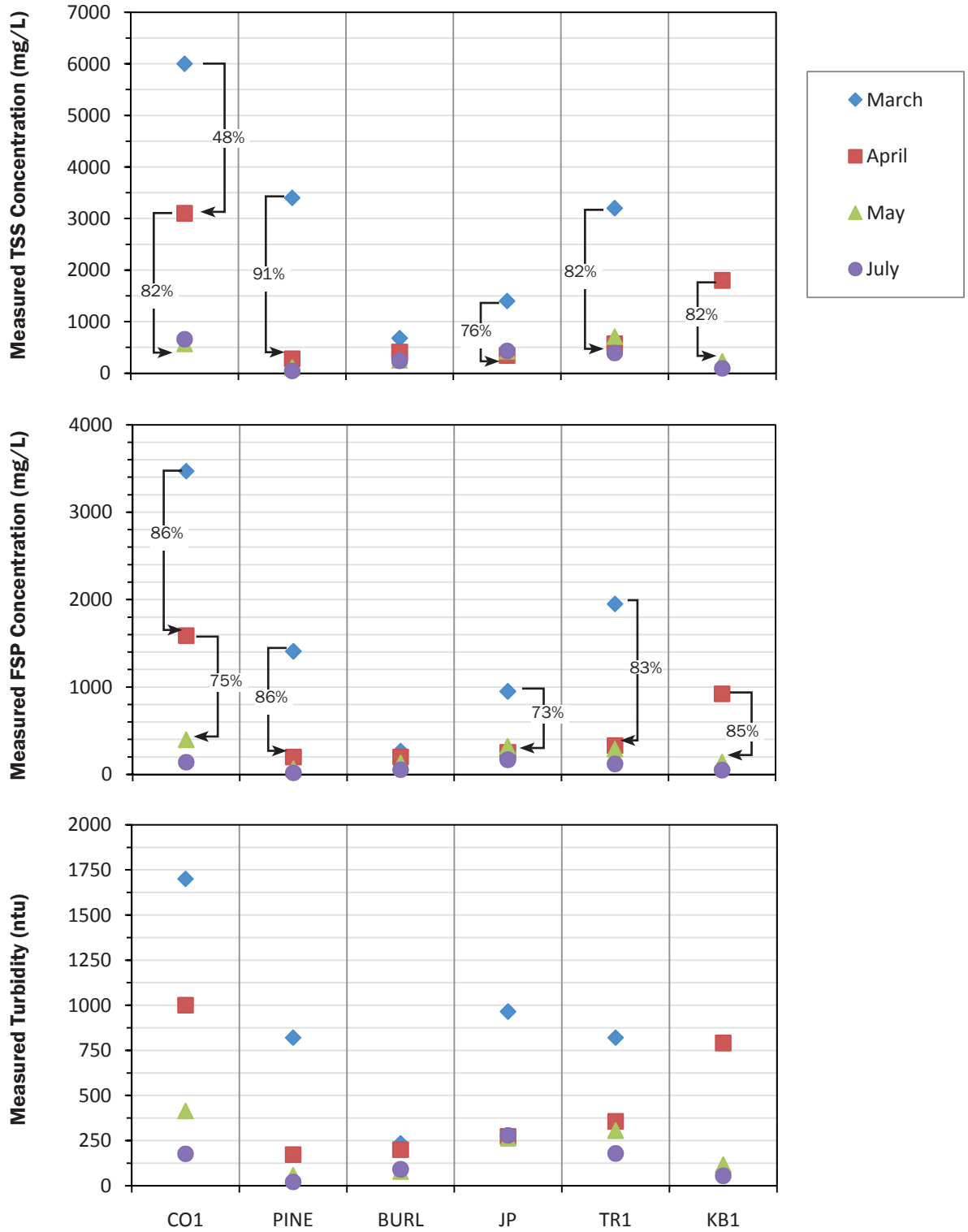
PHASE I MEASURED FSP CONCENTRATION BY JURISDICTION

FIGURE 4.9



	CO1	PINE	BURL	JP	TR1	KB1
Road Risk Category	SHR	SHR	SMR	SMR	SMR	SMR
Road Shoulder Condition	1	1	1	1	1	4
Road Surface Integrity	High	Mod	High	Mod	Low	High
# of sweeps	4	1	4.5	7.5	5	5

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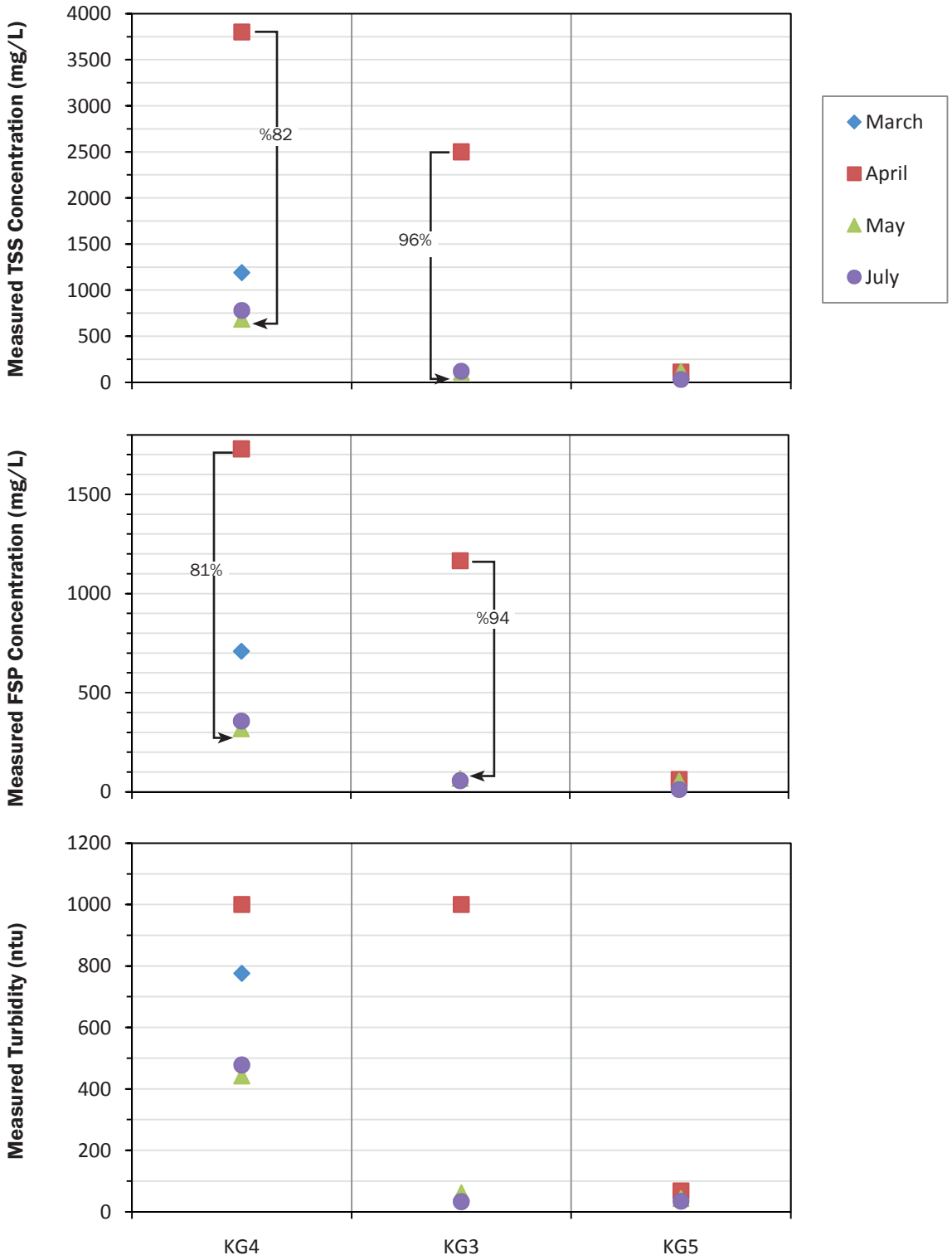
PHASE I URBAN ROAD MONITORING RESULTS: PLACER COUNTY

FIGURE 4.10

  - The poorest wet sample water quality over the entire study period was observed at CO1 in March. CO1 is an erodible secondary high risk road that is a main thoroughfare in the Kings Beach neighborhood.
- **Douglas County** (Figure 4.11):
  - Douglas County reported that they did not sweep any of the sampled road sites within their jurisdiction. Any reductions in observed water quality concentrations from one sampling period to the next are assumed to be due to pollutant wash off as a result of wind, car traffic or entrainment by stormwater runoff events.
  - Over the 2009 winter, Douglas County displayed relatively high maximum, average and median TSS and FSP concentrations (Figures 4.8 and 4.9) in comparison to other jurisdictions.
  - The two SMR road segments displayed observed significant reductions in TSS and FSP concentrations between the April and May sampling efforts. Between these two sampling efforts well over 2 inches of rain fell during a storm in early May. In this instance, it is assumed the road condition improved between April and May because a rainstorm mobilized the pollutants and transported them downslope within the stormwater system.
  - KG5, a stable, secondary low risk road with high road surface integrity, displays some of the lowest values observed throughout the entire study period across all jurisdictions. This may be due to the lack of pollutant sources to the road. It is highly improbable that a large amount of road abrasives are applied to this secondary low risk (SLR) road segment and road shoulder erosion is unlikely due to the existing road shoulder improvements.
- **NDOT** (Figure 4.12):
  - Currently NDOT does conduct road sweeping and they use a regenerative air (dustless) sweeper.
  - Over the 2009 winter, NDOT displayed relatively moderate maximum, average and median TSS and FSP concentrations (Figures 4.8 and 4.9) in comparison to other jurisdictions.
  - Based on the limited dataset, KG1 consistently has among the lowest TSS and FSP concentrations throughout the monitoring period, and it is a Primary High Risk (PHR) road. The road shoulder condition is stable and road surface integrity is high. Since this is a heavily trafficked intersection of Kingsbury Grade and Highway 50, detailed sweeping and abrasive application records for this road segment would be extremely valuable. Based on information provided by NDOT personnel, KG1 was swept a total of 12 times from mid-February through mid-May using a regenerative air (dustless) sweeper.
  - NDOT resurfaced Highway 28 between Spooner Meadow and Incline Village in the spring of 2009. The July 2009 FSP concentration at H28B, a primary low risk road, represents observations conducted on a new urban road and is among the lowest measured values (< 20mg/L) during the entire study period.
- **Caltrans** (Figure 4.13):
  - Currently data on Caltrans Phase I pollutant recovery details are unavailable, but representatives confirm the use of Tymco (DST-6) regenerative air sweeper. The lack of sweeping information makes comparisons between the road segments challenging.
  - All of Caltrans road segments monitored are either primary high risk (PHR) or primary moderate risk (PMR) roads and thus assumed to have a relatively higher frequency and amount of road abrasive applications during winter road conditions, yet the measured wet sample results are lower than many other road segments with a lower expected water quality risk.
  - Observations and discussions with Caltrans (L. Case, pers. comm.) following the water quality measurements made at the EI site indicated Caltrans was testing a regenerative air sweeper in this area in March 2009. The EI site is located in front of the office of Environmental Incentives (a



	KG4	KG3	KG5
Road Risk Category	SMR	SMR	SLR
Road Shoulder Condition	4	4	4
Road Surface Integrity	Mod	Mod	High
# of sweeps	0	0	0

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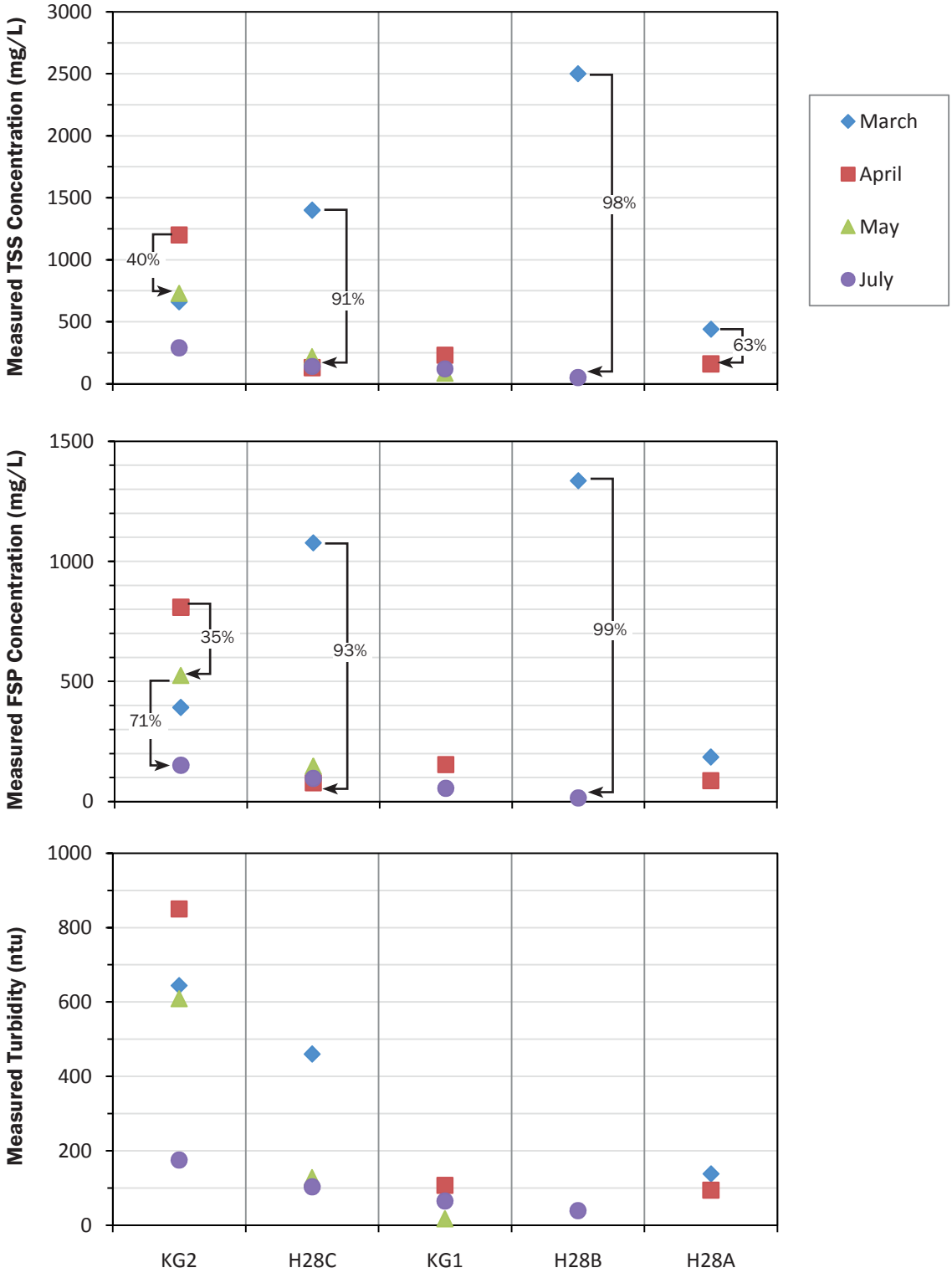
PHASE I URBAN ROAD MONITORING RESULTS: DOUGLAS COUNTY

FIGURE 4.11



	KG2	H28C	KG1	H28B	H28A
Road Risk Category	PHR	PHR	PHR	PLR	PLR
Road Shoulder Condition	1	5	5	3	5
Road Surface Integrity	Mod	High	High	High	High
# of sweeps	15	9	12	6	9

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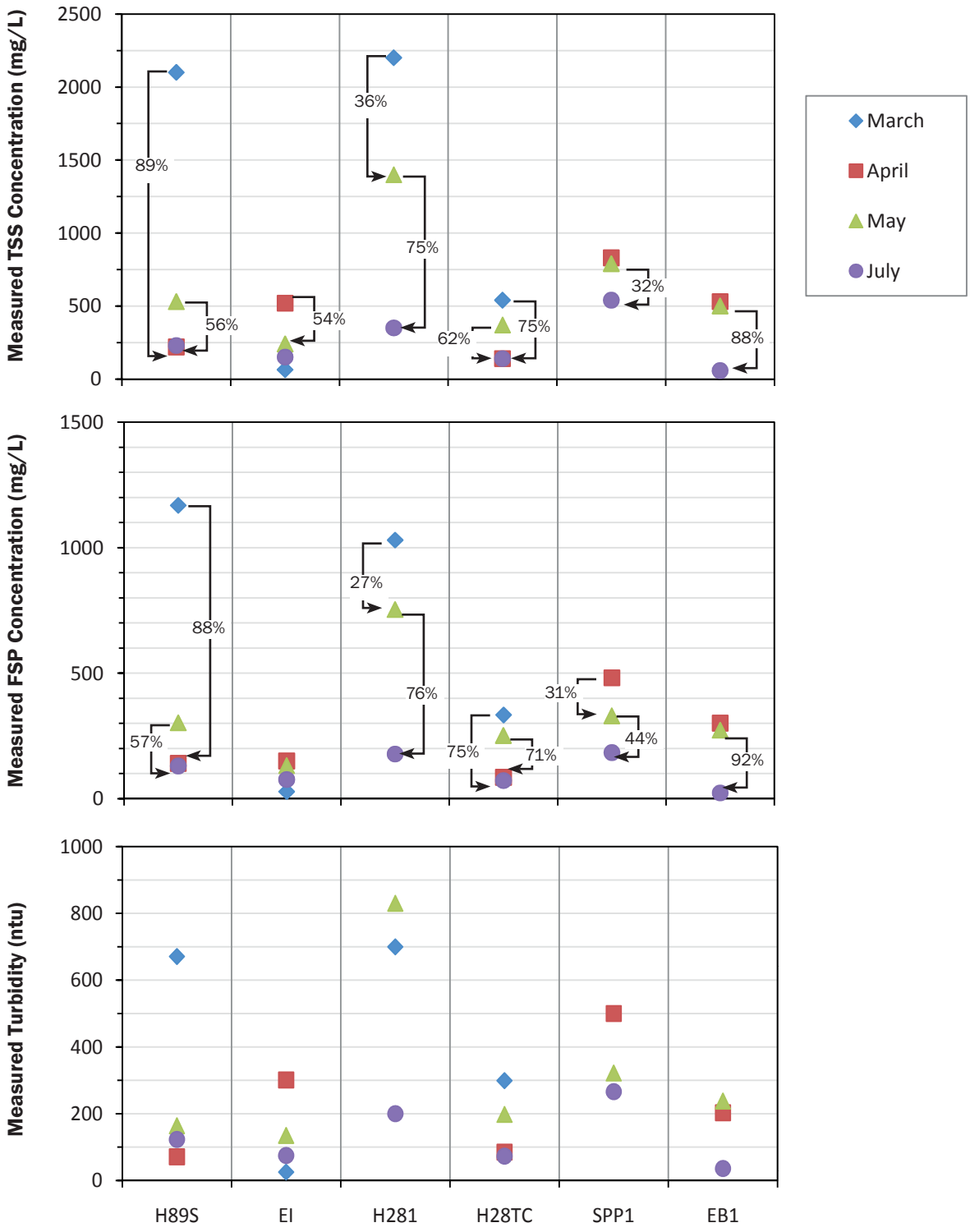
PHASE I URBAN ROAD MONITORING RESULTS: NDOT

FIGURE 4.12



	H89S	EI	H281	H28TC	SPP1	EB1
Road Risk Category	PHR	PHR	PHR	PHR	PMR	PMR
Road Shoulder Condition	3	5	5	5	3	3
Road Surface Integrity	Mod	Mod	Mod	Mod	Mod	Mod
# of sweeps	n/a	n/a	n/a	n/a	n/a	n/a

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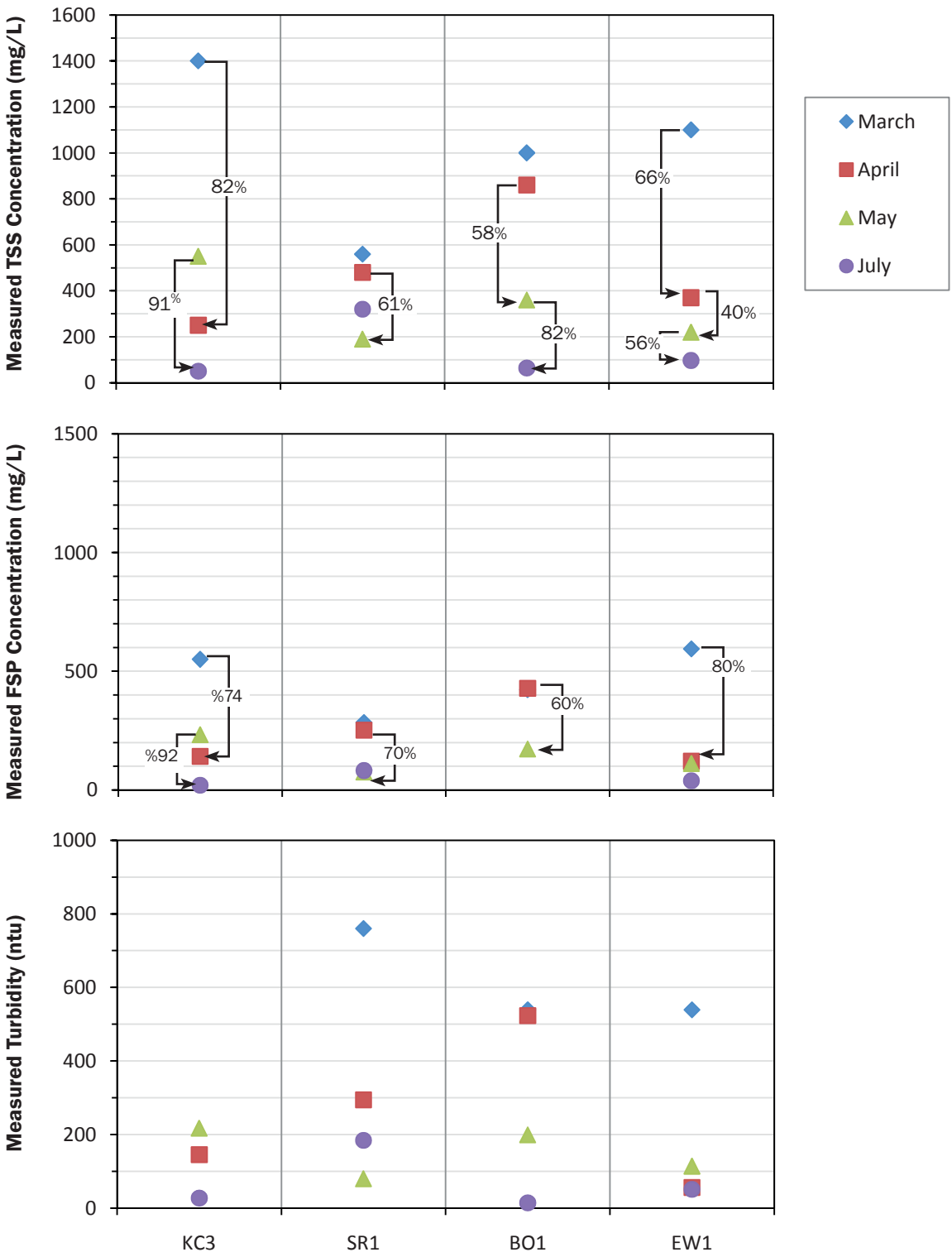
PHASE I URBAN ROAD MONITORING RESULTS: CALTRANS

FIGURE 4.13

2NDNATURE partner) at the high traffic density area at the "Y" in South Lake Tahoe. Visual reports from EI personnel confirmed multiple passes by a regenerative air sweeper prior to the March 2009 road sampling at this site, which was the cleanest road observed during the 3-day sampling period with TSS concentration of 64 mg/L and FSP concentration of 27.5 mg/L. The EI March road condition strongly supports the water quality value of increased sweeping frequency using a high efficiency sweeper.

- **City of South Lake Tahoe [CSLT]** (Figure 4.14):
  - CSLT averaged two sweeps per road segment using a mechanical broom sweeper from April through July.
  - Over the 2009 winter, CSLT displayed relatively moderate to low maximum, average and median TSS and FSP concentrations (Figures 4.8 and 4.9) in comparison to other jurisdictions.
- **El Dorado County** (Figure 4.15):
  - Based on the limited data available, El Dorado County appears to target primary roads for substantial sweeping efforts and currently uses a regenerative air sweeper.
  - Over the 2009 winter, El Dorado County displayed relatively moderate to low maximum, average and median TSS and FSP concentrations (Figures 4.8 and 4.9) in comparison to other jurisdictions.
  - HM2, which is located on Pioneer Trail near Sierra House School, was swept an estimated 36 times between March and July and has relatively low observed water quality concentrations. FSP concentrations are consistently below 300 mg/L, but unfortunately it was not sampled in March when most road segments were observed in relatively poorer conditions.
  - The maximum observed TSS and FSP concentrations at HM3 are very high (2300 mg/L and 501 mg/L, respectively) and this road segment has perhaps the worst road surface integrity of any road segment monitored during the Phase I with both dry and wet sampling indicating the significant pollutant storage capability of cracks within the road surface (see photo in Figure 4.10). More information on the ability of different sweeper types to clean material from roads with low integrity is necessary.
- **Washoe County** (Figure 4.16):
  - Washoe County has a very proactive road maintenance strategy that prioritizes sweeping as a source control technique to protect downslope water quality. All road segments were swept a minimum of 4 times using a high-efficiency vacuum-assisted sweeper (dustless).
  - Over the 2009 winter, Washoe County displayed relatively low maximum, average and median TSS and FSP concentrations (Figures 4.8 and 4.9) in comparison to other jurisdictions.
  - VIL1, a secondary high risk road maintained for traffic safety throughout the winter season (i.e., likely high road abrasive application), has FSP concentrations consistently below 100 mg/L during the entire 5-month sampling period. VIL1 was targeted by road maintenance personnel throughout the Phase I and was consistently swept 2-3 times in the month prior to urban road monitoring.
  - Road segment JEN also shows FSP concentrations below 100 mg/L throughout the sampling period. This is likely due to a combination of consistent sweeping practices (once prior to each sampling effort) and lower road abrasive applications.



	KC3	SR1	BO1	EW1
Road Risk Category	SHR	SHR	SMR	SLR
Road Shoulder Condition	5	5	1	1
Road Surface Integrity	High	High	Low	Low
# of sweeps	4	2	2	2

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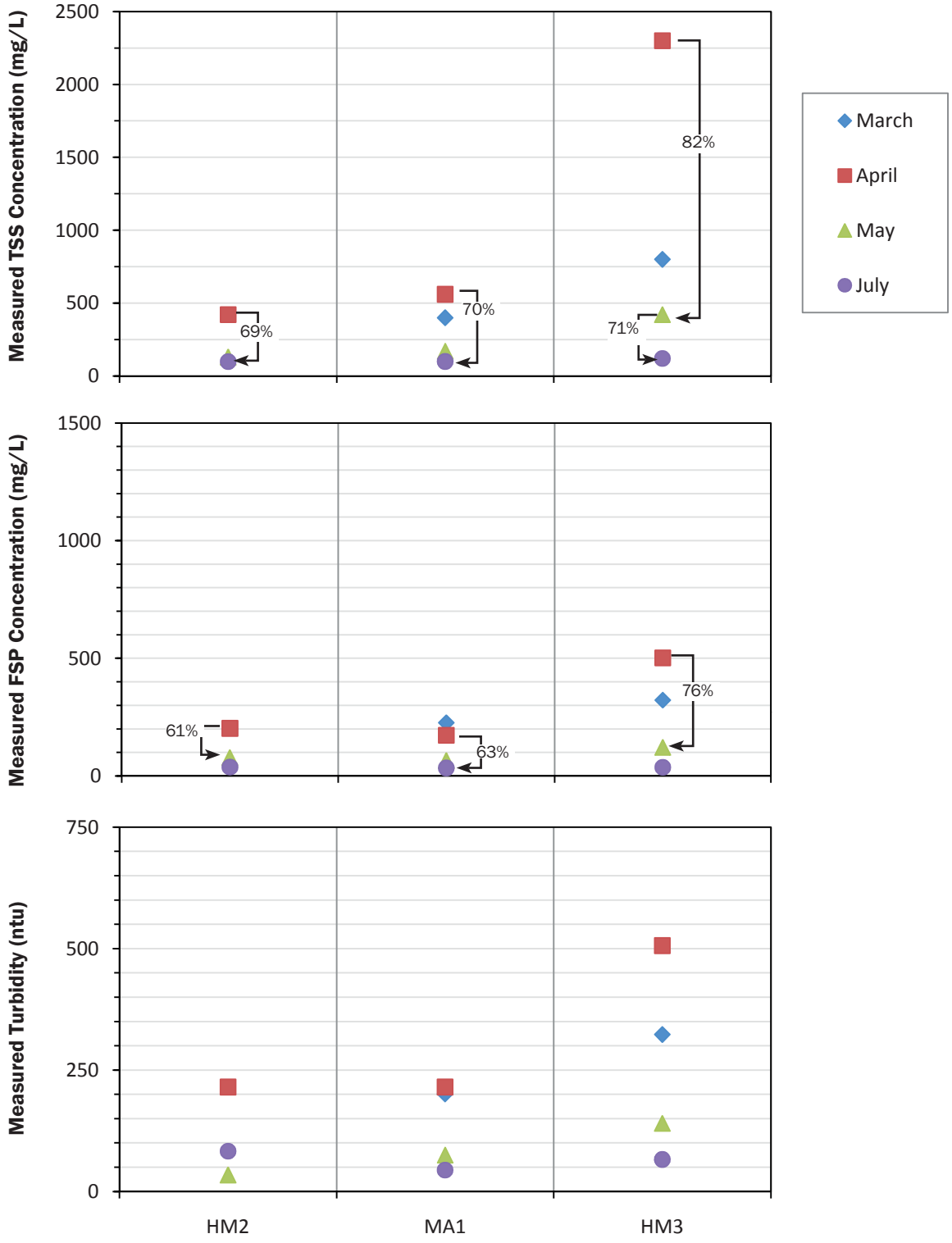
PHASE I URBAN ROAD MONITORING RESULTS: CSLT

FIGURE 4.14



	HM2	MA1	HM3
Road Risk Category	PLR	SHR	SLR
Road Shoulder Condition	4	4	5
Road Surface Integrity	High	Low	Low
# of sweeps	36	2	4

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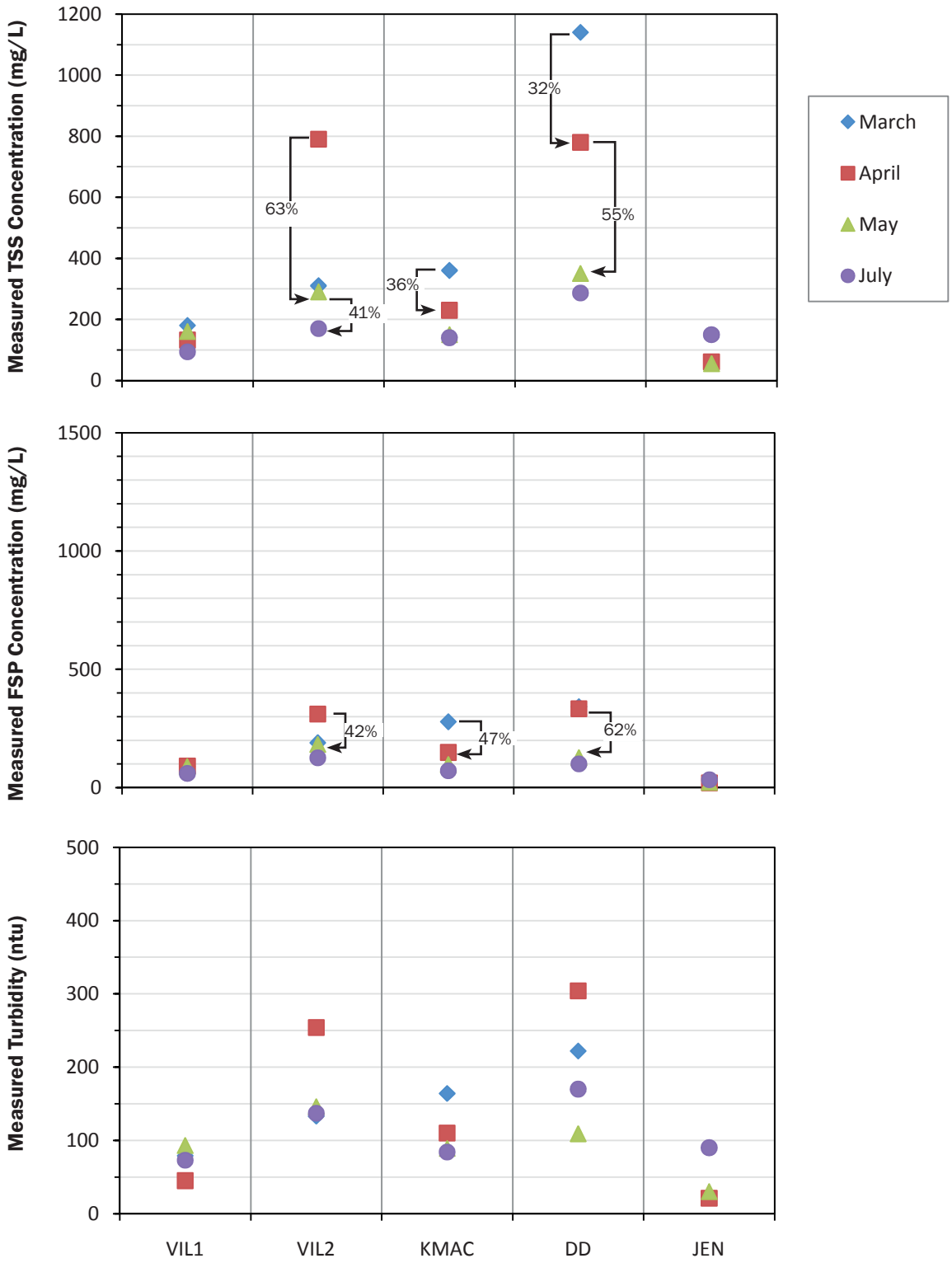
PHASE I URBAN ROAD MONITORING RESULTS: EL DORADO COUNTY

FIGURE 4.15



	VIL1	VIL2	KMAC	DD	JEN
Road Risk Category	SHR	SHR	SMR	SMR	SLR
Road Shoulder Condition	1	5	3	5	1
Road Surface Integrity	Mod	Mod	Mod	High	Mod
# of sweeps	11	7	5	4	4

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PHASE I URBAN ROAD MONITORING RESULTS: WASHOE COUNTY

FIGURE 4.16

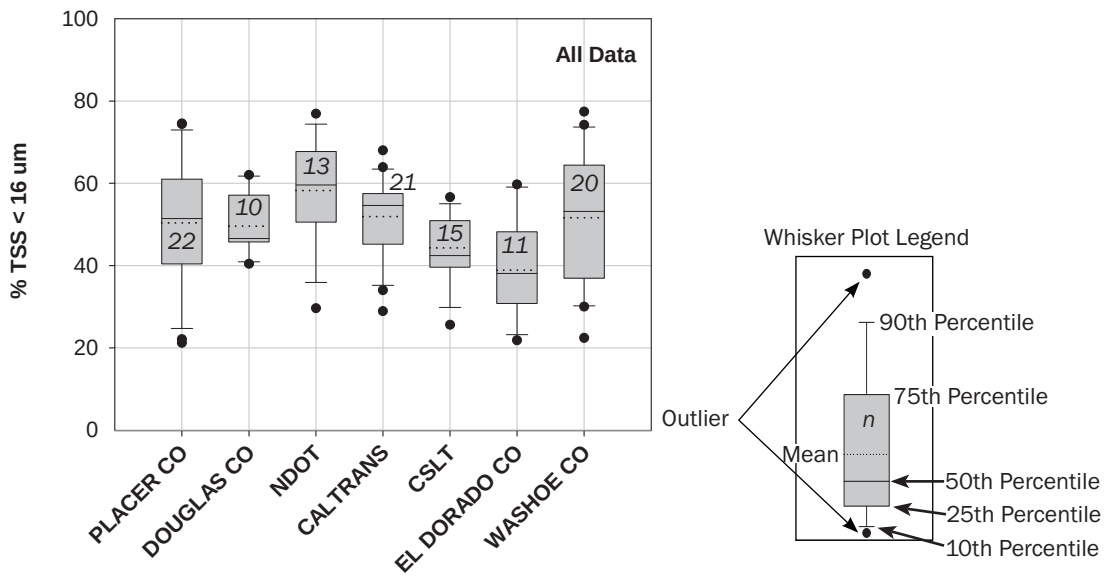
The Phase I data and somewhat vague comparison of jurisdictional road maintenance practices prior to 2NDNATURE road sampling do suggest three preliminary conclusions with respect to road maintenance practices.

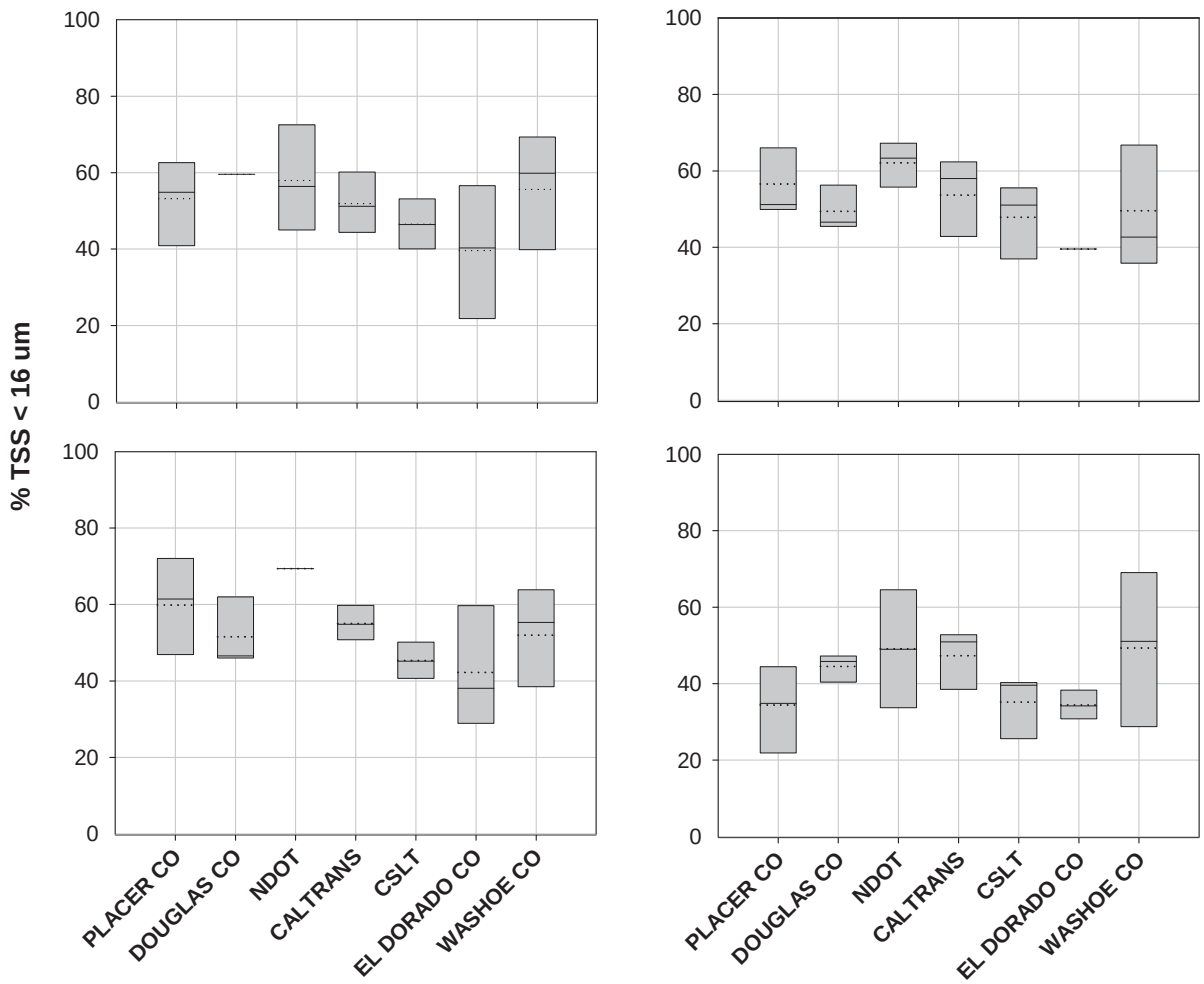
1. There is evidence to support that both sweeping frequency and sweeper type do improve road condition on short time scales as measured by the portable wet sample simulator and supported by rapid and visual observations.
2. The existing data suggests poor road integrity also can influence the magnitude of fine particles stored on the urban road surface and potential available for transport during a subsequent runoff event.
3. PLRM v1 estimates the maximum reduction in TSS and FSP CRCs for high frequency sweeping practices using a high efficiency vacuum-assisted sweeper is 38.1% and 26.7%, respectively. The comparisons of PLRM CRC predictions with measured TSS and FSP concentrations indicate a consistent overestimate of Caltrans primary high risk (PHR) roads where frequent sweeping using high efficiency vacuum sweepers was assumed in some cases. Continued and more focused controlled studies, including catchment-scale sweeping efficiency, need to be completed to better inform these preliminary hypotheses.

Figure 4.17 presents the % of the TSS <16µm (% FSP) with the jurisdictions in the same order as the Figure 4.9 to illustrate that the isolated interpretation of % FSP as an indicator of water quality risk can be misleading and FSP should be evaluated in the context of mass (or total number of particles) when assessing water quality. For instance, Washoe County roads were observed to have a lower range of and lower maximum FSP and TSS concentrations, and thus lower FSP and TSS loading during subsequent runoff events. However, the observed % FSP values were relatively higher than other jurisdictions. This result is likely due to a reduction in the mass of the material > 16µm on Washoe County roads due to frequent sweeping, thereby increasing the relative fraction of the fines. The results of % FSP are variable by jurisdiction for all data. The seasonal plots suggest a general coarsening of urban road sediment from March to July.

Specific Site Comparison

The PLRM Road Methodology (Appendix B) included contrasting water quality data from urban catchment data from two relatively similar catchments, with respect to slope, size and land-use distribution (sites AD and DD). The 2009 winter road sampling included road segments within each of the AD and DD catchments to validate previous assumptions in the PLRM Road Methodology development. The Phase I wet sampling results for road segments KG4 and DD are compared to illustrate the possible effects of road sweeping on observed TSS and FSP concentrations. KG4 is a stable, steeply sloped secondary moderate risk road with moderate road surface integrity within the jurisdiction of Douglas County. DD is a stable and protected steeply sloped secondary moderate risk road with high road surface integrity within Washoe County's jurisdiction. Based on conversations with jurisdiction road maintenance personnel, these two jurisdictions have very different sweeping strategies. Douglas County did not sweep any of the sampled urban roads within their jurisdiction (KG3, KG4 and KG5) (M. Azad, pers. comm.). In contrast, Washoe County has a very proactive sweeping strategy and sweeping is considered a "mobile water quality BMP" by Dick Minto of Washoe County (pers. comm.). Figure 4.18 shows the observed water quality concentrations for the two road segments from March through July. The March observed TSS concentrations are similar for KG4 and DD (742 mg/L and 705 mg/L, respectively); however the FSP concentration observed at KG4 were over 1.5 times DD (427 mg/L compared to 252 mg/L). As documented in Table 4.3, DD was swept once in the month preceding the March monitoring event using a high-efficiency vacuum-assisted sweeper (dustless). April 2009 monitoring shows a marked difference in both the TSS and FSP concentrations observed at these two SMR road segments. KG4 values (3800 mg/L TSS and 1730 mg/L FSP) are nearly five times higher than those measured at DD (780 mg/L TSS and 330 mg/L FSP).DD was again swept once during the month before the April monitoring, using the same high-efficiency vacuum-assisted sweeper (dustless).





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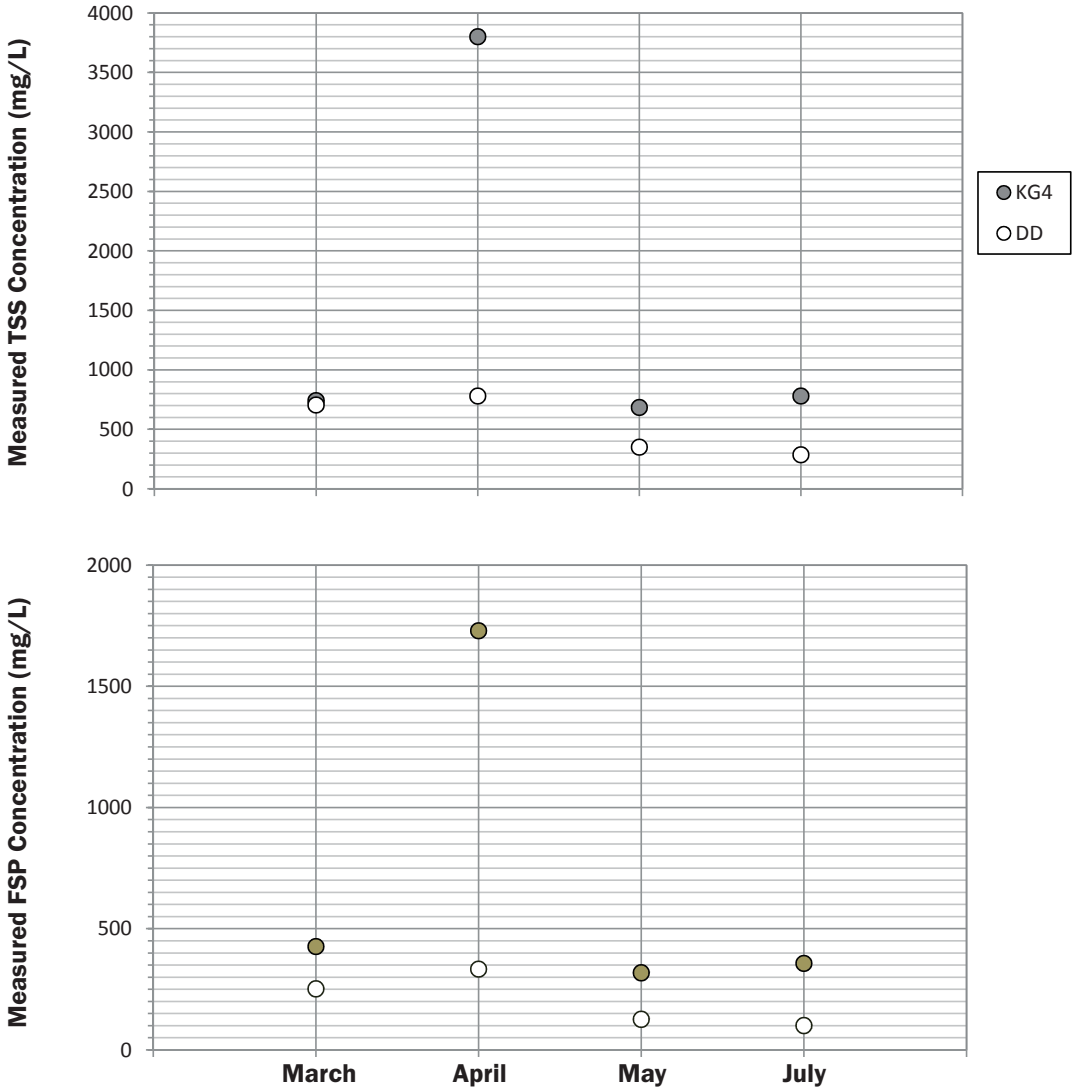
PHASE I MEASURED %FSP VALUES BY JURISDICTION

FIGURE 4.17



KG4 Road Segment March 2009

DD Road Segment March 2009

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ROAD SEGMENT COMPARISON: SWEEPING PRACTICES

FIGURE 4.18

ROAD RAM DEVELOPMENT

The Phase I road sampling efforts were conducted in a manner to inform the Road RAM tool being developed by 2NDNATURE, nhc and Environmental Incentives with the initial version release in the Spring of 2010. Road RAM will be a rapid assessment tool to determine the condition of an urban road with respect to relative water quality risk if a runoff event were to occur. Road RAM will be consistent with a lot of the urban rapid assessment concepts defined in the initial version of BMP RAM (2NDNATURE 2009), including the tool components (Technical Document, Users Manual and custom Road RAM database), scoring concepts (0-5), and the general RAM STEPs undertaken by the user to evaluate, obtain and track Road RAM scores over time on Lake Tahoe urban roads. Below we present the results of a multivariate analysis of covariance (ANCOVA) conducted to determine the predictive capability of visual observation results for wet sample water quality values from each road segment sampled. We then utilize the empirical road CRC and condition score relationship used in PLRM v1 to estimate the observed condition score for each road segment location sampled to inform both Road RAM protocols and validate the assumed synergy between condition scores and CRC values used in PLRM with our Phase I dataset.

Visual Observations to Determine Road Condition

An analysis of covariance (ANCOVA) was performed to test the predictive capability of road factors and rapid measurements/observations on the measured wet sample water quality results. ANCOVA was implemented using a General Linear Model (GLM) approach to determine which factors (categorical variables) and covariates (continuous variables) have significant effects in models to predict water quality components (response variables). The analysis utilizes built-in regression using the covariates to predict the dependent (i.e., response) variables. An ANCOVA on the residuals (the predicted minus the actual dependent variables) determines if the factors are still significantly related to the dependent variable after the variation due to the covariates has been removed.

The datasets used in the analysis were one of two types, either continuous values (i.e., TSS concentration (mg/L) or dry material mass (mg)) or categorical (i.e., integrity (H, M, L). A natural log (LN) transformation was applied to continuous independent and dependent variables that were found to be significantly non-normal by the Anderson Darling normality test. The variables are transformed to avoid unequal variance and non-normality in the model residuals, which can violate the linear model assumptions required for the statistical analysis.

Categorical predictors were included in the model as discrete factors, and continuous predictors are included as covariates. For each response variable, a manual backward stepwise procedure was used to remove insignificant predictor variables. At each step, the least significant predictor was removed until either the performance of the model substantially worsened as indicated by the adjusted R^2 and S performance measures, or all of the predictors were significant at the alpha = 0.10 level (i.e., 90% confidence interval).

The predictor variables included in the initial models were:

- Road risk category (categorical)
- Jurisdiction (categorical)
- Road shoulder condition (1-5) (categorical)
- Road surface integrity (H, M, L) (categorical)
- Month of sample collection (categorical)
- Degree of fines (H, M, L) at location of wet sample collection (categorical)
- LN of dry sample mass (mg) at location of wet sample collection (continuous)
- LN of FSP dry mass (mg) at location of wet sample collection (continuous)
- Percent of dry fines (<16µm) at location of wet sample collection (continuous)

The water quality parameters tested as response variables were:

- LN of wet sample TSS concentration (mg/L)
- LN of wet sample FSP concentration (mg/L)
- LN of wet sample turbidity (ntu)
- % FSP (% of TSS <16µm) of wet sample

Results of the ANCOVA are given as a matrix of F statistics and p-values for each predictor and response variable (Table 4.5). The F statistics indicate which individual factors and covariates have a significant effect in the best predictive model determined for the individual response variables and can be expressed as a ratio of explained variance/unexplained variance. *Thus the higher the F statistic value the lower the unexplained variance.* The p-value (or alpha level) tells us the probability of incorrectly rejecting the null hypothesis that the predictor variable has no effect on the response variable. *The smaller the p-value the greater the significance the variable is as a predictor variable in the model.* For example, a p-value of 0.10 indicates there is a 10% chance that the effect on the response variable is due purely to random chance. Inversely, we are 90% confident that the predictor variable has a significant and consistent effect on the response variable. The results of the ANCOVA for each water quality parameter (response variable) are explained below. As explained above, some of the predictor and response variables have been natural-log transformed to satisfy normality assumptions of the GLM procedure.

Table 4.5. Statistical results from ANCOVA analysis of Phase I urban road monitoring dataset. Blank cells (represented by "-") indicate the predictor was removed during stepwise procedure.

	Response Variable							
	TSS (mg/L)		**FSP (mg/L)**		**Turbidity (ntu)**		**% FSP (% of TSS <16µm)**	
Predictor Variable	F	p-value	F	p-value	F	p-value	F	p-value
Road Risk Category	3.84	0.012	4.12	0.004	2.88	0.037	2.78	0.043
Degree of Fines	4.70	0.016	8.17	0.001	10.4	0.000	4.92	0.013
Month	2.72	0.061	11.1	0.000	2.82	0.054	-	-
Dry Mass (mg)	0.84	0.367	8.44	0.004	-	-	7.44	0.010
FSP Dry Mass (mg)	4.99	0.033	-	-	0.18	0.676	-	-
Road Shoulder Condition	4.38	0.011	-	-	-	-	-	-
Jurisdiction	-	-	-	-	-	-	4.07	0.003
Dry FSP %	-	-	-	-	-	-	2.35	0.135
Road Surface Integrity	-	-	-	-	-	-	-	-
Performance	**TSS (mg/L)**		**FSP (mg/L)**		**Turbidity (ntu)**		**% FSP**	
R^2	77.8%		65.0%		69.5%		63.7%	
R^2 adjusted	68.1%		61.7%		60.6%		50.6%	
S	0.631		0.729		0.653		9.05	

The goodness of fit for each ANCOVA model is indicated by the following performance measures:

- **R^2** represents the proportion of variation in the response data that is explained by the predictor. R^2 is calculated as the ratio of the sum of squares for regression over the total sum of squares.
- **R^2 adjusted** is a modified R^2 that has been adjusted for the number of terms in the model. If you include unnecessary terms, R^2 can be artificially high. Unlike R^2, adjusted R^2 may get smaller when you add insensitive terms to the model.
- **S** is measured in the units of the response variable and represents the standard distance of the observed from the predicted values. The better the model predicts the response variable, the lower the S value.

TSS (MG/L)

The predictor variables 'Road Risk Category', 'Degree of Fines', 'Month', 'Dry Mass', 'FSP Dry Mass', and 'Road Shoulder Condition' explained 68.1% of the variance (R^2 adjusted) in the TSS concentrations (mg/L). All of the predictors in the model were significant at the 0.10 alpha level except for 'Dry Sample Mass'. However, substantial reductions in R^2 adjusted and S occurred when 'Dry Sample Mass' was removed from the model.

FSP (MG/L)

The predictors 'Road Risk Category', 'Degree of Fines', 'Month', and 'Dry Mass' were included in the model that explained 61.7% of the variance (R^2 adjusted) in LN of FSP concentrations. All of the predictor variables for the final FSP model were significant at the 0.01 (99%) confidence level.

TURBIDITY

The final predictors 'Road Risk Category', 'Degree of Fines', 'Month', and 'FSP Dry Mass' explained 60.6% of the variance (R^2 adjusted) in LN of turbidity. Other predictors were iteratively removed from the turbidity model using the procedure described above. All of the predictors included in the model were significant (alpha = 0.10 level) except for 'FSP Dry Mass' (see Table 4.5). However, when 'FSP Dry Mass' was removed from the model the variance in turbidity was reduced by approximately 20%, so it was included in the final model.

% FSP

Predictor variables 'Road Risk Category', 'Degree of Fines', 'Dry Mass', 'Jurisdiction', and 'Dry FSP%' explained 50.6% of the variance in % FSP measured in wet samples. All of the predictors included were significant except for 'Dry FSP%', whose removal resulted in approximately 10% reduction in the R^2 adjusted performance of the model.

FUTURE TESTING

The results of the ANCOVA are very encouraging for the application of rapid field observations/measurements to predict water quality parameters such as TSS and FSP concentrations, and inform the Road Rapid Assessment Method (Road RAM) tool. This simple GLM integration of independent rapid observation and road factors resulted in models that explained 68% of TSS concentration variance and 62% of FSP concentration variance. We know there are interaction effects between model variables that have not been taken into account. Interaction effects are the joint effects of pairs, triplets, or higher-order combinations of predictor variables, different from what would be predicted from any of the predictors acting alone. Additionally, there may be colinearity between model variables (e.g., dry mass and dry mass FSP) that was not constrained during the initial analysis. Interactions between two or more predictor variables likely contributed to the inclusion of variables during the model fitting procedure that substantially improved the model performance even though they were not significant on their own. In addition, some of the predictive variables are visual observations of a road segment that are expected to change with road condition (i.e., degree of fines, dry mass, etc.) and others are road segment factors that are expected to influence condition (i.e., road risk category, road shoulder condition, etc.).

We did not begin to address and solve the predictive and response variable interactions in this initial analysis. The next steps in the Road RAM development process by the 2NDNATURE team is to determine the best way that field observations and measurements can be adjusted, augmented, and statistically combined with one another to determine Road RAM scores for each evaluation. Additional GLM development including a principal components

or a factor analysis will be completed to identify a robust approach to integrating these variables and to create a model that explains more of the variance in the response variable and eliminates non-significant predictors (p-value > 0.1). We anticipate the predictive capacity of field observations and measurements will be refined and improved as more data are collected and complete water years of road condition observations are obtained.

The similar occurrence of significant predictor variables (e.g., road risk category) in each of the turbidity, TSS and FSP response variables is likely due to covariation of these response variables. A Pearson correlation matrix shows very strong, highly significant (alpha level <0.001) association between the LN of TSS and turbidity and between LN of TSS and FSP concentration. This statistical correlation is expected and implies that a similar set of field measurements/observations may be appropriate for prediction of TSS, FSP and/or turbidity. Conversely, selected field measurements may be used as proxies to estimate other water quality parameters. For example, regression slope of the log-transformed variables may be used to estimate TSS from field turbidity measurements.

Road Condition Scores

The initial version of the Road RAM will be released in the spring of 2010 and the Phase I dataset is extremely informative as specific components of the tool are being developed by the 2NDNATURE team. This initial road sampling dataset suggests that the PLRM urban road CRC ranges are representative of measured wet sample values (see Table 4.4). PLRM Road Methodology is based on an empirical relationship between condition scores and expected TSS and FSP CRCs. The PLRM Road Methodology (Appendix B) estimates the TSS and FSP CRC for a specific road risk category using empirically derived equations presented in Figure 4.19. The PLRM equations are:

$$PLRM\ TSS\ CRC\ (mg/L) = 1971e^{-0.689*\ Conditiontss\ score} \quad \text{[EQ1]}$$

$$PLRM\ FSP\ CRC\ (mg/L) = 1592e^{-0.850*Conditionfsp\ score} \quad \text{[EQ2]}$$

The CRC equations can be rearranged to calculate the condition score (0-5) for each road segment and each sampling period based on the measured TSS and FSP concentrations obtained during this study from the controlled experiments.

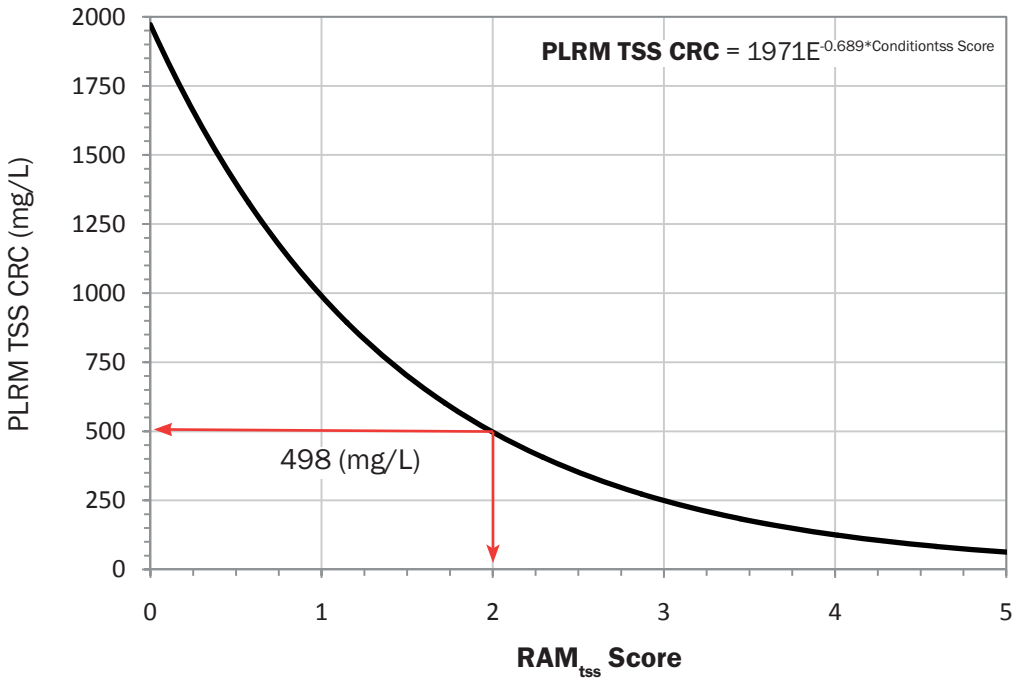
$$Condition_{tss}\ score = (ln\ (measured\ TSS\ concentration\ (mg/L)/1971))/-0.689 \quad \text{[EQ3]}$$

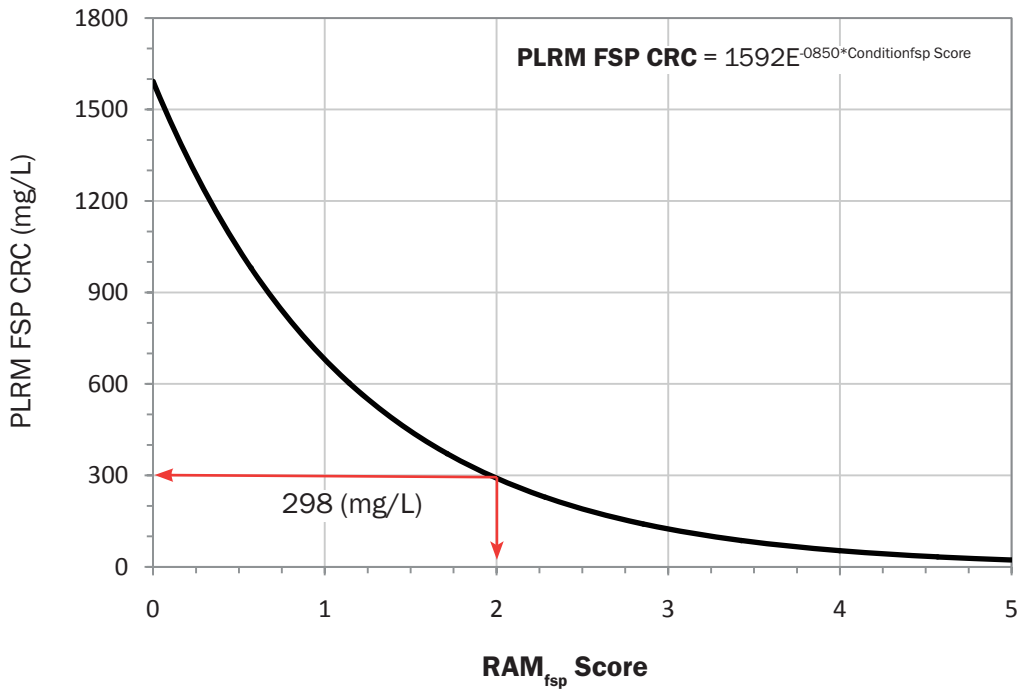
$$Condition_{fsp}\ score = (ln\ (measured\ FSP\ concentration\ (mg/L)/1592))/-0.850 \quad \text{[EQ4]}$$

The rearrangement of these equations to solve for condition scores based on measured TSS and FSP concentrations are representative of only the specific location where the water sample was obtained from each sampling effort. These measured conditions scores calculated by the equations above are not directly comparable to the estimated condition scores obtained from PLRM, as PLRM is estimating over both different spatial and temporal scales. However, these comparisons are informative for the next steps in Road RAM tool development. In most instances the $Condition_{tss}$ score and $Condition_{fsp}$ score were similar, but in order to present just one measured condition score for each sampling period per road segment, the condition scores were integrated using a weighted average, prioritizing the FSP concentration signal as the primary pollutant of concern in Lake Tahoe.

$$Condition\ Score = (Condition_{fsp}\ score*0.75) + (Condition_{tss}\ score*0.25) \quad \text{[EQ5]}$$

Figure 4.20 presents the 119 measured condition scores as calculated from the equations above. Road segments are ordered by increasing road condition as predicted by PLRM from left to right. The condition scoring system is taken directly from the BMP RAM (2NDNATURE 2009) and shown in Table 4.6. A condition score of 2 is defined as





Condition$_{tss}$ Score = (ln(measured TSS concentration/1971))/-0.689
Condition$_{fsp}$ Score = (ln(measured FSP concentration/1592))/-0.850
Condition Score= (Condition$_{fsp}$ score*0.75) + (Condition$_{tss}$ score*0.25)

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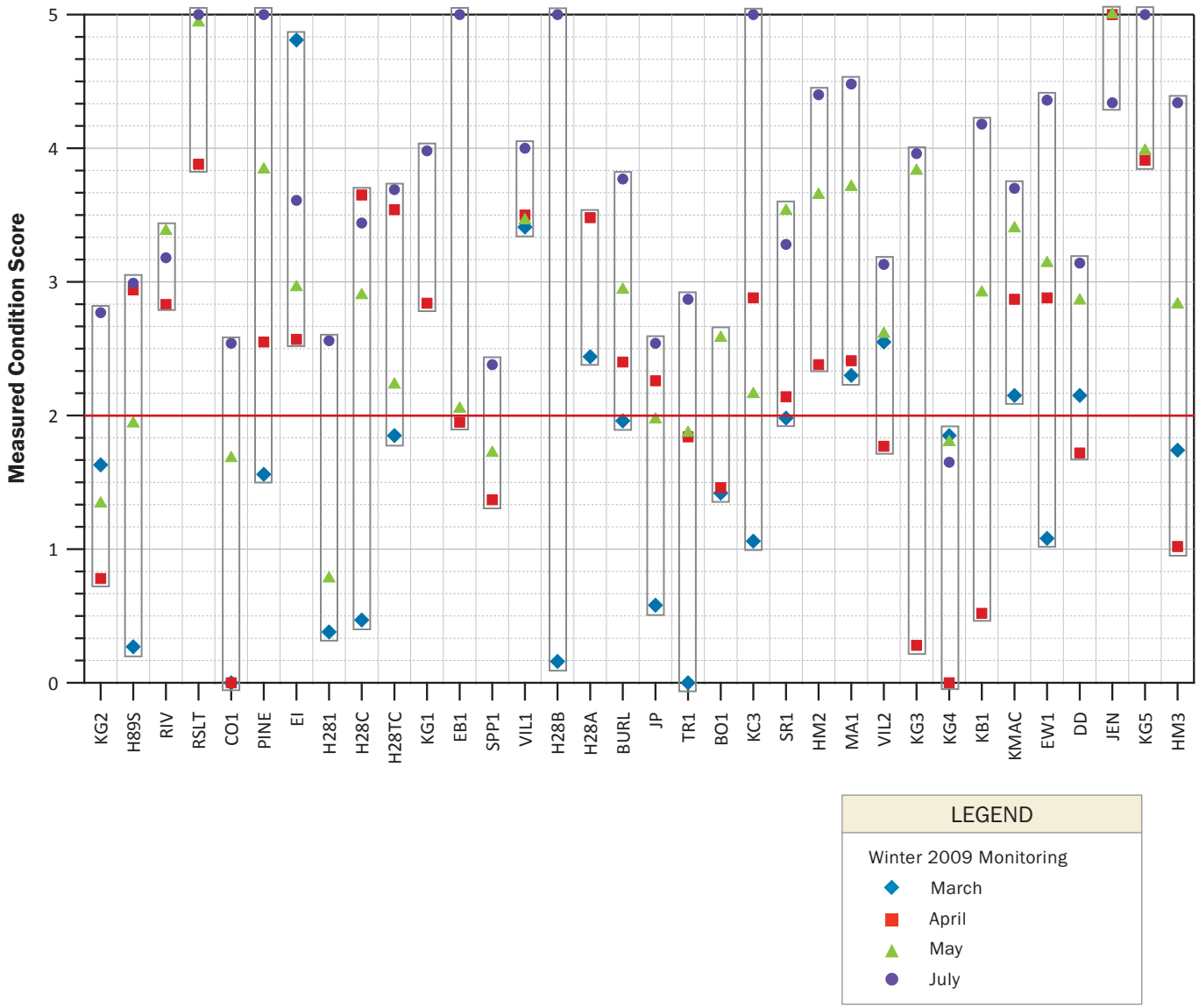
PLRM V1 TSS AND FSP CRC RATING CURVES

FIGURE 4.19



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PHASE I MEASURED CONDITION SCORES

FIGURE 4.20

the threshold, below which a specific road condition is considered unacceptable with respect to water quality. Based on the PLRM v1 equations, TSS (mg/L) > 498 mg/L and FSP (mg/L) > 298 mg/L, equate to the threshold condition score of 2. Using this evaluation approach, 37 (31%) of the 119 road observations equated to a condition score of 2 or lower, with the highest incidence of occurrence in March and April. Eleven road segments (9%) were observed to be above a condition score of 2 for all observations. The 2NDNATURE team will use these spatial and temporal condition score patterns to inform Road RAM scoring concepts over the coming months.

Table 4.6. RAM score definitions, defined as a numeric range from 0-5. Road RAM scores will be defined consistently with BMP RAM (2NDNATURE 2009), where 5 is the best achievable road condition with respect to water quality and 2 defines the threshold where road condition is no longer acceptable from a water quality perspective.

RAM Score	Condition	Maintenance Urgency
0 - 1.0	Failure	**Required**
> 1.0 - < 2.0	Below acceptable	
2.0	**Threshold**	
> 2.0 - < 3.0	Acceptable	**Moderate**
> 3.0 - < 5.0		**Low**
5.0	Benchmark	**None**

This condition score analysis is primarily for comparison purposes to validate and apply initial PLRM assumptions and to begin to inform Road RAM protocols and should not be interpreted as a Road RAM Score. While not all of the steps are currently funded, the path towards developing, testing and refining the Road RAM tool is clear. The next steps of the Road RAM development are to:

1. Identify the most statistically robust predictive model to estimate TSS and FSP concentrations measured on urban roads by integrating visual and rapid observations, given available data. These relationships will continue to be tested into the future as the road dataset continues to be expanded.
2. Identify the most appropriate spatial scaling approach of the road sampling locations to represent the entire road segment, taking into consideration road shoulder condition, road surface integrity, and road risk category.
3. Identify recommendations for site selection applications of Road RAM to ensure results are representative on a broader spatial scale as necessary.
4. Identify recommendations on appropriate temporal observation strategies on urban roads to evaluate the relative effectiveness of road management actions on reducing water quality risk.
5. Recommend appropriate strategies to integrate discrete temporal observations to determine average annual condition.

The Phase I dataset used for this analysis is only from one winter and limited to 4 months of observations. A much more temporally representative dataset is needed to continue to validate and improve the synergistic linkages between RAM observations, wet sampling results, high resolution water quality sampling, and other discrete measurements of water quality with average annual PLRM pollutant loading estimates.

URBAN ROAD MONITORING CONCLUSIONS

- The Phase I dataset is temporally limited. PLRM estimates are on average annual time scales and the road results obtained from March to July equate to only a fraction of the annual conditions for one distinct water year.
- Road condition was observed to improve seasonally, with the maximum and the variability of TSS and FSP concentrations significantly decreasing each month (see Figure 4.5) likely due to the combination of:
  - Warmer climatic conditions increasing the duration since the last road abrasive application,
  - increased time since last winter storm increasing the # of sweeps since last road abrasive application, and,
  - the occurrence of late spring/summer rain events mobilizing sediment accumulated on the road surface and virtually rinsing the road of pollutants.
- The range of PLRM urban road CRCs for TSS (60 to 1398 mg/L) and FSP (22 to 1014 mg/L) appear to be representative of measured road conditions in Lake Tahoe (see Table 4.4). Continued controlled urban road monitoring will improve our confidence in and refine the PLRM urban road CRC values.
- Additional data and continued analytical strategy development is needed to appropriately identify reliable temporal and spatial integration of discrete observed data into long-term annual average simulations.
- PLRM estimates the maximum reduction in TSS and FSP CRCs for high frequency sweeping practices using a high efficiency regenerative air sweeper to be 38.1% and 26.7%, respectively. Preliminary findings based on this very limited dataset suggest that sweeping practices may strongly influence TSS and FSP concentrations on urban roads, and that further monitoring and analysis should focus on appropriate variability in PLRM CRCs to account for sweeping practices. The support for this hypothesis is two-fold:
  1. The jurisdictional comparisons provide evidence to support that both sweeping frequency and sweeper type result in an increase in road condition and a reduction in the water quality risk downslope (see Figure 4.8 and 4.9). Caltrans and Washoe County roads were consistently in better condition than other roads of the same road risk category, inferring that the rate and magnitude of road abrasive applications were similar, but the recovery practices were more effective from a water quality perspective. Improved communication with the jurisdictions to collect road segment-specific abrasive application history will greatly improve our ability to understand and parse out the differences in road condition relative to specific road maintenance practices.
  2. The EI road segment was observed to have the best road condition out of all roads sampled in March 2009. This is a very high risk primary road located at the “Y” in South Lake Tahoe. The repeated passes using a regenerative air sweeper prior to sampling resulted in observed TSS concentration of 64 mg/L and FSP concentration of 27.5 mg/L. The observed and measured EI March road condition strongly supports the water quality value of increased sweeping frequency using a high efficiency sweeper.
- The sites with the highest maximum TSS and FSP observations in March and April were in jurisdictions with less aggressive road sweeping programs. By July the measured TSS and FSP values were in the range of other road segments managed by jurisdictions that do actively recover road material. The difference is that where sweeping is not implemented, the material washed from the road during a subsequent rain event is entrained and now must be removed from the stormwater system elsewhere prior to reaching Lake Tahoe. Particularly with respect to FSP, source control strategies that prevent the accumulation and subsequent transport are likely more consistently reliable than the stormwater capture and subsequent passive water quality treatment processes, such as particle settling, nutrient cycling, infiltration and/or media filtration, relied upon by typical Treatment BMPs in the Lake Tahoe Basin.

- A number of visual and rapid proxies appear to be promising predictors for TSS and FSP concentrations, specifically, degree of fines by the finger test and dry material mass. Road risk category, month and road shoulder condition also show promise as predictive variables for TSS and FSP concentrations, and likely these three factors set the range of concentrations expected based on the visual observations. Road integrity appears to influence relative magnitude of TSS and FSP concentrations and is assumed to have a role in calculating RAM scores from visual observations. The road sampling dataset will continue to be used to test, develop and validate the primary observations, integration methods and scoring approach of the Road RAM in the following months.

URBAN ROAD MONITORING: NEXT STEPS

Perhaps the greatest value of this urban road research is the establishment of standardized and consistent protocols to sample stormwater runoff water quality from urban roads. This dataset is rich with information to test PLRM assumptions and urban road CRC values and inform Road RAM and will continue to be analyzed as specific road condition and pollutant generation questions are asked. The 2NDNATURE team will continue the road sampling efforts through WY2011 using SNPLMA Round 9 funds that are intended to build upon the efforts initiated by this Army Corps of Engineers contract. This consistent and expanded dataset will allow the research team to refine the sensitivity of specific source and sink factors in PLRM to improve predictive capability of average annual road conditions. A lesson learned from this effort is the need to continue to improve the accuracy and communication of jurisdictional records on 1) abrasive application frequencies and magnitudes, and 2) respective sweeping practices to continue to inform estimates of the potential benefits of road maintenance practices on water quality. Coordination and collaboration with other researchers addressing urban road sweeping practices and water quality is encouraged. These two complementary funding resources from ACOE and SNPLMA provide valuable continuity to facilitate the continued testing, improvement and validation of the recently developed Lake Tahoe urban stormwater management tools, namely the PLRM and the Road RAM.

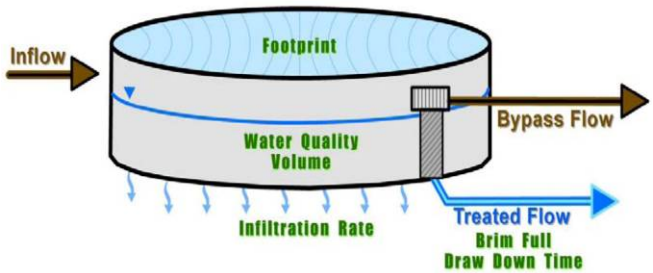
4.2 SWT MONITORING

In order to build the initial SWT water quality dataset to improve the Lake Tahoe urban stormwater management tools, 2NDNATURE obtained the following data from 4 SWTs:

- Treatment BMP condition using Best Management Practices Maintenance Rapid Assessment Methodology (BMP RAM) protocols (http://www.swrcb.ca.gov/rwqcb6/water_issues/programs/tmdl/lake_tahoe/index.shtml),
- Continuous surface water hydrology of the SWTs to develop a comprehensive surface water budget and cost-effectively estimate event volumes and hydrograph characteristics, and
- Event-based surface water sampling using automated and passive techniques to determine inlet and outlet TSS and FSP concentrations and inform PLRM CEC estimates by SWT type.

PLRM Q-TREATMENT AND CEC

The PLRM estimates pollutant load reductions achieved by an SWT facility using basic design information for the SWT facility and a long-term simulation of hydrology to continuously compute hydraulic capture for the SWT. Runoff captured by the SWT is considered "treated", and is assigned a characteristic effluent concentration (CEC) for pollutants of concern that is specific to each SWT facility. Runoff that is not captured by the SWT is considered untreated or bypassed, and is assigned an effluent concentration equaling the influent concentration to the SWT. Pollutant loads can be reduced in a SWT facility through reductions in stormwater volumes and/or improvements in stormwater quality. Both processes are controlled by the hydraulic capture of the SWT (i.e., the percent of the runoff volume captured and treated/removed by the SWT). The hydraulic capture of an SWT is defined by basic hydraulic parameters such as storage capacity, hydraulic residence time, and specified flow treatment rates. The parameters used to determine the portion of the flow that is treated vary by SWT type. Q-treatment is the term used by PLRM to express the volume treatment rate of a SWT. For example, for dry basins:



PLRM Dry Basin schematic illustrating water quality volume, bypass flow through the bypass outlet structure, and treated flow through the treatment outlet. See PLRM (nhc et al. 2009) for complete discussion and definition of terms.

Q-treatment (ac-ft/hr) = Water Quality Volume (ac-ft) / Brim Full Draw Down Time (hr) [EQ6]

When the SWT water quality volume is exceeded, PLRM assumes the excess volume is bypass and the bypass CEC = the inflow CEC. The treated water flow is assigned a static CEC that assumes appropriate brim full draw down time (i.e., hydraulic residence time) within the SWT and improved water quality. For wet basins, a slightly more complex scheme is used to compute treated flows through the wet pool based on a minimum hydraulic residence time (HRT) and treated flows though the surcharge storage above the wet pool based on volume and draw down time (nhc et al. 2009). The CEC assigned in PLRM varies by SWT type and pollutant of concern, as presented in Table 4.7. One of the primary challenges of this SWT research is to identify appropriate field sampling protocols, as well as data analysis techniques of SWT-specific and temporally-specific data, to inform PLRM CEC values for water quality volumes by SWT type.

Table 4.7. PLRM v1 SWT CEC values for each pollutant of concern (nhc et al 2009).

Data Source	SWT Type	Pollutants of Concern					
		FSP (mg/L)	TSS (mg/L)	SRP (mg/L)	TP (mg/L)	DIN (mg/L)	TN (mg/L)
PLRM V1	Dry Basin	25	25	0.05	0.16	0.12	1.1
	Wet Basin	10	10	0.04	0.1	0.1	0.95
	Bed Filter	13	13	0.04	0.14	0.68	1.5
	Cartridge Filter	13	13	0.04	0.14	0.68	1.5
	Treatment Vault	48	48	0.09	0.18	0.28	1.42

SWT DESCRIPTIONS

The BMP RAM v1 developed and defined the classification of 11 Treatment BMP types used in the Lake Tahoe Basin (2NDNATURE 2009). The stormwater treatment BMPs (SWTs) used in PLRM v1 (nhc et al. 2009) are a subset of the Treatment BMP types defined by the BMP RAM, and BMP types and definitions are consistent between PLRM and BMP RAM. Table 4.8 defines and describes the primary water quality treatment processes for the SWT types monitored during the Phase I (dry basins, wet basins, and cartridge filters) to provide the reader with the appropriate context for terminology used to define the SWTs evaluated during this 2009 data collection effort.

Osgood Basin

Osgood Basin, located in South Lake Tahoe, CA, approximately 800 feet from the Lake Tahoe shoreline, was constructed in 1985 as a dry basin and reconfigured in 1997 (E. Wallace, pers. comm.) to treat stormwater from the Bijou Park and Keller Canyon catchments (see Figure 3.6 in Section 3.2). The total catchment area contributing to Osgood Basin is 527.6 acres (Table 4.9). The upper catchment, Keller Canyon, has an area of roughly 373.3 acres and is dominated by densely wooded areas and sparse residential neighborhoods with 9.0% impervious coverage. The lower catchment, Bijou Park Creek, includes 154.6 acres and contains significant residential and commercial development with 24.4% impervious coverage. The urban roads make up 7.4% of the total catchment area, or 38.8 acres. It is assumed that the urban road network is directly connected impervious area within the Osgood catchment.

Stormwater from the contributing catchment is routed through a series of drop inlets and drainage pipes and enters an approximately 225-ft long by 20-ft wide concrete settling basin forebay at one distinct inlet (OSG_IN; Figure 4.21) at the corner of Ski Run Boulevard and Paradise Avenue. The long, narrow settling basin is designed to slow incoming flow velocities and settle coarser sediment before water enters Osgood Basin through a notch weir when water depth in the settling basin is approximately 1.3 ft.

Stormwater flows through a double oval-shaped wet basin (see Figure 4.21), with a water quality volume (i.e., storage capacity) of 0.44 ac-ft. Treated outflow occurs through three 6-in holes located at the base of a concrete outfall structure when basin water depth exceeds approximately 1.4 ft. The bypass outlet of Osgood Basin is a trapezoidal concrete outfall structure (OSG_OUT) at the corner of Ski Run Boulevard and Osgood Avenue. The bypass outlet is a 20.1ft wide cement weir that outflows when basin water depth exceeds 2.88ft. The basin was constructed with a third, lower-flow treatment outlet with a solar-powered valve that was designed to route low flows to the SEZ east of the basin (E. Wallace pers. comm.). However, this outlet is not currently functional, likely

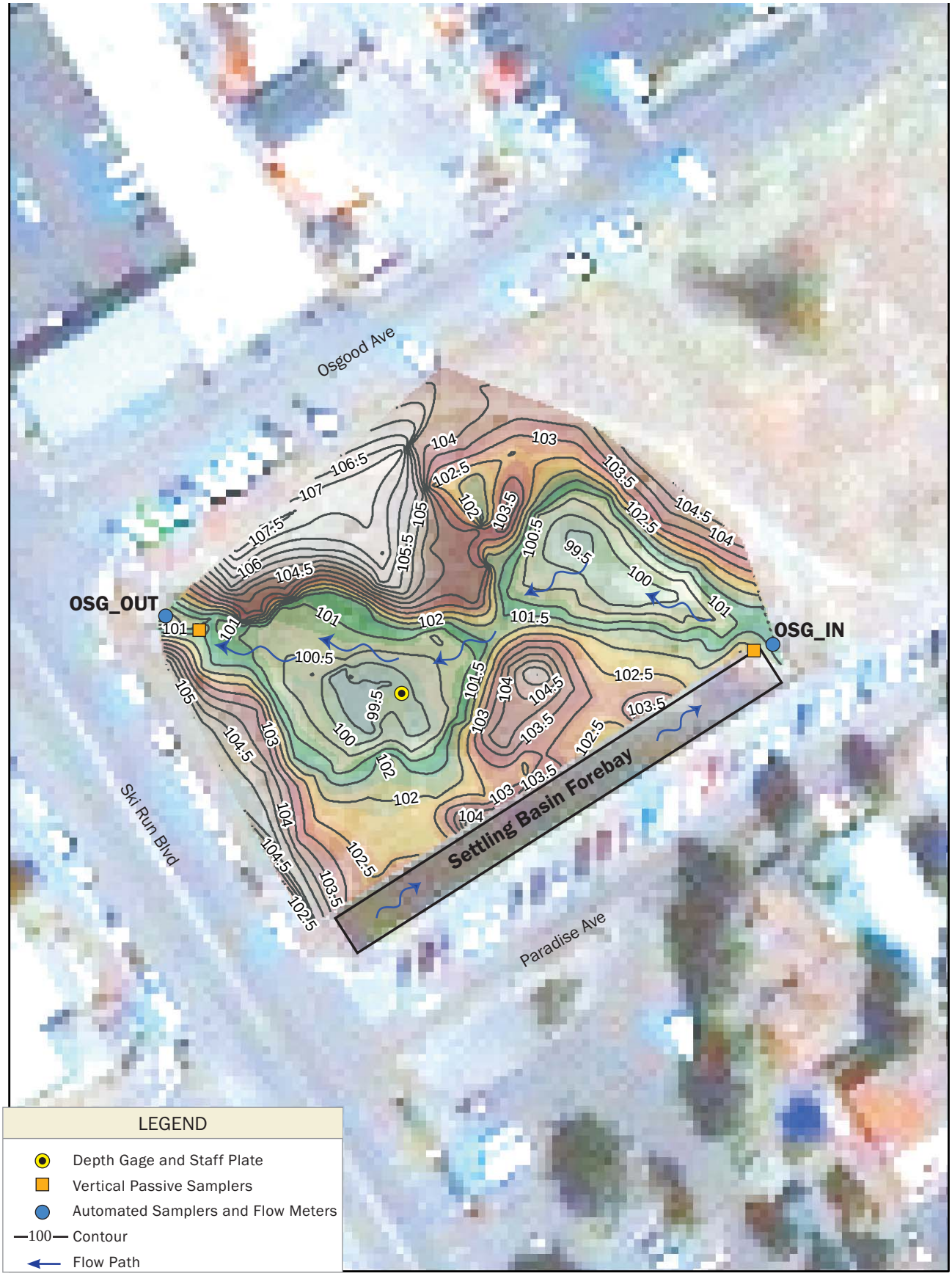
Table 4.8. Treatment BMP Types definitions for Winter 2009 monitoring sites, as defined by BMP RAM (2NDNATURE 2009) and PLRM v1 (nhc et al 2009).

Treatment BMP Type	Other Names	Description	Process relied upon for water quality treatment
Dry Basin	Extended Dry Basin, Dry Pond, Detention Pond	• A constructed basin with riser outlets designed to detain stormwater runoff for some minimum time to allow particle and associated pollutant settling. Outflow occurs at the top of the water column and/or through drain holes at discrete depths. • Water quality improvements downgradient expected as a result of (1) volume reduction via infiltration due to high hydraulic conductivity of footprint soil, (2) effluent concentration due to residence time and particle capture. • Wetland and riparian vegetation species distribution is minimal to absent. Moderate distribution of grass and/or tree species likely and acceptable. • Stormwater is typically routed to the BMP and expected to be conveyed downgradient after treatment. • Typically a larger sized Treatment BMP type constructed in Lake Tahoe.	Infiltration, Particle Capture, Conveyance
Wet Basin	Wet Pond, Retention Pond, Wetland Swale, Wet Extended -Retention Pond, Stormwater Wetlands, Constructed Wetland	• A constructed basin with discrete inlet(s) and outlet(s) that detains runoff and has a persistent pool of surface water typically through the wet season and intermittently and/or consistently in the dry season. • Wet basin detention result in flow rate reductions, increased hydraulic residence times and particle aggregation and subsequent settling. Substrate is typically fine organic matter and silt making infiltration rates relatively low. Pollutant load reductions realized by particle capture and biogeochemical processes due to high vegetation presence. Annual stormwater volume reductions occur primarily by evapotranspiration. • High inundation frequency increases the vegetation density. Dominant vegetation is wetland species and can be supplemented with riparian species with very high densities. • Stormwater is typically routed to the BMP and expected to be conveyed downgradient after treatment. • Typically a larger sized Treatment BMP type constructed in Lake Tahoe. • Note that a wet basin does not include open types of wetland systems that do not have discrete inlets and outlets.	Particle Capture, Nutrient Cycling, Conveyance
Cartridge Filter	Propietary Media Filter (e.g., Stormfilter®)	• Cartridge filters are contained within a confined space similar to treatment vaults. • Granular or media filter to remove fraction of stormwater pollutants. • The proprietary filter media type should be specifically selected to target removal of the pollutants of concern, resulting in downgradient stormwater concentration reductions. No volume loss occurs due to impervious base. • Treatment BMP strategically placed in stormwater drainage path and treated water is conveyed downgradient. • Typically a moderate sized Treatment BMP type constructed in Lake Tahoe.	Media Filtration, Conveyance

Table 4.9. SWT metadata for Winter 2009 monitoring sites. Study period is from December 2008 through July 2009.

Catchment Characteristics					
Catchment	Park Avenue		Osgood		Stormfilter®
Location	South Lake Tahoe, CA		South Lake Tahoe, CA		South Lake Tahoe, CA
Year Constructed	Originally constructed in 2001, modified in 2003		Originally constructed in 1985, reconfigured in 1997		Installed in 2001, filters replaced in 2008
Catchment Land Use	Unimpacted Vegetation (42%), Residential (25%), Commercial (21%), Roads (13%)		Unimpacted Vegetation (69%), Residental (20%), Commercial (4%), Road (7%)		Commercial 100%
Catchment Area (acres)	220.2		527.6		1.6
% Catchment Impervious	33.5%		13.5%		100%
Sub-Catchment	Park	Rocky Point	Bijou Park	Keller Canyon	*n/a*
Area (acres)	70.4	149.8	154.6	373.3	*n/a*
% Impervious	67.8%	17.5%	24.4%	9%	*n/a*
SWT Characteristics					
SWT	Upper Basin (PA1)[1]	Lower Basin (PA2)[1]	Osgood Basin		Stormfilter®
SWT Type	Wet Basin	Dry Basin	Wet Basin		Cartridge Filter
Water Quality Volume (V) (ac-ft)	1.04	1.70	0.44		0.01
Footprint Area (A) at WQ Volume (ft^2)	28,200	31,600	16,500		250
A:V Ratio at Capacity	0.63	0.43	0.86		0.5
Longitudinal Flow Path (ft)	225	275	300		10
Morphology Notes	C-shaped, maximized flow path	Oval-shaped, maximized flow path	Double Oval-Shaped, maximized flow path		Enclosed Rectangle
Distance to Lake Tahoe from Outlet (ft)	1050	950	815		280
Treatment Outflow Water Depth (ft)	0.47	0.60	1.38		0.5
Maximum Treated Water Depth (ft)	PA1_OUTA 1.55 PA1_OUTB 1.65	PA2_OUT 1.60	OG_OUT 2.88		SF_OUT 2.0
Phase I Hydrology Statistics (December 2009 through July 2009)					
Average Frequency of Inundation	100%	0.47%	100%		*n/a*
Maximum Observed Water Depth (ft)	1.65	1.73	3.25		2.0
Average Frequency of Outflow (% of Time)	83%	0%	98%		*n/a*
Average Basin Volume (ac-ft) (% of Capacity)	0.43 (41%)	0 (0%)	0.16 (36%)		*n/a*

[1]Data for certain SWT characteristics are from 2NDNATURE (2008).



Shaded topographic contours of Osgood Basin plotted over a 2001 IKONOS image. Elevations values are in feet, with a contour interval of 0.5 feet. Elevation is relative to 0ft on staff plate where: 0ft staff = 100ft elevation

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OSGOOD BASIN MONITORING LOCATIONS

FIGURE 4.21

due to a lack of maintenance. The Osgood effluent stormwater drains into 2 culverts and is routed to the Ski Run Marina outfall through three 48-in concrete pipes at the end of Ski Run Boulevard that discharge directly into the Ski Run Marina (nhc 2003).

Key hydraulic structures in Osgood Basin. Inflowing water enters the concrete settling forebay (on left) and then enters the basin through a notch weir at the east end of the forebay (center). Stormwater outflow occurs (on right) by either overtopping the concrete outfall (bypass outlet) or flowing through holes at the base of the wall (treatment outlet).

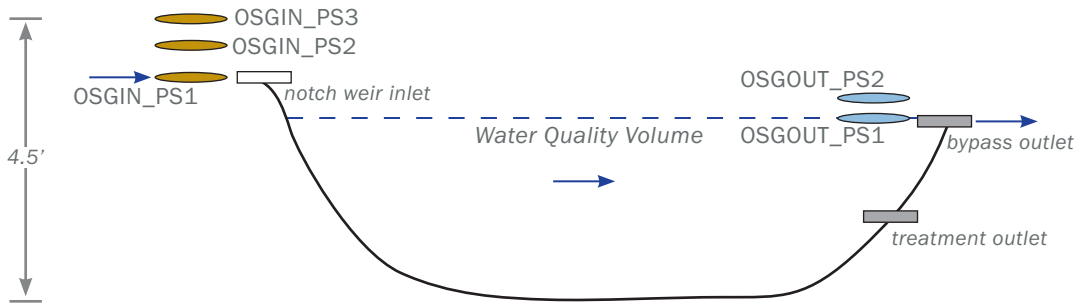
Based on field observations conducted throughout the monitoring period (and the Treatment BMP type definitions provided in Table 4.8), Osgood Basin is currently functioning as a wet basin. The basin has a persistent surface water pool during dry summer months. Cattails and sedge dominate the frequently inundated areas and a dense willow community surrounds the edges of the frequently and occasionally inundated areas. Field personnel observed the basin substrate to be fine organic matter, indicating very low infiltration rates. The primary water quality treatment processes are presumed to be particle capture and nutrient cycling (Table 4.8).

During the Phase I monitoring, Osgood Basin was instrumented with a depth transducer and staff plate within the basin; a flow meter, automated sampler and 3 passive samplers at the inlet; and a flow meter, automated sampler and 2 passive samplers at the outlet (see Table 3.3). Osgood topography and all relevant elevations of data collection points were surveyed in Spring 2009. Basin elevations are set relative to the basin staff plate (100ft elevation equals 0ft on staff plate) and instrumentation elevations are provided in Table 3.3. The relative elevations and locations of the passive samplers in Osgood Basin are visually presented in Figure 4.22. As shown in Figure 4.22A and in the center photo above, the inlet passive samplers (OSGIN_PS1-3) are installed on the settling basin side of the inlet at elevations 0.9 - 1.3ft higher than the outlet passive samplers (OSGOUT_PS1-2). The passive samplers were installed 0 to 0.5ft above the inlet and bypass outlet structures and the controlled elevation of the inlet notch weir is 102.80 ft, approximately 0.6 ft above the bypass outlet. During installation in January 2009, the three 6-in treatment outlets were covered in snow and not noticed by field personnel. Therefore, the outlet passive samplers were installed above the elevation of the outlet weir, at elevations corresponding to what PLRM considers bypass flows (Figure 4.22A) for Osgood Basin. This discrepancy was noticed following the completion of the Phase I data collection. All data from the effluent sampling at Osgood is presented below, however the effluent pollutant concentrations and loads are expected to be higher than those directly applicable to PLRM v1 CEC values. More discussion of this follows in the section on Potential PLRM CEC Comparisons.

In preparation for continued water quality monitoring at Osgood by the 2NDNATURE team (SNPLMA Round 9) several changes have been made to the instrument configuration at Osgood: (1) a third passive sampler has been installed at the outlet at an elevation consistent with the treatment outlets; (2) the existing outlet passive samplers have been lowered to provide more representative sampling of the SWT treatment flows; (3) a set of three passive samplers have been installed on the basin-side of the inlet at elevations consistent with the three outlet passive samplers, and (4) the highest elevation passive sampler at the inlet (OSGIN_PS3) has been removed. The current (December 2009) Osgood configuration will remain through the continued SNPMLA funded sampling efforts by the 2NDNATURE team.

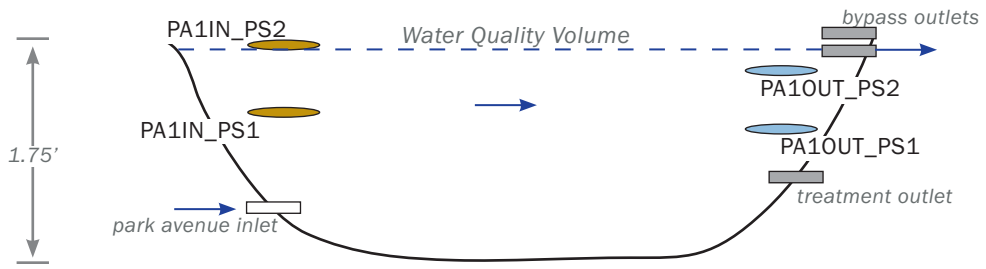
A.

Osgood Basin



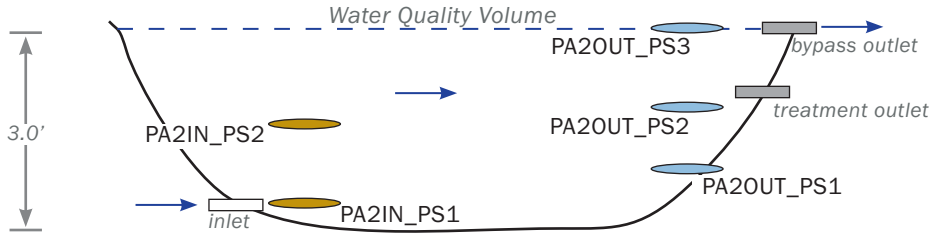
B.

Park Avenue Upper Basin (PA1)



C.

Park Avenue Lower Basin (PA2)



LEGEND
Conveyance Structure
Passive Sampler

Note: Schematics drawn to show relative elevation within each SWT. Horizontal dimension is not drawn to scale.

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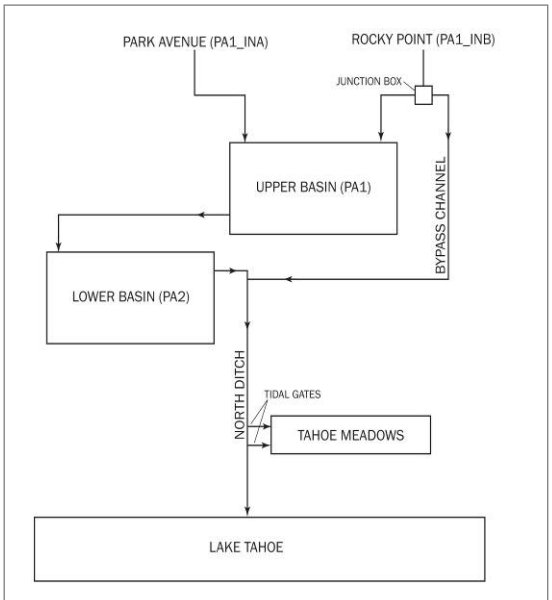
PROFILE SCHEMATICS OF SWTPHASE I SAMPLE COLLECTION

FIGURE 4.22

Park Avenue Basins (PA1 and PA2)

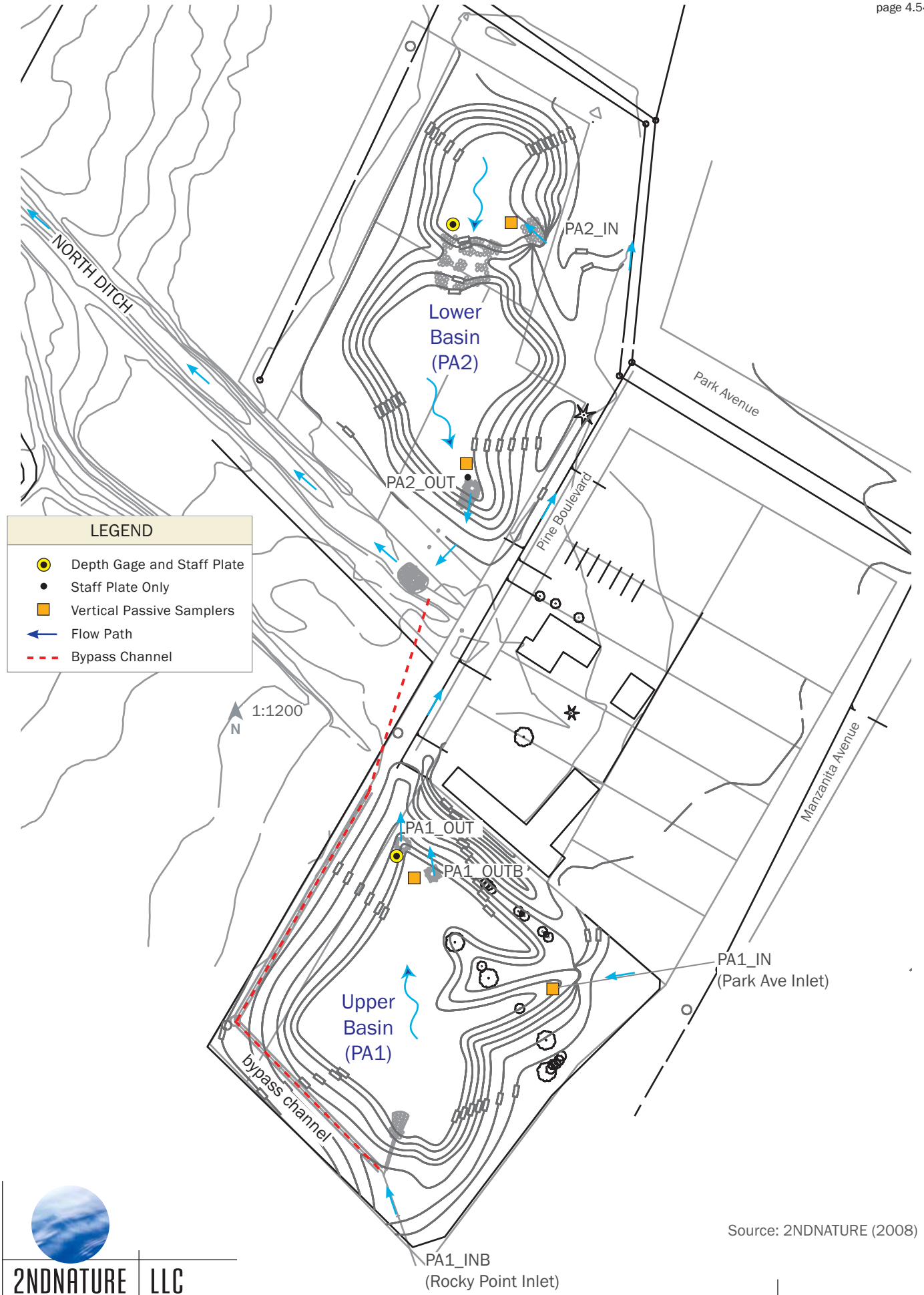
The Park Avenue Basins are located in South Lake Tahoe, CA with outlets approximately 1,000 feet from the Lake Tahoe shoreline (see Figure 3.6). They were constructed in 2001 as a treatment train receiving stormwater runoff from the Park Avenue and Rocky Point catchments (see Figure 3.6). The contributing catchment to the Park Avenue Basins has an area of 220.2 acres and is divided into 2 sub-catchments, Park Avenue and Rocky Point. Park Avenue catchment area is 70.4 acres, which is 67.8% impervious and dominated by commercial land use (Table 4.9). The Rocky Point catchment is 149.8 acres, consisting of mainly residential and vegetation land uses and only 17.5% impervious coverage. Primary and secondary urban roads make up 12.6% of the total catchment area, or 27.7 acres. The Park Avenue catchment accounts for 13.2 acres, or 48%, of the total urban road land use area in the entire catchment; however, the Park Avenue catchment represents only 32% of the total Park Avenue Basin catchment area of 220.2 acres, compared to Rocky Point, which accounts for 68%. A number of hydrologic source control (HSC) structures, road shoulder improvements and stormwater treatment (SWT) structures have been constructed in the Rocky Point catchment by CSLT. Stormwater from the Rocky Point catchment that flow to the Park Avenue Basins are thus already treated to some degree.



Schematic of surface water hydrology of Park Avenue SWTs, illustrating the stormwater treatment train (2NDNATURE 2008).Note: Figure is not to scale.

A 3-year detailed surface water/ groundwater performance evaluation of these SWTs was conducted by 2NDNATURE from 2005-2007 (2NDNATURE 2008). The schematic at left illustrates the surface water hydrologic routing at the Park Avenue Basins. Runoff from the two distinct contributing urban catchments enters PA1 at two inlets, Park Avenue (PA1_INA) and Rocky Point (PA1_INB) (Figure 4.23). A bypass pipe at the Rocky Point Inlet routes stormwater around both the Upper Basin and directly into the North Ditch during large stormwater runoff events. PA1 has a water quality volume of 1.04 ac-ft and outflow from one of three outlet features is directed through a pipe into the Lower Basin (PA2) for additional storage and/or treatment. The treatment outlet consists of four 1.5-in holes punched in the base of PA1_OUTB when the basin water surface elevation is 6234.95. There are two bypass outlets, separate 36-in vertical corrugated metal pipes (CMPs) with trash racks (PA1_OUTA and PA1_OUTB), and overflow when the basin water surface elevations are 6236.03 and 6236.13, respectively. As designed, PA2 (see schematic) receives water directly from the PA1 outlets and has a water quality volume of 1.70 ac-ft. Outflow from the Lower Basin occurs through one of two outlet features similar to the outlet features at PA1. The treatment outlet is four 1.5in holes punched in the riser, and treatment outflow occurs when the basin water surface elevation exceeds 6233.95. The bypass outlet is a 36-in vertical CMP with a trash rack and overflows when PA2 water surface elevation exceeds 6234.95. Outflow from PA2 is routed into the North Ditch and then to Lake Tahoe.

Previous detailed hydrologic monitoring (2NDNATURE 2008) indicates that as much as 50% of the total water volume routed to the Park Avenue Basins during any one storm event enters the bypass pipe to the west and is routed directly around both basins. Additionally, the physical hydraulic routing between the outlet of the Upper Basin and the inlet of the Lower Basin did not appear to be operating as intended. 2NDNATURE (2008) estimated outflow from the Upper Basin occurred approximately 87% of the year; the Lower Basin was only inundated during very large storm events (0.085% of the year).



Source: 2NDNATURE (2008)

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PARK AVENUE BASINS MONITORING LOCATIONS

FIGURE 4.23

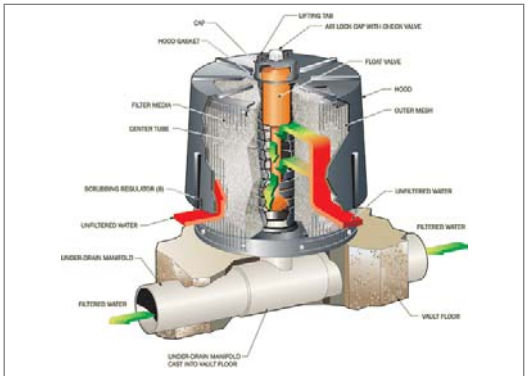
According to BMP RAM definitions (see Table 4.8) PA1 is currently operating as a wet basin. During the past 4 years of detailed instrumentation and monitoring, PA1 has maintains a permanent wet pool and has developed a persistent community of wetland (cattails and sedge) and riparian (willow) vegetation species. 2NDNATURE (2008) calculated the annual average infiltration rate of the Upper Basin to be 1.0×10^{-5} cm/s or 0.012 in/hr. These low infiltration rates are consistent with the assumption that particle capture and nutrient cycling are the dominant water quality treatment processes. PA2 is a typical dry basin, with clearly defined inlet and outlet structures, no persistent wet pool, sandy substrate with high hydraulic conductivity, and no wetland or riparian vegetation communities. Consistent with the definitions provided in Table 4.8, infiltration and particle capture are assumed to be the key water quality treatment processes at PA2.

Each Park Avenue basin was instrumented with a depth transducer at the location of existing staff plate installations in December 2008 (2NDNATURE 2008). Figures 4.22B and C provide profile schematics of the passive sampler installation at both basins. In PA1, two passive samplers were installed each at the inlet and outlet; the lower passive samplers at both the inlet and outlet (PA1IN_PS1 and PA1OUT_PS1) are installed roughly 0.5 ft above the elevation of the treatment outlet and the higher passive samplers (PA1IN_PS2 and PA1OUT_PS2) are approximately at the elevation of the PA1_OUTA bypass outlet (Figure 4.22B). The samples collected from both outlet passive samplers at PA1 are assumed to be representative of the treated flow leaving this SWT, thus applicable for CEC comparisons.

The PA2 lower elevation inlet and outlet passive sampler pairs (PS1) are roughly 0.25 ft above the inlet elevation at PA2_IN, the higher samplers (PS2) are approximately 0.25 ft below the elevation of the treatment outlet, and the third outlet passive sampler (PA2OUT_PS3) is installed at the same elevation as the top of the vertical CMP bypass outlet (PA2_OUT). Figure 4.22C illustrates that all outlet passive samplers at PA2 are assumed to be representative of the treated flow leaving Park Avenue Lower Basin. In preparation for additional monitoring using SNPLMA Round 9 funds, slight modifications of the elevation of the PA2 inlet passive samplers were conducted in the fall of 2009 to be more consistent with the outlet passive sampler elevations.

Stormfilter® Vault

The Stormfilter® Vault was installed in the Ski Run Marina parking lot in 2001 as a passive, flow-through stormwater filtration system designed to reduce outflow particulate and dissolved pollutant loads (see Figure 3.6). The Stormfilter® vault is a cartridge filter SWT (see Table 4.8), a confined underground vault with 50 cartridge filters designed to filter and remove dissolved and particulate pollutants via gravity forced media filtration. Surface water runoff from approximately 1.6 acres of commercial parking lot is routed first to a small basin and then to an inlet junction box fitted with a high flow bypass. Stormwater enters the first of 3 vaults within the SWT structure. The pretreatment vault allows coarser material to settle out of at the bottom, before overflowing into the cartridge vault. In the PLRM, cartridge filters are represented as flow-through devices because the storage volume provided in pretreatment vaults is negligible relative to the treatment capacity of the cartridge filters. The cartridge bay houses 50 cartridge media filters designed to treat particulate and dissolved pollutants. Stormwater exits the cartridge bay to the outlet bay initially through the treatment outlet when depths reach 0.5 ft and then through the bypass outlet structure at water depths greater than 2 ft. Stormwater from the outlet bay is routed through an 18-in culvert to the same Ski



Stormfilter® Vault cartridge media filter schematic

Run Marina outfall as Osgood Basin outflow. A 2.5-year stormwater quality monitoring effort was conducted from 2001-2004 to evaluate the ability of the Stormfilter® Vault to reduce nutrient and FSP loads from the parking lot (2NDNATURE 2005). Currently the Stormfilter® Vault is maintained by the Ski Run Marina property owner and all cartridges may have been replaced in August 2008 (R. Townsend, pers. comm.).

The Stormfilter® Vault inlet and outlet were instrumented with Sigma flow meters and automated samplers in March 2009. Backwatering issues at both the inlet and outlet prevented the instruments from being stored continuously on site and therefore were only deployed in advance of an anticipated runoff event. A depth transducer was deployed in July 2009 within the outlet to record continuous outflow water depths. This data will be used in conjunction with site survey data and outlet pipe dimensions to create a continuous outflow hydrology time series into the future. Passive samplers were not installed at the SWT structure, given the complicated installation requirements of an underground cartridge filter. Because a high flow bypass was constructed upstream of the Stormfilter® Vault, all effluent samples collected during these efforts are assumed to represent treated flow and thus appropriate for comparisons to PLRM CECs.

CONDITION OF SWT

2NDNATURE field personnel performed the field observations (STEP 4) of BMP RAM at each of the 4 SWTs in September 2009 according to the detailed protocols in the BMP RAM User Manual v.1 (2NDNATURE 2009). BMP RAM condition scores (STEP 5) were not calculated because BMP RAM scoring requires that the jurisdictions in charge of maintaining the Treatment BMP have set the Treatment BMP-specific benchmark and threshold values (STEP 3; 2NDNATURE 2009). Based on field observations and an in-depth understanding of the BMP RAM rationale, the following describes the general relative condition for each SWT evaluated:

- OSGOOD BASIN: Vegetation cover, material accumulation, and conveyance (BMP RAM STEP 4) field observation protocols were performed at Osgood Basin. Wetland and riparian vegetation percent cover was found to be high (70%), but still within the default acceptable range (40-75%) as prescribed by the BMP RAM. Some material accumulation (<0.1 ft) was noted at the location of the installed staff plate; however, the relative significance of this observation cannot be well understood without an established benchmark value. The existing staff plate was installed in early 2009, over 20 years following Osgood construction. The observed condition of Osgood suggests no maintenance actions have been implemented within the wet basin in recent years. Both the inlet and outlet structures appeared to be in good working order, free of debris and sediment. Overall, the wet basin was found to be in acceptable condition and does not require immediate maintenance. This conclusion is based on the presumption that Osgood is planned to be maintained as a wet basin. Should its function be a dry basin, then maintenance would be required to restore the primary treatment processes (infiltration and particle setting) to acceptable conditions.

- PARK AVENUE 1 UPPER (PA1): Following BMP RAM STEP 4 protocols, vegetation cover, material accumulation, and conveyance field observations were conducted at this wet basin. The percent cover of wetland and riparian vegetation was measured as approximately 65%, within the acceptable range (40-75%) designated by the BMP RAM. Material accumulation of 0.05 ft was observed at the staff plate. The staff plate at PA1 was installed in September 2005, four years following basin construction. By that time a substantial wetland community had already been established at the site, suggesting 0 ft on the existing staff plate may not be an appropriate benchmark value. Both inlets (PA1_INA and PA1_INB) and all three outlet structures (PA1_OUTA, PA1_OUTB, and the low flow outlet) were in good condition and visually appeared capable of conveying stormwater into and out of the wet basin. Results of the BMP RAM observations indicate PA1 is in an acceptable condition and does not require immediate maintenance if it is to be maintained as a wet basin.
- PARK AVENUE 2 LOWER (PA2): BMP RAM STEP 4 protocols require the following field observations at a dry basin: vegetation cover, constant head permeameter (CHP), material accumulation, and conveyance. Wetland and riparian vegetation species were nearly absent (<1%), CHP readings indicated very high infiltration rates throughout the basin (average of 13 in/hr), and no measurable material accumulation was noted at either staff plate, which have been installed at the site since September 2005. The inlet and outlet features appeared to be in good working order. Based on field observations, PA2 is in good condition and functions within the acceptable range for a dry basin.
- STORMFILTER® VAULT: Confined space and conveyance BMP RAM STEP 4 field observations were performed at the Stormfilter®. Approximately 2 inches of standing water was observed within one of the treatment bays on September 18, 2009, over 27 days following the last runoff event. The presence of standing water indicates the Stormfilter® did not drain completely since the last runoff event. This observation is consistent with findings by 2NDNATURE (2005) that noted as much as 6 inches of water remained in the cartridge filter following a runoff event. Further investigations may be necessary to determine if maintenance actions could improve the overall SWT condition. Both the inlet and outlet were visually observed to be free of debris and appeared to be functioning properly.

Photo comparison of vegetation community composition and distribution in PA1 (upper photo) and PA2 (lower photo).

SURFACE WATER HYDROLOGY

Continuous water surface elevations were recorded from December 2008 through July 2009 and the time series for Osgood, Upper Park (PA1) and Lower Park (PA2) Basins are presented in Figures 4.24-4.26. Site topographic surveys were used to convert the continuous water depth time series recorded by the in-basin LevelTrolls to water surface elevation (upper graph) and basin water volume (lower graph). To create the volume time series, a depth to volume rating curve was created based on GIS analysis of the topographic data. These continuous volume time series are used to create surface water budgets for each SWT basin. The elevations of all outflow features, as well as the passive samplers used for sample collection, are noted in Figures 4.24-4.26. Due to backwatering problems

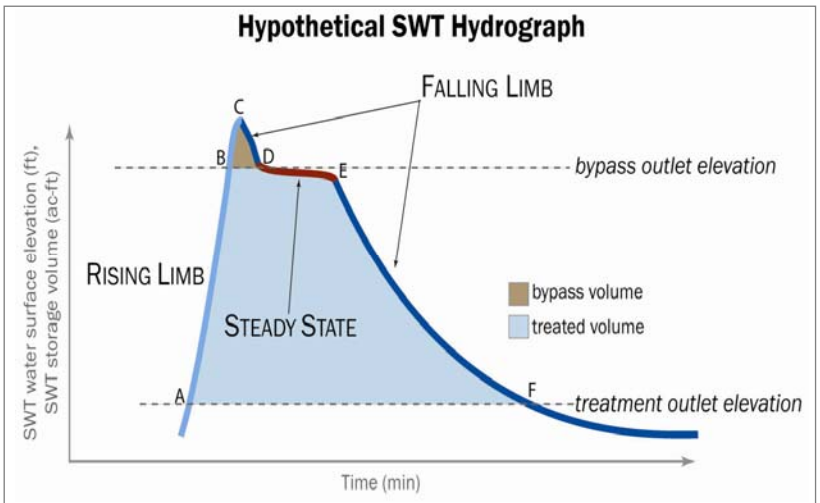
at the Stormfilter® cartridge filter, hydrology for only one stormwater runoff event was captured and continuous hydrology between events was not obtained. Table 4.9 presents key hydrologic characteristics observed at each SWT during the study period and a discussion of the hydrology at each site is presented below.

Surface Water Budgets

The continuous water surface elevation and associated volume time series is used to calculate a surface water budget for each SWT on event, seasonal and/or annual time scales using the following mass balance equation:

Change in Storage (volume) = Water Input (volume) – Water Loss (volume) [EQ7]

Change in basin water storage volume at any one time is the net balance of inputs minus losses over the same duration. Water inputs include surface water runoff entering the SWT through constructed inlets and direct precipitation. Direct precipitation on an event time scale is considered negligible for our purposes. Water losses include water exiting the SWT through infiltration, outflow through one or more of the SWT outlet features, and/or evapotranspiration. Evapotranspiration as a water volume loss on an event time scale is assumed negligible for our purposes, but is considered for seasonal or annual budgets. California Department of Water Resource's CIMIS website (www.cimis.water.ca.gov) provides monthly evapotranspiration rates for use in these calculations.



Hypothetical SWT hydrograph illustrating rising limb (light blue line), steady state (brown line), and falling limb (dark blue lines). Hydrograph stages are used to estimate SWT surface water budget. Note points A-F in schematic and see adjacent text for calculations.

EQ7 is used to calculate total event input and outflow volumes for each discrete runoff event. The input volume = the inflow volume at the SWT inlet(s) and can be multiplied by the inlet sample concentrations of the pollutants of concern to obtain event, seasonal or annual inflow pollutant loads. For application to validate PLRM v1 CECs, the outflow volume via the treatment outlet feature is quantified and can be multiplied by the outlet concentrations of the pollutants of concern to obtain event, seasonal or annual treated surface water outflow pollutant loads.

An SWT hydrograph of the volume time series can be categorized into 1 of 3 stages: rising limb (inputs > losses), steady state (inputs=losses), and falling limb (losses > inputs) (see schematic to left). EQ7 is applied to each stage of the hydrograph in order to calculate input, loss and outflow rates and volumes. The rising limb is net volume input where *input = change in storage + losses*. The change in storage (ac-ft) of the rising limb is calculated by subtracting the volume at the peak of the hydrograph from the initial volume at the beginning of the rising limb. In the schematic on the left, change in storage = volume at point C – volume at point A. This is the net volume input during each rising limb. Infiltration continues to occur once the SWT is inundated. Once the SWT water surface elevation exceeds the treatment outlet elevation, outflow also occurs during the rising limb, and thus must be accounted in the water budget and total volume input calculations. In other words, EQ7 is rearranged where:

Water Input (volume) = Change in Storage (volume) + Water Loss (volume) [EQ8]

The rate of outflow volume depends upon the water surface elevation within the SWT relative to the invert elevations of each outlet feature in the SWT. To calculate water outflow rates, occurrences when water inputs = 0 were identified by comparing multiple runoff events and determining when the slope of the falling limb is similar across events. Similar slopes across a range of runoff events suggest the change in volume is due to a constant outflow rate controlled by the SWT outlet feature(s) at a distinct water surface elevation (i.e., treatment outlet(s) or bypass outlet(s)) and any losses via infiltration:

Water Loss Rate (ac-ft/min) = Outflow Rate (ac-ft/min) + Infiltration Rate (ac-ft/min) [EQ9]

Loss rates are determined at a distinct water surface elevation within an SWT based on volume change over the duration of time the falling limb exceeds the elevation of each outlet feature. Loss rates estimated from the volume time series for each SWT outlet feature are estimated based on average loss rates over the duration of discrete runoff events, and include volume losses due to infiltration. Infiltration volumes are estimated from sediment sample hydraulic conductivity analyses and applied over the estimated surface area of inundation. Outflow rates are estimated for the flow of surface water through each outlet feature by subtracting the estimated volume losses due to infiltration from the total volume change. Outflow rates can also be calculated by the sum of engineering flow calculations through the dimensions of the existing outlet features, such as three 2-in diameter holes. Estimated outflow rates at Osgood Basin were also compared to the continuous flow data recorded at the outlet to refine estimates.

For each discrete event, the estimated outflow rates (ac-ft/minute) are then applied to the total duration when the SWT WSE is greater than the respective outlet feature elevations to yield total bypass volume (ac-ft; shaded brown in schematic) and total treated volume (ac-ft; shaded blue) for each event. Event total outflow volume (ac-ft) equals the sum of bypass and treated volumes. The total event loss volume is equal to total outflow volume plus total infiltration volume. The event treated volumes are the applicable volumes to evaluate PLRM CECs.

Using EQ8, event water input volumes are calculated for each of the three hydrograph stages based on the above calculations of change in storage and water output rates and the duration (minutes) each hydrograph stage lasts:

Water Input (volume) = Change in Storage (volume) + Water Loss (volume), where
*Water Loss (volume) = [Water Loss Rate (volume/time) * Duration of Hydrograph Stage (time)]* [EQ10]

The applicable loss rate for the calculations is dependent on the SWT water surface elevation relative to the invert elevations of outlet features. For example, the rising limb in the schematic uses 2 loss rates: (1) from point A to point B, loss rate = treatment outlet rate + infiltration rate, and (2) from point B to point C, loss rate = bypass outlet rate + treatment outlet rate + infiltration rate. The discussion below references key terms illustrated in the schematic above:

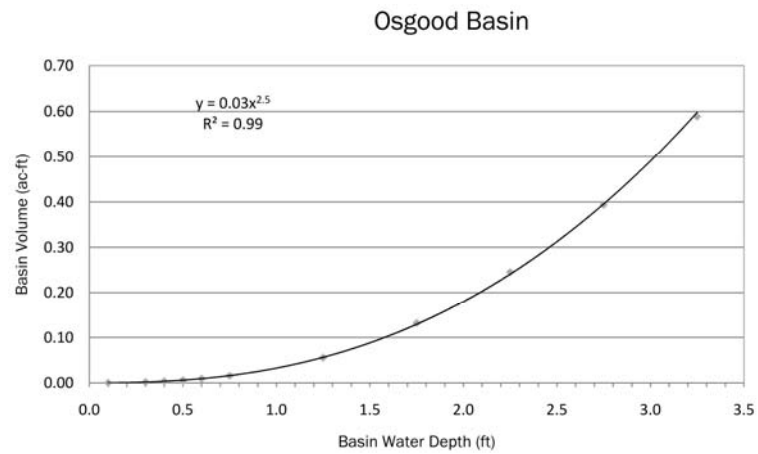
- ***Rising Limb:*** Water Input (ac-ft) = Change in Storage (ac-ft) + Water Loss (ac-ft), where:
  - Change in Storage = Volume (C-A)
  - Water Loss = [(Infiltration Rate * Time (C-A)) + (Treatment Outlet Rate * Time (C-A)) + (Bypass Outlet Rate Output Rate * Time (C-B))]
- ***Steady State:*** Water Input (ac-ft) = Change in Storage + Water Loss (ac-ft), where:
  - Change in Storage = 0
  - Water Loss = [(Infiltration Rate * Time (E-D)) + (Treatment Outlet Rate * Time (E-D))]
- ***Falling Limb***:
  - If the slope of the falling limb is equal to or greater than the estimated water loss rates,
    - Water Input = 0.

- If the slope of the falling limb is less than the estimated output rates, Water Input (ac-ft) = Change in Storage (ac-ft) + Water Loss (ac-ft), where:
  - Change in Storage is negative = Volume (F-E)
  - Water Loss = [(Infiltration Rate * Time (F-E)) + (Treatment Outlet Rate * Time (F-E))]

These estimates provide a standardized and cost effective methodology to create SWT surface water budgets on event, seasonal and annual time scales without the installation of expensive, temperamental flow meters at both the inlet and outlet of each SWT. Note the volume units are expressed as 0.01 ac-ft, reflecting our relative confidence in the estimates. For more detailed description of the water budget calculations using a mass balance analysis of a continuous surface water volume time series, see Appendix B of 2NDNATURE 2008.

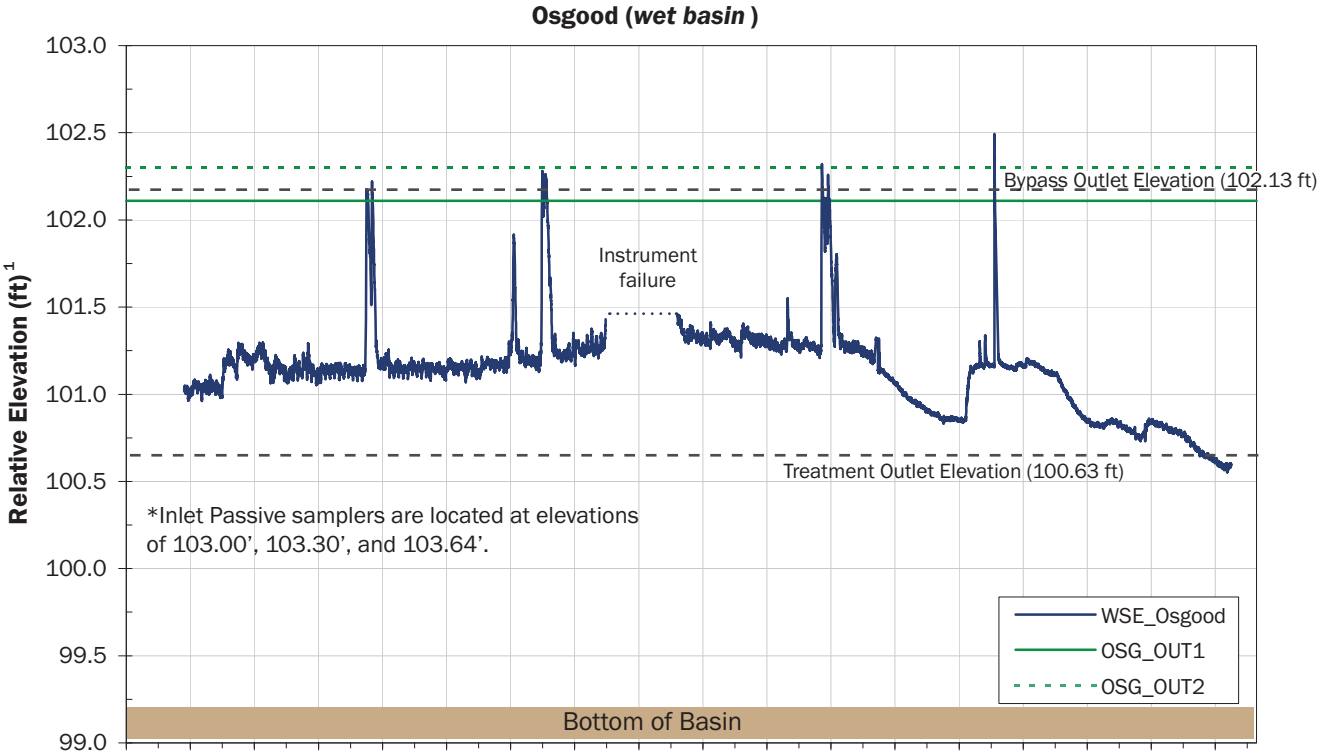
OSGOOD BASIN

Figure 4.24 presents the continuous time series of relative water elevation from December 2008 through July 2009. The basin was surveyed in July 2009 and the resulting water depth to water volume rating curve used to create the basin water volume time series is presented in the graph below. Due to instrument failure there is a brief data gap in March 2009.

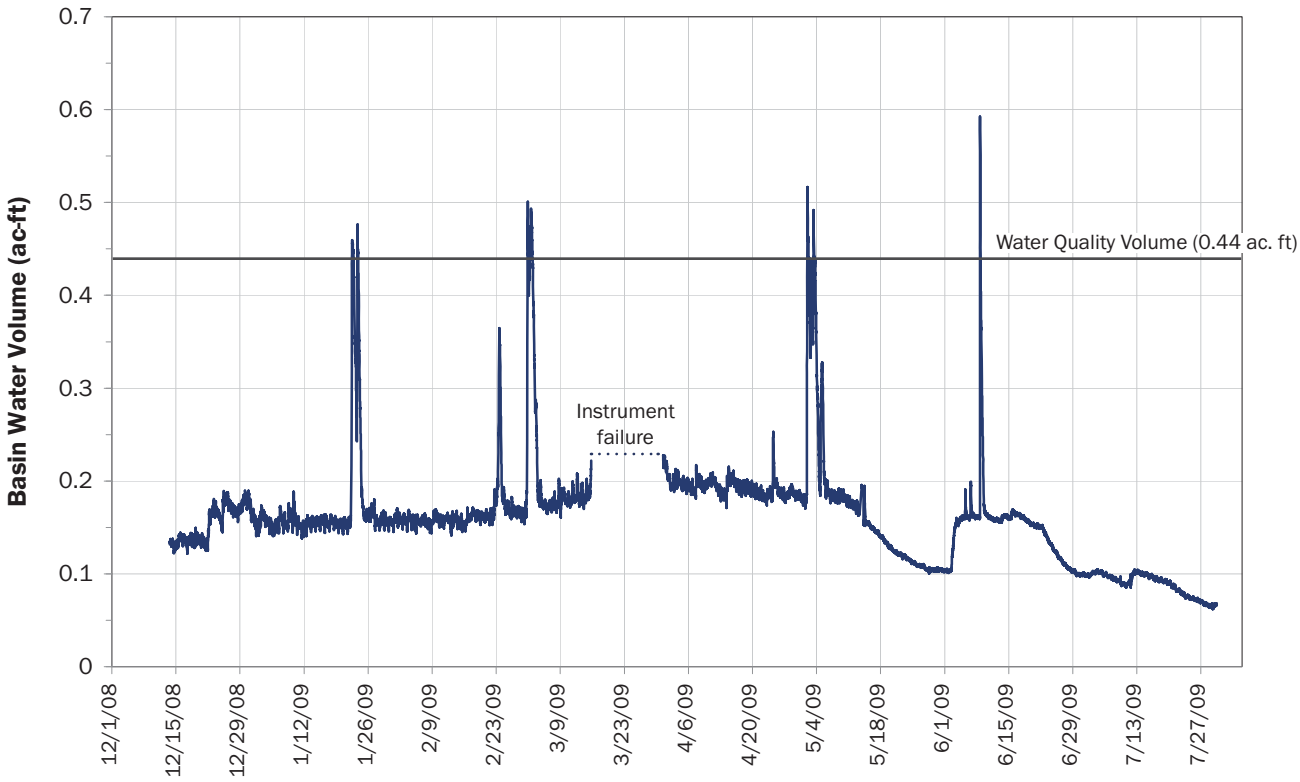


Basin water depth to water volume rating curve for Osgood Basin.

Typical of a wet basin (see Table 4.8), Osgood Basin showed constant inundation during the study period (see Table 4.9) with minimum summer water depths above 1 ft (see Figure 4.21). The average water volume stored within Osgood Basin was 0.16 ac-ft, or 36% of its total storage capacity, throughout the study period (see Table 4.9). This observed sustained inundation indicates that the stormwater delivered to the basin is not infiltrating, suggesting very low infiltration rates perhaps influenced by minimal vertical distance between the base of the basin and the shallow groundwater table.



[1]Elevation is set relative to the staff plate installed in the basin (see Figure 3.7). 0' on staff plate = 100' elevation in basin.



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OSGOOD BASIN SURFACE WATER HYDROLOGY

FIGURE 4.24

PA1 (PARK AVENUE UPPER BASIN)

Figure 4.25 presents the continuous time series of water surface elevation and basin water volume from December 2008 through July 2009. Basin topography and the depth to volume rating curve were developed as part of the previous Park Avenue study (2NDNATURE 2008) and the resulting equation is given on Figure 4.25. Instrument failure during February 2009 has resulted in a data gap for the PA1 surface water hydrology time series.

Previous detailed hydrologic monitoring (2NDNATURE 2008) indicates that as much as 50% of the total water volume routed to the Park Avenue Basins during any one storm event enters the Rocky Point bypass pipe and is routed directly to Lake Tahoe (see schematic on page 4.53), completely bypassing treatment from both PA1 and PA2.

The average water volume stored within PA1 was 41% (0.43 ac-ft) of the total basin storage capacity (see Table 4.9) over the 2009 observations. The basin water surface elevation was frequently greater than the elevation of the treatment outlets, resulting in basin outflow during 83% of the study period (or nearly 154 days). Water budget estimates suggest that 15.2 ac-ft of water can be considered "treated", or 94.5% of the total 16.0 ac-ft of water routed through PA1 over the study period. This is the effluent volume that is assumed to exit via the low outlet elevation orifice, although based on surveyed elevations some volume of water does exit PA1 through the Rocky Point bypass channel when the water surface elevation exceeds 6235.86 ft. Basin capacity in PA1 was exceeded 4 times during the large storm events, causing outflow through one or both of the vertical CMP risers.

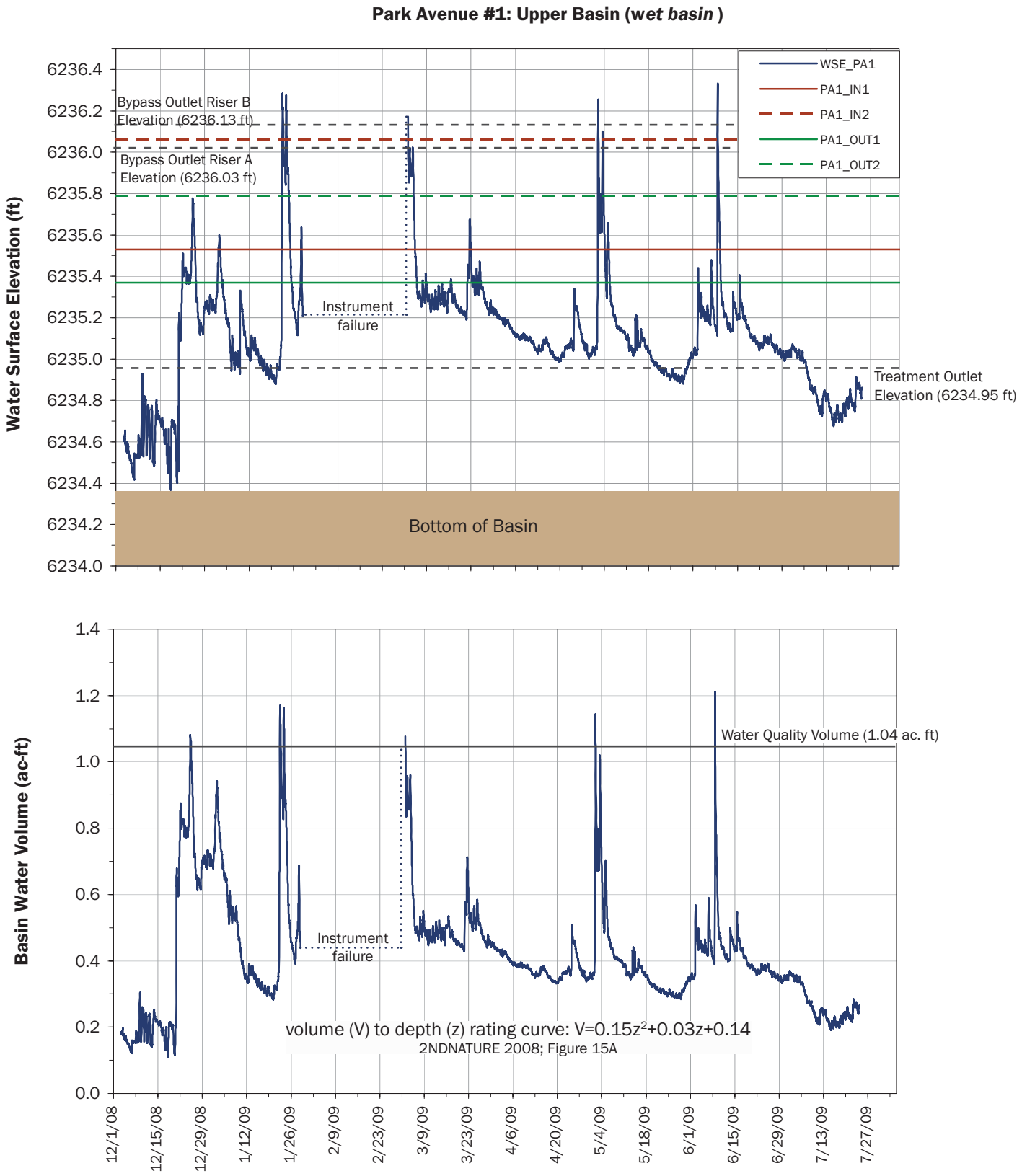
OSGOOD AND PARK AVENUE UPPER BASIN Q-TREATMENT

The Osgood Basin appears to be undersized relative to its contributing catchment area and land use. The water quality volume of Osgood Basin is 0.44 ac-ft, while the total catchment area is 527.6 acres, including over 70 acres of impervious surfaces and 38.8 acres of urban road. Assuming the urban roads are directly connected impervious area, a more appropriate capacity may be closer to 3 ac-ft to retain 1 in of runoff from these surfaces (roughly a 1-hr/20-yr storm). In comparison, PA1 has a greater water quality volume (1.04 ac-ft), a smaller catchment (220.2 acres) with nearly 70 acres of impervious surface and 27.7 acres of directly connected urban roads. PA1 is also undersized relative to capture of 1 in of runoff from the road surfaces, but Osgood Basin is treating a significantly bigger catchment with less than 50% of the water quality volume of PA1. In addition, a portion of the PA1 catchment is treated by the Rocky Point dry basins located on the south side of Highway 50, and PA1 is designed to function as a treatment train with PA2. The limited water storage volume in Osgood Basin results in near constant outflow through the treatment outlets (98% of the study period, Table 4.9).

A Q-treatment flow rate was calculated for both wet basins to compare the effluent flow rates between Osgood Basin and PA1 relative to their storage capacity using the following equation:

Q-treatment (ac-ft/hr) = Storage Capacity (ac-ft) / Minimum Hydraulic Residence Time (hr) [EQ11]

A minimum hydraulic residence time (HRT) of 24 hours was assumed for comparative purposes and resulted in Q-treatment of 0.018 ac-ft/hr and 0.043 ac-ft/hr for Osgood Basin and PA1, respectively. Basin Q-treatment (ac-ft/hr) was compared to the changes in basin storage volume over time (see Figures 4.24-4.25) to estimate the number of hours the change in basin volume rate exceeded Q-treatment in both basins. In Osgood Basin, Q-treatment was exceeded nearly twice as often as PA1 over the Phase I monitoring (64 hours compared to 35 hours), suggesting that Osgood Basin storage volume is significantly undersized compared to its catchment's contributing volumes. The sizing of Osgood Basin will be considered as SWT performance is evaluated.



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PARK UPPER BASIN (PA1) SURFACE WATER HYDROLOGY

FIGURE 4.25

PA2 (Park Avenue Lower Basin)

Figure 4.26 presents the continuous time series of water surface elevation and basin storage volume from December 2008 through July 2009 at PA2. The depth to volume rating curve calculated by 2NDNATURE (2008) is based on a 2005 basin topographic survey and the resulting equation is presented on Figure 4.26. Inflow was observed in PA2 only 5 times during the monitoring period, coinciding with large storm events during the winter and spring 2009 (see Figure 4.1) when the storage capacity of PA1 was exceeded (see Figure 4.25). PA2 inundation duration was only 1.4 days (or 0.47% of the overall study period), and the peak volume observed was 1.0 ac-ft, well below the 1.7 ac-ft of water quality volume capacity (Table 4.9). These results are similar to the findings of the detailed hydrologic study (2NDNATURE 2008), where outflow from the Upper Basin occurred approximately 87% of the year, the Lower Basin was only inundated during very large storm events (0.085% of the year). The relatively fast infiltration rates, $3x10^{-3}$ cm/s (3.6 in/hr), contribute to the lack of outflow from the PA2, but these observations suggest that only a small fraction of the water routed from the Upper Basin outlet (PA1) is reaching the Lower Basin inlet (PA2). Volume losses are occurring somewhere in the routing between the outlet of PA1 and inlet to PA2.

STORMFILTER® VAULT

Due to delays in procuring available, functional equipment, Sigma flow meters were not installed at the site until March 2009. Backwatering issues at both the inlet and outlet prevented the instruments from being stored continuously on site and therefore were only deployed in advance of an anticipated runoff event. Only the May 2009 storm event was captured by the Sigma instruments at the Stormfilter® and no continuous time series is available at this monitoring site. An In-Situ LevelTroll 500 was deployed in July 2009 within the outlet to record continuous outflow water depths. This data will be used in conjunction with site survey data and outlet pipe dimensions to create a continuous outflow hydrology time series into the future.

INLET/OUTLET WATER QUALITY

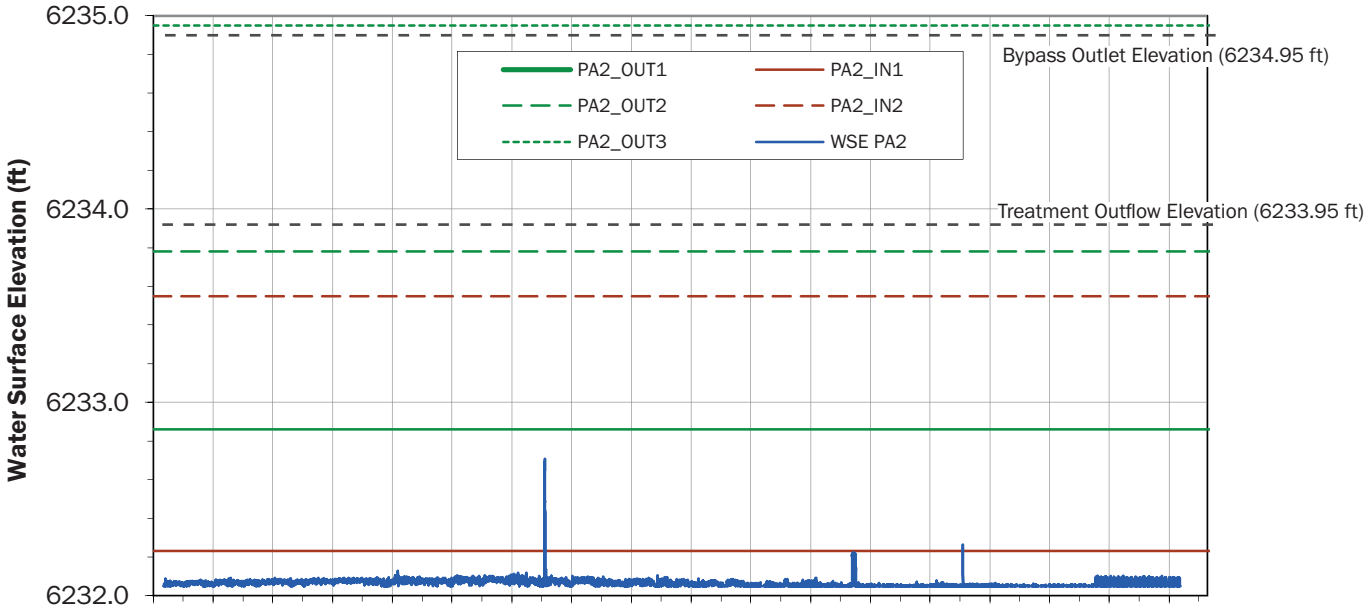
Data Collection Summary

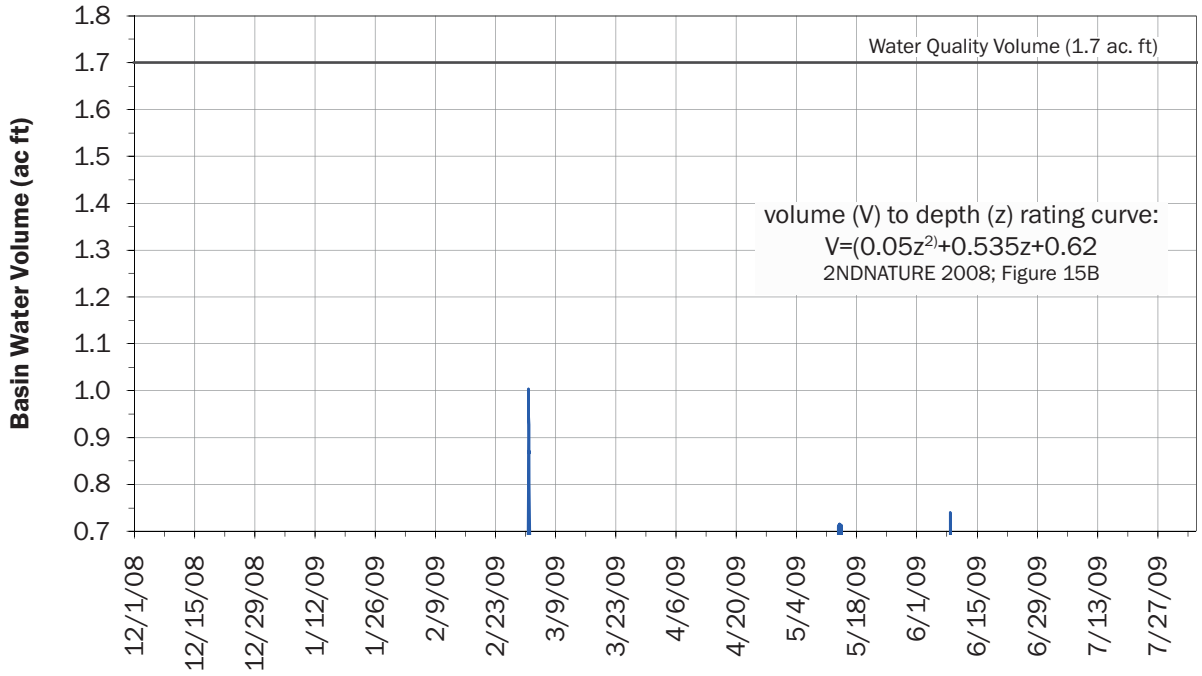
SWT monitoring and data analysis pairs the inlet and outlet samples collected from similar water surface elevations at the time of sample collection (see Table 3.3 and Figure 4.22). The assumption is that the water surface elevation is level within the SWT at any point in time, and it thus reasonable to assume that paired inlet and outlet samplers are sampling similar water at similar locations on the hydrograph. This passive sampling technique is a great improvement over grab sampling because the sampling is nearly simultaneous at the inlet and outlet and the location on the storm hydrograph is known. These are also cost-effective sampling alternatives to expensive, complicated and temperamental automated sampling techniques.

Figure 4.27 summarizes the sample collection dates, event precipitation and duration, and the distribution of samples collected, analyzed and incorporated into the SWT analysis. Five (5) stormwater runoff events (3 rain on snow, 1 winter rain and 1 summer thunderstorm) were monitored between January and July 2009 and a total of 46 samples were collected and submitted to the laboratory for TSS and PSD analysis.

- January 2, 2009: The rain on snow event occurred prior to passive sampler installation at all 4 SWTs. Field personnel on-site during the runoff event collected grab samples from the inlet and outlet of PA1 and the inlet of PA2.

Park Avenue #2 Lower Basin





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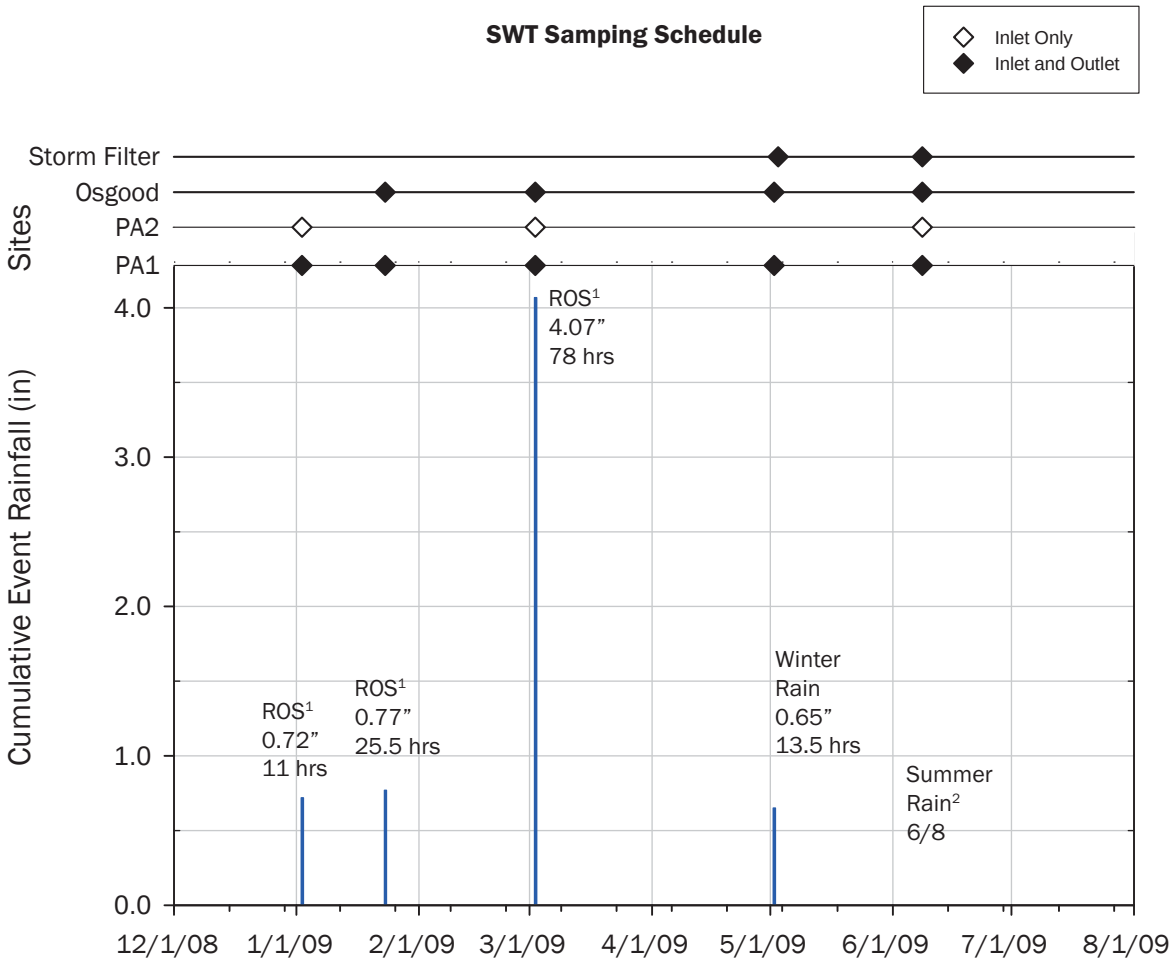
PARK LOWER BASIN (PA2) SURFACE WATER HYDROLOGY

FIGURE 4.26



[1]ROS=Rain on Snow
[2]6/8 localized event, did not register on City Lab weather station.

SWT Sample Summary

SWT Monitoring Site		1/2/09	1/23/09	3/2/09	5/2/09	6/8/09	Totals (by event)
Osgood (Passive)	in	-	1	1	1	2	9
	out	-	1	1	1	1	
Osgood (Auto)	in	-	1	1	2	1	10
	out	-	1	1	2	1	
PA1	in	1	2	2	2	2	18
	out	1	2	2	2	2	
PA2	in	1	-	1	-	1	3
	out	-	-	-	-	-	
Stormfilter® (Auto)	in	-	-	-	2	1	6
	out	-	-	-	2	1	
Totals		**3**	**8**	**9**	**14**	**12**	**46**

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PHASE I SWT MONITORING SUMMARY

FIGURE 4.27

- January 23, 2009: During this rain on snow event, 0.77 inches of rain fell in just over 25 hours. Basin water surface elevation exceeded the lower elevation passive sampler pairs at Osgood Basin and both passive sampler pairs at PA1.
- March 2, 2009: This rain on snow event was nearly four times larger than any other runoff event. Over 4 inches of rain fell over a 78-hour period, resulting in both PA1 and Osgood Basin reaching capacity and the highest observed water volumes in PA2 during Phase I.
- May 2, 2009: This winter rain event was the first significant rain following instrumentation at the Stormfilter® cartridge filter. Other than PA2, which was not inundated during the event, at least 2 samples each were collected from the inlet and outlet of the monitored SWTs.
- June 8, 2009: This was a highly localized summer rain event that did not register at the City Lab weather station located approximately 5 miles from the SWTs. The high-intensity, short-duration event generated a rapid response in all three basins (see Figures 4.24, 4.25-4.26) and most likely resulted in high inlet flow velocities.

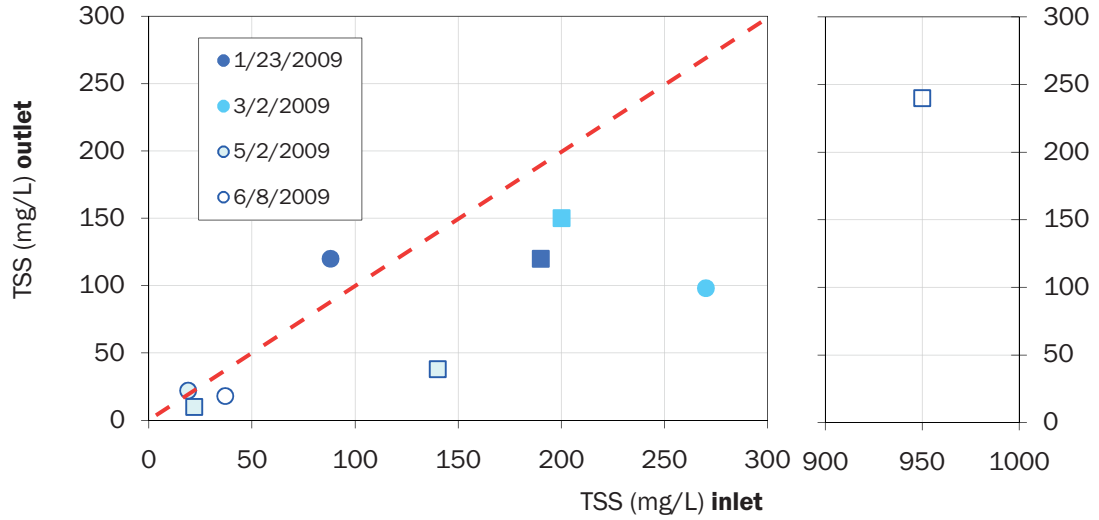
Inlet and Outlet Sample Concentrations

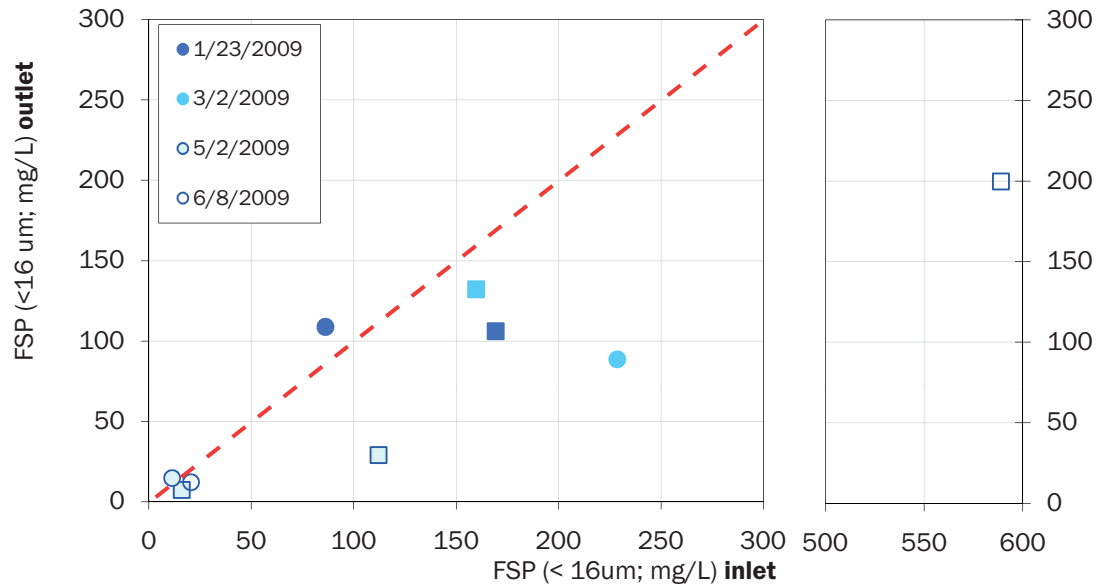
Figures 4.28-4.31 provide a comparison of the inlet and outlet paired concentrations of TSS and FSP for each SWT for each event, as well as the % FSP of the TSS sample. The dashed red lines on the graphs on Figures 4.28-4.29 and 4.31 represent where the inlet concentration = outlet concentration. Above the line, outflow concentration is greater than inflow concentration (the concentration increased between the inlet and outlet of the SWT); below the line, inflow concentration is greater than the pollutant concentration measured in its respective outflow sample pair (positive net treatment by BMP). Of the total 21 inlet/outlet sample pairs collected, 86% indicate water quality treatment as reflected in the reduction of TSS and FSP concentration at the outlet relative to the inlet. FSP % measures the fractionation of the total TSS load and shows greater event variability than the concentration data. A reduction in % FSP is not necessarily expected through SWT because % FSP may increase in the paired samples while FSP concentration decreases. This would indicate preferential removal of the coarser TSS fraction, an expected result. Approximately 67% of the sample pairs indicate net % FSP increases. We ultimately are concerned with reduced FSP concentrations and loads when considering the water quality issues with respect to reversing Lake Tahoe Clarity, thus the metric % FSP should always be evaluated within the context of mass and concentration.

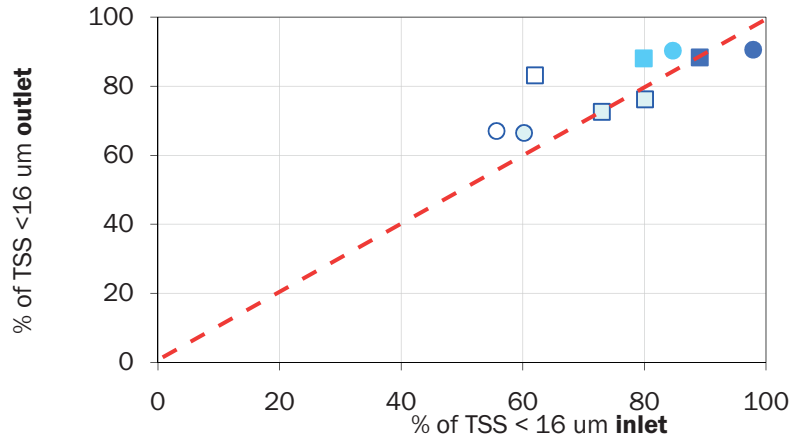
The highest inlet TSS and FSP concentrations seen at all sites occurred during the June summer rain event, with inlet concentrations 2 to 5 times greater than the concentrations sampled during any of the winter/spring events. This data is consistent with other BMP performance evaluation findings that summer/fall concentrations in urban stormwater are consistently higher than winter/spring, likely due to the more intense, shorter duration thunderstorm and rain events have a greater transport capability (2NDNATURE 2005, 2NDNATURE 2008). Compared to the four winter/spring events, the June 2009 hydrographs at the three basin SWTs (see Figures 4.24-4.26) show a steeper and narrower peak. The shape of these peaks indicates a rapid response in the basin storage volume as a result of faster inflow velocities capable of transporting a greater amount and larger-sized material accumulated on the catchment land surface.

A consistent seasonal reduction in the % FSP was observed at all sites, where the lowest % FSP in both inlet and outlet samples were observed during the June (summer) event. We suspect this seasonal difference may be due to a combination of (1) increased fines on the catchment land surface during the winter due to winter road conditions and the pulverization of applied road abrasives and (2) higher event flow velocities increasing the transport capability for coarser sediment during the high intensity summer runoff event.

Osgood Basin (*wet basin*)







1/23/2009
3/2/2009
5/2/2009
6/8/2009

Square indicates sample collected from auto sampler.
Circle indicates sample collected from passive sampler.

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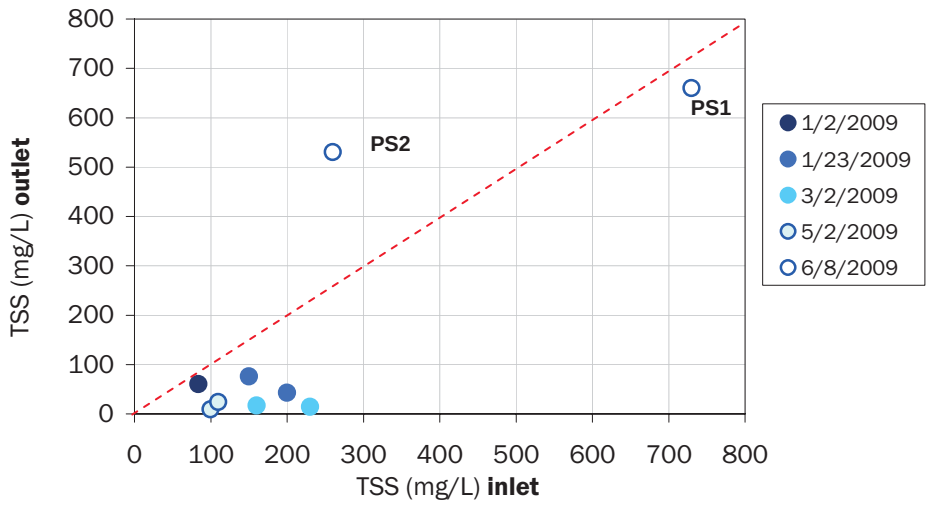
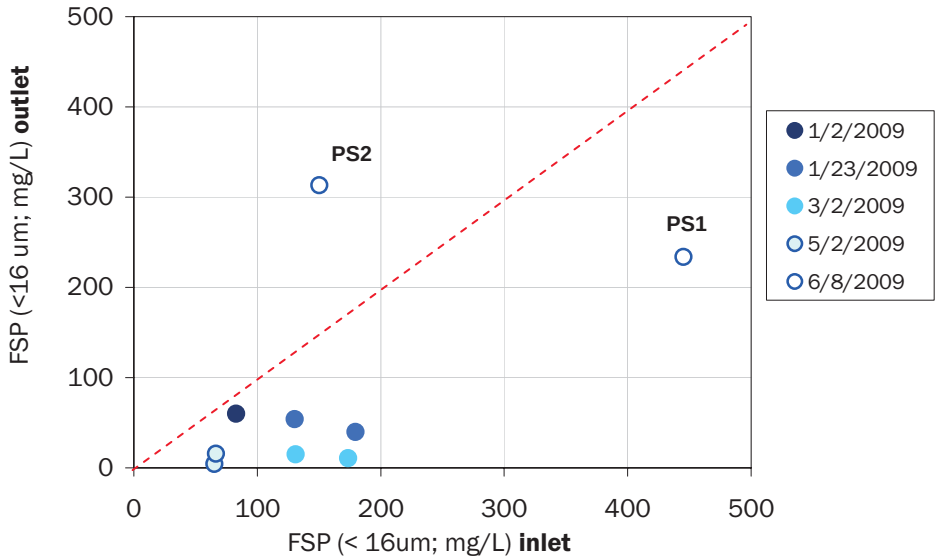
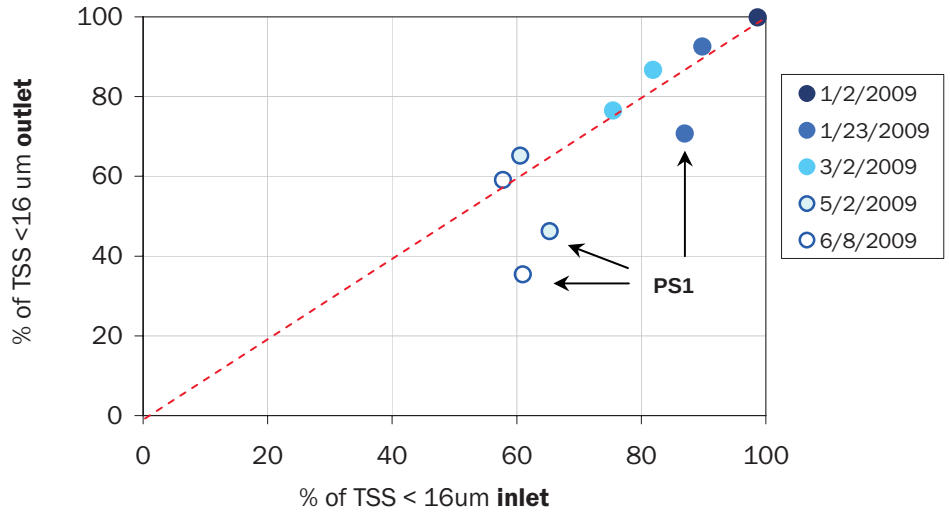
OSGOOD BASIN WATER QUALITY CONCENTRATIONS

FIGURE 4.28

Park Avenue Upper Basin (PA 1) (wet basin)







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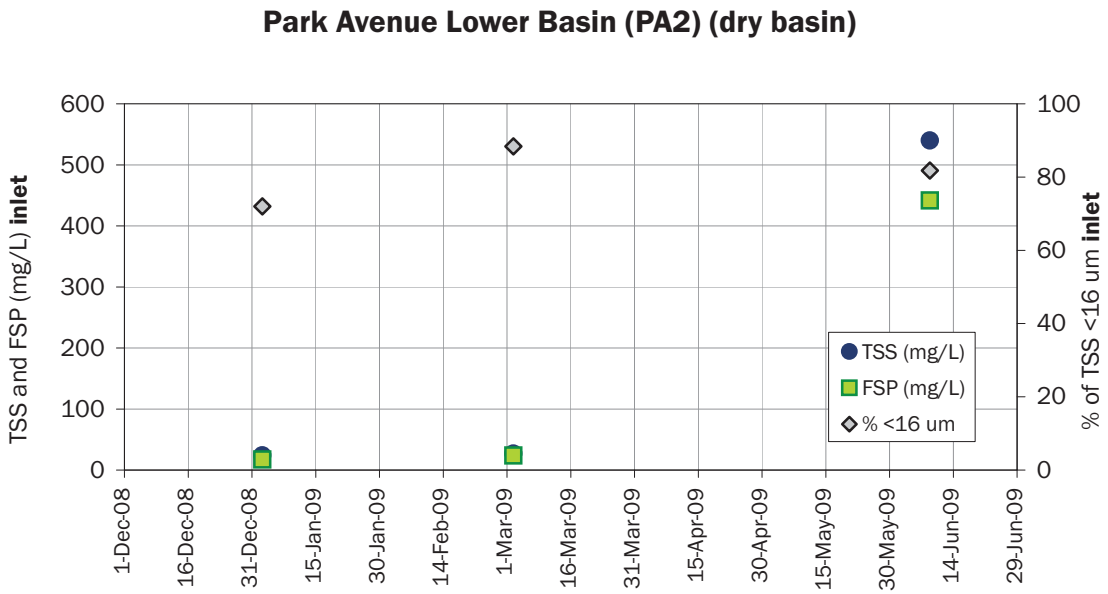
PA1 WATER QUALITY CONCENTRATIONS

FIGURE 4.29



PA2 sampling consisted of only 3 distinct passive samples collected at PA2_IN1, the lowest elevation sampler at the inlet. During the sampling duration none of the outlet passive samplers (PA2_OUT1, PA2_OUT2, PA2_OUT3) collected a sample due to lack of SWT inundation.

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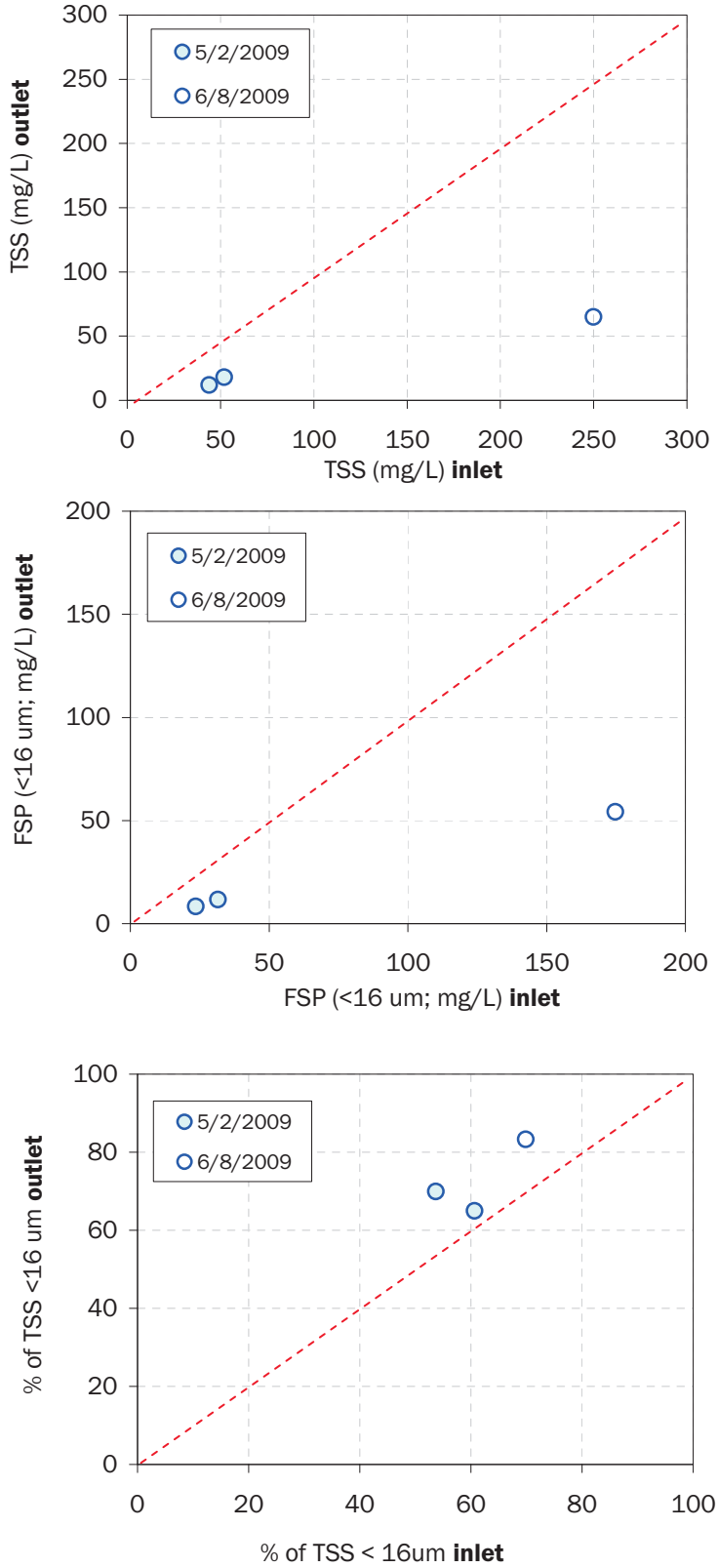
PA2 WATER QUALITY CONCENTRATIONS

FIGURE 4.30

Stormfilter® Vault (cartridge filter)



OSGOOD BASIN

In Osgood Basin, the greatest concentration reductions between the inlet and outlet samples for both TSS and FSP are observed during the March and May runoff events. As the inflow concentrations get lower (< 30 mg/L TSS and < 25 mg/L FSP) the treatment capability of the SWT is minimal. This is consistent with findings from the synthesis of SWT water quality performance evaluations in Lake Tahoe (2NDNATURE 2006) that suggested that there is an achievable limit to effluent concentrations for each pollutant in stormwater below which the typical SWTs in Lake Tahoe can no longer reduce. The CEC estimates used for PLRM v1 also embrace this assumption (nhc et al. 2009).

UPPER PARK AVENUE BASIN (PA1)

The inflow concentrations at PA1 are consistently higher than those observed at Osgood Basin (see Figures 4.28-4.29). We suspect these differences are due to the differences in catchment land use distribution and condition. Residential, commercial and road land uses combine to equal 59% of the total area within the Park Avenue catchment; those land uses are only 31% of the Osgood Basin catchment (see Table 4.9). The percentage of urban roads is nearly double in the Park Avenue Basin contributing catchment and includes Highway 50, a high risk primary road. Park Avenue is also 33.5% impervious, compared to only 13.5% in the Osgood Basin catchment. These urban land uses are more likely a source for the pollutants of concern in Lake Tahoe urban stormwater, and the higher percent impervious suggests a greater watershed connectivity and higher pollutant transport capacity.

With the exception of the June event, PA1 displays a consistent and reliable reduction in inflow TSS and FSP concentrations. When inlet concentrations are below 300 mg/L and 250mg/L for TSS and FSP, respectively, the outlet concentrations are, on average, 97 mg/L for TSS and 64 mg/L for FSP. These outlet values are very similar to the 2009 outlet concentrations observed at the other wet basin, Osgood Basin, despite the much higher inflow concentrations generated from the Park Avenue catchment. The inflow rates at PA1 exceed the estimated Q-treatment flow rate for that wet basin 50% less often than the Osgood Basin inflow rates exceed its Q-treatment (see Section 4.2.3). This increased capability to retain surface water volumes during a runoff event, at or above a minimum hydraulic residence time may improve the TSS and FSP treatment capability within wet basins because of greater particle capture through particle settling and increased time for soil-water and water-vegetation interactions.

LOWER PARK AVENUE BASIN (PA2)

During Phase I, outflow was never observed at PA2 (Figure 4.26) and only 3 inlet samples from PA2 were collected (see Figure 4.30). In general, the PA2 inlet TSS and FSP concentrations are consistent with PA1 outlet concentrations, which we would expect based on the hydraulic connection between the two basins (see schematic on page 4.53). The one exception is during the June summer event, when the PA2 inlet FSP concentration is 1.5 times higher than the outlet PA1 concentration. The high volumes associated with the summer event may have flushed the stormwater connection, contributing to the higher concentrations observed at the PA2 inlet.

STORMFILTER® VAULT

Though the dataset is extremely limited, the Stormfilter® appears to be effective at reducing outlet concentrations relative to inflow, especially at higher inlet concentrations.

Grain Size Distribution

Figures 4.32-4.34 show the results of the particle grain size distribution analysis from the inlet and outlet SWT sampling. The graphics pair the inlet and outlet samples and present each of the 8 size fractions (from <1mm to <0.5um) per sample, descending from larger particle sizes (dark colors) to finer particles (light colors). The fine sediment particle (<16um) division is represented by the break between the dark red and bright red fractions. The fraction below that line represents the % of the sample <16um, or the fine sediment fraction.

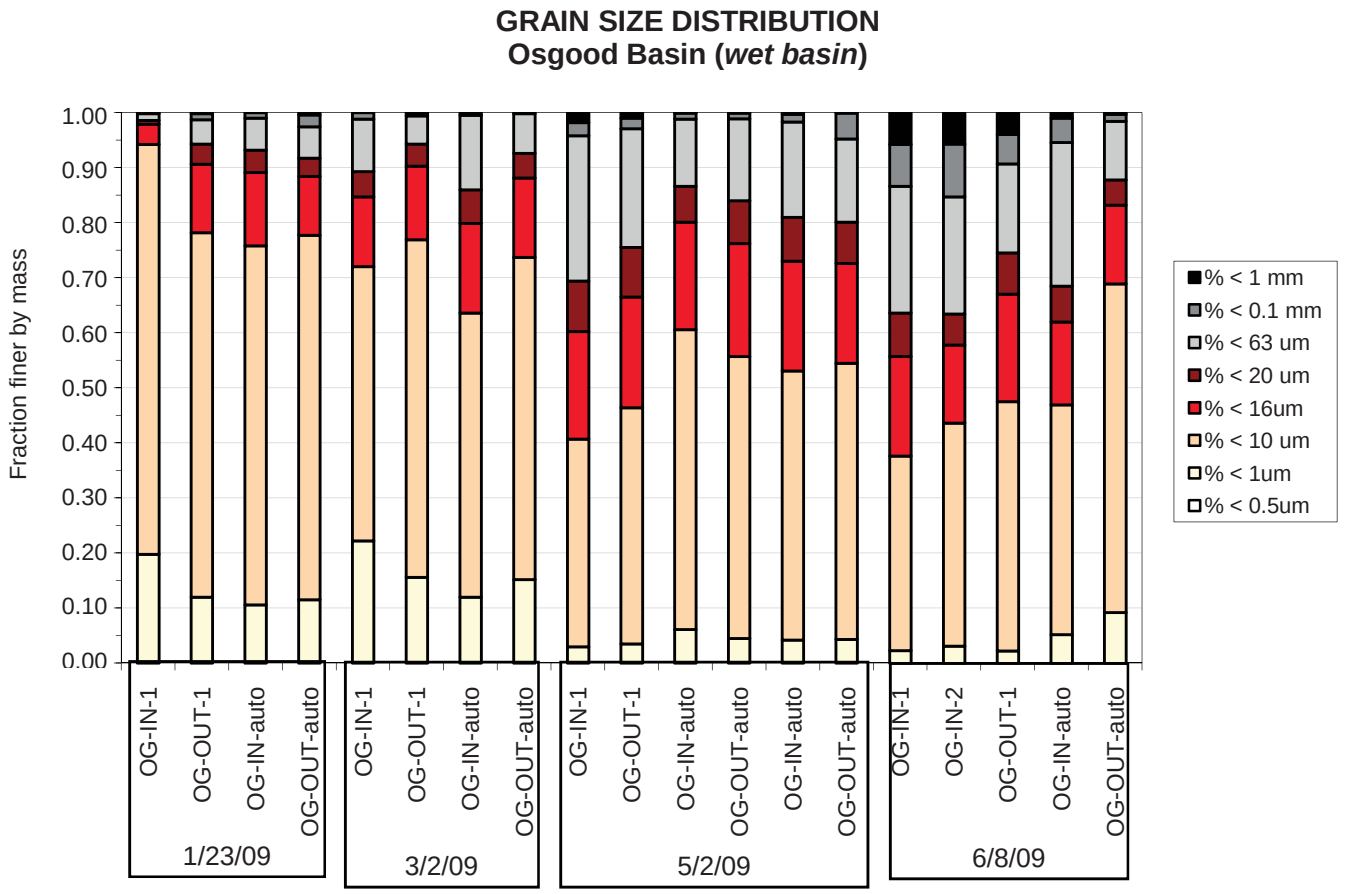
Proper interpretation of the percent grain size distribution (% FSP) of a sample must also consider the absolute FSP concentration. The effluent FSP mass or concentration may decrease compared to influent FSP mass or concentration, while the % FSP in outflowing waters may be higher as a result of preferential settling of coarser material (>16um). An increase in the % FSP between two samples should not be considered indicative of a decline in water quality. In terms of Lake Tahoe Clarity, metrics evaluating the reductions in the FSP concentrations and loads are critical and the % FSP variations should always be interpreted in the context of mass.

The grain size distribution data displays a general coarsening of the sediment within the water samples from January to June. We suspect this may be due to increased fines in the catchment during winter road conditions and/or the greater transport capacity for larger-sized material during the higher intensity summer runoff events.

Event Loads and SWT Performance

Table 4.10 presents the inflow and outflow FSP loads by SWT for each sampling event. Analysis is provided for FSP only, as it is the primary pollutant of concern affecting Lake Tahoe Clarity. Inflow and outflow event volumes were calculated using the continuous hydrology dataset obtained from each SWT and following the water budget calculations described above. The outflow volumes presented here are the sum of both treated and bypass outflow volumes for each event. Inflow and outflow FSP concentrations were averaged for all inflow and outflow samples collected per SWT per event. Loads (kg) are calculated as the product of event volume (ac-ft) and FSP concentration (mg/L). FSP load reduction is calculated as (Load FSP In – Load FSP Out), and % reduction is (FSP Load Reduction)/ (Load FSP In).

In general, measurable FSP mass reductions are observed throughout the monitoring period, irrespective of SWT or runoff event type. Absolute FSP mass reductions in Table 4.10 range from 1.9 kg to 300 kg. The wide range of absolute load reductions is largely due to differences in catchment size and catchment conditions and is not directly an indication of individual SWT performance. The relative magnitude of load reductions are more comparable across SWT types, and are consistently 60% or greater on an event time scale. As Figures 4.32-4.34 show, these load reductions are not only due to volume loss via infiltration by the SWTs, but are also the result of FSP concentration reductions.



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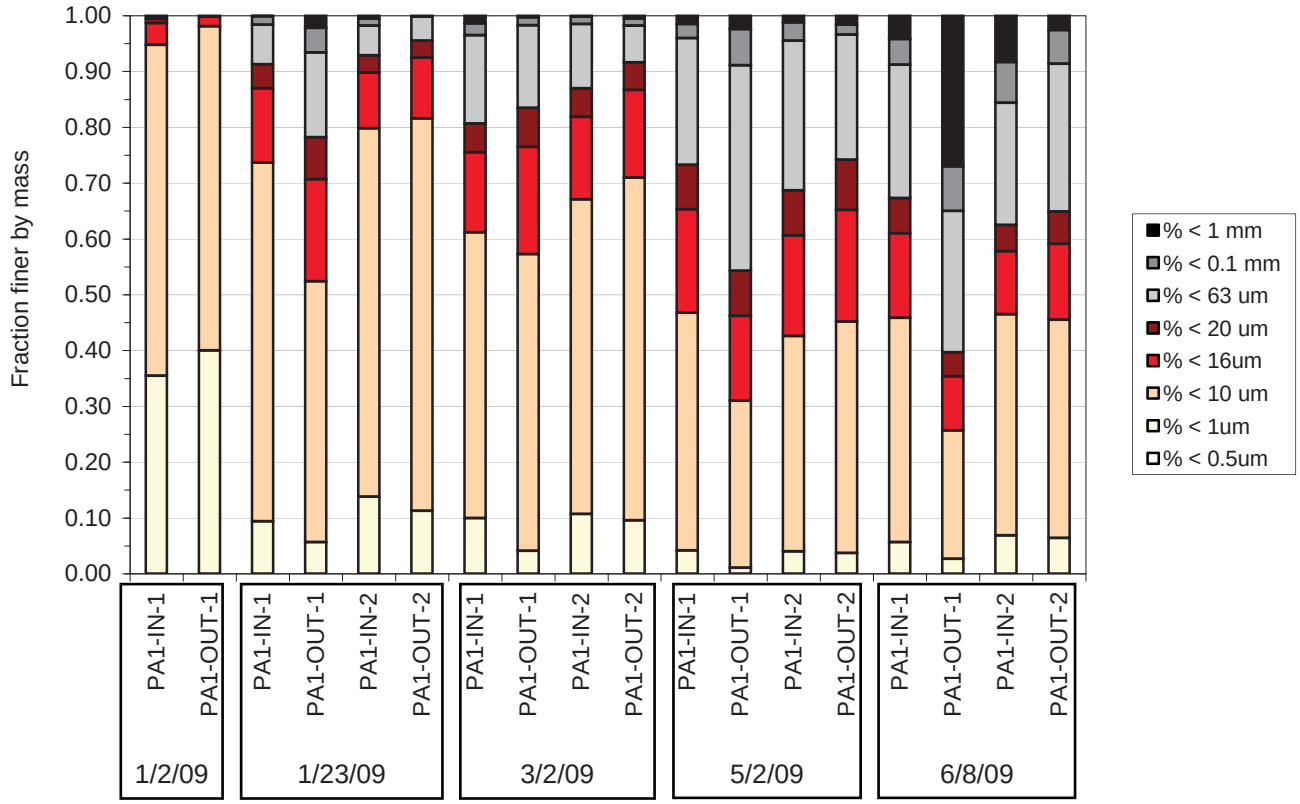
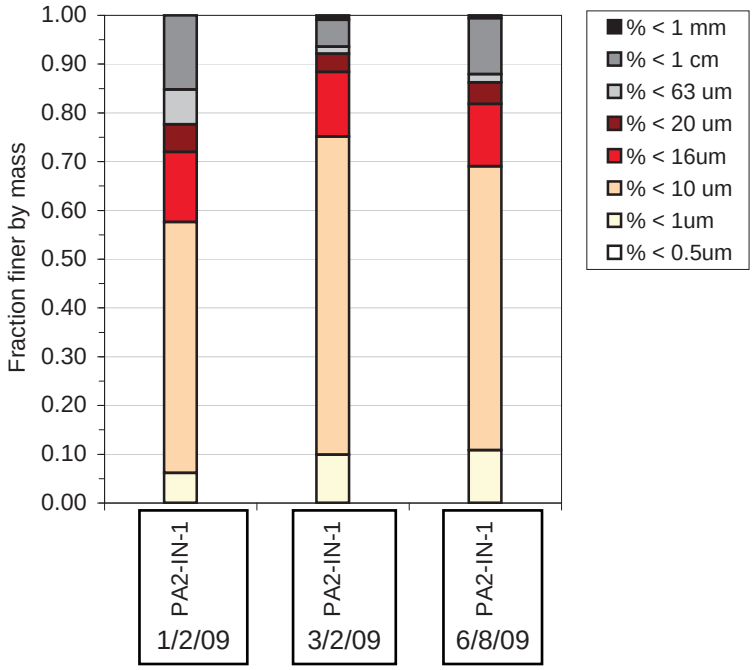
OSGOOD BASIN SAMPLE GRAIN SIZE DISTRIBUTION

FIGURE 4.32

GRAIN SIZE DISTRIBUTION
Park Avenue Upper Basin (PA1) (wet basin)



Park Avenue Lower Basin (PA2) (dry basin)



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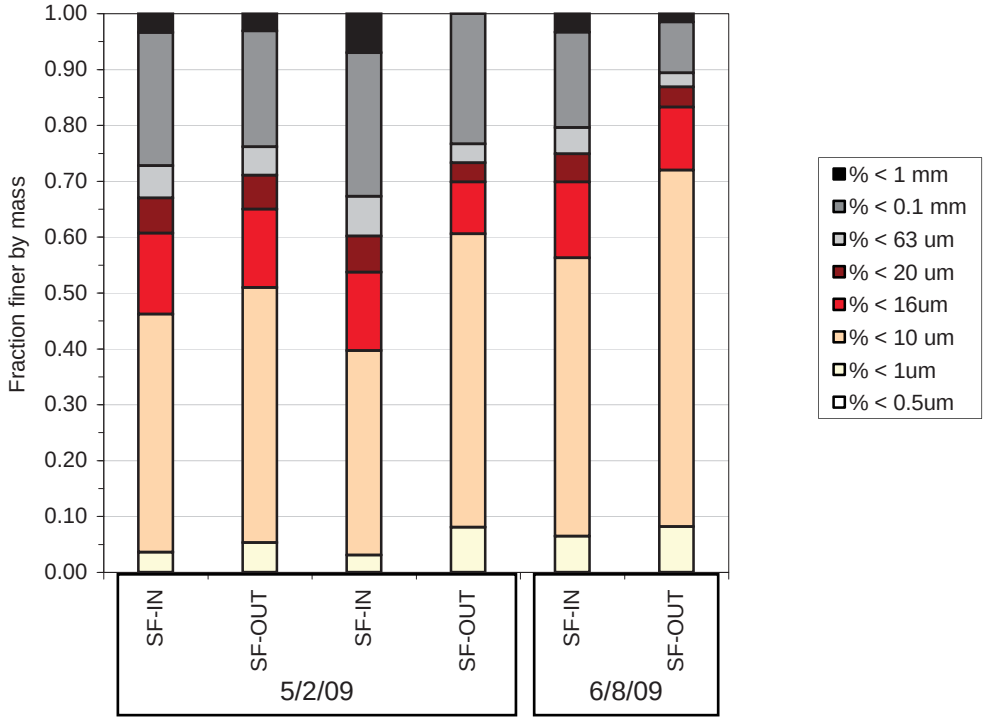
PARK AVENUE SAMPLE GRAIN SIZE DISTRIBUTION

FIGURE 4.33

GRAIN SIZE DISTRIBUTION

Stormfilter® Vault (cartridge filter)



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STORMFILTER® SAMPLE GRAIN SIZE DISTRIBUTION

FIGURE 4.34

Table 4.10. Phase I SWT water quality performance.

SWT	SWT Type	Event date	V in (ac-ft)	FSP in (mg/l)	Load FSP in (kg)	V out (ac-ft)	FSP out (mg/l)	Load FSP out (kg)	FSP Load Reduction (kg)	Percent Reduction
Osgood	Wet Basin	1/23/2009	0.52	128	82	0.49	107	65	17	21%
		3/2/2009	1.44	194	345	1.11	110	151	194	56%
		5/2/2009	0.72	47	41	0.55	17	11	30	72%
		6/8/2009	0.65	207	166	0.47	106	61	105	63%
Upper Park Ave (PA1)	Wet Basin	1/2/2009	0.34	83	35	0.14	60	10	24	70%
		1/23/2009	1.96	155	375	1.16	47	67	308	82%
		3/2/2009	*	152	-	*	13	-	-	-
		5/2/2009	0.87	66	71	0.49	10	6.0	65	92%
		6/8/2009	0.90	298	331	0.40	273	135	196	59%
Lower Park Ave (PA2)	Dry Basin	1/2/2009	*	17	-	0	-	-	-	-
		3/2/2009	1.96	24	58	0	-	-	58	100%
		6/8/2009	0.17	442	93	0	-	-	93	100%
Storm Filter	Cartridge Filter	5/2/2009	0.09	28	3.1	0.09	10	1.1	1.9	63.6%
		6/8/2009	0.09	175	19	0.09	54	6.0	13.4	69.0%

* Instrument failure.

OSGOOD BASIN

Using the continuous water budget data, the bypass outflow rate from Osgood is estimated by an integration of volume loss when the water level exceeds the outlet elevation of the bypass weir (102.13 ft; Figure 4.24). Average bypass outflow rates ranged from 0.35 cfs during the March 09 event to 1.4 cfs during the June 09 event. Any water that leaves Osgood via this concrete outlet would be considered bypassed in a PLRM simulation. When the water level in Osgood is less than 102.13 ft, but greater than 100.63 ft the treated outflow is estimated to be 0.16 cfs through the 3 low flow outlet holes.

Some volume loss is observed during each event, which is suspected to occur as infiltration via the side slopes of the Osgood Basin during elevated stage conditions. While the bottom of the Osgood basin has very low infiltration capabilities due to the high accumulation of fine grained organic material, the side slopes of the Osgood Basin are less frequently inundated and likely remain fairly permeable. This characteristic was well documented in a detailed evaluation of Eloise Basin in South Lake Tahoe (2NDNATURE 2006). The combined event volume and FSP concentration reductions from the inlet to the outlet samples from Osgood Basin resulted in FSP load reductions over each of the 4 monitored events.

PARK AVENUE BASINS

Basin infiltration rates and outlet flow rates for critical water surface elevations developed by 2NDNATURE (2008) for the Park Avenue Basins were used for this analysis: infiltration rates of 1.0×10^{-5} cm/s and 3×10^{-3} cm/s for PA1

and PA2, respectively, and average bypass outflow rate over the runoff events of 0.7 cfs through the vertical CMPs and 0.033 cfs for the treated outflow through each of the low flow outlets.

Consistent with the catchment land use and % impervious differences between Park Avenue and Osgood catchments (Table 4.9), inflow volumes are always higher at PA1 compared to Osgood Basin (Table 4.10). Despite the fact that the Osgood Basin's contributing area is nearly twice the area of the Park Avenue catchment, there is a much higher density of directly connected impervious area dominated by urban and commercial land uses in close proximity to the Park Avenue inlets, as compared to Osgood Basin. FSP load reductions in PA1 are due to both reductions in concentration and volume reductions for each of the 2009 events. Detailed groundwater monitoring for 2NDNATURE 2008 observed the persistence of an unsaturated zone between the base o f PA1 and the shallow groundwater table throughout the year. Based on soil sample collection, the base of PA1 has a very low infiltration rate, but when the stage in PA1 is elevated it is possible some loss of basin surface water occurs through the sides of the basin on event time scales.

Based on the existing elevation configuration of PA1, when the water surface elevation in the basin exceeds 6235.86 ft water can exit PA1 through the Rocky Point inlet pipe and proceed down the bypass pipe to the west. The capacity of PA1 is exceeded when the water surface elevation in the basin exceeds 6236.03 ft (Figure 4.25). It is possible that some of the volume differences for events are the result of surface water loss via the bypass pipe.

Due to the lack of outflow at PA2, the dry basin is calculated to have 100% treatment of FSP loads because all stormwater discharged into PA2 infiltrates.

STORMFILTER® VAULT

Based on the very limited dataset, the Stormfilter® cartridge filter had a 60%+ FSP load reduction (Table 4.10) for the two runoff events sampled.

POTENTIAL PLRM CEC COMPARISONS

One continuing primary objective of this stormwater research effort is to collect and analyze site and event-specific water quality and hydrologic data from existing SWTs in the Lake Tahoe Basin to inform, validate and/or improve the PLRM v1 CEC estimates (Table 4.7). The data collection and data analysis strategy, as well the breadth of the dataset itself, must continue to improve in order to meet this objective. Below we provide two **preliminary** data analysis strategies to potentially analyze the water quality data obtained from SWTs in order to compare to PLRM CECs. Using subsequent funding, the research team will continue to evaluate the data analysis options below as well as consider other approaches to best meet our needs of integrating temporally and spatially specific data to inform PLRM average annual CEC estimates. Given that this Phase I dataset is both temporally and spatially limited, the research team does not recommend any modifications to the PLRM v1 CECs at this time.

Seasonal Weighting Approach

The climatic variability with respect to season and event types in the Lake Tahoe Basin is significant to both hydrology and observed water quality. One simple way to preserve these seasonal climatic differences is to define two distinct seasons, winter/spring (W/S, December-May) and summer/fall (S/F, June to November), as done for the TMDL UGSCG Pollutant Control Options analysis (LRWQCB and NDEP 2007). The PLRM hydrologic module and the 18-yr meteorology dataset were used to estimate the average runoff fractionation between these two

seasons. The results suggest that 79% of the annual volume occurs from December to May and the remaining 21% occurs between June and November, on an average annual basis.

Since load is the product of both concentration and volume, one potential simple approach to estimating the average annual treated pollutant concentration given a number of discrete seasonal values is to average the applicable SWT treated concentrations per site per season and then seasonally weight the averages based on the annual runoff fractionation. Ideally, only outflow samples representative of the treated flow from the SWT would be included, meaning the passive sampler is located at an elevation below the water quality treatment capacity of the subject SWT. The calculations are as follows:

Average of all applicable treated outflow sample concentrations (December 1 – May 31) = W/S conc.

Average of all applicable treated outflow sample concentrations (June 1 – November 30) = S/F conc.

*(0.79 * W/S conc.) + (0.21 * S/F conc.) = CEC for specific SWT [EQ12]*

CEC estimates for SWTs of the same type are averaged to obtain a value comparable to PLRM CECs.

For illustrative purposes only, the seasonal weighting approach produced the following CEC estimates for each of the 3 SWTs where outflow was monitored (Table 4.11). As stated in the sections above, the water quality samples collected from Osgood during the Phase I were collected at a water surface elevation above the invert elevation of the high-flow bypass and are not representative for calculating a PLRM CEC. All other dataset and sampling limitations apply as well.

Table 4.11. Hypothetical seasonally-weighted CEC estimates based on Phase I data.

SWT	SWT Type	TSS CEC (mg/L)	FSP CEC (mg/L)
Osgood Basin	Wet Basin	90.1	77.1
Park Avenue Upper	Wet Basin	152	79.8
Stormfilter®	Cartridge Filter	25.5	19.3

The benefit of this approach is simplicity and cost-effectiveness, only requiring a temporally and spatially representative water quality sample dataset for each SWT type and pollutant of interest. Hydrologic and inflow water quality to the SWT are not necessary, however, the reliability and accuracy of this simplified method will need to be well validated prior to recommendation.

Integration of Event Effluent Load and Volume

Another SWT data analysis approach is the integration of the total treated outflow pollutant mass (kg) and total treated outflow volume (ac-ft) for each monitored event by SWT. This approach constrains seasonal volumes by preserving the measured data. Using the water quality performance data previously presented (Table 4.10), Table 4.12 provides the CEC estimates based on the ratio of the integrated event effluent loads and volumes for each SWT where treated effluent was monitored.

Table 4.12. Hypothetical load volume integrated CEC estimates based on Phase I data.

SWT	SWT Type	TSS CEC (mg/L)	FSP CEC (mg/L)
Osgood Basin	Wet basin	103	89.4
Park Avenue Upper	Wet basin	148	80.8
Stormfilter®	Cartridge filter	40.0	32.1

There are a number of possible data analysis approaches to integrate and evaluate the event-specific water quality data obtained from Lake Tahoe SWTs to inform and improve PLRM CEC values, and the continued research beyond this ACOE funded effort will provide the resources and increase the dataset available to better address this objective.

Annual Water Budget and Discrete Sample Integration

Continuous annual water budgets at each SWT provide an opportunity to extrapolate the collection of discrete treated and bypass water quality samples across specific event characteristics (type, volume, etc.) and estimate continuous treated pollutant and bypass water effluent loads over the duration of the observations. Likely the most effective approach will be to continue to measure a reasonable representation of event types from a selection of SWT types while obtaining continuous annual hydrologic records. The event water quality (pollutant concentration and load) data can be extrapolated using reasonable seasonal event type assumptions to estimate annual loads. Efforts to place the observed water year(s) into the overall precipitation pattern context of the PLRM 18 years of Lake Tahoe meteorological records would be necessary, but may provide another applicable approach to apply temporally and spatially discrete observations to inform the average annual PLRM CEC estimates.

SWT MONITORING CONCLUSIONS

- The Phase I dataset is temporally very limited; sampling included only 3 winter/spring and 1 summer fall event. PLRM estimates are on average annual time scales and the 4 stormwater runoff events monitored represent only a limited fraction of one distinct water year. Additional monitoring to include a greater temporal range of data is necessary to strengthen the usability of this data.

- The Phase I sampling configuration failed to capture the water quality treatment volumes outflowing from the Osgood Basin because the effluent passive samplers were all placed at or above the bypass outlet elevation. Modifications to the site sampling configuration were made in the fall of 2009 to rectify this issue as monitoring continues at this site through 2011 using SNPLMA Round 9 funds. Familiarity of SWT configuration and the continued knowledge gained regarding site idiosyncratic conditions is essential to ensure effective site instrumentation and sampling techniques of SWTs.

- The sampling configuration at Park Avenue Upper (PA1) and the Stormfilter® did include representative outflow sampling of the water quality treatment volumes. Park Avenue Lower (PA2) did not have any treated outflow occur during the Phase I sampling.

- Of the 21 inlet and outlet passive sample pairs collected at Osgood and PA1 wet basins, 86% indicated an FSP concentration reduction. This finding is consistent with the limited inlet and outlet sampling of FSP at PA1 by 2NDNATURE (2008) and supports the ability of wet basins to provide some FSP load reductions that are not solely due to volume reductions within the SWT.

- Consistent with our current understanding of seasonal stormwater quality in Lake Tahoe, the highest inlet TSS and FSP concentrations sampled at all sites occurred during the June summer rain event, with inlet concentrations 2 to 5 times greater than the concentrations sampled during any of the winter/spring events. The higher-intensity, short-duration summer thunderstorm and rain events have a greater transport capability than the winter/spring rain, rain on snow and snowmelt runoff events. While these

Summer/Fall concentrations are typically higher, only 21% of the annual surface water volume delivered to Lake Tahoe occurs from June – November, with the remaining 79% occurring from December – May.

- In general, measurable FSP mass reductions are observed throughout the monitoring period, irrespective of SWT type or runoff event type. While the absolute magnitude of FSP mass reductions varies per event, consistent load reductions occur and are measureable on an event time scale. As stated above, these load reductions are not only due to volume loss via infiltration, but are also the result of FSP concentration reductions. Additional data collection will be key in the continued investigation of the seasonal and average annual water quality treatment performance of SWTs with respect to fine sediment particles in urban stormwater.

- While the existing data is limited and will not be used to recommend changes to PLRM v1 CECs at this time, two potential SWT data analysis approaches are presented to apply temporally and spatially specific data to PLRM average annual CECs for each SWT type and pollutant of interest. Approaches that utilize the continuous annual water budgets to estimate average annual CECs will also be explored. Developing the data analysis approach that best meets one of the primary goals of this research, to inform PLRM v1 water quality values, will continue to be a focus of the continued research efforts using SNPLMA Round 9 funds.

SWT MONITORING: NEXT STEPS

This Phase I PLRM database refinement monitoring has made great strides toward developing standardized and consistent protocols to collect, manage and analyze data to inform and test the assumptions underlying PLRM v1 CEC estimates. The data analysis and report generation has stimulated a lot of questions and improved the understanding of the research team on how to address the PLRM water quality data needs. Using SNPLMA Round 9 funds, Phase II of the PLRM v1 Database Refinement monitoring includes the instrumentation of additional SWTs that will be monitored through 2011 along with the 4 sites described above to expand the current dataset and to continue the sampling efforts initiated by this Army Corps of Engineers (Phase I) contract.

Currently funded Phase II steps include:

- Expand the existing dataset by continuing the collection of inlet and outlet concentrations and SWT surface water hydrology to inform PLRM CECs for SWTs modeled by PLRM. SNPLMA Round 9 does not include ample resources to instrument and evaluate all SWT types. It is anticipated Phase II will continue to evaluate dry basins, wet basins, cartridge filters and may include one or two treatment vaults as resources allow.

- Continue data collection and analysis to understand the influence of SWT design parameters (e.g., water quality volume, brim drawdown time, outlet design, etc.) on the overall treatment performance capability of SWTs to retain and remove fine sediment particles (<16µm) from urban stormwater. Expand analyses to include SRP and TP on a subset of SWT water samples as resources allow.

- Continue BMP RAM condition assessments on the monitored SWTs to improve our understanding on the role of SWT maintenance on long-term SWT water quality performance.

- Continue to develop and validate the appropriate data collection and data analysis methodology to separate the bypassed load from the treated load to calculate CECs for stormwater samples when bypass is occurring in a SWT.

- Based on the strong FSP and turbidity correlation observed with the road sampling efforts, all stormwater samples collected for the SNPLMA research (including SWT inlet and outlet samples) will be analyzed for in-field turbidity readings. This correlation may provide a cost effective alternative to collect FSP data sufficient data to inform both PLRM CRCs and CECs in the future.

- Additional work is necessary to refine both our data collection and data analysis strategies of each SWT to appropriately inform PLRM v1 assumptions and predictions. The data collection and data analysis process significantly improved the 2NDNATURE team's understanding of appropriate and necessary SWT sampling and data analysis needs in order to directly apply site and temporally specific data to PLRM estimates. The Phase II (SNPLMA Round 9 funded) PLRM Database Refinement monitoring will continue to optimize these strategies by beginning to compare observed and PLRM predicted hydrologic and water quality metrics for a collection of SWTs monitored.

- While the stormwater sampling techniques applied by the 2NDNATURE team to inform PLRM and other stormwater tools are relatively cost-effective, the cost and technical expertise necessary for this data collection, data management, and data analysis approach are still substantial. Through the SNPLMA Round 9 funded efforts and beyond, the team will continue to address potential recommendations on how future data collection and data analysis should be conducted to cost effectively inform and improve PLRM load reduction estimates and the associated annual Lake Clarity Credit awards.

- There is a continued need to align urban stormwater tools with identified pollutant of concern, fine sediment particles, by developing appropriate conversion from mass of FSP (<16µm) to # of particles. Phase II stormwater samples will continue to be delivered to DRI for particle size distribution analyses to determine concentrations of FSP. All associated metadata will be made available to the DRI researchers should they desire to conduct additional particle count analyses on the stormwater samples provided.

Additional next step priorities beyond the currently funded Phase II efforts include:

- Catchment-scale integration and testing of site-specific, cost-effective monitoring techniques, RAM tool observations, and PLRM predictions. Once our datasets and knowledge of specific monitoring and evaluation techniques to inform the PLRM CRC and CEC database are improved, the imperative next step of integrating all of these tools is a complete and detailed urban catchment evaluation that includes the initiation and completion of all of the recommended Lake Tahoe stormwater tools intended to support the Lake Clarity Crediting Program (LRWQCB and NDEP 2009). The 2NDNATURE team has submitted a SNPLMA Round 10 research proposal to undertake this critical next step in tool integration and testing.

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Attachment C

Focused Stormwater Quality Monitoring to Inform Assumptions & Evaluate Predictive Capabilities of Existing Tools (June 2012)

FOCUSED STORMWATER QUALITY MONITORING

To Inform Assumptions and Evaluate Predictive Capabilites of Existing Tools

2NDNATURE
ecosystem science + design

nhc

FINAL REPORT
★ June 2012 ★

Focused Stormwater Quality Monitoring to Inform Assumptions & Evaluate Predictive Capabilities of Existing Tools

Final Technical Report
June 2012

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LIST OF KEY ACRONYMS AND TERMS

A&T Tool	TMDL Accounting & Tracking Tool; Data management tool that stores, tracks and reports credit information and load reduction achievement over time in association with the Crediting Program.
Baseline	Baseline Condition; Conditions present during TMDL baseline period, Oct 1, 2003 – May 1, 2004.
BMP RAM	Best Management Practice Maintenance Rapid Assessment Methodology; Tool for Tahoe Basin urban stormwater community to determine relative condition of an urban stormwater BMP.
CEC	Characteristic Effluent Concentration; Represents the effluent concentration typically achieved by a SWT facility in PLRM dependent upon the type of SWT facility specified.
CICU	Commercial/Industrial/Communications/Utilities; Land use designated in Tahoe Basin TMDL.
CRC	Characteristic Runoff Concentration; Representative concentration for a pollutant of concern in runoff from a specific land use and associated land use condition in PLRM.
Credit	Lake Tahoe Clarity Credit; Related to pollutant load reductions and used to evaluate progress towards TMDL.
Crediting Program	Lake Tahoe Clarity Crediting Program; Tahoe Basin program that defines system to track and evaluate pollutant load reductions and related credits within context of TMDL by urban catchment.
DCIA	Directly Connected Impervious Area; Impervious surfaces draining through a direct hydraulic connection to a surface water drainage system.
Existing	Existing Condition; Conditions present during the development of this Strategy Report, Oct 1, 2010 – May 1, 2011.
FSP	Fine Sediment Particle; Mass fraction of TSS concentration <16µm.
LRWQCB	Lahontan Regional Water Quality Control Board; California regulatory agency overseeing Tahoe Basin TMDL implementation.
MFR	Multi-Family Residential; Land use designated in Tahoe Basin TMDL.
NDEP	Nevada Division of Environmental Protection; Nevada regulatory agency overseeing Tahoe Basin TMDL implementation.
PLRM	Pollutant Load Reduction Model; Tool for Tahoe Basin urban stormwater community to estimate pollutant load reductions associated with catchment-scale water quality improvement actions.
Road RAM	Road Rapid Assessment Methodology; Tool for Tahoe Basin urban stormwater community to determine the condition of impervious road surfaces.
Road Risk	PLRM term that incorporates road characteristics to describe relative risk of pollutant generation and transport downslope from impervious road surfaces.
SFR	Single Family Residential; Land use designated in Tahoe Basin TMDL.
SNPLMA	Southern Nevada Public Lands Management Act; Key funding source of this research.
SRP	Soluble Reactive Phosphorous; Also known as orthophosphate, it is the dissolved inorganic fraction of total phosphorous that is biologically available to primary producers.
SWMM	Storm Water Management Model; EPA-developed dynamic rainfall-runoff simulation model used for single event and long term (continuous) simulation of surface hydrology quantity from primarily urban/suburban areas.
SWT	Stormwater Treatment Facility; Treatment BMP designed to reduce urban stormwater volumes and/or pollutant concentrations from a concentrated stormwater flow path.
TMDL	Tahoe Basin Total Maximum Daily Load; Implementation plan that establishes pollutant load reduction allocations for urban stormwater to improve Lake Tahoe clarity.
TSS	Total Suspended Sediment; Mass of sediment contained in a known volume of water.
UPC	Urban Planning Catchment; A contiguous area containing urban land uses with runoff draining to a surface water body. Any single square foot of land is included in only one urban catchment
WQIP	Water Quality Improvement Project; Typically a suite of improvements (pollutant source control, hydrologic source control, and stormwater treatment facilities) implemented within an urban catchment to reduce the pollutant loading to surface waters.

CHAPTER 1. EXECUTIVE SUMMARY

The primary focus of this research was to obtain a representative and reliable stormwater dataset to compare to applicable predictions from the Pollutant Load Reduction Model (PLRM; NHC et al 2009) and provide road specific data to inform the development of Road Rapid Assessment Methodology (Road RAM; 2NDNATURE et al 2010). These currently are the only tools approved for use by the Lake Clarity Crediting Program (Crediting Program; LRWQCB and NDEP 2009), a program intended to incentivize and measure progress toward the attainment of urban stormwater load reductions established in the Lake Tahoe TMDL (LRWQCB and NDEP 2010). However the initial versions of each tool were developed with known limitations. The research documented herein is the culmination of three years of intensive experimental design, stormwater data collection, modeling efforts and data analysis that has greatly improved our understanding of Tahoe Basin urban stormwater quality. This report serves as the final deliverable for a USDA Forest Service Pacific Southwest Research Station grant using SNPLMA Round 9 funding, but relevant information and data obtained from preceding efforts are included in the following analyses when applicable to improve interpretations.

Chapters 2, 3 and 4 provide the background, research context and methods employed. **Chapter 2** provides the research purpose, funding mechanisms, and an overview of the function and structure of the stormwater tools that support the Lake Tahoe TMDL as it relates to the research conducted herein. **Chapter 3** documents site selection, data collection, data management, data analysis techniques, and other relevant methods employed in extensive detail. **Chapter 4** summarizes the specific water year conditions critical to interpreting the context of these monitoring results, including weather and road maintenance practices as documented by the jurisdictions. Since PLRM was designed to be a relatively simple tool to predict average annual potential pollutant load reductions from stormwater quality improvement projects in the Tahoe Basin over a long-term continuous simulation, water year specific hydrology and water quality data is inherently challenging to relate to average annual PLRM predictions generated using the 18 year historic dataset.

Chapter 5 reviews the data and associated findings from land use specific data collection and modeling. PLRMv1 estimates pollutant loads by integrating catchment runoff and land use specific estimates of water quality concentrations for pollutants of concern to lake clarity. PLRMv1 contains a database of characteristic runoff concentrations (CRCs) for each land use type and for a range of land use conditions by pollutant. A significant amount of the land use research was focused on our ability to estimate pollutant generation from roadways, due the assumption that roads in the Tahoe Basin are the largest source per unit area of the primary pollutant of concern, fine sediment particles (FSP; < 16um), impairing Lake clarity (LRWQCB and NDEP 2010). Key road research findings include:

1. Comparison of road specific sampling and mixed land use catchment water quality data support assumptions that the average FSP and TSS concentrations from roads per unit area are significantly higher than the average mixed land use signal. In contrast, the average SRP concentration is lower, suggesting that roads may not be a primary source of SRP to catchment pollutant loads.
2. Roadway condition (as measured by the concentration of FSP obtained from the portable simulator and/or Road RAM) has a significant seasonal variability with the poorest road conditions consistently observed during winter months (see Figure 5.3). Given that the observed roadway conditions consistently improve at all road segments through the summer and fall, all available information suggests road condition is most sensitive to, and controllable by, winter road maintenance practices (see Figure 5.4). Poor road condition in the late winter/early spring can result in a substantial downslope water quality risk when rains efficiently

transport these pollutants into the stormwater system, requiring treatment and/or retention to prevent FSP from reaching the Lake.

3. Periodic evaluations of road condition from winter 2009 through summer 2011 and records of annual road abrasive application volumes by jurisdictions suggest a trend of decreasing abrasive application and improved winter road condition for water quality. This trend was found despite a sequential increase in winter snowfall totals each of the monitored years.

4. The range, minimum and maximum road CRC values in PLRMv1 Road Methodology appear reasonable given the road specific dataset obtained. PLRMv1 bounds anticipated runoff quality and achievable runoff quality through improvements in road conditions based on the concept of road risk. Comparison of the volume weighted average FSP concentrations from this study indicates that the PLRMv1 guidelines for defining and categorizing road risk may be insufficient to reasonably capture differences in operational practices across jurisdictions and detailed recommendations for PLRMv1 user guidance improvements are recommended. The obtainment of consistent road condition observations over a range of water year types on roads maintained in a consistent manner (same road prescriptions across years) would greatly improve our ability to compare annual estimates of road FSP concentrations to PLRM CRC predictions.

5. Comparisons of observed and calculated FSP concentration ranges suggest that frequent street sweeping may provide greater FSP reductions than currently allowed in PLRM; however, more research would be necessary to determine potential adjustments to PLRM CRCs as a result of street sweeping actions. Observations support previous assumptions that increased sweeping frequency during the winter months removes coarse material delivered to road surface prior to pulverization. Observations and discussion with road maintenance personnel suggest the opportunity exists between winter storms to sweep roads where material accumulation occurs. The lowest observed FSP concentrations were actually on high and moderate risk roads where high abrasive applications were coupled with frequent sweeping with high efficiency sweepers.

6. Road surface integrity is not a factor included in PLRM v1, but there is anecdotal evidence that suggests poor road surface integrity can increase the downslope water quality risk as a combination of reduced sweeper effectiveness and the degrading pavement being an additional source of FSP.

7. Two potential long-term PLRM Road Methodology improvements are suggested.

    a. Revise the PLRM Road Methodology to a user defined CRC. A road network classification would be conducted by jurisdictions based on road maintenance practices, and PLRM user inputs would be the specific road condition and associated FSP CRC expected. The main benefits of a condition based approach to the PLRM Road Methodology are the alignment between model inputs and observations that can be verified in the field, and the elimination of the need for PLRM developers to estimate the incremental benefit of individual actions on the long-term average road condition. A number of information and data gaps exist and detailed user guidance on how observation data should inform CRC inputs would need to be developed. This is the preferred recommendation of the research team and technical advisory committee.

    b. PLRMv1 adjusts CRCs from road land uses based on a set of user-defined actions, which reduce CRCs in the model assuming that user-defined actions improve water quality by either reducing pollutant sources or increasing pollutant sinks. Future improvements would replace road risk classification with a grouping based on road maintenance prescriptions by road network and adjust action-specific algorithms to estimate the reduction in the expected CRC as a result of a series of maintenance actions. The main advantages of continuing with an action-based approach to the PLRM Road

Methodology are: 1) user familiarity with the current approach; 2) ease of model use as model inputs can be readily defined with some certainty; and 3) a manageable system to link and track PLRM modeling assumptions with actual road maintenance practices. The main challenges for continuing with an action-based approach would be (1) continued shortcomings linking field observations of road condition, which ultimately drives road runoff quality, with PLRM predictions and (2) overcoming the inherent difficulty in estimating the incremental benefit (or CRC reduction) of specific actions (e.g., modifications to abrasive specifications, changes in road shoulder condition, differences in sweeper efficiency, etc.).

Chapter 5 private parcel research experienced a myriad of challenges associated with cost-effectively sampling the runoff quality from pervious land use types. Given the objectives and the resources available for this effort, an appropriate and cost effective technique to obtain water quality data from pervious surfaces to compare to PLRMv1 CRC values was, unfortunately, not identified. Realistically, the greatest influence on stormwater pollutant load reductions from private parcels will result from implementation and maintenance of private parcel BMPs that infiltrate runoff volumes and provide effective source controls on site, reducing the necessary capacity and treatment capabilities of downstream public stormwater treatment BMPs.

The land use specific research (**Chapter 5**) also developed a framework for refining user inputs and adapting PLRMv1 technical algorithms to better represent pervious road shoulder condition and its effect on infiltration and runoff calculations in the model. A simple method was developed to categorize pervious road shoulder compaction at a road shoulder to guide the PLRM user to infer a default K_{sat} in PLRM. Suggested revisions to the PLRM user guidance are provided; however, no changes to the model technical algorithms have been made at this time.

Chapter 6 reports the results from the stormwater treatment BMP research that obtained cost-effective hydrologic and water quality datasets from nine different treatment BMPs (termed SWTs in PLRM) within the Tahoe Basin in a manner that would allow comparisons of measured data to PLRM hydrologic predictions and inform the PLRMv1 characteristic effluent concentration (CEC) values.

8. A comparison of seasonal estimates generated from 3 water years of SWT hydrology data collection to PLRM predictions show a very strong correlation (significant above 99% confidence) between measured and modeled treated outflow volumes across a range of hydrologic conditions experienced by dry and wet basins (see Figure 6.2B). Given that treated outflow is the hydrology metric used in PLRM to adjust pollutant loads as a result of SWT construction, this is a valuable finding. However, the current PLRM hydrology module was not developed to simulate baseflow, and during wet water years and associated times of high seasonal groundwater the model will likely underestimate actual inflow and therefore overestimate the hydraulic capture performance of the SWT. When the modeled to measured hydrologic comparisons are limited to seasons when baseflow is negligible, the alignment between measured and modeled hydrologic performance greatly improves (see Figure 6.3). Future PLRM improvement should consider allowing a user to define a baseflow component for a modeled SWT facility.
9. PLRM algorithms include static rates of infiltration and flow through treatment outlets over the long-term continuous simulation. These static rates assume that SWTs are maintained over time to ensure continued function at some standard level of performance. However, as noted by this research team and others previously, consistent maintenance of SWTs in the Tahoe Basin is lacking (see Chapter 3.1.4 and Table 3.5). A number of hydrologic functional issues were noted in the monitored SWTs from lack of inspections and maintenance to ensure proper conveyance, maintain storage capacity and preserve expected infiltration rates. Anecdotal evidence obtained from this research and previous research efforts suggests that SWTs in the Tahoe Basin are generally not maintained to the level of maintenance assumed

in PLRMv1. Implementation of the Best Management Practice Maintenance Rapid Assessment Methodology (BMP RAM; 2NDNATURE et al. 2009) can assist stormwater managers and regulators with ensuring that SWTs are maintained to the level of maintenance assumed in PLRM.

10. PLRMv1 currently assigns a static CEC value to all treated effluent volumes for each pollutant modeled based on the type of SWT facility modeled. Results suggest that: 1) the PLRMv1 CEC FSP and TSS values are currently lower than achievable effluent quality from wet basins and dry basins for typical Tahoe Basin maintenance practices; and 2) the treatment capability to achieve effluent FSP concentrations < 100 mg/L are limited when inflow concentrations are relatively elevated (> 300 mg/L) (see Table 6.8). These findings support the assumption that effective pollutant source control actions in the catchment will reduce the concentrations and loads of pollutants delivered to public stormwater treatment systems, thereby increasing their effectiveness and duration of adequate performance prior to maintenance needs. Future PLRM modifications may need to include algorithms that vary CECs as a function of incoming catchment water quality while maintaining limits on the maximum achievable quality of treatment runoff.

11. To ensure that modeled estimates of SWT performance are reasonable, user inputs for PLRM should reflect a strong understanding of the hydrologic function of an SWT based on actual observations and measurements taken after construction of the SWT and not rely upon design specifications. SWT design and function is frequently more complicated than can be readily modeled in PLRM or assumed during design. Therefore, users of the PLRM will typically need a strong understanding of actual SWT function and the PLRM algorithms to develop a reasonable model representation. Future improvements to PLRM SWT modeling should consider allowing a PLRM user to input customized stage-discharge relationships for SWTs and potentially allow a user to define more than one treatment outlet or bypass outlet structure.

There are inherently many limitations and assumptions in the both the data collection and data analysis approaches necessary to express observed data in a manner comparable to PLRM predictions, which are based on long-term (18 yr) continuous simulations. Identified deviations between PLRM and observed data are attributable to both limitations of the data and the models representation of complex environmental systems. The ability to validate and improve a water quality model that is based on physical hydrologic processes and pollutant fate and transport assumptions with site-specific datasets will be improved as the spatial and temporal resolution of the data is increased. There is no question that achieving sustained pollutant load reductions in the Tahoe Basin require continued commitments to source control actions and frequent inspections and maintenance of treatment facilities to ensure they perform, on average, in a manner consistent with the functional condition represented in PLRM.

CHAPTER 2. RESEARCH BACKGROUND

Recently a suite of Tahoe Basin urban stormwater management tools has been developed and adopted by the Lake Clarity Crediting Program (Crediting Program; LRWQCB and NDEP 2009) to support the implementation and tracking of pollutant load reduction actions associated with the Lake Tahoe TMDL. The Lake Tahoe TMDL analysis has identified that fine sediment particles (<16 μm; FSP) are the primary pollutant of concern impacting lake clarity and stormwater runoff originating in urban areas is estimated to contribute 72% of the annual FSP pollutant load to Lake Tahoe (LRWQCB and NDEP 2010). The Crediting Program recommends the use of the Pollutant Load Reduction Model (PLRM; NHC et al. 2009a), Road Rapid Assessment Methodology (Road RAM; 2NDNATURE et al. 2010c) and Best Management Practice Maintenance Rapid Assessment Methodology (BMP RAM; 2NDNATURE et al. 2009a) by local jurisdictions and regulators to estimate and track urban load reductions over time. These currently are the only tools approved for use by the Lake Clarity Crediting Program (Crediting Program; LRWQCB and NDEP 2009), a program intended to incentivize and measure progress toward the attainment of urban stormwater load reductions established in the Lake Tahoe TMDL (LRWQCB and NDEP 2010). However the initial versions of each tool were developed with known limitations. This research has been funded to allow focused testing and evaluation of specific components of these tools to improve their accuracy, precision and compatibility.

RESEARCH FUNDING SOURCES

Since 2009, 2NDNATURE and Northwest Hydraulic Consultants (NHC) have conducted research to test, inform and validate a number of critical assumptions and data gaps for PLRM and Road RAM. Two complementary research contracts have allowed focused stormwater data collection to improve the scientific basis of the water quality algorithms used in PLRMv1 and inform the technical development of Road RAM. Phase I, funded by the US Army Corps of Engineers (US ACE), included the development of the monitoring strategy and initial data collection efforts during 2009. The final Phase I Technical Report was released in March 2010 (*Focused Stormwater Monitoring to Validate Water Quality Source Control and Treatment Assumptions*; 2NDNATURE and NHC 2010a). Prior to completion of Phase I, the USDA Forest Service Pacific Southwest Research Station awarded 2NDNATURE a grant using SNPLMA Round 9 funding to build upon the Phase I data collection from late 2009 through 2011. The majority of this final report includes methods, results and recommendations from the US ACE and SNPLMA funding.

Subsequent to this funding, in 2010 the US ACE funded *The Pilot Catchment Validation Study* to test the integration of the urban stormwater management tools on a single urban catchment for WY2011. The primary objective of the *Pilot Catchment Validation Study* was to develop, test and refine data collection protocols, PLRM modeling techniques, and data analysis approaches to facilitate a catchment scale comparison of pollutant load observations with PLRM predictions. The methods, results and recommendations from this research are provided in a separate, complementary final report entitled *Pilot Catchment Validation Study* (2NDNATURE and NHC 2012). A SNPLMA Round 11 research grant was awarded in November of 2011 to build upon the US ACE-funded study, resulting in the instrumentation, PLRM modeling and analysis of 3 urban catchments from March 1 2012 to February 28, 2013, with a final report expected by the end of 2013.

2.1 TOOL OVERVIEW

Below we provide a simple overview of the PLRM and Road RAM approach and key components addressed by objectives of this research.

2.1.1 POLLUTANT LOAD REDUCTION MODEL (PLRM)

NHC, 2NDNATURE, and Geosyntec Consultants released the initial version of the PLRM (NHC et al. 2009a) in October 2009 through grants provided by the US ACE and the Nevada Division of Environmental Protection (NDEP). The latest versions of the PLRM software and supporting documentation are available for download at: http://www.tiims.org/TIIMS-Sub-Sites/PLRM/docs-downloads.aspx.

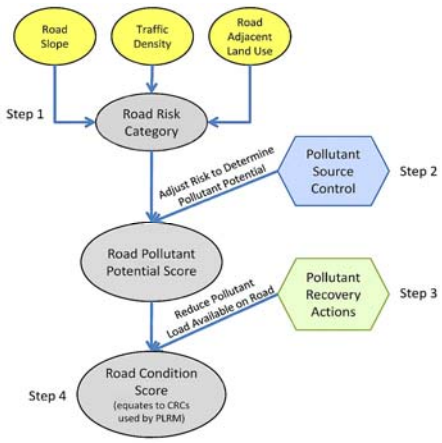
The PLRM provides Tahoe Basin resource managers with a tool to compare stormwater quality improvement alternatives in an urban catchment based on predicted load reductions for pollutants of concern to Lake Tahoe clarity. The desktop estimation tool combines SWMM (Storm Water Management Model) hydrology with a customized water quality module to predict the average annual pollutant loads from the outfall of a mixed land use catchment (NHC et al. 2009a). The continuous simulation model uses local 18-year historic meteorological datasets (WY1989-WY2006) to generate urban hydrology and pollutant loading and provide average annual loads at the catchment outlet for 6 pollutants of concern (total suspended solids [TSS], fine sediment particles [FSP], total nitrogen [TN], dissolved inorganic nitrogen [DIN], total phosphorous [TP], and soluble reactive phosphorous [SRP]). A variety of user inputs are required to represent the modeled urban catchment, including physiographic characteristics, land use distribution and condition, hydrologic source controls, and design characteristics of stormwater treatment BMPs.

The PLRM estimates pollutant concentrations in urban catchments using two primary water quality algorithms: characteristic runoff concentrations (CRCs) and characteristic effluent concentrations (CECs). CRCs are representative average runoff concentrations expected from a specific land use and associated land use condition, while CECs represent the average treated outflow concentrations for stormwater treatment BMPs (SWT) commonly used in the Tahoe Basin. The *PLRM Model Development Document* (NHC et al. 2009a) identifies the need to obtain Tahoe specific land use and SWT data to evaluate the appropriateness of the CRC and CEC algorithms and estimation approaches included in the initial version of PLRM. Also, at the time of PLRM development there was very limited stormwater data available for fine sediment particles in particular (see the *PLRM Model Development Document* (NHC et al. 2009a) for more details).

The PLRM hydrology module (SWMM-based) integrates the native soils and relative permeability of land surfaces within an urban catchment to generate a continuous time-series of surface runoff. The algorithms in PLRM provide a simple method to estimate saturated hydraulic conductivity (K_{sat}) based on soil type and land use type. However, current PLRM algorithms for estimating the fraction of precipitation that becomes surface runoff have two primary limitations: 1) hydrologic properties of soil are based on the 2006 Tahoe Basin Soil Survey (Soil Survey), which is a dataset for undisturbed soils; and 2) algorithms used to adjust saturated hydraulic conductivity (K_{sat}) apply compaction factors that vary by land use and do not consider site-specific conditions. While the PLRM Drainage Conditions Editor (NHC et al. 2009b) allows the modeler to override the suggested default value for K_{sat} derived from technical algorithms in PLRM by land use, little guidance has been provided on how to adjust K_{sat} to better represent site-specific soil conditions that have been altered by development. The *PLRM Model Development Document* (NHC et al. 2009a) identifies the need to better characterize hydrologic properties of soil impacted by development to inform simulations of infiltration in PLRM.

LAND USE POLLUTANT GENERATION

The PLRMv1 Road Methodology assumes that the CRC for pollutants of concern generated by roads can be predicted based on the integration of physiographic characteristics and the distribution of pollutant source controls, road abrasive application practices, and pollutant recovery actions (i.e., sweeping practices) (see schematic at right). Each factor has a variable level of influence on the predicted road condition and associated CRC within PLRM. The combination of user inputs to the Road Methodology results in an expected CRC for each road risk category. Figure 2.1 illustrates the road condition to CRC rating curves using in PLRM for FSP, TSS and SRP, respectively. At the time of PLRM development, the identified data limitations included: (1) minimal FSP data from roads available, (2) the majority of urban water quality monitoring stations measured runoff from mixed land use catchments, and (3) the relative condition of the land uses within the sampled catchment had not been documented concurrent with water quality monitoring. This research developed and implemented a sampling protocol to isolate the pollutant concentration emanating from a road surface at the time of sampling. These techniques were used to consistently sample a series of Tahoe road segments over 3 water years and evaluate the range and shape of the FSP, TSS and SRP CRC rating curves, as well as compare observed FSP concentrations to PLRM predictions.



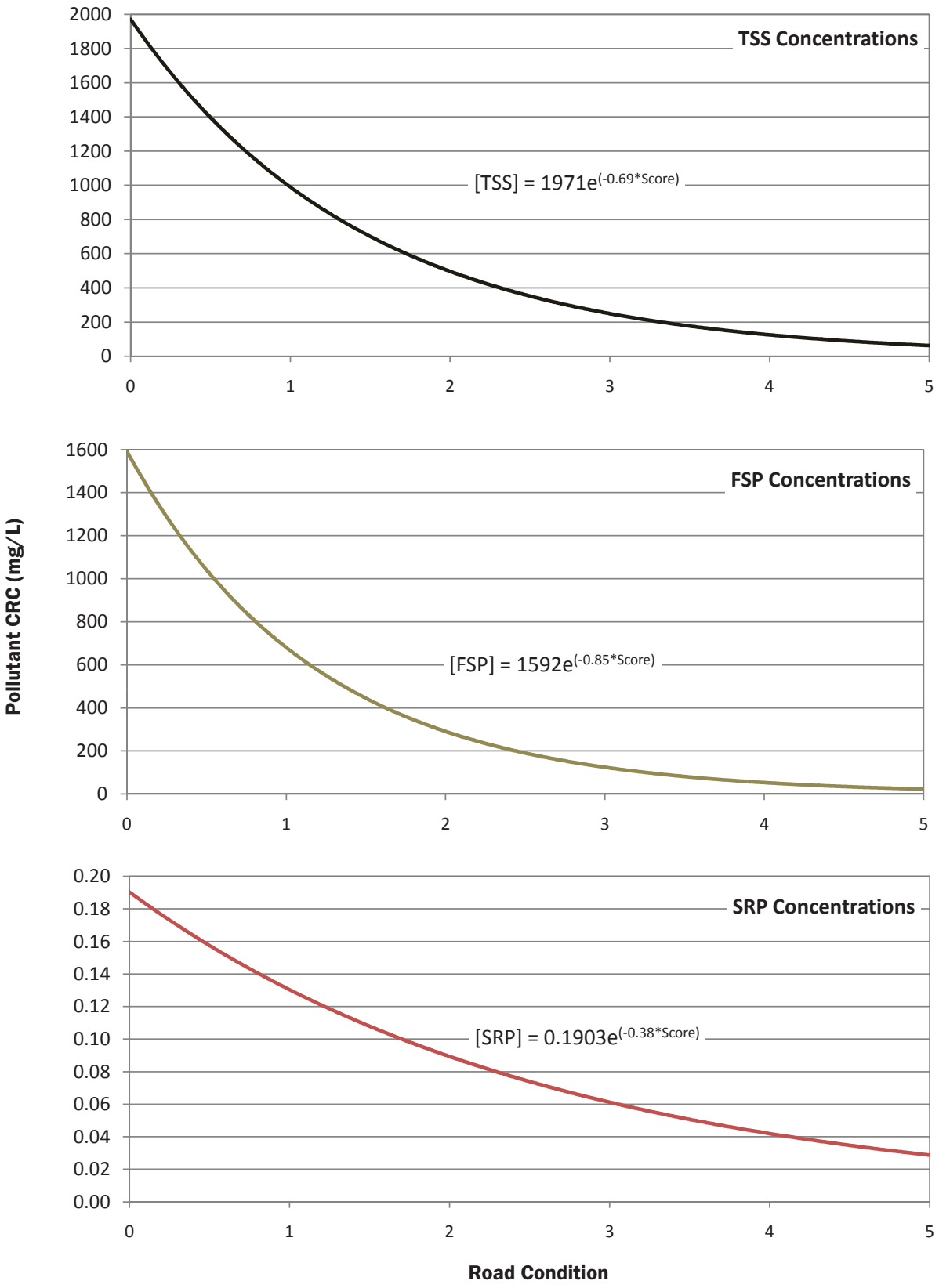
Simplified schematic illustrating PLRM Road Methodology approach.

The PLRM Parcel Methodology defines private parcel land use condition based on the presence/absence of private party pollutant best management practices (BMP) for the other 4 urban land uses: single-family residential (SFR), multi-family residential (MFR), commercial-industrial-communication-utilities (CICU), and vegetated turf. PLRM applies the Tahoe TMDL existing conditions event mean concentration values for parcels without BMPs and the Lake Tahoe TMDL Treatment Tier 1 values for parcels with BMPs (LRWQCB and NDEP 2008b). The initial PLRM private parcel CRC values are not based on a continuum of private parcel condition and are not distinct for the pervious and impervious fractions of the land use types. This research tested a variety of sampling techniques to identify viable methods for improving estimates of FSP CRC values used in PLRM (Table 2.1).

Table 2.1. PLRM land use parcel FSP CRCs with and without parcel BMP implementation certificates issued by TRPA. BMP certification includes both Source Control Certificates and BMP Retrofit Certificates **(**http://www.tahoebmp.org/Default.aspx**)**. CRC values are derived from the TMDL existing condition EMCs (no BMP certification) and Tier 1 EMCs (BMP certification) (LRWQCB and NDEP 2008b).

Land Use Type	**FSP CRC (% TSS by mass)**	
	No BMP certification	BMP certification
SFR	20.3 (36%)	14.0 (36%)
MFR	87.0 (58%)	32.7 (58%)
CICU	186.7 (63%)	128.5 (63%)
Vegetated Turf	4.3 (36%)	4.3 (36%)

PLRM v1 Road Condition to CRC Curves



Equations used in PLRMv1 Road Methodology (NHC et al. 2009a) based on limited Tahoe Basin catchment water quality data and associated road distribution and conditions.

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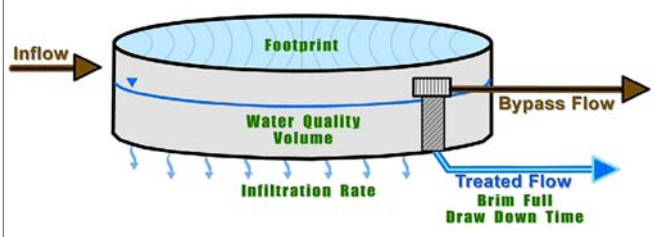
PLRMV1 ROAD CONDITION TO CRC RATING CURVES

FIGURE 2.1

STORMWATER TREATMENT BMPS



PLRM Dry Basin schematic illustrating inflow, bypass flow through the bypass outlet structure, and treated flow through the treatment outlet.

PLRM defines a stormwater treatment BMP (SWT) as a facility that reduces pollutants of concern from a concentrated stormwater flow path and defines 6 specific SWT types: dry basin, infiltration basin, wet basin, treatment vault, cartridge filter, and bed filter. PLRM estimates SWT treatment performance based on the time series of surface runoff from catchments, runoff quality from catchments, SWT type and design characteristics, and a static characteristic effluent concentration (CEC) for each pollutant of concern for runoff routed through the treatment outlets of an SWT. Based on SWT type and key design attributes (Table 2.2), PLRM predicts the average annual volume captured and treated by the SWT (treated flow) and the average annual volume bypassed (see schematic above). SWT types, by definition, rely upon different physical processes to reduce pollutant concentrations in stormwater runoff and decrease stormwater runoff volumes (see Table 2.2). A critical component of PLRM SWT load reductions is the calculation of volume reductions via infiltration and the proportion of stormwater runoff estimated to be treated relative to the volume estimated as bypass. This research included continuous hydrology monitoring of select SWTs to develop measured event, seasonal and annual water budgets to compare with PLRM predictions.

Table 2.2. Examples of PLRM SWT types and key design attributes that the PLRM user inputs.

SWT Type	Description	Key Design Attributes
Dry Basin	Volume-based SWT designed to detain runoff for an extended period of time to allow particle settling. Provides pollutant load reductions through (1) volume reduction via infiltration and (2) effluent concentration reduction via particle capture.	• Water Quality Volume (cu-ft) • Footprint (sq-ft) • Infiltration Rate (in/hr) • Brim Full Draw Down Time (hr)
Wet Basin	Volume-based SWT with a permanent or seasonal pool of water. Provides pollutant load reductions through effluent concentration reduction via particle capture and nutrient cycling.	• Wet Pool Volume (cu-ft) • Wet Pool Footprint (sq-ft) • Minimum Hydraulic Residence Time of Wet Pool (hr) • Surcharge Basin Volume (cu-ft) • Brim Full Draw Down Time (hr)
Cartridge Filter	Flow-based SWT that houses a number of cartridges that contain engineered filtration media. Provides pollutant load reductions through effluent concentration reduction via media filtration.	• Maximum Treatment Flow (cfs)

This research obtained SWT water quality monitoring data from a number of dry basins, wet basins and one cartridge filter to evaluate the CEC values presented in Table 2.3. CEC values are expected to specifically represent only treated outflow concentrations. While a significant amount of SWT high resolution water quality monitoring had been conducted in the Tahoe Basin prior to 2006, past monitoring did not focus on separately analyzing the water quality of treated versus bypassed flows, which is necessary to assess the SWT methodologies and CECs used in PLRM. Furthermore, very little FSP stormwater data was available at the onset of this research. Therefore, resources were prioritized to target FSP data collection and to separately evaluate the quality of stormwater runoff considered to be either treated or bypassed by a SWT.

Table 2.3. PLRM SWT CEC values for FSP, TSS and SRP (NHC et al. 2009a).

SWT Type	FSP (mg/L)	TSS (mg/L)	SRP (mg/L)
Dry Basin	25	25	0.05
Wet Basin	10	10	0.04
Cartridge Filter	13	13	0.04

2.1.2 ROAD RAM

Road RAM is a simple, standardized and repeatable tool to determine the relative condition (i.e., downslope water quality risk) at the time of observation of urban roads in the Tahoe Basin. Road condition is determined by the integration of a series of standardized rapid visual proxies and simple measurements, and Road RAM results can be expressed as a road condition score (0-5) or a corresponding expected FSP concentration at the time of observations (Table 2.4). 2NDNATURE, NHC, and Environmental Incentives released the initial version of the Road RAM (2NDNATURE et al. 2010c) in November 2010 through grants provided by the California Tahoe Conservancy (CTC) and Nevada Division of Environmental Protection (NDEP). The technical document and user's manual can be downloaded at: http://ndep.nv.gov/bwqp/tahoe8.htm and the online tool is located at www.tahoeroadram.com. A portion of the road specific water quality sampling and data collection to inform Road RAM protocols was funded by the SNPLMA Round 9 research grant. *Chapter 6: Experimental Validation of Road RAM Concepts and Protocols* of the *Road RAM Technical Document* (2NDNATURE et al. 2010c) details the data collection and research findings used to support Road RAM protocols. These details are not repeated within this final report. The *Road RAM Technical Document* (2NDNATURE et al. 2010c) identified the need for an analysis of user precision, which is summarized and presented herein.

Table 2.4. Road RAM scores relative to road condition and relative risk to downslope water quality.

Road RAM Score	Condition	FSP Concentration (mg/L) Range
0 - 1.0	Poor	1,592-680
>1.0 - ≤ 2.0	Degraded	679-291
> 2.0 - ≤ 3.0	Fair	290-124
> 3.0 - ≤ 4.0	Acceptable	123-53
> 4.0 – 5.0	Desired	52-23

Road specific sampling techniques, including Road RAM, were used to compare observed and PLRM-predicted road FSP concentrations. Road RAM was intentionally developed to be complementary and consistent with PLRM v1 Road Methodology to the extent possible. However, PLRM predicts a likely average annual road FSP CRC, while Road RAM allows discrete temporal condition assessments at the time of observation. Road RAM scores can be converted to an estimated FSP concentration based on the correlations and statistical analysis conducted during Road RAM development (see Table 2.4). The road-specific FSP sampling and Road RAM observations conducted at a collection of Tahoe road segments over 3 water years for this research are integrated to represent a single observed volume-weighted average FSP concentrations and compared to PLRM predictions. These results provide additional insight for future PLRM Road Methodology recommendations.

2.2 RESEARCH OBJECTIVES

Below we provide the research objectives for the SNPLMA Round 9 research funding. The location where the specific objective has been addressed in the technical report is provided for easy reference. Data collection, management, and analysis techniques implemented for this research are presented in *Chapter 3 (Methods)*.

1. Expand and apply the urban road monitoring dataset to:
   a. Test and refine the PLRM v1 Road Methodology assumptions regarding the role urban road factors may have on urban roadway water quality condition (Chapter 5.1.1);
   b. Inform PLRM v1 estimates of the total (TSS) and fine sediment particles (FSP; TSS< 16 µm) CRCs from roads varying in condition, with inclusion of soluble reactive phosphorous (SRP) analyses as resources allow (Chapter 5.1.1);
   c. Improve the breadth and quality of urban stormwater data on the generation, fate and transport of TSS and FSP, as well as SRP where resources allow (Chapter 5.1.1); and
   d. Collect focused and controlled data from urban roads to inform and improve the Road RAM tool (see *Chapter 6: Experimental Validation of Road RAM Concepts and Protocols* of the *Road RAM Technical Document*; 2NDNATURE et al. 2010c).
2. Apply cost-effective and comparable sampling techniques to increase our understanding of FSP generation from other urban land use types, including commercial and residential surfaces, and their variability of condition (Chapter 5.2).
3. Expand and apply the SWT monitoring dataset to:
   a. Improve the understanding of water quality treatment performance, specifically with respect to FSP, and SRP as resources allow, based on SWT type and key design parameters (Chapter 6.2);
   b. Inform and improve the PLRM v1 CEC estimates based on SWT type and key design parameters (Chapter 6.2); and
   c. Link average annual infiltration rates with measured CHP saturated hydraulic connectivity values to inform PLRM v1 infiltration input requirements (Chapter 6.1.2).
4. Apply the PLRM v1 to estimate and compare hydraulic capture among SWTs monitored. Hydraulic capture is estimated in the PLRM using basic design information for each SWT facility and the drainage conditions of the catchment(s) tributary to each SWT. Information on hydraulic capture allows the research team to estimate the frequency and magnitude of storm events that cause bypass to occur at each SWT, which is a key consideration when developing improved CECs based on the monitoring data collected from this study (Chapter 6.1.1).
5. Collaborate with academic researchers in data and sample sharing for their development of appropriate numeric conversions from FSP concentrations and loads to # of particles.[1]

Above are the original research objectives developed in fall of 2008, which are fairly broad in scope. The research team continued to refine these objectives as new information was gained or priorities shifted, with the intent of maximizing the knowledge and data obtained to meet pressing management, modeling and tool development needs. An additional objective was identified during Phase II development:

6. Develop data collection techniques to inform PLRMv1 modeling assumptions regarding the infiltration rate (i.e., K_{sat}) of compacted pervious road shoulders. Create a framework for refining user inputs and adapting PLRM technical algorithms to allow for better representation of road shoulder condition and its effect on infiltration and runoff calculations in PLRM (Chapter 5.3).

[1] DRI researchers have been provided access to all stormwater samples collected for this research effort. Coordination and data sharing of necessary sample information has been offered to DRI researchers for when they choose to conduct any additional particle count analysis of the stormwater samples provided.

CHAPTER 3. METHODS

To address the current data gaps within the Tahoe Basin urban stormwater management tools and improve upon existing land use and stormwater treatment BMP datasets, the 2NDNATURE team tested cost-effective protocols to maintain the quality of the hydrologic and chemical datasets, but minimize the need for high-resolution stormwater monitoring instrumentation and laboratory analysis. The methods described below focus on generating a reliable dataset with which to compare land use pollutant generation and SWT treatment performance from a range of monitoring sites. Some methods, particularly the roadway water quality data collection techniques, were more effective than others, and the research team will continue to develop, test and refine standardized and consistent data collection methodologies that provide scientifically defensible analyses of sites with varying characteristics at minimal cost.

3.1 DATA COLLECTION

The 2NDNATURE team developed a complete data collection strategy, including monitoring goals and objectives, site selection justification, detailed instrumentation and field monitoring protocols, sample QA/QC requirements and data management specifications. The Phase I Final Monitoring Plan, funded by ACOE, was produced in July 2009 (2NDNATURE and NHC 2009c); the Phase II Monitoring Plan (Appendix A), funded by SNPLMA Round 9, was completed in July 2010 with updated protocols based on the lessons learned from Phase I. Below we provide a summary of these methods for the monitoring and analysis of roadway water quality, road shoulder infiltration, private parcel water quality, and stormwater treatment BMP data. Please refer to Appendix A for specific sampling techniques and detailed protocols.

3.1.1 ROADWAY WATER QUALITY

2NDNATURE field personnel collected roadway-specific water quality data at a range of road sites throughout the Lake Tahoe Basin. The following describes the process by which the sites were selected and field measurements were collected and analyzed.

ROAD SEGMENT SELECTION AND CHARACTERIZATION

Using GIS, the research team selected thirty-four (34) road segments, including thirty-two (32) roads and two (2) commercial parking lots (Figures 3.1-3.2), to represent a range of attributes including: road type (primary, secondary); jurisdictions responsible for maintenance; and road risk (high, moderate, and low) as defined in PLRMv1 using road slope, traffic density, and adjacent land use. A road segment is defined as 10,000 ft^2 and includes all continuous lateral impervious area within the right of way. The road segments were selected during the Phase I effort funded by US ACE and additional details on road segment selection and characterization can be found in *Chapter 3.1* of the *Phase I Technical Report* (2NDNATURE and NHC 2010a).

ROAD SEGMENT FIELD DATA COLLECTION TECHNIQUES

Figure 3.3 summarizes the road characteristics and data collected in the field at each urban road segment. The following provides a summary of the data collected; detailed protocols are provided in the *Phase II Monitoring Plan* (see Appendix A).

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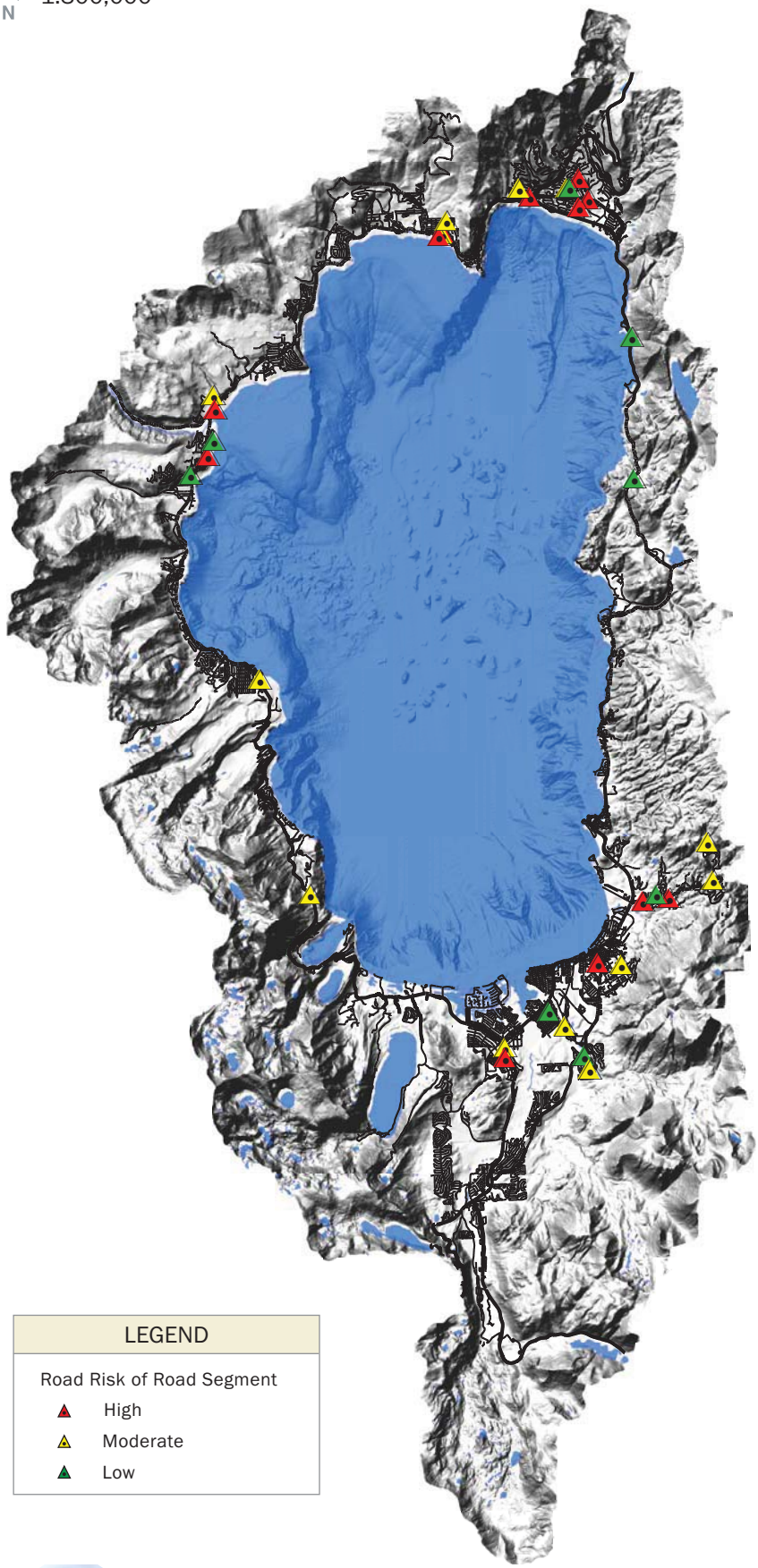

LEGEND

Road Risk of Road Segment

- High
- Moderate
- Low

Road segment sampling sites by jurisdiction, road type, and road risk (as calculated September 2009).[1]

Jurisdiction	# High Risk		# Mod Risk		# Low Risk	
Road Type[2]	*P*	*S*	*P*	*S*	*P*	*S*
Caltrans	4		2			
City of South Lake Tahoe		2		1		1
KGID				2		1
El Dorado County		1			1	1
NDOT	3				2	
Placer County		2		4		
Washoe County		2		2		1

[1] Table does not include the 2 commercial parking lot sites under private jurisdiction.

[2] P= Primary Road; S = Secondary Road

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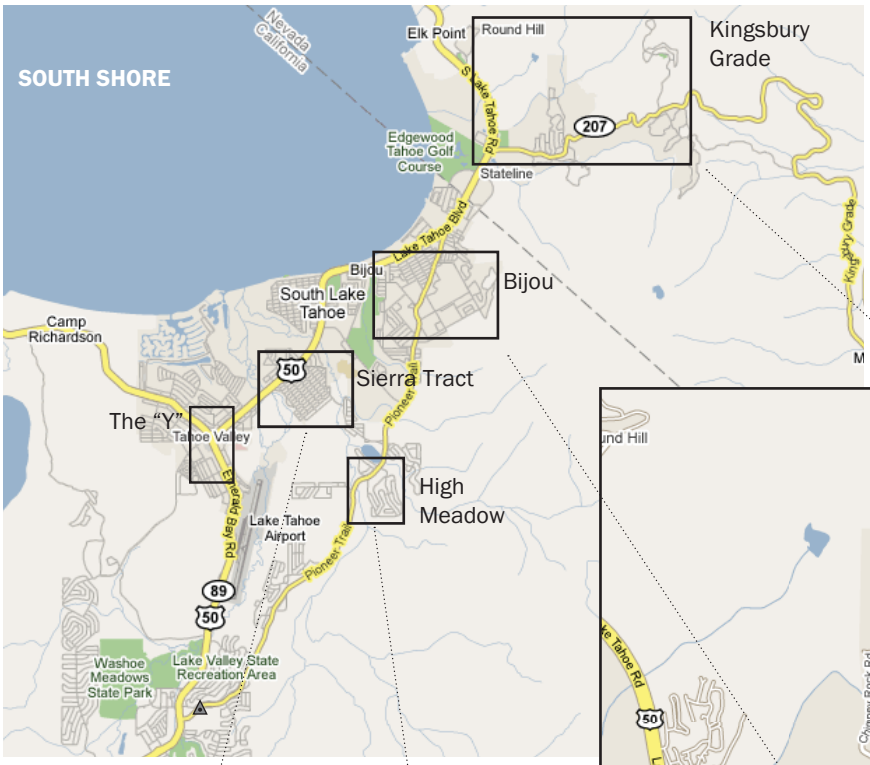
ROAD SEGMENTS - OVERVIEW

FIGURE 3.1



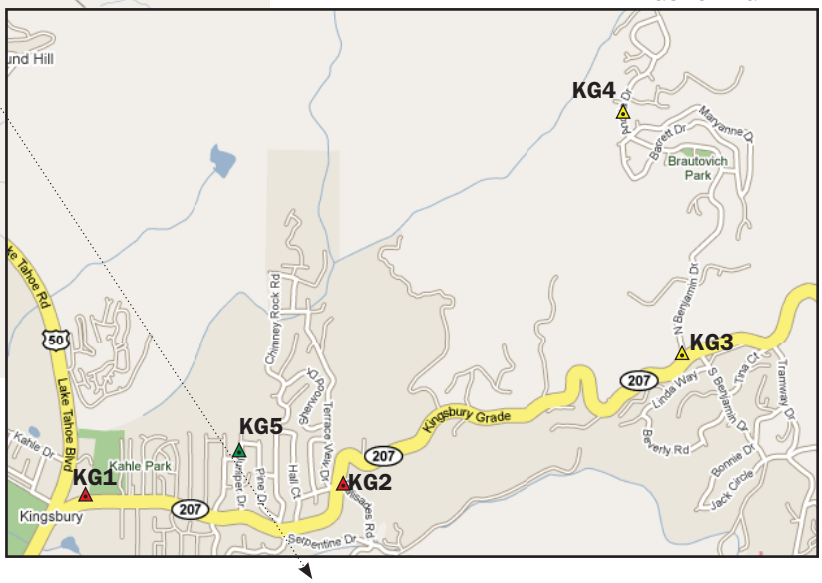
LEGEND

Road Risk of Road Segment

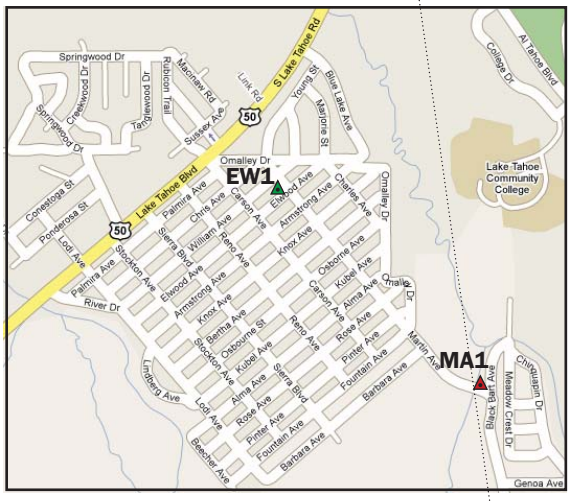
- High
- Moderate
- Low

N

KINGSBURY GRADE



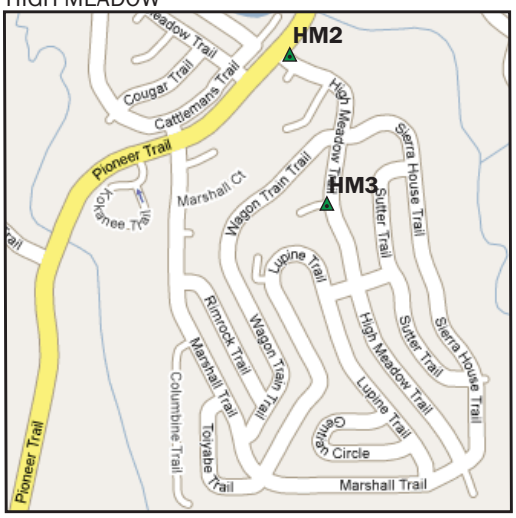
SIERRA TRACT



BIJOU

THE "Y"

HIGH MEADOW



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ROAD SEGMENTS - SOUTH SHORE

FIGURE 3.2A

N

LEGEND

Road Risk of Road Segment

- High
- Moderate
- Low

KINGS BEACH

INCLINE VILLAGE

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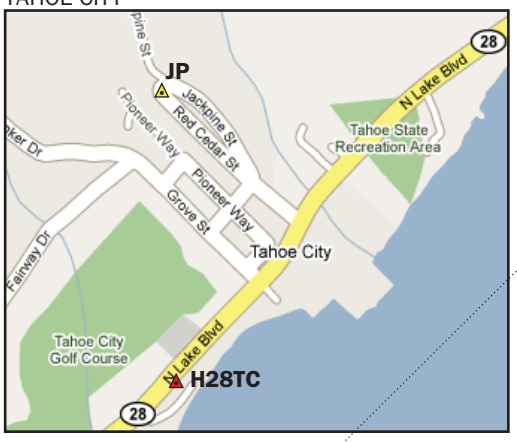
ROAD SEGMENTS - EAST AND NORTH SHORE

FIGURE 3.2B

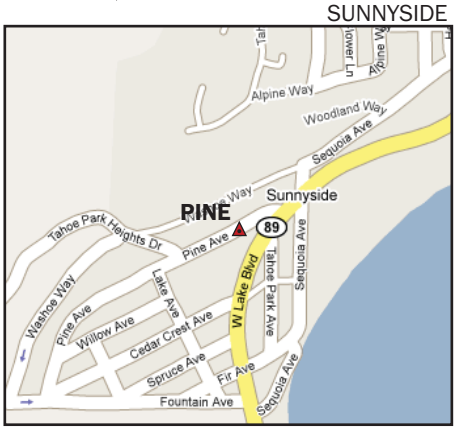
N

TAHOE CITY



GRANLIBAKKEN

SUNNYSIDE



LEGEND
Road Risk of Road Segment
▲ High
▲ Moderate
▲ Low

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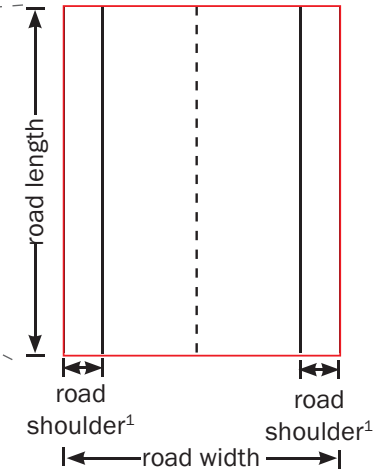
ROAD SEGMENTS - WEST SHORE

FIGURE 3.2C

ROAD SEGMENT CHARACTERIZATION

Lake Tahoe Basin

Road Segment (10,000 ft²)

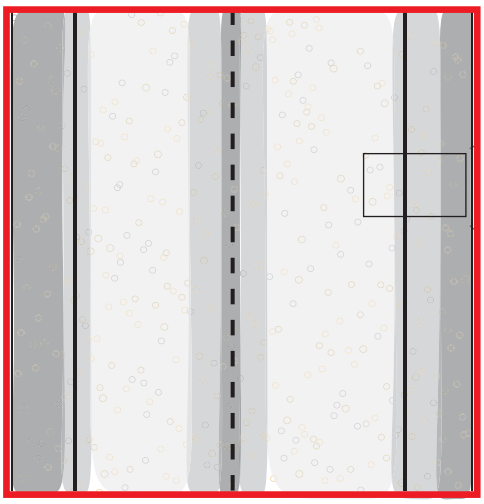


GIS analysis of:
- Road Type [Primary, Secondary]
- Road Risk
  - [PHR, PMR, PLR/SHR, SMR, SLR]
- Jurisdiction

Field characterization of:
- Right and Left Road Shoulder[1] Condition
  - [1, 3, 4, 5]
- Road Surface Integrity
  - [H, M, L]

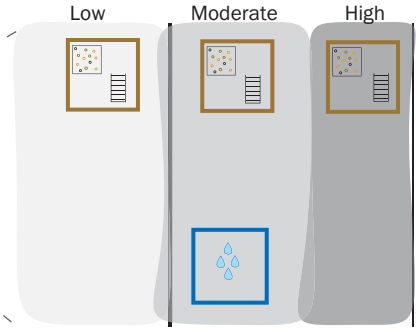
ROAD SEGMENT MONITORING EFFORTS

Road Segment (10,000 ft²)



Road RAM STEP 4B visual observations of material accumulation distribution on road segment of up to 3 material accumulation categories:
- High
- Moderate
- Low

Representative 1'x1' squares within each Material Accumulation Category



Road RAM STEP 4B visual observations of proxies for FSP concentration:
- Volume/Mass [ml, mg]
- Degree of Fines [H, M, L]
- Particle Size Distribution (limited)

Controlled experiments using portable simulator to obtain water quality sample from 1 (typically moderate) material accumulation category:
- TSS and FSP Concentrations [mg/L]
- Turbidity [ntu]
- Particle Size Distribution [% of TSS]

[1] PLRM defines the road shoulder to include the pervious area of the right-of-way. For the purposes of this monitoring and to be consistent with Road RAM, the road segment is defined by the width of the impervious surface area between the two edges of pavement and includes bike lanes or sidewalks if the impervious surface is continuous from the drive lane outward. The road length is determined based on the road segment width and the standardized road segment area of 10,000 ft².

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ROAD MONITORING DATA COLLECTION SCHEMATIC

FIGURE 3.3

Road segment characteristics determined in the field during the initial site visit included right and left road shoulder condition as defined by PLRM (erodible, protected, stable, stable and protected; NHC et al. 2009a) and road surface integrity (high, moderate, and low) based on a visual assessment of the pavement condition.

During each road segment monitoring effort, both road condition evaluations and controlled water quality experiments were conducted. Road condition evaluations included visual observations consistent with Road RAM protocols, which can be found in detail in *STEP 4B* of the *Road RAM User Manual* (2NDNATURE et al. 2010d). Visual observations include the % distribution of high, moderate, and low material accumulation categories on the road segment and observations of volume of material and degree of fines within 1 ft^2 area of each material accumulation category. A limited number of the material samples were kept and submitted to Cooper Analytical Laboratory for particle size distribution analysis. Controlled water quality experiments were conducted using a portable simulator (described below). The controlled experiments were at a minimum conducted in the moderate accumulation category to ensure consistency in comparisons across sites and observation periods. Water quality samples were analyzed for turbidity (ntu) in the field using a Hach 2100P portable turbidimeter, TSS and SRP concentrations were analyzed by WETLAB, and particle size distribution analysis was performed by DRI.

Road segment monitoring efforts conducted for this research are summarized in Table 3.1, including both Road RAM observations for road condition evaluations and water quality sample collection via controlled experiments using the portable simulator.

Table 3.1. Summary of road segment monitoring efforts conducted at 34 road segments from March 2009 through April 2011.

Road Segment Monitoring	Number
Condition evaluations (road segment score as defined by Road RAM)	310
1 ft^2 controlled water quality experiments (Field turbidity and/or laboratory TSS, FSP, SRP concentrations)	315[1]

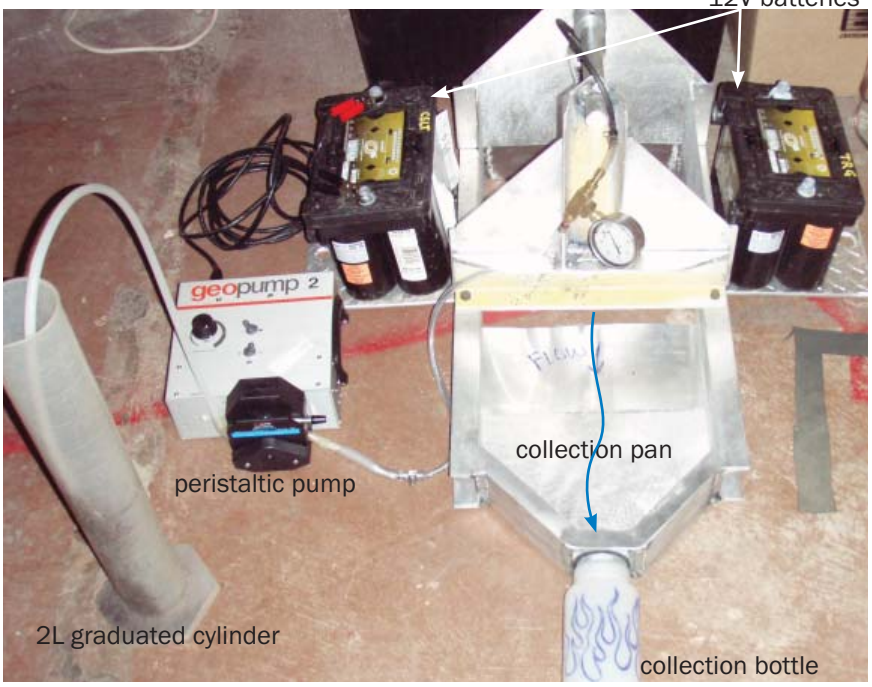
[1] Controlled experiments were not conducted during every road segment monitoring effort either due to weather or resource constraints. However, multiple controlled experiments were conducted at some road segments during each observation period for precision analyses.

PORTABLE SIMULATOR

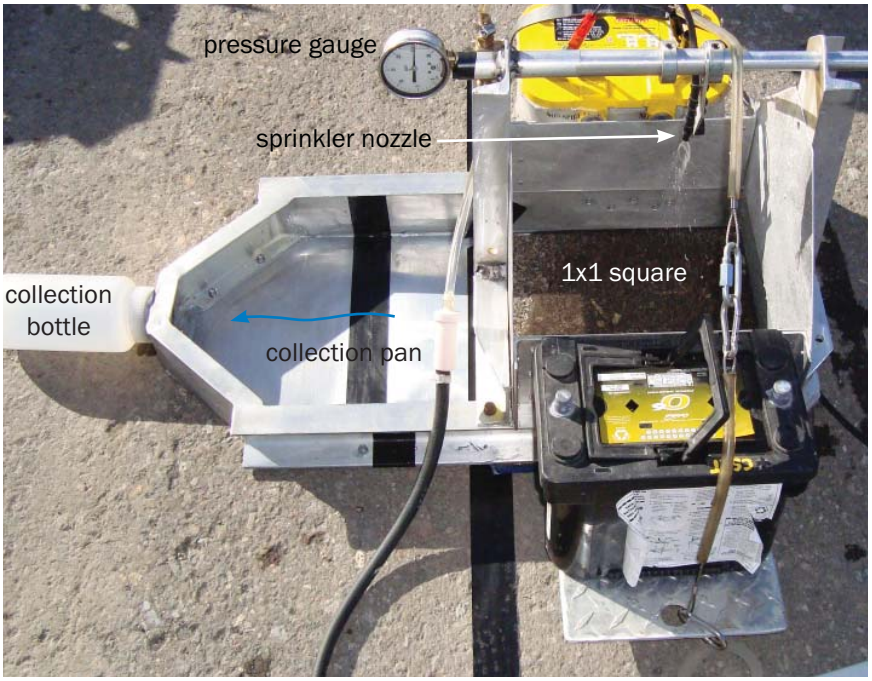
Using a custom-built portable runoff simulator designed and fabricated with assistance by Liquid Innovations and El Dorado County (Figure 3.4), field personnel collected water quality samples from a 1 ft^2 area on the road surface (typically in the moderate accumulation category) to provide a consistent, repeatable, rapid and cost-effective technique to sample the TSS, FSP and SRP concentrations derived from urban roads. Detailed protocols are documented in the *Phase II Monitoring Plan* (see Appendix A), including sample collection, bottle labels, and chain of custody. Key objectives of the portable simulator design included:

- Obtain water quality samples from over 30 Tahoe Basin urban roads in less than 3 days by 2 field personnel.
- Consistently sample a number of urban roads while keeping the water application rate, intensity, contributing area, and water sample collection methods constant. Constraining these primary hydrologic parameters increases our confidence that the measured differences in water quality constituents are due to differences in roadway pollutant mass and not due to sampling variability.
- Recover a minimum of 600ml of water from the simulation for proper analysis by the analytical laboratory.

PORTABLE SIMULATOR - FRONT VIEW



PORTABLE SIMULATOR - TOP VIEW



SIMULATOR IN ACTION IN THE FIELD

site set-up

simulation

sample collection

transfer to collection bottle

collection pan rinse

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PORTABLE SIMULATOR USED IN CONTROLLED EXPERIMENTS

FIGURE 3.4

The above design characteristics require that the portable simulator was run at an estimated intensity of 5 in/hr. While this intensity is higher than rain events in the Tahoe Basin, this increased rate is necessary to minimize the sampling duration and remain cost-effective. The relatively high intensity of simulated rainfall was assumed to be a reasonable trade off that compensates for our inability to simulate runoff from the entire road segment, including sheet flow across the road surface, which is common on impervious surfaces and efficiently entrains and transports pollutants.

ROAD SEGMENT DATA COLLECTION FREQUENCY

2NDNATURE field personnel conducted road sampling at each of the 34 road segments during a total of 10 observation periods from March 2009 through April 2011. Table 3.2 summarizes the 310 road observations completed during this research by road type, jurisdiction in charge of road maintenance, and month of sample collection. Due to a variety of reasons, including road construction and inclement weather, not all road segments were monitored during every observation period.

Table 3.2. Road segment monitoring summary by road type, jurisdiction in charge of road maintenance practices, and observation period. As noted, not all 34 road segments were monitored during every observation period due to inclement weather and/or road construction.

Road Type	Jurisdiction	Mar 09	Apr 09	May 09	Jul 09	Oct 09	Jan 10	Feb 10	Mar 10	Jan 11	Apr 11	Jurisdiction Totals	Road Type Totals
Primary	Caltrans, CA	4	5	6	6	6	4	6	5	5	6	53	**121**
	El Dorado County, CA	0	1	1	1	1	1	1	1	1	1	9	
	NDOT, NV	4	4	3	4	5	4	3	4	5	5	41	
	Private	0	2	2	2	2	2	2	2	2	2	18	
Secondary	CSLT, CA	4	4	4	4	4	4	4	4	4	4	40	**189**
	Douglas County, NV	1	3	3	3	3	2	3	3	3	3	27	
	El Dorado County, CA	2	2	2	2	2	2	2	2	2	2	20	
	Placer County, CA	5	6	6	6	6	4	6	5	4	6	54	
	Washoe County, NV	4	5	5	5	5	4	5	5	5	5	48	
Monthly Total		**24**	**32**	**32**	**33**	**34**	**27**	**32**	**31**	**31**	**34**	**310**	

3.1.2 ROAD SHOULDER INFILTRATION MEASUREMENTS

NHC field personnel collected measurements of K_{sat} and soil compaction across a range of Lake Tahoe Basin road shoulder conditions. The following summarizes the site selection process and the field data collection methods; more complete documentation is provided in Appendix B (*Measuring Road Shoulder Saturated Hydraulic Conductivity to Inform and Refine PLRM Algorithms*).

ROAD SHOULDER SITE SELECTION & CHARACTERIZATION

The characteristics of the 42 sites selected to evaluate if correlations between soil type or road shoulder condition could be related to measured K_{sat} are summarized in Table 3.3. Factors used to select sites included: soil type based on dominant texture, road type (primary or secondary road), and observed road shoulder condition.

Table 3.3. Summary of the road shoulder infiltration sites and key characteristics, including soil type, road shoulder condition, and road land use type.

Neighborhood	Texture of Soil Horizon	PLRM Road Shoulder Conditions	Road Type	# Sites
West Sunnyside, Placer County	Gravelly Medial Sandy Loam	Erodible, Stable, Stable and Protected	Secondary	5
Dollar Point, Placer County	Very Cobbly Sandy Loam	Erodible, Stable and Protected	Secondary	3
Sierra Tract, City of South Lake Tahoe	Loamy Coarse Sand	Erodible, Stable and Protected	Secondary	14
Montgomery Estates, El Dorado County	Gravelly Loamy Coarse Sand	Stable, Stable and Protected	Secondary	4
Meyers, El Dorado County	Coarse Sandy Loam	Erodible, Stable, Stable and Protected	Secondary	8
Gardner Mountain, City of South Lake Tahoe	Loamy Coarse Sand	Erodible	Secondary	2
Highway 89, City of South Lake Tahoe	Loamy Coarse Sand	Erodible	Primary	6
			Total	**42**

ROAD SHOULDER FIELD DATA COLLECTION TECHNIQUES

Simultaneous compaction and saturated hydraulic conductivity (K_{sat}) measurements were conducted at each site 3-5 foot from the edge of the impervious road surface (e.g., asphalt travel lane, bike lane, top back of curb). Compaction was measured using an analog cone penetrometer to measure the relative resistance of soil at each sample site to infer the degree of compaction. Each measurement was taken in dry soil using the ½" tip for the cone penetrometer and at many sites multiple readings were averaged to ensure that soil heterogeneity did not bias the depth of penetration recorded. K_{sat} was measured using a constant head permeameter (CHP) in accordance with NRCS guidelines (NRCS 2010) at approximately 6" below the soil surface. Readings were taken at the shallowest depth the CHP would allow to better infer surface infiltration conditions.

To test the hypothesis that K_{sat} is lowest near the impervious edge of the road surface and increases with distance from the road shoulder, 24-foot transects were established at several sites extending perpendicular to the road shoulder to evaluate if declining soil compaction and increasing K_{sat} could be observed. Compaction measurements were taken at roughly one foot intervals. K_{sat} measurements were taken at a distance of 3-5 feet and at 24 feet from the impervious edge of the road surface, with a third measurement taken along the transect if a notable change in soil compaction was identified along the transect.

3.1.3 PRIVATE PARCEL WATER QUALITY

The research team aimed to develop a cost-effective data collection and analysis technique to evaluate the relative water quality risk from pervious urban land use types in the Tahoe Basin and inform the CRC values used in PLRMv1 for private parcels. The primary objective of the data collection effort was to test various data collection

techniques in order to identify viable methods for improving estimates of FSP CRC values used in PLRM for the private parcel land uses targeted.

PRIVATE PARCEL SITE SELECTION & CHARACTERIZATION

Thirty six sites were selected throughout the Tahoe Basin to represent a range of observed existing conditions on the private parcel land uses (CICU, MFR, SFR). In addition to the private parcel land uses, non-urban land uses (EP1-5) were also selected to provide a greater range of surface conditions. Vegetated turf was not included because PLRM assumes that improved water quality management of turf surfaces does not result in a reduction in FSP generation from this land use (see *Table 6.5* in *PLRM User Manual*, NHC et al. 2009b). Field personnel categorized the relative condition of each site based on visual observations of the degree of exposed, disturbed and potentially erodible soils on the parcel (see photos at right). This approach was used to expand upon the binary concept in the PLRM Parcel Methodology, which is based on whether or not a site has received a TRPA BMP Certificate of Completion, and to determine relative condition based on the assessment of the site at the time of observations. For each land use type, 3 sites were selected in each condition category (good, moderate and poor). In addition to the private parcel water quality methods described below, 2 commercial parking lot sites (see sites RIV and RSLT in Figure 3.2) were included in the roadway water quality research described above in Chapter 3.1.1, and are included in the summary shown in Table 3.2.

Range of private parcel conditions observed.

PRIVATE PARCEL FIELD DATA COLLECTION TECHNIQUES

Field personnel collected land use data over the course of 3 observation periods – October 2010, April 2011 and June 2011, visiting each site once. Initial testing of data collection techniques included the use of the portable simulator on pervious surfaces to determine if the simulator could improve comparisons across land use types by reducing sampling variability. However, the use of the portable simulator on pervious surfaces was discarded because of (1) the high and variable water volume required to generate enough runoff to collect an adequate volume for laboratory analysis, and (2) the difficulty in sealing the portable simulator to ensure runoff is not lost underneath the collection pan and out the sides of the sampling area.

At each site, a representative 1 ft^2 area was selected, similar to the methodology used for road data collection (see Chapter 3.1.1). The relative condition within the square was documented, considering level of disturbance or compaction and type of material. Approximately 200 ml of material was collected from the upper soil layer and stored in a labeled Ziploc bag for future analysis. In some locations, a runoff test, similar to the protocols detailed in the *BMP RAM User Manual* (2NDNATURE et al. 2009b), was conducted to measure the length of time it takes for 1 L of water to infiltrate. Two analysis methods were tested using the dry material sample collected from each site:

- Particle grain size analysis (described in Chapter 3.1.5) by Cooper Testing on 23 samples from a range of land use types representing poor and good conditions.

- Turbidity measurements on a subset of 24 samples by adding 10 g of material to 1 L of water, with the hypothesis that the dry material samples with a greater fraction of FSP would yield higher turbidity values.

3.1.4 STORMWATER TREATMENT BMPS (SWTS)

2NDNATURE designed and implemented stormwater monitoring at 3 typical Lake Tahoe SWT types (as defined by BMP RAM (2NDNATURE et al. 2009a) and PLRM (NHC et al. 2009a)): dry basins, wet basins, and cartridge filters. Cost-effective data collection included continuous surface water hydrology monitoring, event-based surface water sampling, and treatment BMP condition evaluations. Field data was used in the analysis of SWT treatment performance and as inputs to the modeling techniques described in Chapter 3.2 of this technical report.

SWT SITE SELECTION & CHARACTERIZATION

2NDNATURE developed a site prioritization matrix based on overall research cost effectiveness and considered a number of factors, including site proximity, team familiarity with the site, and ease of instrumentation, when making the final site selections. A total of 9 SWTs (Figure 3.5) were monitored during this research: 4 sites (Osgood Basin, Park Avenue Upper [PA1] and Lower [PA2] Basins, and Stormfilter® Vault) were monitored from WY09 through WY11 and 5 sites were added in WY10-WY11 (Rocky Point Basin, Eloise Basin, Blue Lakes Basin, Wildwood Basin, and Coon Basin).

To compare the treatment performance to PLRM predictions, key characteristics of the contributing catchment and SWT design were detailed for each SWT (Tables 3.4-3.5). The urban catchment contributing to the BMP was delineated (Figures 3.6A-B) and a GIS analysis was performed to calculate the total area, average slope, land use distribution, % impervious area, and dominant soils (see Table 3.4) as described in the PLRM Applications Guide (NHC et al. 2010). Reconnaissance level field inspections were used to validate PLRM inputs derived from the GIS data and to inform PLRM input parameters that cannot be developed from a GIS analysis (e.g., stormwater treatment (SWT) parameters). Key stormwater treatment BMP design attributes, as well as construction and maintenance history, were also cataloged based on field visits, existing design reports, and conversations with jurisdiction public works personnel (see Table 3.5).

The following key points should be noted about the monitoring sites (see Tables 3.4 and 3.5):

- Catchment area ranged from 1.7 acres (Stormfilter) to 340 acres (Osgood).
- Catchment % impervious area ranges from 18% (Rocky Point) to 81% (Stormfilter), while total impervious area ranges from 1.4 acres (Stormfilter) to 118 acres (Eloise).
- Roads, including primary and secondary roads, typically account for 10-20% of the total catchment area. Both Osgood and Rocky Point catchments are dominated by non-urban land uses (e.g., EP1-5) (43 and 56%, respectively) and residential land uses (39 and 29%, respectively). Residential land uses account for approximately 50% of the total area in the Blue Lakes and Wildwood catchments, while the percent of commercial land use is highest in Park Avenue and Eloise catchments (19 and 27%, respectively).
- The cartridge filters in the Stormfilter® Vault were replaced in 2008. Based on conversations with CSLT personnel, there has been no recent maintenance activity at any of the other SWTs monitored.
- 2NDNATURE has monitored the Park Avenue basins almost continuously since 2004 (2NDNATURE 2008). During this time, the basin treatment train has never functioned completely as designed, as the water inflowing from the Rocky Point inlet bypasses PA1 more frequently than intended and the total volume of water outflowing from PA1 does not reach the inlet of PA2 as designed because of notable infiltration occurring at the joints in the storm drain pipe connecting PA1 to PA2.

LEGEND

- Major Roads
- Minor Roads
- SWT

LAKE TAHOE

Park Avenue Basins

StormFilter Vault®

Rocky Point Basin

Wildwood Basin

Osgood Basin

Ski Run Blvd

Blue Lakes Basin

Eloise Basin

Pioneer Trail

50

89

A ninth SWT (Coon Basin) was also monitored; however it is located on the north shore in Kings Beach, CA, and therefore is not shown on this map.

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SWT MONITORING SITE LOCATION MAP

FIGURE 3.5

Catchment Name[1]	Osgood	Park Avenue	Eloise	Rocky Point	Blue Lakes	Wildwood	Stormfilter
Location	South Lake Tahoe, CA	South Lake Tahoe, CA	South Lake Tahoe, CA	South Lake Tahoe, CA	South Lake Tahoe, CA	South Lake Tahoe, CA	South Lake Tahoe, CA
Total Area (ac)	341	225	281	169	17.3	108	1.7
Impervious Area (%, ac)	23% (79 acres)	30% (67)	42% (118)	18% (30)	35% (6.1)	43% (46)	81% (1.4)
Average Slope (%)	9%	7%	1%	10%	2%	4%	2%
Land Use Distribution (% Total Area)							
Primary Roads	3%	1%	0%	1%	0%	1%	
Secondary Roads	11%	12%	13%	10%	19%	20%	
Commercial Industrial Communications Utilities (CICU)	4%	19%	27%	4%	9%	14%	90%
Multi-Family Residential (MFR)	14%	9%	23%	8%	30%	20%	
Single Family Residential (SFR)	25%	16%	4%	21%	24%	27%	
Unimpacted Vegetation (EP 1-5)	43%	44%	32%	56%	18%	17%	10%
Catchment Soils							
Dominant Soil Type	Cassenai; Cagwin Rock	Cassenai; Christopher-Gefo	Ubaj; Christopher-Gefo	Cassenai; Cagwin Rock	Christopher-Gefo	Oneidas; Marla	Marla
Private Parcels (% TRPA Certification)							
CICU	27%	0%	6%	0%	0%	2%	0%
MFR	21%	4%	0%	6%	7%	10%	0%
SFR	20%	16%	13%	17%	71%	14%	0%

[1] Given inconsistent instrument data collection at Coon Basin, a GIS analysis of the catchment was not performed.

SWT Name	Osgood	PA1	PA2	Eloise	Rocky Point	Blue Lakes	Wildwood	Coon[1]	Stormfilter
PLRM Inputs									
SWT Type	Wet Basin	Wet Basin	Dry Basin	Wet Basin	Dry Basin	Dry Basin	Dry Basin	Dry Basin	Cartridge Filter
Water Quality / Wet Pool Volume (ac-ft)	0.07	0.47	0.96	0.35	0.27	0.17	2.25		-
Footprint / Wet Pool Footprint (sq-ft)	2,250	25,100	27,600	19,700	8,200	2,400	98,000		-
Infiltration Rate (in/hr)	-	-	0.40	-	0.1	0.15	0.02	n/a	-
Min Wet Pool HRT (hrs)	24	24	-	24	-	-	-	-	-
Surcharge Basin Volume (ac-ft)	0.43	0.73	-	1.05	-	-	-	-	-
Brim Full Draw Down Time (hrs)	48	48	48	60	41.2	170	96	n/a	-
Max Treatment Flow (cfs)	-	-	-	-	-	-	-	-	0.75
Additional Details									
Year Constructed	1985; mod. 1997	2001; mod. 2003	2001; mod. 2003	1980s					2001
Morphology	Max flow path; pre-treatment settling forebay	Max flow path	Max flow path	Max flow path	Max flow path	Max flow path	Max flow path	Max flow path	Enclosed Rect-angle
Outlet Type	20' Rect. Weir w/ 3 6" orifices	1 2.5' Perf. CMP; 1 5' CMP	1 2.5' Perf. CMP	1 6' CMP	2' Rect. Weir w/ 1 3" hole	1 3' Perf. CMP	Notch Weir	1 5' CMP	Weir
Treated Depth (ft)	1.90	0.58	1.04	-	0.65	1.69	-	-	0.5
Bypass Depth (ft)	2.85	1.66 / 1.76	2.04	4.68	2.68	2.94	2.06	2.96	2.00
Discharges to	Ski Run Marina	PA2/North Ditch	North Ditch	SEZ/Tahoe Keys	PA1	Trout Creek SEZ	Wilwood Basin #3	Culvert to Lake Tahoe	Ski Run Marina
Last Known Maintenance	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2008 (replaced filters)
Research Monitoring Details									
Date Surface WLR Installed	Dec 2008	Dec 2008	Dec 2008	Sept 2009	Sept 2009	Sept 2009	Sept 2009	Sept 2009	n/a
Date of Topo Survey	July 2009	Aug 2011	Aug2011	June 2010	June 2010	Aug 2011	June 2010	Oct 2010	n/a
# Inlet PS Installed (Date)	3[2] (Nov 2009)	2[3] (Jan 2009)	2[3] (Jan 2009)	4 (Nov 2009)	5 (Sept 2009)	4 (Sept 2009)	n/a	n/a	n/a
# Outlet PS Installed (Date)	3[2] (Nov 2009)	2[3] (Jan 2009)	3[3] (Jan 2009)	4 (Nov 2009)	4 (Sept 2009)	4 (Sept 2009)	n/a	n/a	n/a
Monitoring Summary	Water Budget & CEC data	Water Budget & CEC data	Water Budget & CEC data	Water Budget & CEC data	Water Budget & CEC data	CEC data only; poor WLR data	CEC data only; poor WLR data	CED data only; poor WLR data	CEC data only; poor WLR data

[1] Given inconsistent instrument data collection at Coon Basin, a a full analysis of the basin was not performed.
[2] Originally, 3 inlet and 2 outlet passive samplers were installed at Osgood Basin in Jan 2009. However, following Phase I research, it was determined the passive samplers had not been installed at the correct elevations and new passive samplers were installed in Nov 2009. All 3 inlet passive samplers were moved, and 1 additional outlet passive sampler was installed.
[3] Based on lessons learned during Phase I monitoring, the elevations of the Park Avenue basin passive samplers were modified to more appropriately sample the inlet and outlet surface waters.

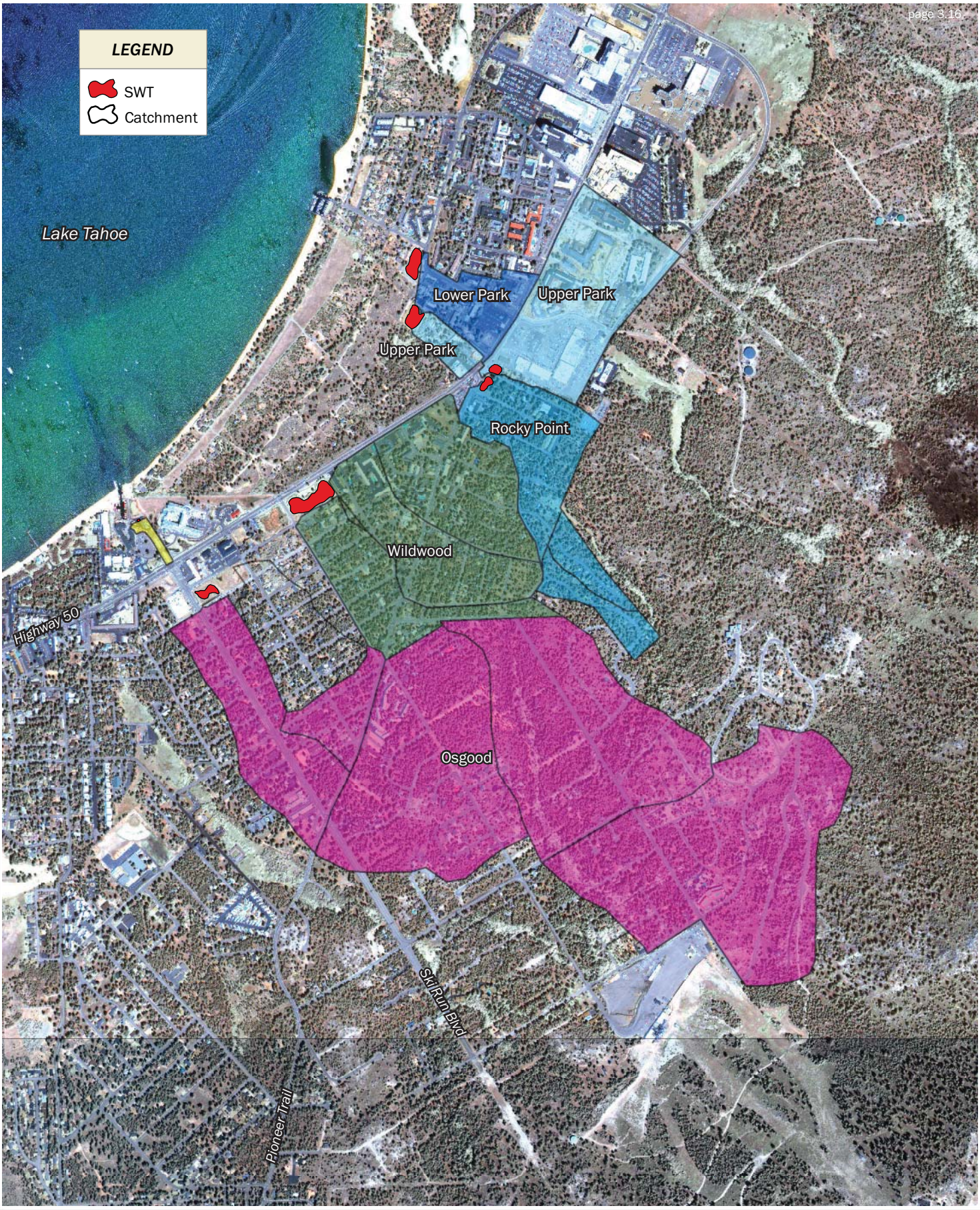

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Figure 3.6A. SWT Catchment Location Map - South Lake Tahoe, East

Feet
0 450 900 1,800
N

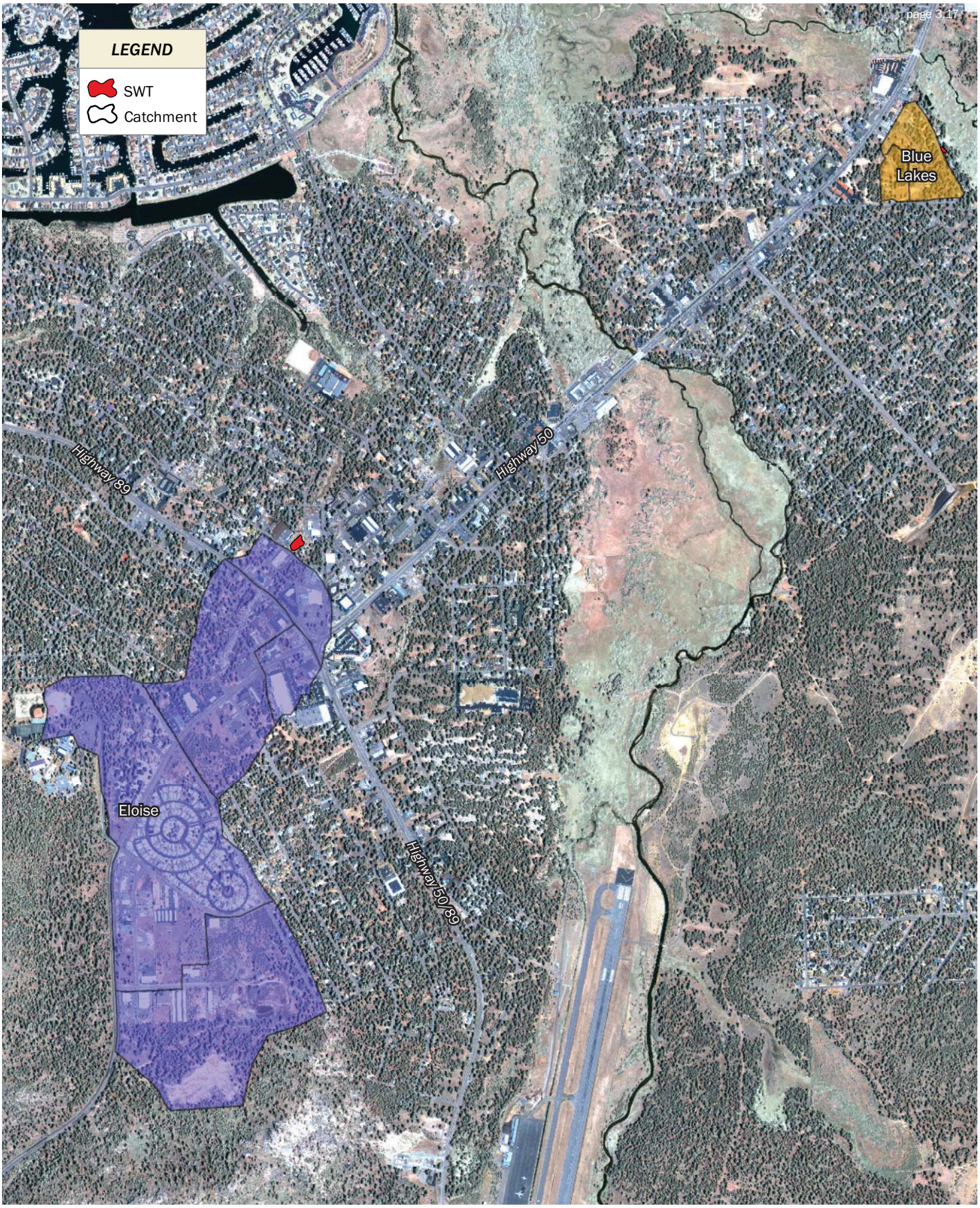

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Figure 3.6B. SWT Catchment Location Map - South Lake Tahoe, West

Feet
0 500 1,000 2,000
N

SURFACE WATER HYDROLOGY DATA COLLECTION TECHNIQUES

At all nine SWTs, an unvented In-Situ LevelTroll 500 and staff plate were installed to record water depth on 15-minute intervals. An In-Situ BaroTroll maintained at the offices of Environmental Incentives in South Lake Tahoe, CA recorded barometric pressure on the same time interval to correct the SWT depth data for changes in atmospheric pressure. All instrument gages were downloaded and maintained regularly during site visits, and the staff plates were used to visually verify instrument performance and complete data QA/QC. Accuracy of the water level recorders is ±0.05 ft, as documented in the manufacturer's specifications. Due to the cold climate and frequent freeze/thaw conditions, several level recorders did not perform reliably during the winter months. Data from Blue Lakes, Wildwood and Coon Basins could not be consistently correlated to staff plate measurements and, therefore, were not used in this research analysis (see Table 3.5). Data collection from the Stormfilter® Vault was also unreliable, as there is constant backwatering within the outlet and accurate depth readings were not obtained.

2NDNATURE field personnel surveyed the three wet basins and four dry basins to obtain detailed topography and elevations of critical features (inlet(s), outlet(s), instrumentation, etc.) for each basin. The basin topographic data was tied to the water level recorder elevation to create a basin stage to storage rating curve using the ArcGIS 3D Analyst surface volume tool and the subsequent development of a continuous basin water storage time series and detailed water budget (described below in Chapter 3.2.1). Site instrumentation details for each SWT are provided in Table 3.5, and Figures 3.7A-G illustrates site-specific topographic contours and monitoring locations.

WATER QUALITY SAMPLE FIELD DATA COLLECTION TECHNIQUES

A total of 299 water quality samples were collected from the nine SWTs during WY09-WY11 using a combination of passive samplers, grab samples, and automated instrumentation and submitted to Western Environmental Testing Laboratory (WETLAB).

As indicated in Table 3.5, passive samplers (Nalgene® Stormwater Samplers) were installed at 6 SWTs to characterize the inlet and outlet water quality. Passive samplers are a low-cost method to collect discrete water quality samples associated with a specific basin water surface elevation. Samplers collect the rising limb of the hydrograph (standardizing sample collection across all sites) and are self-sealing to preserve the sample until field personnel can safely visit the site (top half of Figure 3.8). In some instances, water samples collected from passive samplers may be slightly higher than event mean concentrations (EMCs) because they sample the rising limb and do not represent the entire hydrograph. However, the reduced cost of passive sampler installation and lower data management complexity compared to flow-weighted automated samplers allow for a significant increase in the number of sites monitored and the temporal extent of monitoring for the resources available.

Two to three passive samplers were installed at both the inlet and outlet of each basin (bottom half of Figure 3.8) and sample collection is standardized based on relative basin stage. Inlet/outlet pairs were installed at near equivalent water surface elevations to ensure collection of samples occurs at a similar location on the storm hydrograph and the difference pollutant concentrations between the inlet and outlet pair can be attributed to the water quality treatment as a result of flow through and interaction with the treatment BMP (Figures 3.9A-B). Sampler elevations are determined relative to the treatment and bypass outlet elevations of the SWT, in order to compare treated and bypass flow, as defined by PLRM.

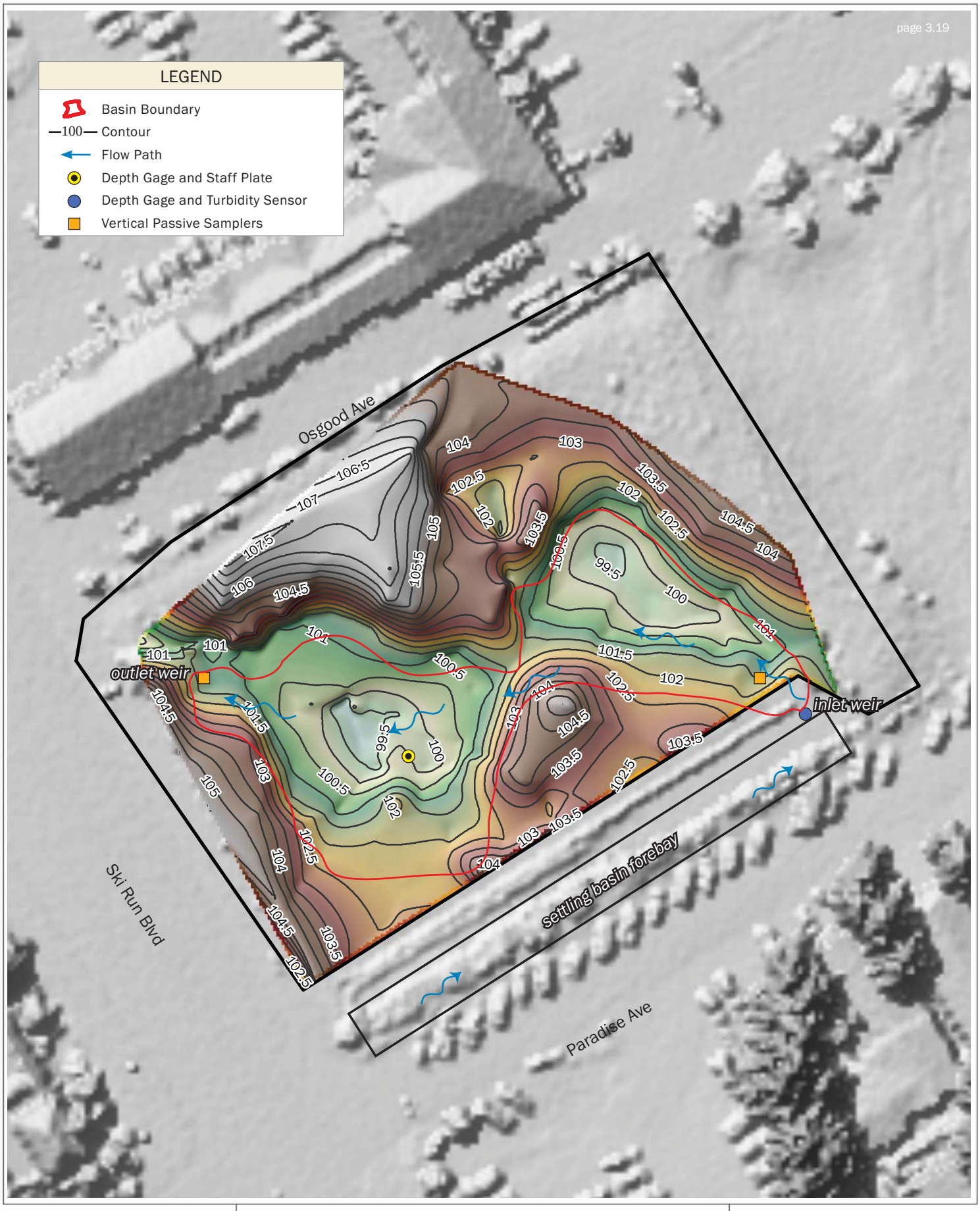

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Figure 3.7A. Osgood Basin Site Map Shaded topographic contours of Osgood Basin plotted over a 2010 LiDAR data. Elevations values are in feet, with a contour interval of 0.5 feet. Elevation is relative to 0ft on staff plate where: 0ft staff = 100ft elevation

Feet
0 15 30 60
N

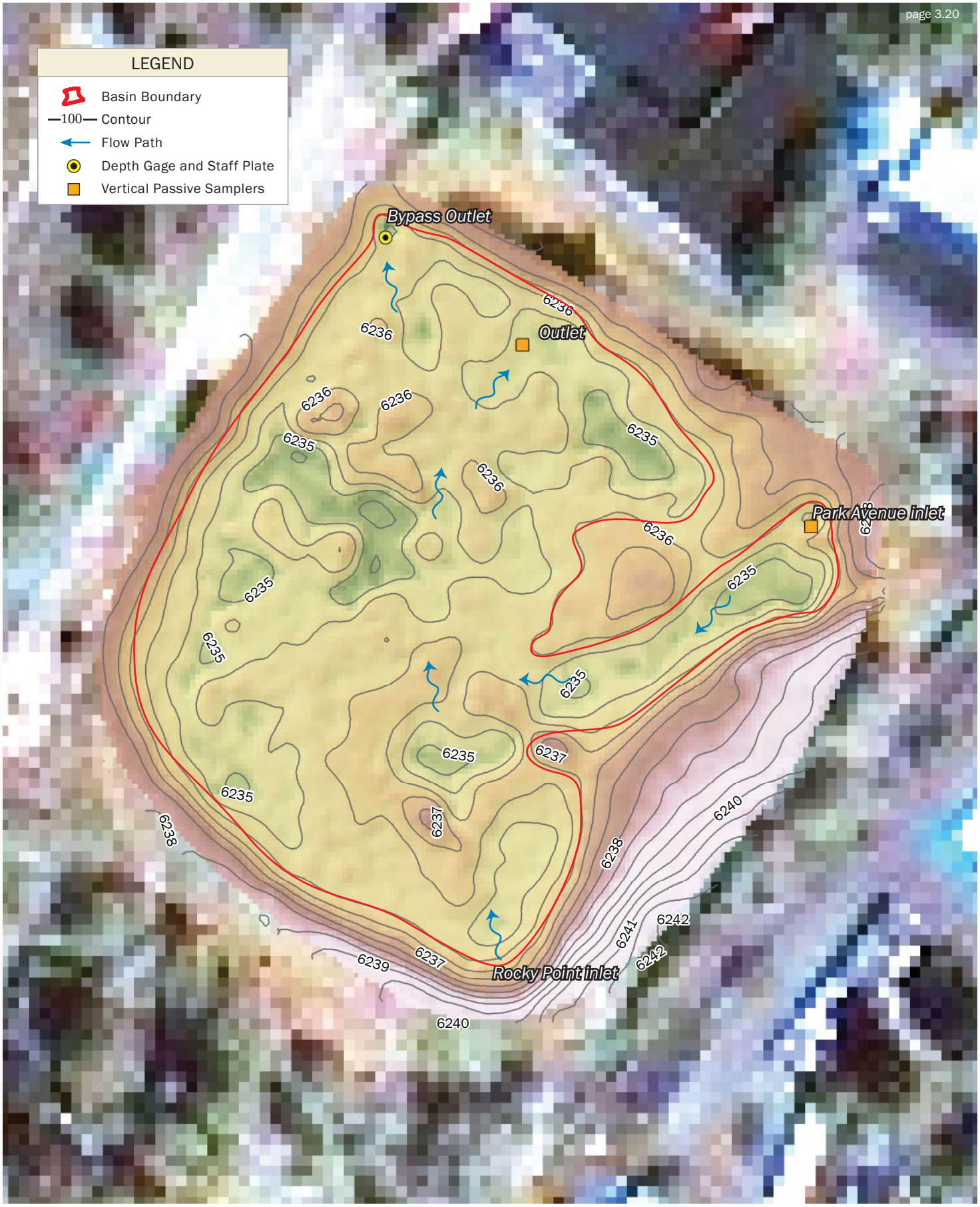

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Figure 3.7B. PA1 Basin Site Map Shaded topographic contours of Upper Park Basin (PA1). Elevations values are in feet, with a contour interval of 0.5 feet. Elevation is relative to 0ft on staff plate where: 0ft staff = 6234.5 ft elevation

Feet
0 12.5 25 50
N

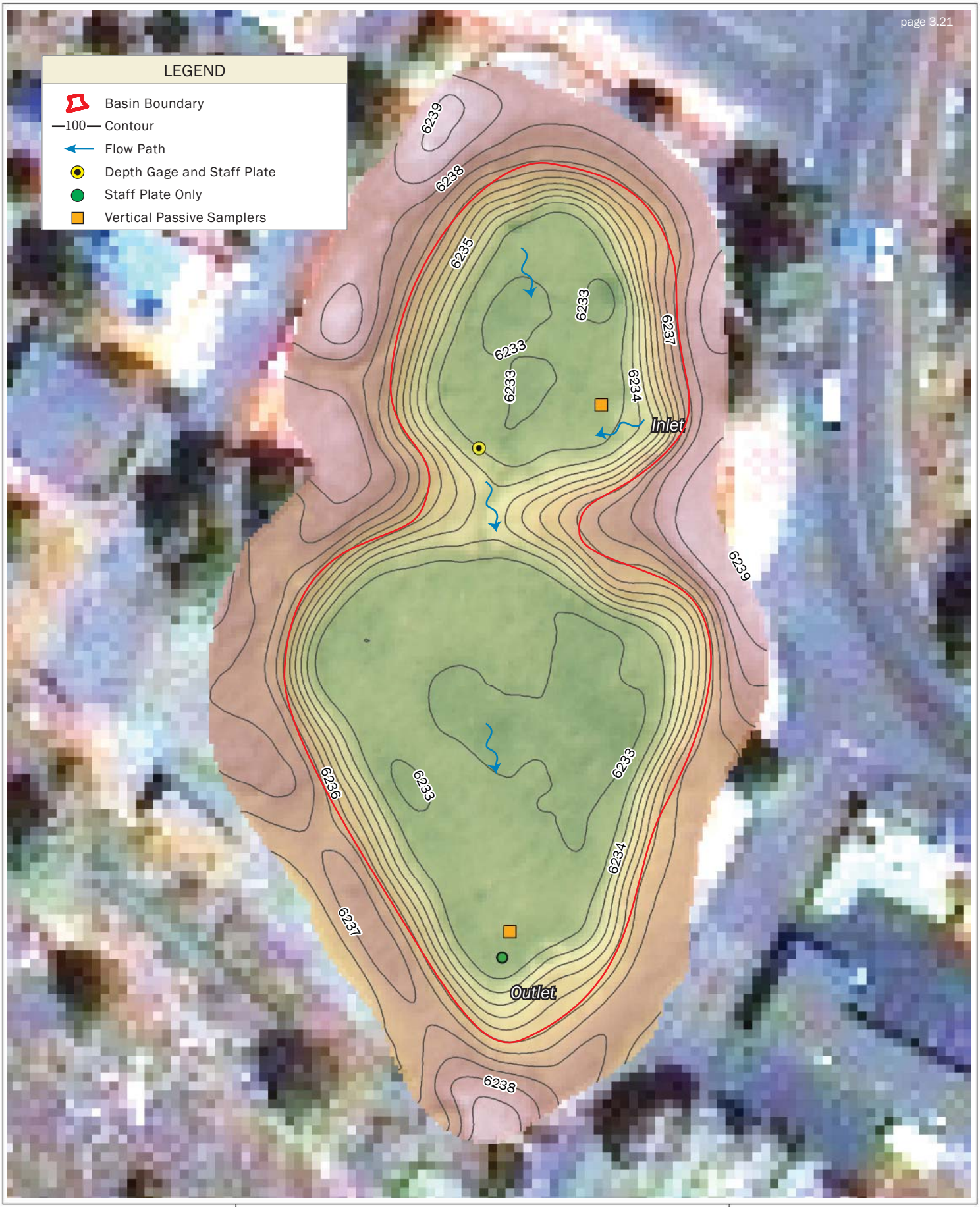

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Figure 3.7C. PA2 Basin Site Map Shaded topographic contours of Lower Park Basin (PA2). Elevations values are in feet, with a contour interval of 0.5 feet. Elevation is relative to 0ft on staff plate where: 0ft staff = 6232.9 ft elevation

Feet
0 15 30 60
N

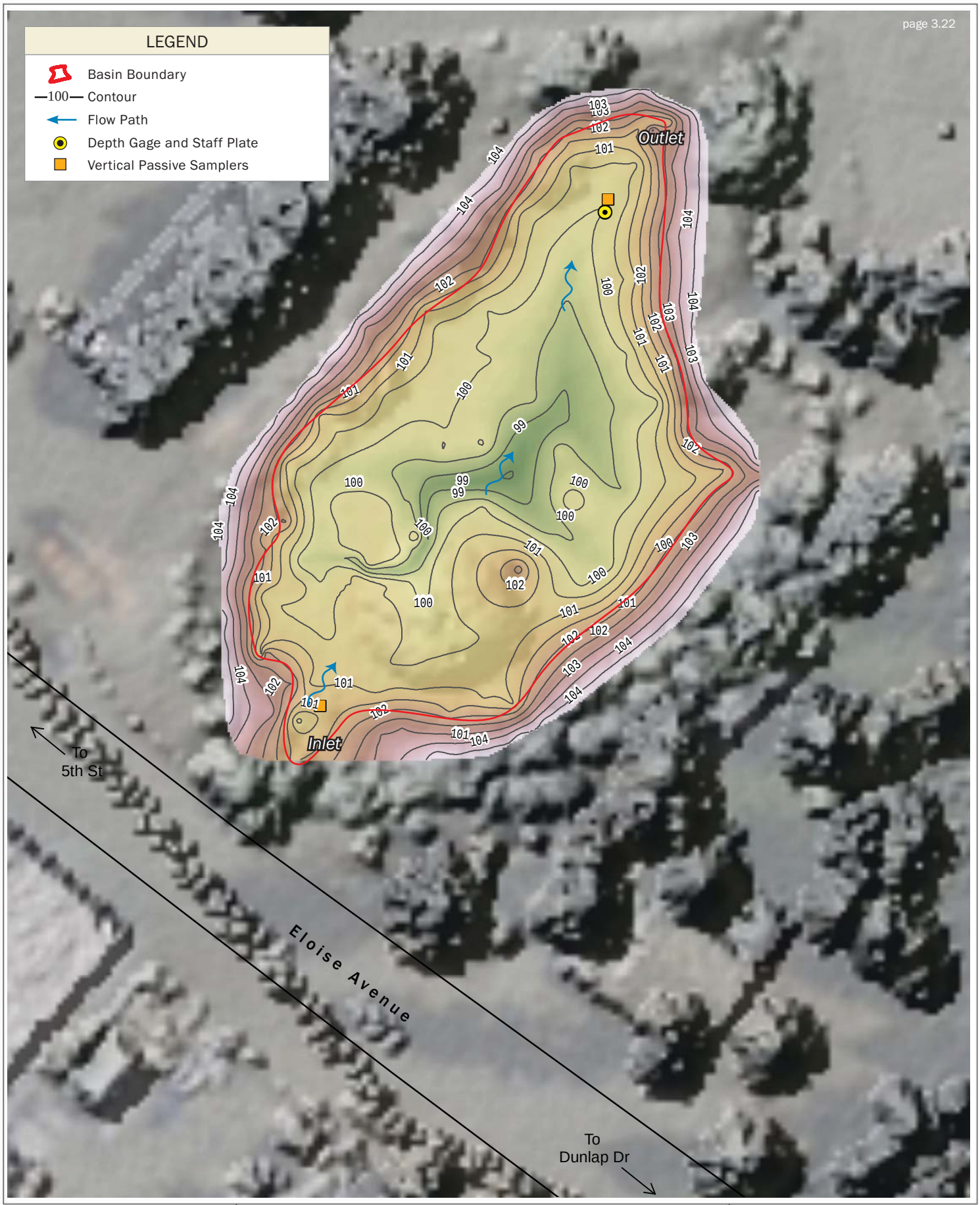

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Figure 3.7D. Eloise Basin Site Map Shaded topographic contours of Eloise Basin. Elevations values are in feet, with a contour interval of 0.5 feet. Elevation is relative to 0ft on staff plate where: 0ft staff = 100 ft elevation

Feet
0 12.5 25 50
N

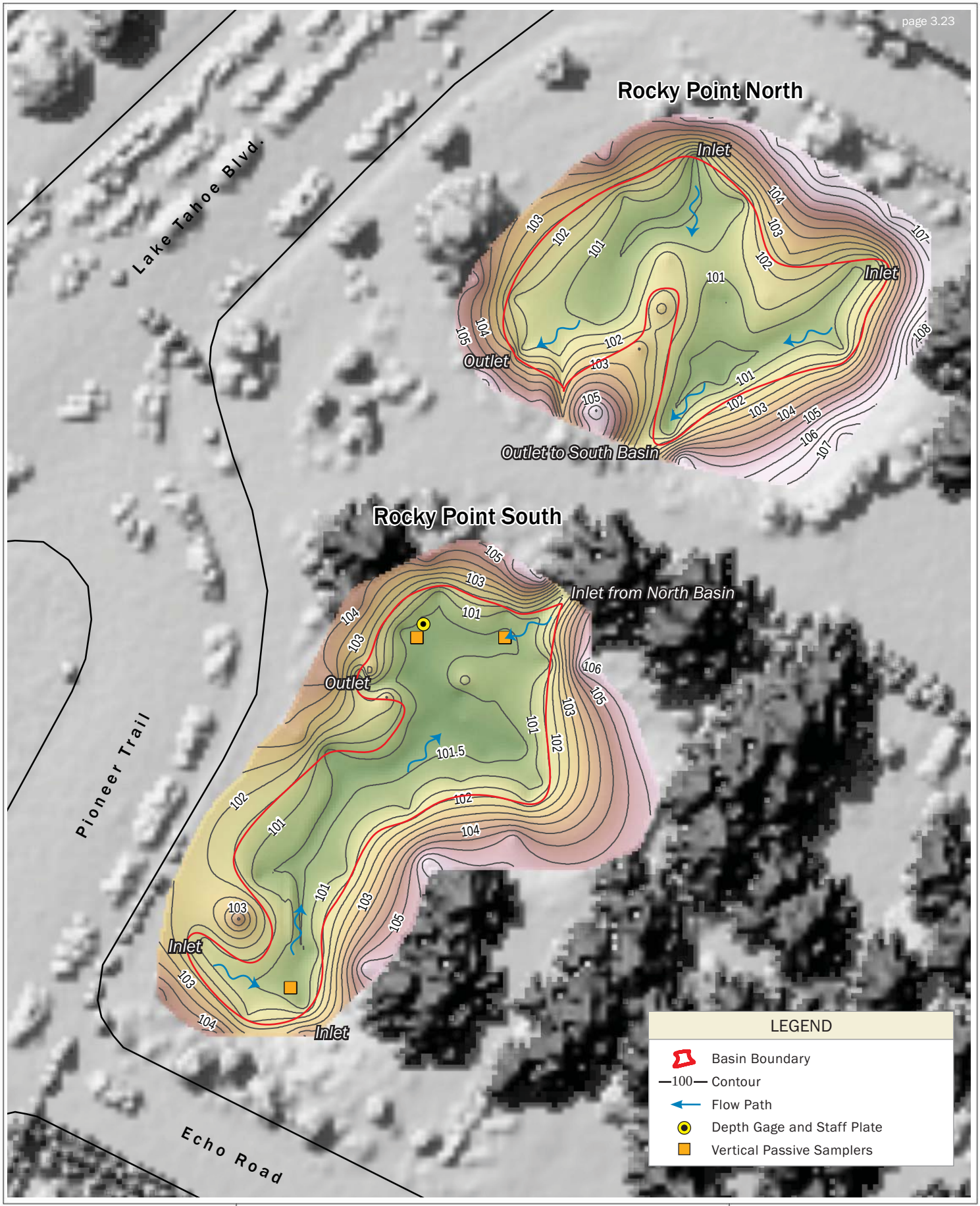

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Figure 3.7E. Rocky Point Basins Site Map Shaded topographic contours of Rocky Point Basins. Elevations values are in feet, with a contour interval of 0.5 feet. Elevation is relative to 0ft on staff plate where: 0ft staff = 100 ft elevation

Feet
0 12.5 25 50
N

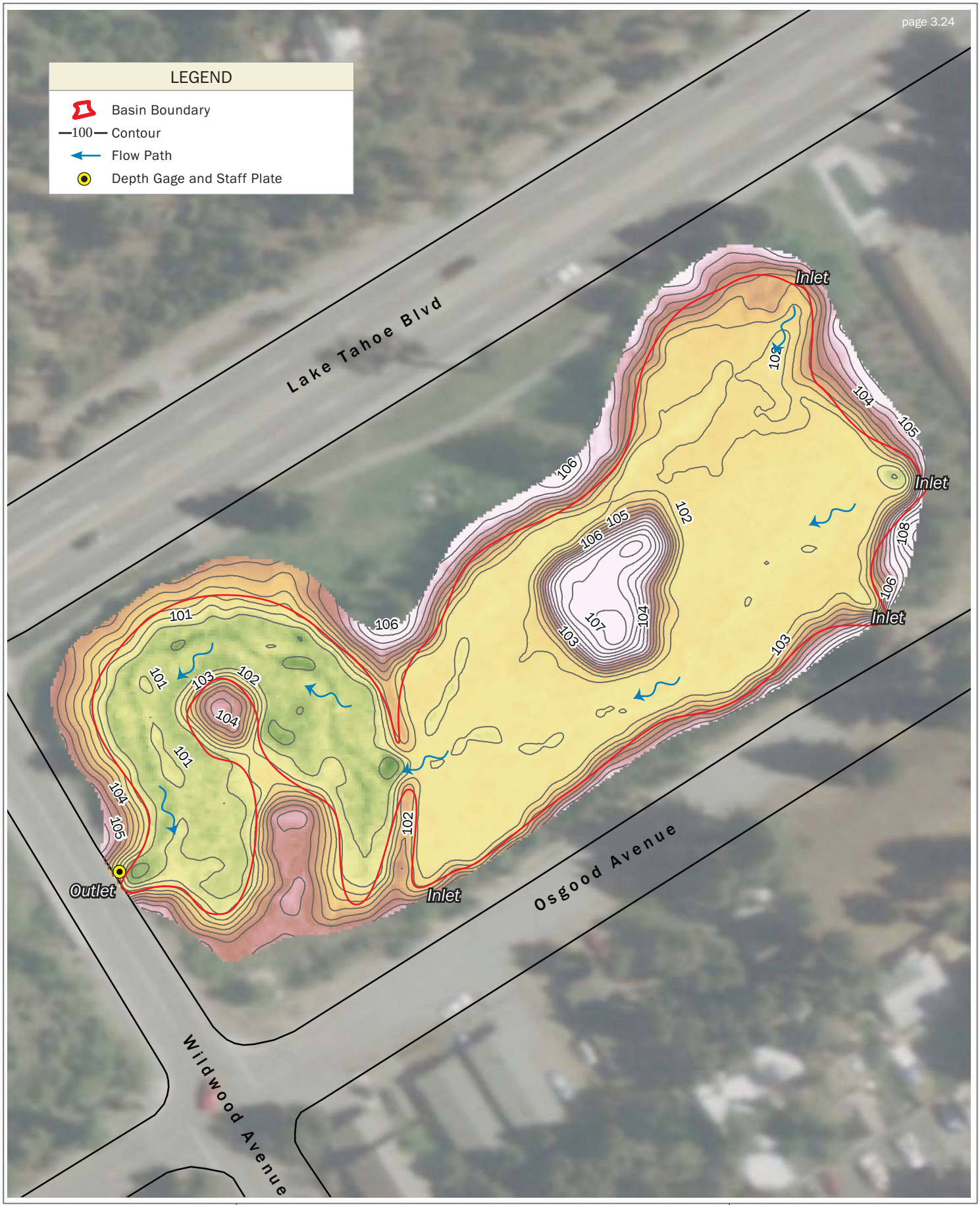

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Figure 3.7F. Wildwood Basin Site Map Shaded topographic contours of Wildwood Basin. Elevations values are in feet, with a contour interval of 0.5 feet. Elevation is relative to 0ft on staff plate where: 0ft staff = 100 ft elevation

Feet
0 25 50 100
N

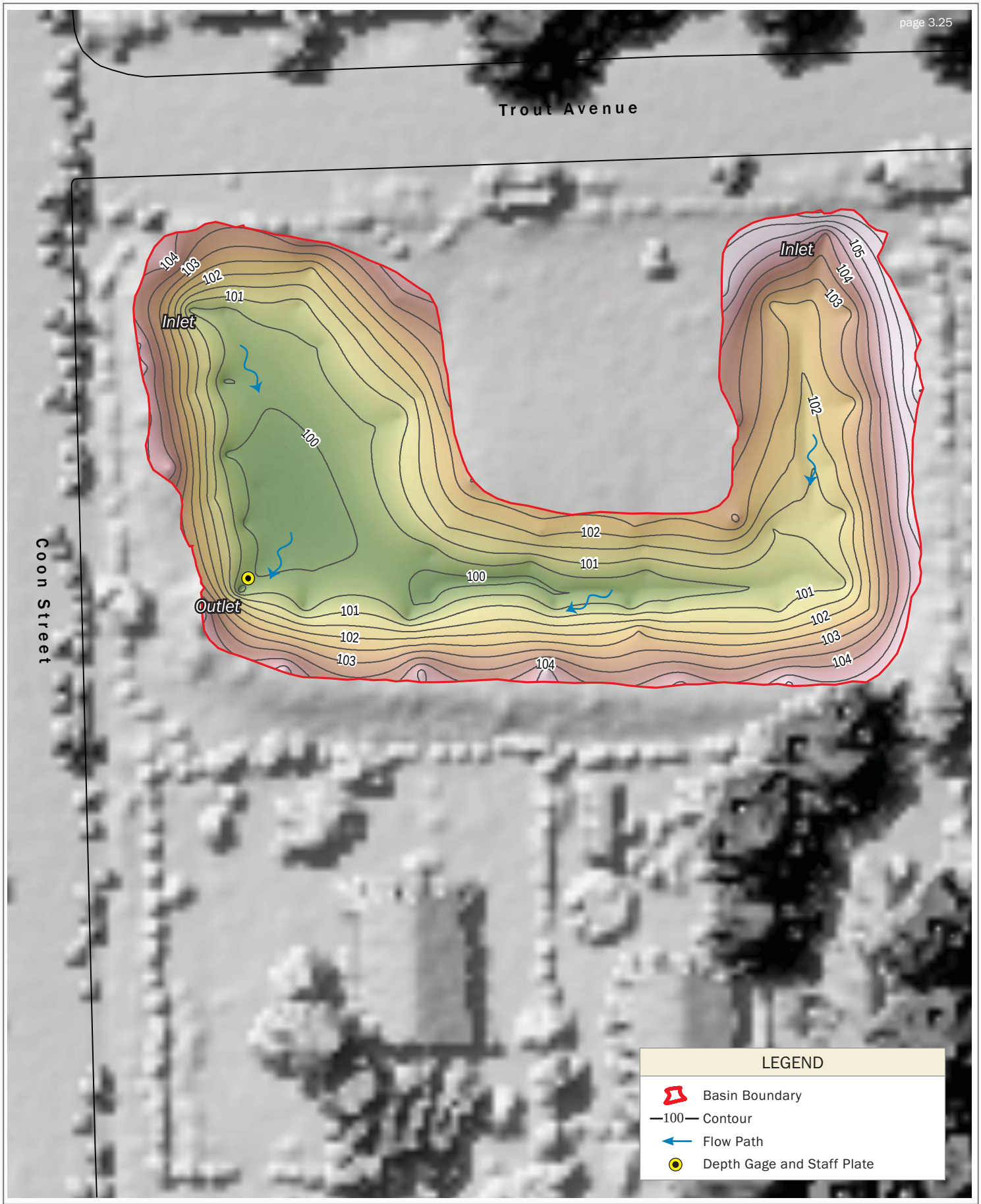

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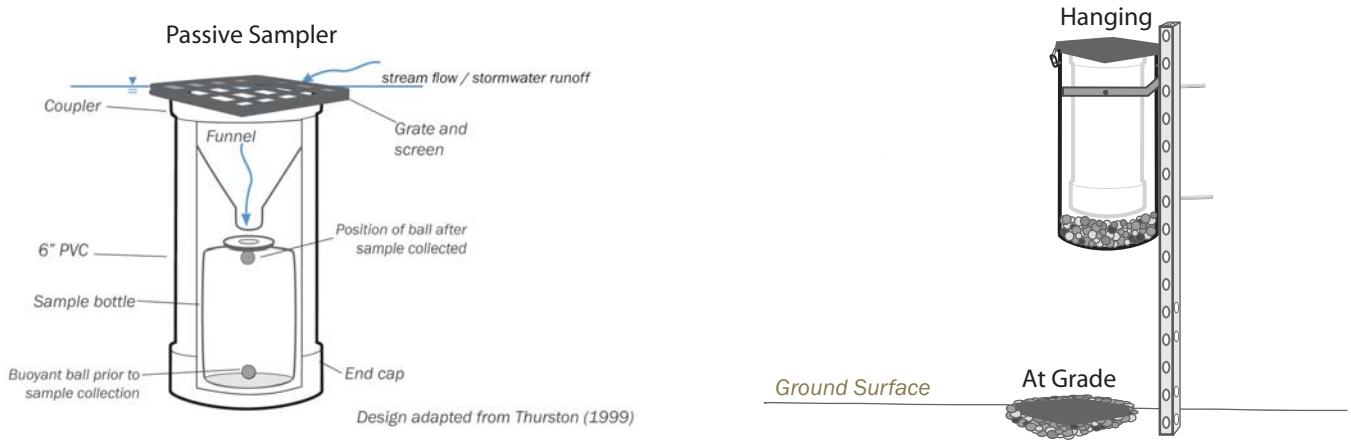
Figure 3.7G. Coon Basin Site Map Shaded topographic contours of Coon Basin. Elevations values are in feet, with a contour interval of 0.5 feet. Elevation is relative to 0ft on staff plate where: 0ft staff = 100 ft elevation

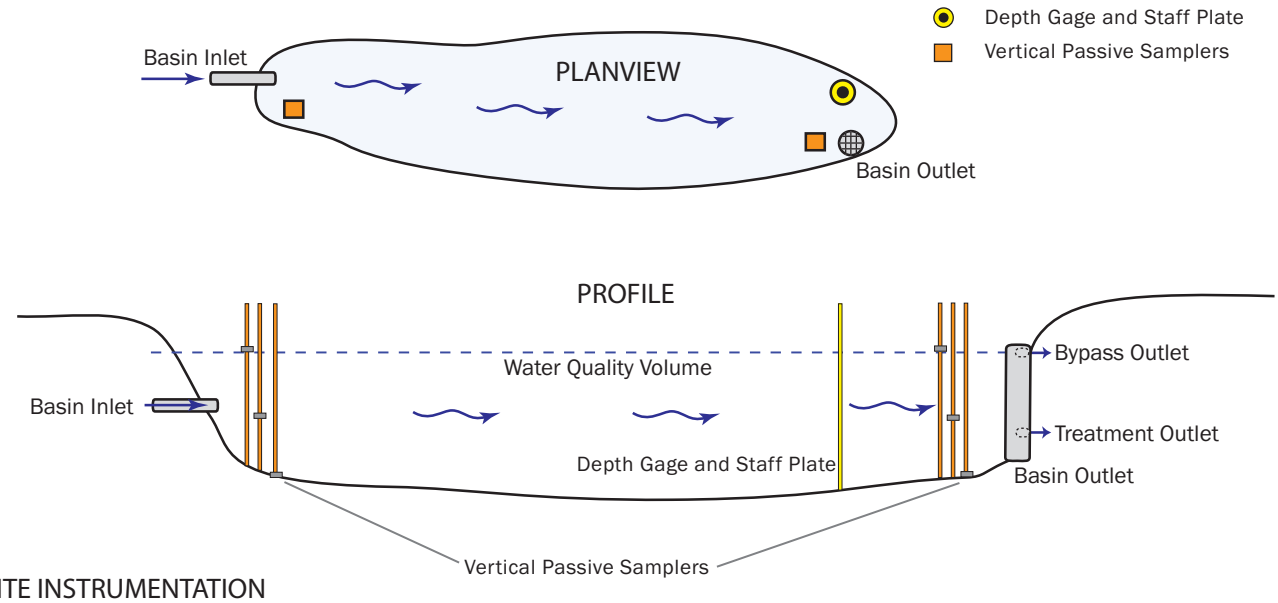
Feet
0 10 20 40
N

BASIN SWT PASSIVE SAMPLER DESIGN



- Passive samplers can be custom fabricated to meet site-specific needs, but typically are Nalgene Stormwater Samplers®.
- Passive samplers can be (1) buried in the flow path to collect sample at grade or (2) secured to vertical sign post to collect a sample at a targeted stage elevation (i.e., hanging).
- Sample is collected when water surface exceeds elevation of top of sampler. Sample flows over grate, through funnel and into bottle. As bottle fills with water during the event, the ping pong ball floats to the top and plugs the hole in the lid and seals the sample until it is collected by field personnel.

BASIN SWT



SITE INSTRUMENTATION

- Depth Gage installed in basin to record water depth continuously on 15-minute intervals and create surface water hydrology time series.
- Staff Plate is installed to QA/QC depth data.
- 4 - 8 Basin Passive Samplers are installed within basin (2-4 at inlet and 2-4 at outlet, depending on basin depth at invert of bypass outlet).
  - Samplers are installed to collect samples at various water surface elevations to standardize sampling based on relative basin stage.
  - Inlet and outlet sampler elevations are matched as closely as possible to create inlet/outlet sample pairs. This technique assumes that at the same basin stage, the inlet/outlet sampler pairs are collecting samples at a similar location on the storm hydrograph and observed water quality differences between the samples is the result of flow through and interaction with the SWT.

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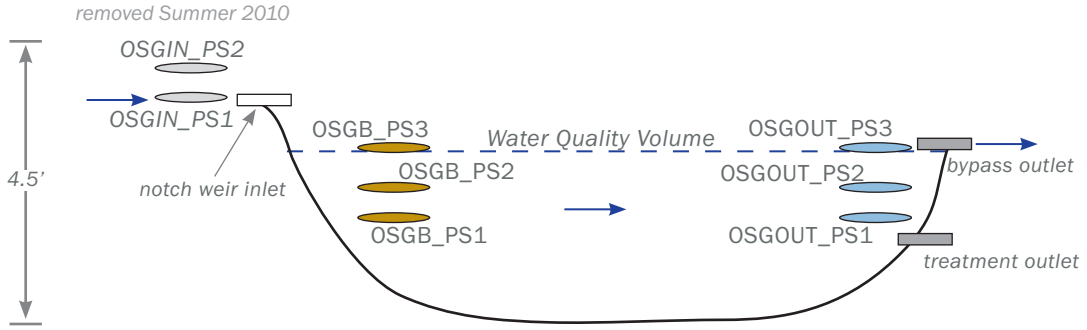
SWT SAMPLING SCHEMATIC

FIGURE 3.8

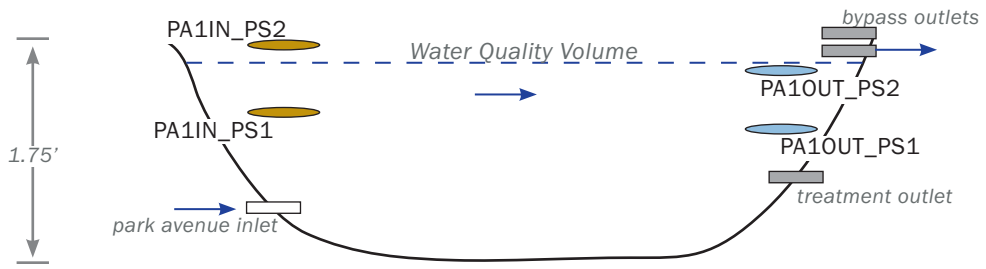
1.

Osgood Basin



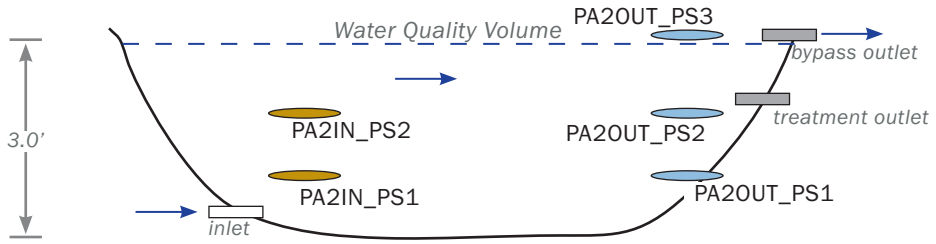
2.

Park Avenue Upper Basin (PA1)



3.

Park Avenue Lower Basin (PA2)



LEGEND	
▭	Conveyance Structure
⬭	Passive Sampler

Note: Schematics drawn to show relative elevation within each SWT. Horizontal dimension is not drawn to scale.

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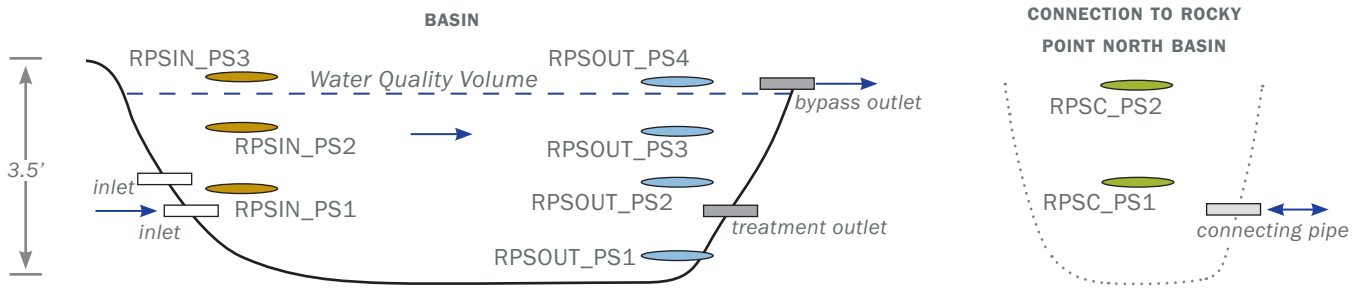
CROSS SECTION SCHEMATICS OF SWT SAMPLE COLLECTION

FIGURE 3.9A

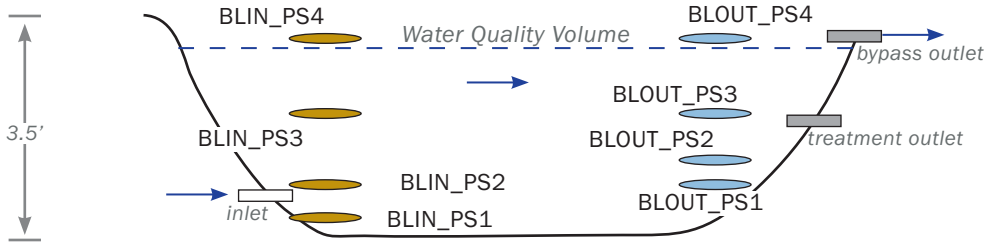
4.

Rocky Point South Basin



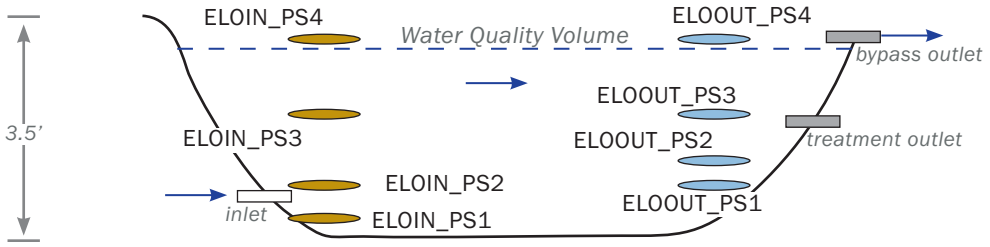
5.

Blue Lakes Basin



6.

Eloise Basin



LEGEND
Conveyance Structure
Passive Sampler

Note: Schematics drawn to show relative elevation within each SWT. Horizontal dimension is not drawn to scale.

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CROSS SECTION SCHEMATICS OF SWT SAMPLE COLLECTION

FIGURE 3.9B

Grab samples were periodically collected at the treatment and bypass outlets of all nine SWTs throughout WY10-WY11. The date and time of sample collection was noted and compared to the SWT volume time series to determine hydrograph position. These water quality results are compared to the passive sampler results to address any bias introduced by the passive sampler monitoring technique, as well as provide water quality data for those SWTs where passive samplers were not installed.

At Osgood Basin and the Stormfilter® Vault, Sigma 900 series automated samplers also collected inlet and outlet water quality samples during WY09. The two samplers at Osgood Basin were originally installed by the CSLT in November 2007 for other monitoring needs and remained in place until winter 2010. 2NDNATURE field personnel installed the automated samplers at the Stormfilter® Vault in March 2009 because the passive sampling technique was not feasible within the cartridge filter. However, due to backwatering effects at both the inlet and outlet, reliable water quality data was not obtained and the instruments were removed in October 2009. Subsequently, grab samples from the outlet were collected during runoff events instead.

SWT CONDITION FIELD DATA COLLECTION TECHNIQUES

2NDNATURE field personnel performed the field observations (STEP 4) of the Best Management Practices Maintenance Rapid Assessment Methodology (BMP RAM) at each SWT every summer per the protocols detailed in the BMP RAM User Manual v1 (2NDNATURE et al. 2009b). BMP RAM observations were conducted in September 2009, July 2010, June 2011, and August 2011 to evaluate the condition of each SWT. While BMP RAM scores could not be calculated because score calculation requires jurisdictional input to develop benchmark and threshold values (STEP 3), valuable information on the relative changes in SWT condition over the multiple years of monitoring were acquired. As noted above, communications with responsible jurisdictions and frequent SWT observations indicate none of the SWTs included in this research have had any level of maintenance in the past 4 years.

SWT INFILTRATION FIELD DATA COLLECTION TECHNIQUES

Discrete soil sample collection and simultaneous saturated conductivity measurements were conducted within each of the six dry basins to improve our technical understanding of infiltration volumes, CHP measurements, and SWT treatment performance over time. The data is used to calculate average annual infiltration rates within SWTs and to compare these measured values to the water budget estimates of infiltration (described below in Chapter 3.2.1). A total of 53 soil samples were collected and stored in labeled Ziploc bags and a subset of 34 samples were submitted to Cooper Laboratory (see Chapter 3.1.5) for particle grain size analysis. In accordance with BMP RAM protocols, 2NDNATURE field personnel measured saturated conductivity (Ksat) at a depth of approximately 6” below the soil surface using a CHP fabricated according to NRCS specifications.

3.1.5 SAMPLE ANALYSES

A total of 614 water quality samples collected during controlled road experiments or SWT event-based sampling and a subset of these were analyzed for turbidity in the field and submitted to WETLAB for TSS (mg/L); particle size distribution [PSD] (% by mass for the following particle sizes: <1 µm, <10 µm, <16 µm, <20 µm, <63 µm, <100 µm and <1000 µm); and soluble reactive phosphorous [SRP] (mg/L) analysis. A fraction of the dry material samples collected during Road RAM observations, private parcel sampling, and SWT basin infiltration monitoring were kept and submitted to Cooper Analytical Laboratory for PSD (% mass <16 µm). The particle size analysis (ASTM D 422-63) includes a combination of sieves (for particles >75 µm) and a hydrometer (particles <75 µm), and the resulting

data was provided as % sand (63 µm – 2 mm), % silt and clay (<63 µm), and estimated % FSP (<16 µm). Laboratory standard operating procedures are provided in *Appendix B* of the *Phase II Monitoring Plan* (2NDNATURE and NHC 2010b). Table 3.6 summarizes the sample analyses and frequency of analysis for all samples collected for this research. All water samples obtained for FSP analyses have been submitted to DRI for analysis and DRI researchers were encouraged to use the samples for additional particle size research efforts. Coordination and data sharing of necessary sample information has been offered to DRI researchers should they conduct additional analyses.

Table 3.6. Research analytical laboratory details and frequency of pollutant constituent analysis.

Constituent	Analytical Laboratory	Analytical Method	Frequency of Analysis (n)	Detection Limit
Water Quality Samples				
Turbidity (Field)	n/a	Hach 2100P or Lamotte 2020 portable turbidimeter[1]	87% (535)	0.1 ntu
Total Suspended Sediment (TSS)	WETLAB	SM 2540D	90% (550)	1 mg/L
Soluble Reactive Phosphorous (SRP)	WETLAB	EPA 365.3	47% (288)	10 µg/L
Dissolved Phosphorous (DP)	WETLAB	EPA 365.3	27% (167)	10 µg/L
Total Phosphorous (TP)	WETLAB	EPA 365.3	27% (166)	10 µg/L
Particle Size Distribution	DRI	Saturn Digitizer 5200	89% (547)	1 mg/L
Dry Material Samples				
Particle Size Distribution	Cooper Laboratory	ASTM D422	23% (210)	n/a

[1] The measurement range for the Hach 2100P is 0-1000 ntu, while the Lamotte 2020 is 0-4000 ntu. For samples <1000 ntu field measurements were taken using the Hach 2100P and for samples >1,000 ntu the Lamotte turbidimeter was used in the field.

FIELD QA/QC

Field precision of the portable simulator was calculated by performing field triplicates at 18 road segments over the course of the research (Table 3.7). The road segments represented a range of conditions and road risks. The instances of greatest deviation in measured FSP concentration occurred when the amount of material on the road was high or road surface integrity was poor, allowing water to seep out through the sides of the sampler. Since the distribution of material even within an accumulation area is not completely uniform, we expect some error in our field precision due to the difficulty in selecting and sampling three 1 ft^2 areas with an equal amount of material.

Six field blanks were collected over the course of the research and submitted blind to WETLAB. Distilled water was poured onto the collection pan of the sampler (see Figure 3.4) and collected in a clean sample bottle. The field blank turbidity, TSS and FSP results represent the minimum values measured during the research project, indicating there is likely little sample contamination during field sampling. The average SRP concentration is higher than the analysis detection limit (0.017 mg/L vs. 0.01 mg/L) suggesting the potential for sample contamination during monitoring; however, the average is based on a very limited number of samples. If future monitoring includes SRP analysis, field research will ensure all bottles are pre-rinsed with DI water prior to SRP sample collection and are thoroughly washed by the analytical laboratory.

Table 3.7. Field QA/QC results. Pollutant field precision is expressed as percent error based on field replicate samples and sample integrity is evaluated as the measured concentration of field blanks.

Constituent	Field Precision % Error (n)	Sample Integrity Concentration (n)
Field Turbidity	10.1% (42)	1.2 ntu (6)
TSS	12.5% (40)	2.0 mg/L (6)
FSP[1]	12.2% (40)	1.1 mg/L (5)
SRP	10.7% (14)	17 ug/L(3)

[1] Samples are submitted to laboratory for TSS concentration and particle size distribution. FSP concentrations is calculated as TSS (mg/L) * % of TSS < 16 µm.

Laboratory QA/QC

Laboratory analytical precision calculations and method blank analysis for all water quality samples collected during this research are presented in Table 3.8. The analytical laboratory performs regular quality control efforts that include method blanks, matrix spikes, laboratory duplicates and external standards. The complete laboratory quality assurance plan is provided in *Appendix A* of the *Phase II Monitoring Plan* (2NDNATURE and NHC 2010b). Instrument precision was tested on the field turbidimeter using triplicate subsamples from individual field samples.

Table 3.8. Laboratory QA/QC results. Laboratory precision is expressed as percent error based on replicate samples and sample integrity is evaluated as the measured concentration of method blanks. Number of samples used in calculation is noted in parentheses.

Analysis	Lab Precision % Error (n)	Sample Integrity Concentration (n)
TSS	6.5% (50)	0.93 mg/L (31)
FSP[1]	n/a	n/a
SRP	n/a	10 ug/L (40)
DP	n/a	10 ug/L (14)
TP	n/a	10 ug/L (14)

[1] Samples are submitted to laboratory for TSS concentration and particle size distribution. FSP concentrations is calculated as TSS (mg/L) * % of TSS < 16 µm.
Lab replicate and method blank data for particle size distribution is not available.

3.1.6 ROAD RAM USER PRECISION

During two observations periods (January 2011 and April 2011) 2-4 trained field personnel conducted 46 simultaneous, independent Road RAM observations to determine the variation in road segment scores as a result of reasonable differences in user field observation inputs. Field observations of percent distribution of material accumulation categories, volume measurements, and degree of fines observations between field personnel differed by varying degrees depending upon the categorization of the high, moderate and low areas of accumulation and the selection of the representative 1ft^2 area. The average difference in the road segment condition score was 0.3 (Table 3.9) and never greater than 0.6. For 17 observations (or 37%), field personnel observations resulted in the users arriving at the road segment score +/- 0.1. These analyses of field observation precision should continue to be conducted to validate the Road RAM scoring process and improve the observation protocols, particularly during other times of the year. However, these initial results provide confidence that the Road RAM is a simple, repeatable tool with standardized field observations, consistent with statements in the

Road RAM Technical Document (2NDNATURE et al. 2010c) that the field observation precision between two trained field personnel is within ±0.5 of a road segment condition score.

Table 3.9. Results of Road RAM field observation precision analysis completed in WY2011.

Number of Observation Periods	Number of Observations	Road Segment Condition Score (0-5)				
		Average Difference	Standard Deviation	Maximum Difference	Minimum Difference	Frequency Difference ≤0.1 Score (n)
2	46	0.3	0.2	0.6	0.0	37% (17)

3.1.7 DATA MANAGEMENT

All data collected during this research have been managed in a digital Microsoft Access relational database (CRC.accdb for land use data and CEC.accdb for SWTs; Figure 3.10). Controlled experiment data, road condition data, private parcel site conditions, SWT condition observations and staff plate measurements, and field notes were recorded in field notebooks or custom datasheets during all sampling activities. Instrument data downloads and maintenance activities were recorded on pre-printed data logs. Upon return to the office, office personnel QA/QC'd all data for accuracy and completeness before integration into the database. The laboratory submitted electronic results of analyses, which office personnel checked for data quality and completeness, verified against the chain of custody record, and then entered into the database. Following development of the Road RAM data management tool, field personnel have recorded Road RAM observations directly into the online database in the field (www.tahoeroadram.com).

3.2 MODELING TECHNIQUES

2NDNATURE and NHC staff used cost-effective modeling techniques to develop stormwater datasets to further the analysis of the data collected in the field. Detailed surface water budgets were created for each monitored SWT using the continuous water level data, topographic survey data, and spot measurements described in Chapter 3.1.4 above. PLRM models developed for each drainage catchment were adapted using the EPA's Storm Water Management Model (SWMM), which is the parent model to PLRM, to facilitate analysis of output from the long-term continuous simulations of surface water runoff on seasonal and annual time periods.

3.2.1 WATER BUDGET CALCULATIONS

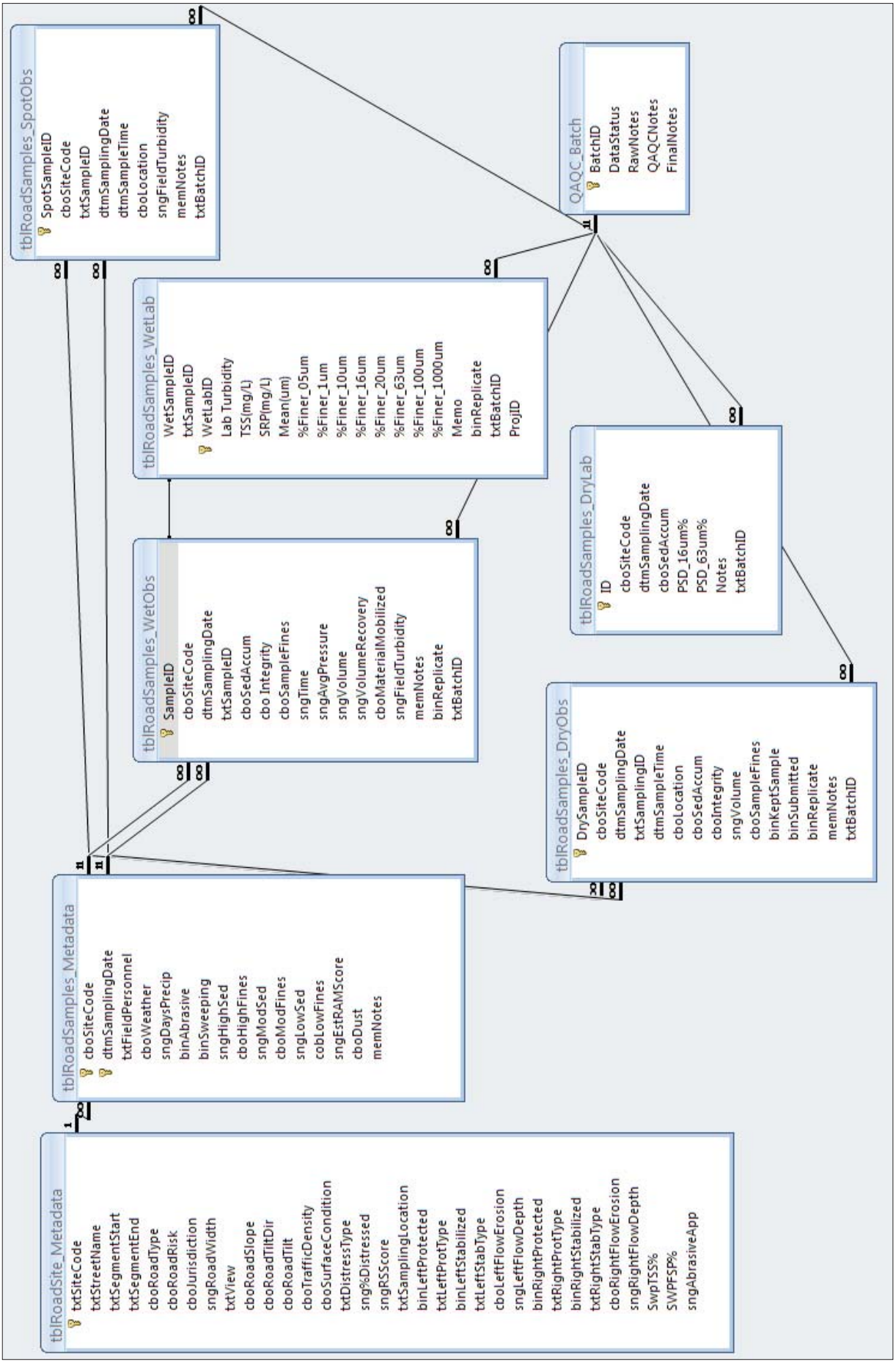
Below we provide a brief overview of the methodology used to created detailed surface water budgets for Osgood, PA1, PA2, Rocky Point and Eloise Basins. A detailed description of the methodology is provided in Appendix C, along with a complete list of all variables defined below, with descriptions and units.

The continuous water surface elevation and associated storage time series obtained from pressure transducers recording water depth on 15-min intervals are used to calculate a surface water budget for each SWT using the following mass balance equation:

Change in SWT Storage = Water Inputs – Water Losses

or

$$\Delta V_{SWT} = V_{INPUT} - V_{LOSS} \quad \text{(EQ 3.1A)}$$



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DATA RELATIONSHIP STRUCTURE FOR RESEARCH DATABASES

FIGURE 3.10

Change in storage is a continual balance of water inputs and losses to the SWT. When water inputs are greater than water losses, the SWT will fill with water over time and the SWT storage volume will increase. Conversely, when losses are greater than inputs, the water storage volume within the SWT will decrease over time. Water inputs and losses can be calculated using the following equations:

$$V_{INPUT} = V_{IN} + V_{PRECIP} \text{ (EQ 3.2)}$$

and

$$V_{LOSS} = V_{OUT_B} + V_{OUT_T} + V_{INF} + V_{ET} \text{ (EQ 3.3)}$$

thus

$$\Delta V_{SWT} = (V_{IN} + V_{PRECIP}) - (V_{OUT_B} + V_{OUT_T} + V_{INF} + V_{ET}) \text{ (EQ 3.1B)}$$

where water inputs include inflow through the constructed SWT inlet (V_{IN}) and direct precipitation on the SWT surface area (V_{PRECIP}), and water losses include outflow through the constructed bypass (V_{OUT_B}) and treated (V_{OUT_T}) outlets, infiltration through the subsurface (V_{INF}), and evapotranspiration (V_{ET}).

Each of the volume terms is the sum of a water flux over a given time period, and can be written as:

$$V = \Sigma\, Q * t \text{ (EQ 3.4)}$$

where Q is the rate (cf/min) of volume change over discrete time intervals (t) defined for the time period of interest (e.g., event, month, season, water year). For example, if the inflow rate (Q_{IN}) is 1 cf/min for an event lasting 10 minutes, then the total inflow volume equals 10 cf (V_{IN}).

To simplify the calculation of seasonal volume losses average water loss rates (Q) are calculated for the evapotranspiration, infiltration, and treated outflow loss terms and standard engineering equations are used to calculate bypass outflow. Water inputs (direct precipitation and inflow) are variable and will depend upon climatic factors in the contributing catchment including precipitation rate, runoff and stormwater transport. In fact V_{PRECIP} is considered negligible on the seasonal-scale (less than 2% of total input volume) and is not included in these calculations. Therefore, the change in basin storage (ΔV_{SWT}) for each time step can be determined using the WSE time series and each water loss rate can be estimated as a function of the water surface elevation of the SWT (WSE). By rearranging the water mass balance equation (EQ 3.1B), the input volume for any time step can be solved:

$$V_{IN} = \Delta V_{SWT} + \Sigma\, (Q_{LOSS} * t) \text{ (EQ 3.5)}$$

where Q_{LOSS} is the SWT total loss rate, summing all of the loss terms shown in EQ 3.3. Total inflow volumes can thus be calculated over any time period of interest (e.g., event, month, season, etc.). Having solved for all variables in EQ 3.5 for every time step when data is available, the desired volume metrics can be calculated including:

- Seasonal volume totals (cf) for all input and loss terms,
- Seasonal infiltration rates (in/hr) as [Seasonal infiltration volumes (V_{INF}) / SWT footprint (sq-ft)],
- SWT hydraulic capture (%) as [Treated outflow volumes (V_{OUT_T}) + infiltration volumes (V_{INF})]/inflow volumes (V_{IN}), and
- Average seasonal pollutant concentrations (mg/L) * volumes (cf) to calculate pollutant loads (MT).

During development of the water budgets for each SWT, a number of difficulties in calculating the seasonal water volumes were identified:

- Data gaps due to instrument failure: The freeze-thaw conditions of the alpine climate resulted in instrument malfunction, especially in dry basins where the instruments were often exposed to the air. The resulting data gaps can be seen in the basin volume time series for each SWT presented in Chapter 6.1.
- SWT Design: Certain design characteristics, such as multiple inlet and/or outlet structures, can complicate the quantification of volume fluxes. Additionally, a number of SWTs do not function as designed. For example, a bypass pipe was installed at the Rocky Point inlet to PA1 to bypass the basin during high-flow events. However, due to the elevation of the structure, water has been observed flowing out of the basin through this pipe during certain times of year. These types of unconstrained characteristics presented challenges to the water budget calculations.
- WLR placement: The locations for WLR installation were determined by (1) the SWT topography to ensure the recorded depth was representative, (2) the ease of instrument maintenance and download during all times of year, and (3) the location of previous instrumentation to improve comparisons to existing data. In some instances, access resulted in the WLR not being installed at the low point of the SWTs. For example, at Eloise Basin the WLR was installed over 1.5' above the base of the basin, which represents 0.1 ac-ft of volume or 10% of the total volume capacity. These missed volumes were not included in the water budget seasonal and annual totals.
- SWT Maintenance: The lack of consistent maintenance at these SWTs complicated the calculation of treated outflow rates. At some SWTs, including Osgood Basin and PA1, the treated outlets are clogged due to sediment accumulation around the outlet structure. In these instances, treated outflow rates were calculated using the water volume time series, because engineering equations based on the outlet design were not appropriate. Additionally, corrosion of the Eloise CMP results in some volume loss through the leaky CMP, which was estimated based on field measurements and accounted for in the water budget calculations.
- Given the large number of variables used in the water budget calculations and the inherent difficulty in isolating each variable, there is some uncertainty associated with the inflow volumes calculated using the water budget methodology. Our SWT hydrologic monitoring illustrated that each SWT has a series of nuances associated with how stormwater enters and leaves the SWT. Future SWT monitoring should include additional field measurement techniques to obtain accurate manual measurements of inflow, treated outflow and bypass outflow rates when possible to calibrate water budget estimates.

3.2.2 SWMM HYDROLOGY ESTIMATES

PLRM uses the EPA's Storm Water Management Model (SWMM) to execute a long-term continuous simulation of stormwater runoff conditions defined through user inputs describing land use conditions, including: pollutant source controls, hydrologic source controls, and stormwater treatment facilities. PLRM output is reported as average annual values based on the results of the entire 18-year continuous simulation (1989-2006). Detailed analysis of the results from the continuous simulation generated by PLRM can be accomplished by running the PLRM input file directly in SWMM and post-processing the time-series outputs generated by SWMM. Running a PLRM model directly in SWMM allows for assessment of output on any time scale, which is useful when comparing modeled output to collected field data.

PLRM INPUTS

The PLRM inputs for each catchment and SWT are detailed in Tables 3.5 and 3.6, respectively. Input data for each PLRM model was developed using: GIS data and reconnaissance level field assessments of drainage conditions and design attributes of the stormwater treatment facilities modeled. The following described the key steps and methods used to develop PLRM inputs.

1. GIS data was queried to develop input data for each PLRM catchment within a model (e.g., land use distribution, soil distribution, average slope, road risk, etc.). The GIS processes and algorithms used to develop the input data are described in the PLRM Applications Guide (NHC et al. 2010). The following GIS datasets were used:
   a. *TMDL Land Use GIS Layer*: The layer can be downloaded from the LRWQCB website at http://www.waterboards.ca.gov/lahontan/water_issues/programs/tmdl/lake_tahoe/index.shtml
   b. *2006 Tahoe Basin Soil Survey*: The layer can be downloaded from the Natural Resources Conservation Service (NRCS) website for Soil Survey Symbol = CA693 at http://soildatamart.nrcs.usda.gov/Survey.aspx?State=CA
   c. *PLRM Road Risk Layer*: The 2009 default Road Risk layer was refined by the City of South Lake Tahoe, Washoe County, and Douglas to better reflect actual road operations and road conditions within their respective jurisdictions. The updated March 2011 road risk GIS layer is available for download at http://tiims.org/TIIMS-Sub-Sites/PLRM/docs-downloads.aspx.
   d. *PLRM Road Shoulder Conditions Layer*: The default Road Shoulder Conditions layer, which reflects conditions in the summer of 2010, was used for model development. The GIS layer is available at http://tiims.org/TIIMS-Sub-Sites/PLRM/docs-downloads.aspx.
2. Reconnaissance level field inspections were used to validate PLRM inputs derived from the GIS data listed above and to inform PLRM input parameters that cannot be developed from a GIS analysis (e.g., stormwater treatment (SWT) parameters). The following are examples where field inspections were used to develop PLRM input data.
   a. *Impervious Area Connectivity of CICU, SFR, and MFR Land Uses:* The amount of impervious area associated with SFR, MFR, and CICU land uses that is directly connected impervious area (DCIA) was estimated through field inspection. Note that a GIS layer is not available for this PLRM input.
   b. *SWT Input Parameters:* PLRM inputs that define the function of each SWT facility modeled (e.g., water quality volume of a dry basin) were estimated through field inspection. For each SWT facility monitored for this study, topographic surveys were conducted (see Chapter 3.1.4) to calculate relationships between water depth and storage volume in each basin.
3. Information on the degree of private property BMP implementation, as of 2011, was received from CSLT. This information was post-processed in GIS to estimate the percentage of private property BMP compliance by land use within each modeled drainage catchment.
4. The publicly available version of the PLRM includes a meteorological record that extends to water year 2006. In order to compare modeled output to field data collected in water years 2009 through 2011, the meteorological record of the PLRM database was extended. The process was completed as follows:
   a. Precipitation and temperature data were downloaded from the NRCS website for the Fallen Leaf and Hagan's Meadow SnoTel gages, which are the two SnoTel gages used in PLRM to generate meteorological data for simulations within the area of interest.
   b. The data was quality assured and added to the PLRM database for the two SnoTel gages.
   c. The PLRM meteorological algorithms were re-run to generate a new time series of meteorological data that extended through water year 2011 for the developed models.

POST-PROCESSING OUTPUT FROM SWMM SIMULATIONS

Running a PLRM model directly in SWMM allows for assessment of output at any time scale, which is useful when comparing modeled output to collected field data for specific events or time periods. To assess time-series output the following process was used:

1. The PLRM program develops an input file that is run by SWMM ("tempSwmm.inp"). This input file was run directly in SWMM to provide access to the time-series output generated by SWMM.
   a. The file "tempSwmm.inp" was saved to a new directory. For a specific PLRM Project and PLRM Scenario, this file is located in the folder: C:\Program Files\PLRM\Projects\Project1\Scenario1.
   b. The "tempSwmm.inp" was opened and run in SWMM version 5.0.014, with the simulation period revised to extend through water year 2011. Note that version 5.0.014 is the specific version of SWMM that PLRM runs. Running a PLRM input file in a different version of SWMM may not generate comparable output relative to that reported by PLRM.
2. The time-series output generated by SWMM was extracted from the program at specific points of interest (e.g., catchment outfalls, SWT treatment junctions) by using the "Report" functions available in SWMM.
3. The time-series output was imported into Microsoft Excel and analyzed for specific events and time-periods against available monitoring data collected during the research effort.

CHAPTER 4. ENVIRONMENTAL SETTINGS

This research focused on data collection and analysis of stormwater quality, land use conditions, and effluent quality from SWTs. In order to appropriately compare hydrology and water quality monitoring data across water years or to inform average annual PLRM predictions, it is critical to constrain the drivers that inherently influenced the data. The primary uncontrollable system driver is the weather where daily, seasonal and water year variations introduce variability into hydrologic, water quality and land use condition observations. We provide a simple approach to put WY09, WY10 and WY11 into a relative hydrologic context by a simple comparison to the long-term Tahoe City precipitation dataset (1911-2011), as well as to the 18 years (1989-2006) used in PLRM simulations. Another uncontrollable influence on the spatial and temporal results of the roadway research is the jurisdictional road maintenance practices, which are assumed to have a high influence on the relative amount of sediment (and FSP) available on a road surface in the Tahoe Basin. The actual road maintenance practices implemented on roads vary within and across jurisdictions. The research team made a significant effort to document the road maintenance practices implemented by each jurisdiction on specific road segments included in this study.

4.1 WATER YEAR CONTEXT

The climatic differences between water years have a direct impact on the resulting urban stormwater runoff observed during the study. Providing climatic context for the monitored years assists the research team with interpretation of these results and will assist researchers with comparisons of these data to future water year observations. The Tahoe City gage, operated by Western Regional Climate Center (WRCC) (http://www.wrcc.dri.edu/), provides the longest period of record for Tahoe Basin climate data. A precipitation frequency analysis was conducted on the 101 years of Tahoe City precipitation data to determine the recurrence intervals (RI) of annual precipitation totals. The water year type definitions were created using reasonable recurrence intervals to bracket average precipitation totals and ensure the extreme (very wet and very dry) categories have less than a 10% probability of occurring (Table 4.1). The Tahoe City gage may not exactly represent the weather conditions experienced at a specific water quality monitoring station included in this research, however, the Tahoe City data is a reliable and easily accessible long-term record that likely provides a reasonable representation of water year types for the Tahoe Basin urban areas as a whole for the purposes of this research.

Table 4.1. Frequency analysis of Tahoe City precipitation gage using 101 years of data and classification of water year types based on recurrence interval (RI) breaks.

WY Type	RI (yr)	Tahoe City[1] WY Precipitation (in)
Very Dry	< 1.1	<18.4
Dry	1.1 - 1.5	18.4 - 24.5
Average	>1.5 - 3.0	>24.5 - 35.0
Wet	>3.0 - 10.0	>35.0 - 49.0
Very Wet	> 10.0	> 49.0
Minimum WY precipitation (in)		8.8
Maximum WY precipitation (in)		69.2
Mean WY precipitation (in)		31.6
Median WY precipitation (in)		30.0

[1] Tahoe City gage (#48758) operated by WRCC.

Using the definitions presented in Table 4.1, Table 4.2 summarizes the total water year precipitation and water year type over the past 5 years, from WY07-WY11.

Table 4.2. Water year types for WY07-WY11 based on frequency analysis, WY definitions (see Table 4.1) and total WY precipitation at Tahoe City gage.

Metric	WY07	WY08	WY09	WY10	WY11
Tahoe City WY precipitation (in)	19.7	19.3	27.2	37.9	45.0
Water year type[1]	Dry	Dry	Average	Wet	Wet

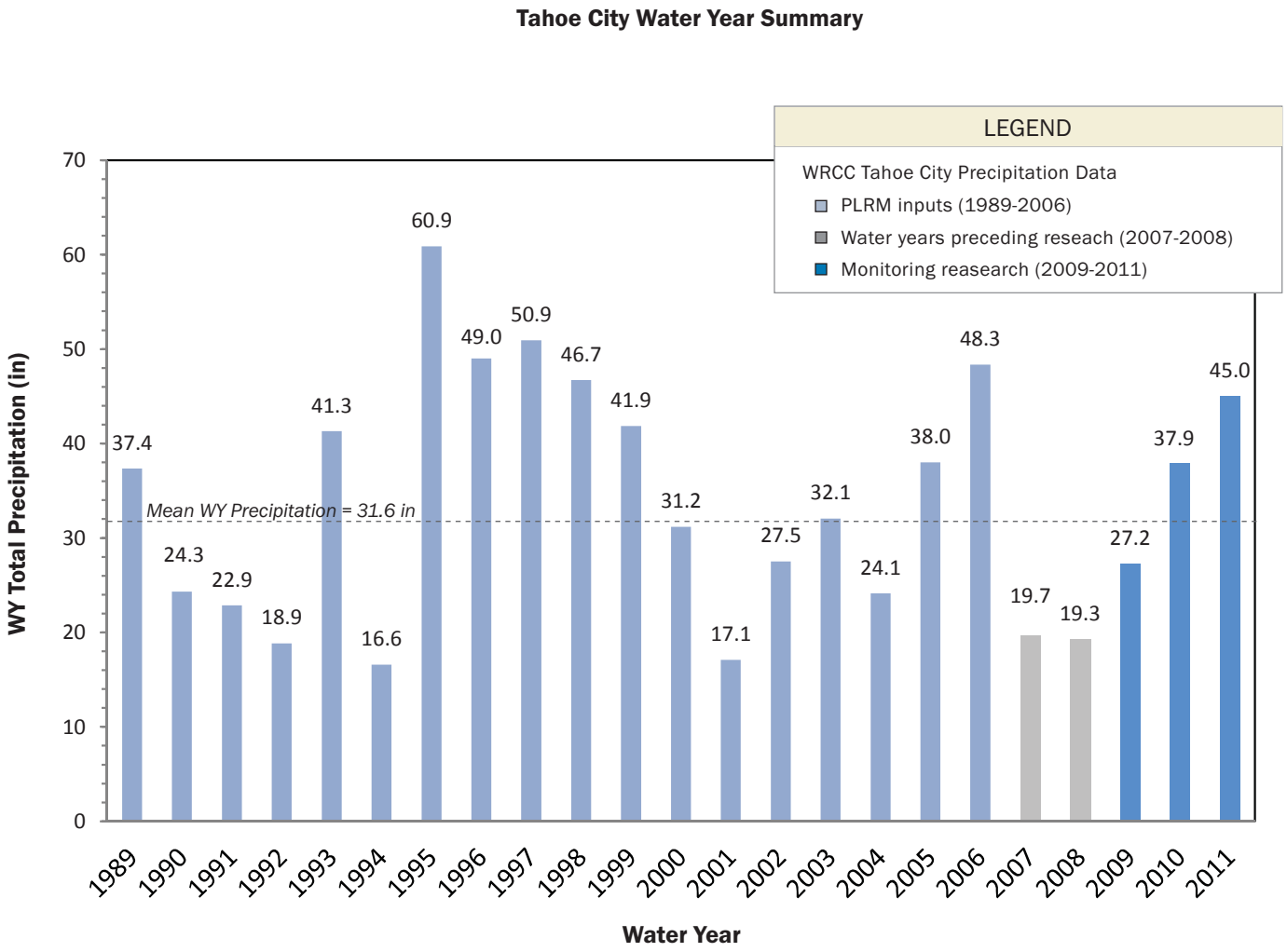
Figure 4.1 graphically presents the Tahoe City gage data for the water years used in the PLRM 18 year simulation, as well as WY07-WY11. The 18 water years used in PLRM simulations represent a range of water year types: 9 years are average or drier and 9 years are above average. WY07 and WY08 were not monitored during this research, but notably were two consecutive dry years. WY09 to WY11 progressively got wetter, which influenced the data obtained and analyzed during this research. The considerations of antecedent and actual water year weather conditions are used in our hydrologic and water quality data interpretations herein.

4.2 WEATHER CONDITIONS

Figure 4.2 presents the relevant precipitation and air temperature data from the CSLT City Lab weather station over the duration of the research data collection to provide the climatic context for the urban road and SWT monitoring that occurred from December 2008 through September 2011. The City Lab weather station is located on Lake Tahoe Boulevard and D Street, near the "Y" in South Lake Tahoe and is assumed to be relatively representative of the general winter and spring weather conditions within the Tahoe Basin and adequate for the purposes of this study.

These data were used to determine how weather condition might influence road research findings, and the following describes the meteorological conditions and road maintenance activities leading up to each observation period for road condition evaluations. Road maintenance activities are estimated based on field observations and discussions with jurisdiction road maintenance personnel.

- **March 2009**: There were multiple winter snow storms and instances of winter road abrasive applications. The most recent was 14 days prior to monitoring.
- **April 2009:** Prior to monitoring, meteorology data suggests only one major winter storm occurred. During the monitoring, a minor rain/snow event fell on the North Shore and eliminated the sampling of certain sites. However, field personnel did not observe active abrasive application during this event.
- **May 2009**: Warmer temperatures in late spring eliminated the need for abrasive applications and it was estimated that no abrasives were applied between the April and May monitoring. A rain event exceeding 2 inches occurred prior to monitoring and likely transported sediment accumulated on the road surface downslope, thereby improving the road conditions observed following spring rains.
- **July 2009**: A few summer thunderstorm events occurred in June, again likely improving road conditions due to wash off of material from the roadways. The July monitoring event occurred over 3 months after the last winter storm when road abrasives were applied to select urban roads, and the warmer temperatures allowed some jurisdictions to conduct consistent pollutant recovery actions.
- **October 2009:** Following the dry summer months, fall rain storms began in the 2 weeks leading up to the sampling, including a large rain event (2.6 in) one week prior to monitoring. These rain storms likely washed off any sediment that had been accumulating on the road surfaces.

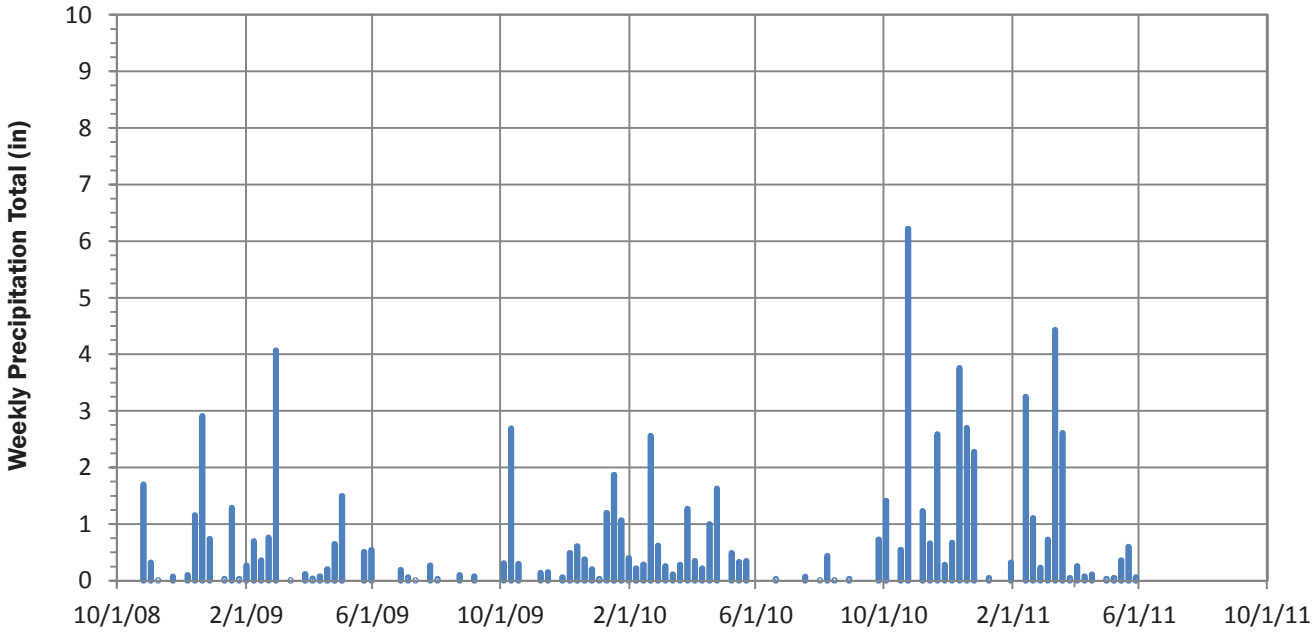


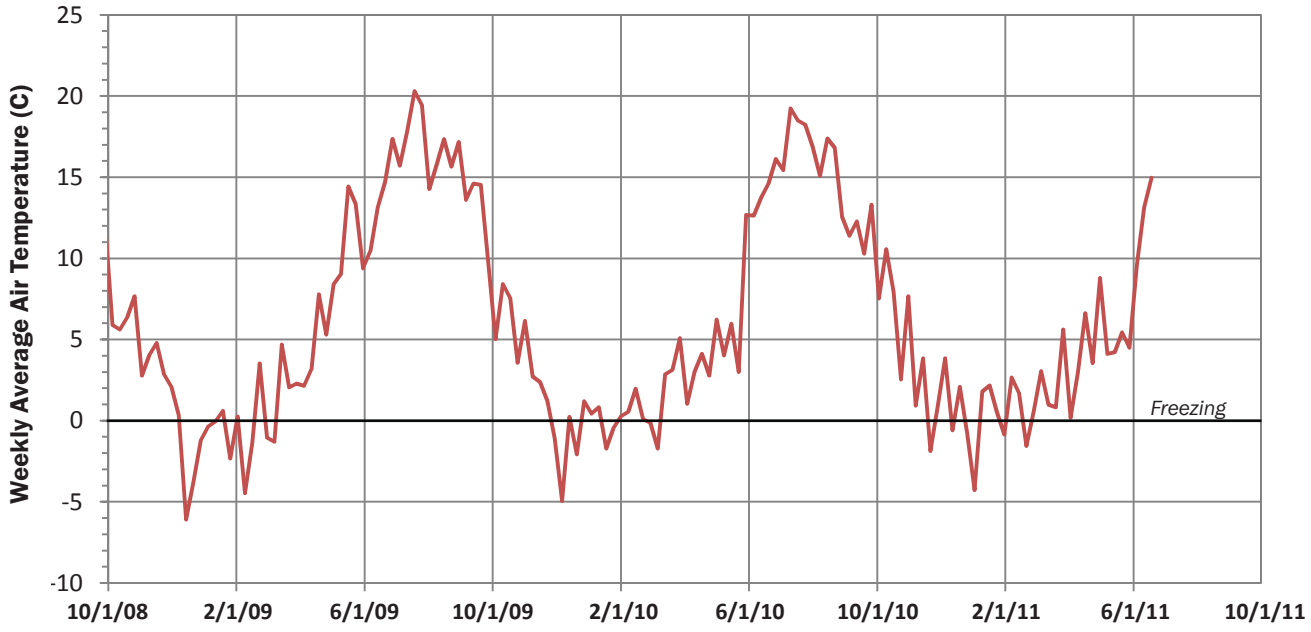
Water year total precipitation is provided from the WRCC Tahoe City weather station for the 18 years (1989-2006; pale blue) used for PLRM simulations, the 2 years preceding the research effort (2007-2008; grey), and the 3 years of the research effort (2009-20011; dark blue). The 18 years of data used in PLRM represent a range of precipitation values, including 2 very dry, 4 dry, 3 average, 6 wet, and 3 very wet years (see Table 4.1 for water year type definitions). The two years prior to our monitoring research were dry years, followed by increasingly wet years in 2009, 2010, and 2010. Understanding the meteorological context of data collection is critical to intrepreting the water quality and hydrology data results presented in this technical report.

TAHOE CITY TOTAL WATER YEAR PRECIPITATION; 1989-2011

FIGURE 4.1

CSLT City Lab Data[1]





[1]CSLT City Lab weather station is located at Lake Tahoe Blvd and D Street near the South Y.

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CSLT CITY LAB WEATHER DATA (WY09-WY11)

FIGURE 4.2

- **January 2010:** In the month prior to the observation period, there were multiple winter snow storms and instances of winter road abrasive applications. The most recent was 7 days prior to monitoring.
- **February 2010:** Prior to monitoring, there were several winter snow storms and instances of winter road abrasive applications. The most recent road abrasive application was 9 days prior to monitoring.
- **March 2010:** In the month leading up to the sampling, there were several winter snow storms, including one large event (>1 in). The most recent was a relatively small event (0.2 in) 2 days prior to monitoring.
- **January 2011:** There were several large snow events in December 2010, but in the weeks prior to monitoring there was little precipitation. However, daily average temperatures were frequently below freezing and it is unlikely that pollutant recovery was occurring with much regularity during this time period.
- **April 2011:** There were frequent snow storms requiring abrasive application throughout the months of March and April. The most recent storm, which resulted in intermittent abrasive application, occurred the day preceding sampling.

The weather conditions also provide the context to conduct event intensity, duration and total magnitude comparisons of catchment and SWT hydrologic volumes and pollutant loads.

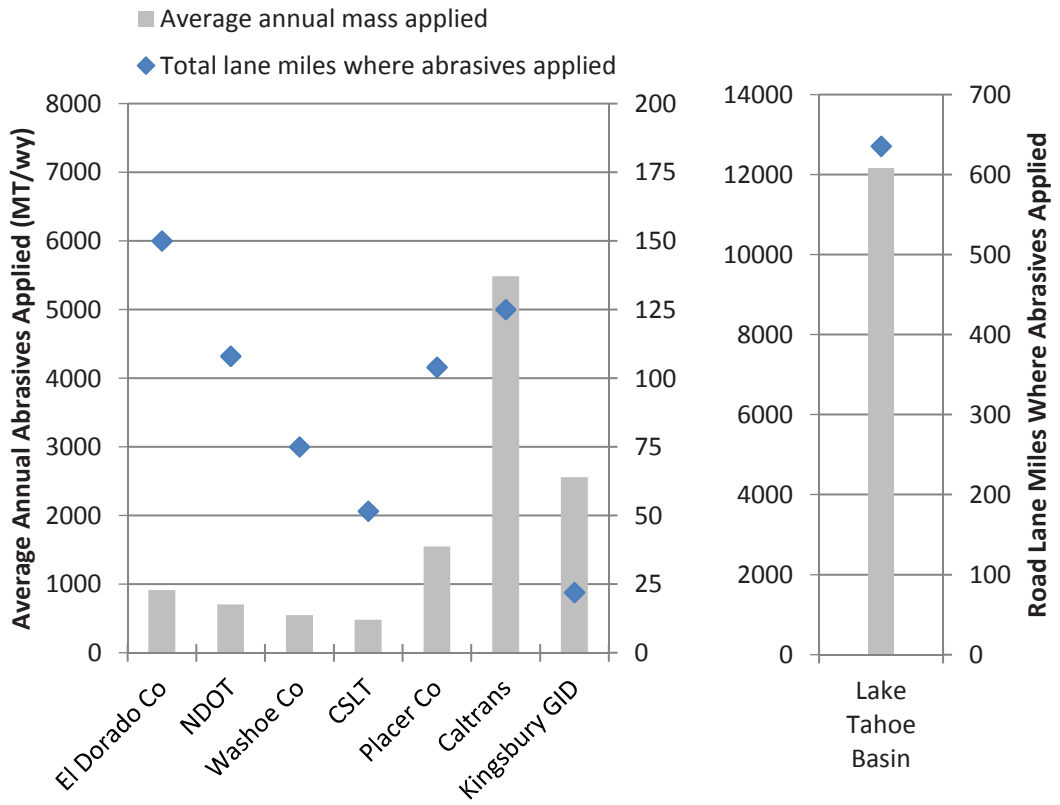
4.3 TAHOE BASIN ROAD MAINTENANCE PRACTICE DOCUMENTATION, WY09-WY11

The *Phase I Technical Document* (2NDNATURE and NHC 2010a) identified accurate documentation of jurisdiction maintenance practices as a significant data gap inhibiting interpretation of road condition data. The observed condition of each urban road is assumed to be the integrated signal of pollutant inputs (sources) and outputs (sinks). The primary maintenance practices implemented on short-time scales are road abrasive application and sweeping, and these two practices can vary widely by jurisdiction, road priority, and weather conditions. Ideally, the specific chronology of these actions on each road segment sampled for this study would be documented, including abrasive application dates and amount applied per unit area, and pollutant recovery dates, sweeper type, and amount of material recovered per unit area. However current documentation practices by most jurisdictions does not allow for this level of spatial and temporal detail.

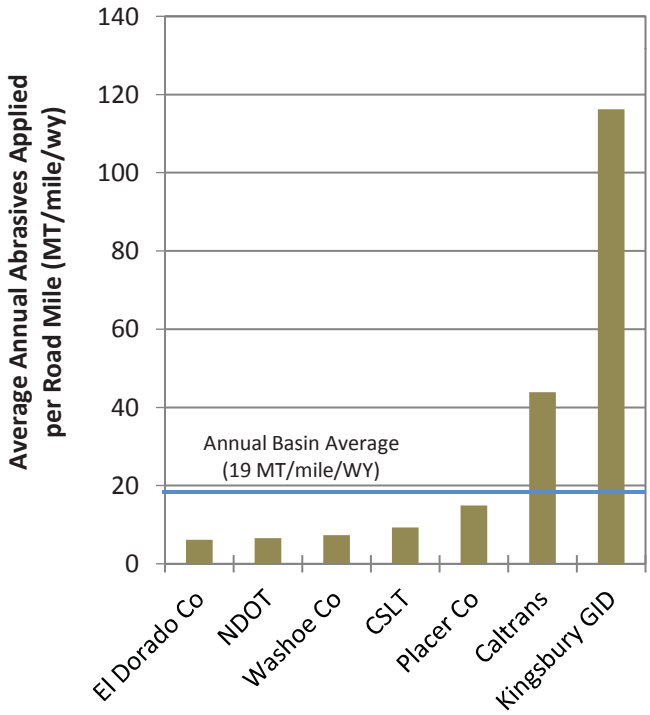
2NDNATURE compiled abrasive application data from the annual road maintenance reports and existing data for all Tahoe Basin urban jurisdictions from WY2001-WY2011. Data suggests the average annual mass of anthropogenic road abrasives applied to Tahoe Basin roads over the last decade is 12,160 MT per water year or 9,850[2] yd^3/wy (Figure 4.3). This mass of road abrasives is brought into the Tahoe Basin and chronically added to the annual stormwater sediment budget each year. Records from the past decade indicate that in recent years jurisdictions have been able to reduce their abrasive application per unit area of road, while maintaining traffic safety as indicated in Figure 4.4. The 2011 Basin-wide total (9,400 MT) was 43% lower than the 2002 amount, despite twice as much winter snowfall in WY2011 compared to WY2002 (see Figure 4.4).

Table 4.3 summarizes the general jurisdiction-wide road maintenance practices for the 7 Tahoe Basin urban jurisdictions. While this data does not provide temporal or spatial-specific data with which to evaluate road segment condition results by observation period, it does provide a relative comparison of the Basin-wide practices with which to evaluate trends in the observed road datasets. In the future, jurisdictions should consistently report annual mass and/or volume of abrasives actually applied to roads. Use of advanced spreader equipment (e.g., user controlled application, GPS-enabled spreaders) would provide the most accurate abrasive application records.

[2] Density of dry sand assumed to be 1.6 g/ml; 2,700 lbs/yd^3.



A. Average annual abrasives applied by jurisdiction based on annual reports from 2001-2011, compared to the total road lane(primary and secondary) miles within each jurisdiction where abrasives are applied. Based on this data, the 635 lane miles are treated with 12,160 MT (9,850 yd^3) of road abrasives on average each water year.



B. Average annual abrasives applied by jurisdiction per road mile where abrasives are typically applied. Based on this data, these road miles are treated with 19 MT of road abrasives on average each water year.

NOTE: In Douglas County, the general improvment districts (GID) are in charge of road maintenace practices within their designated areas. To maintain consistency with the road segments monitored by 2NDNATURE (2010a, 2010b), data from Kingsbury GID is used for comparison to other Lake Tahoe urban jurisdicitions.

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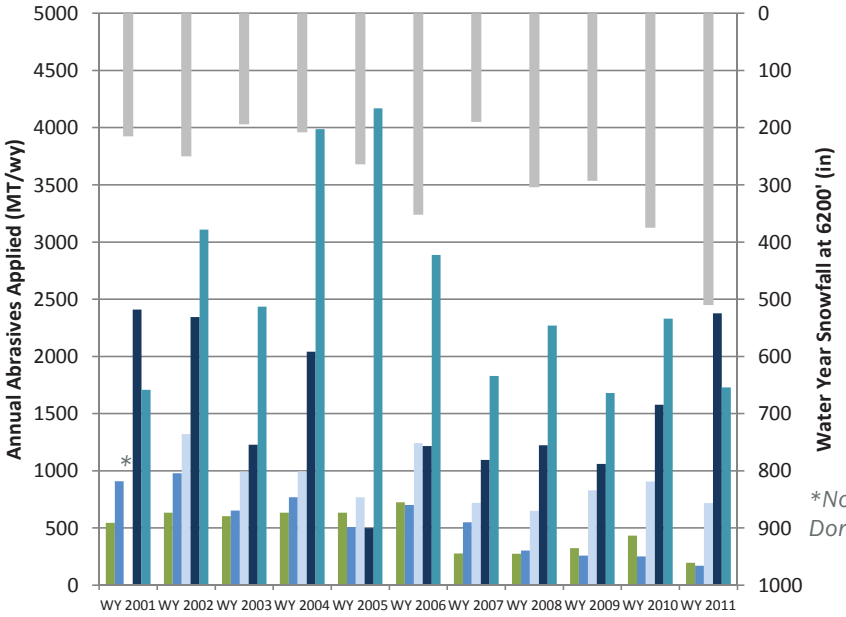
TAHOE BASIN AVERAGE ANNUAL ABRASIVE APPLICATION

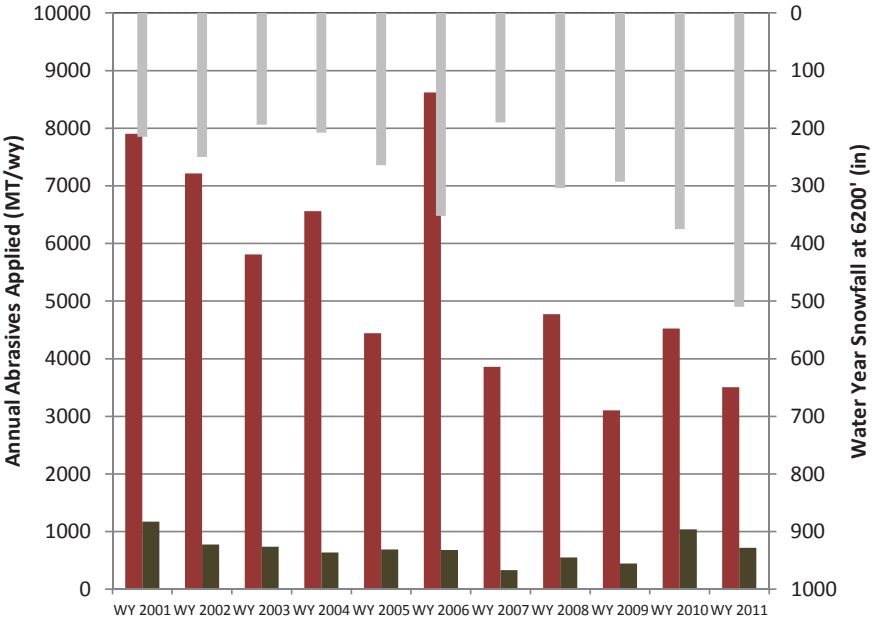
FIGURE 4.3

A. Tahoe Basin jurisdictions annual road abrasives applied by WY as documented in road maintenance annual reports. WY snowfall totals are also provided for climate context (Squaw Valley, 2011).

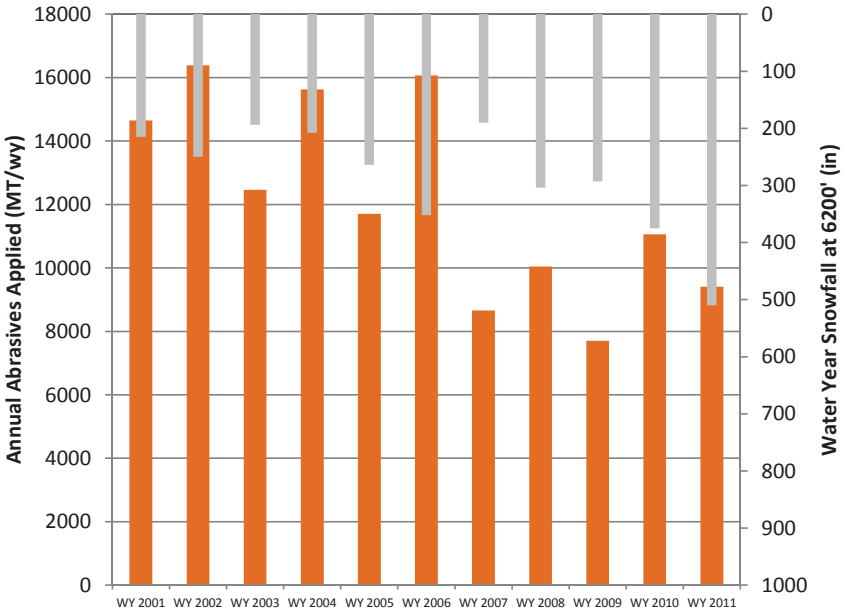


**No data available from El Dorado County for WY2001.*

B. Local Transportation agencies annual road abrasives applied by WY as documented in each road maintenance annual report. WY snowfall totals are also provided for climate context (Squaw Valley, 2011).



C. Total annual abrasives applied each WY in Tahoe Basin. WY snowfall totals are also provided for climate context (Squaw Valley, 2011).



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TAHOE BASIN ANNUAL ABRASIVE APPLICATION , WY01-WY11

FIGURE 4.4

Table 4.3. Summary of Tahoe Basin urban jurisdiction road maintenance practices. For each jurisdiction, key components of their abrasive application and pollutant recovery practices are provided.

Jurisdiction	Abrasive Application			Pollutant Recovery			
	Spreader Equipment	Abrasive Type	Lane Miles where applied (% of Jurisdiction)	Action Types	Sweeper Equipment	Frequency	Location
California Department of Transportation (Caltrans)	Sander + Muncie Controller	De-icing sand; salt/brine	125 miles (100%)	Snow Haul; Sweeping	Allianze 4000	Winter – Event-Based	All Roads
City of South Lake Tahoe (CSLT)	Monroe Spreader + Plow	Eagle Valley Basin Volcanic Cinders; Huck Salt	52 miles (20%)	Sweeping	Tymco (regen air); Athey Mechanical Broom	Winter – Event-Based; Summer – 2x	All Roads
El Dorado County	Truck with hopper	Washoe Sand / Volcanic Cinders	150 miles (40-60%)	Sweeping	Elgin Waterless Eagle	Winter – Event-Based & Weekly; Summer – Every 2 weeks (primary) & 1x (secondary)	All Roads
Kingsbury General Improvement District (KGID)	Truck with hopper	5:1 Concrete Sand and Salt	22 miles (50%)	Drain Cleaning; Sweeping	Schwarze AR8000	Winter – Weather-Based; Spring/Summer – 2x; Fall – 1x	All Roads
Nevada Department of Transportation (NDOT)	3 Epoke 3500/440; 6 Flink	Western Material Spec B Sand; Huck Salt	108 miles (100%)	Snow Haul; Sweeping	Tennant Centurion (mechanical w/ vacuum assist)	Winter – Event-Based; Summer - Monthly	All Roads
Placer County	Truck with hopper	Hansen Brothers De-Icing Sand	140 miles (68%)	Sweeping	Johnson 4000 (mechanical); Tennant Centurion (mechanical w/ vacuum assist)	Winter – Event-Based; Summer – 2x	Roads where abrasives applied
Washoe County	Epoke	Western Material Spec B Sand; Huck Salt	75 miles (50%)	Sweeping	Tymco DST6; Tennant Sentinel	Winter – Daily as weather allows; Summer – Every 6 weeks	Primary roads first, then all roads

CHAPTER 5. LAND USE SPECIFIC RESEARCH

PLRMv1 estimates pollutant loads by integrating catchment runoff and land use specific estimates of water quality concentrations for pollutants of concern to lake clarity. PLRMv1 contains a database of characteristic runoff concentrations (CRCs) for each land use type and for a range of land use conditions. The PLRMv1 values were determined using available Tahoe specific data, which in some cases was limited. In particular, the current database was developed using an extremely limited set of FSP concentration data for Tahoe land uses and road conditions. The Lake Tahoe TMDL (LRWQCB and NDEP 2010) and other stormwater research suggest roadways are the greatest potential source of FSP per unit area, and thus the CRC research contained herein focused on improving the breadth and quality for FSP pollutant generation data from impervious roads. Less intensive research was conducted on other pollutants (TSS and SRP) and other land use types. Another priority research area addressed is the default saturated hydraulic conductivity (K_{sat}) values assigned to compacted road shoulders in PLRMv1.

5.1 ROADWAY RESEARCH

5.1.1 ROADWAY RESEARCH RESULTS

The following section presents the findings from road land use monitoring during WY09-WY11, including controlled road experiments and Road RAM observations, and comparisons of the datasets to the PLRMv1 road CRC estimates.

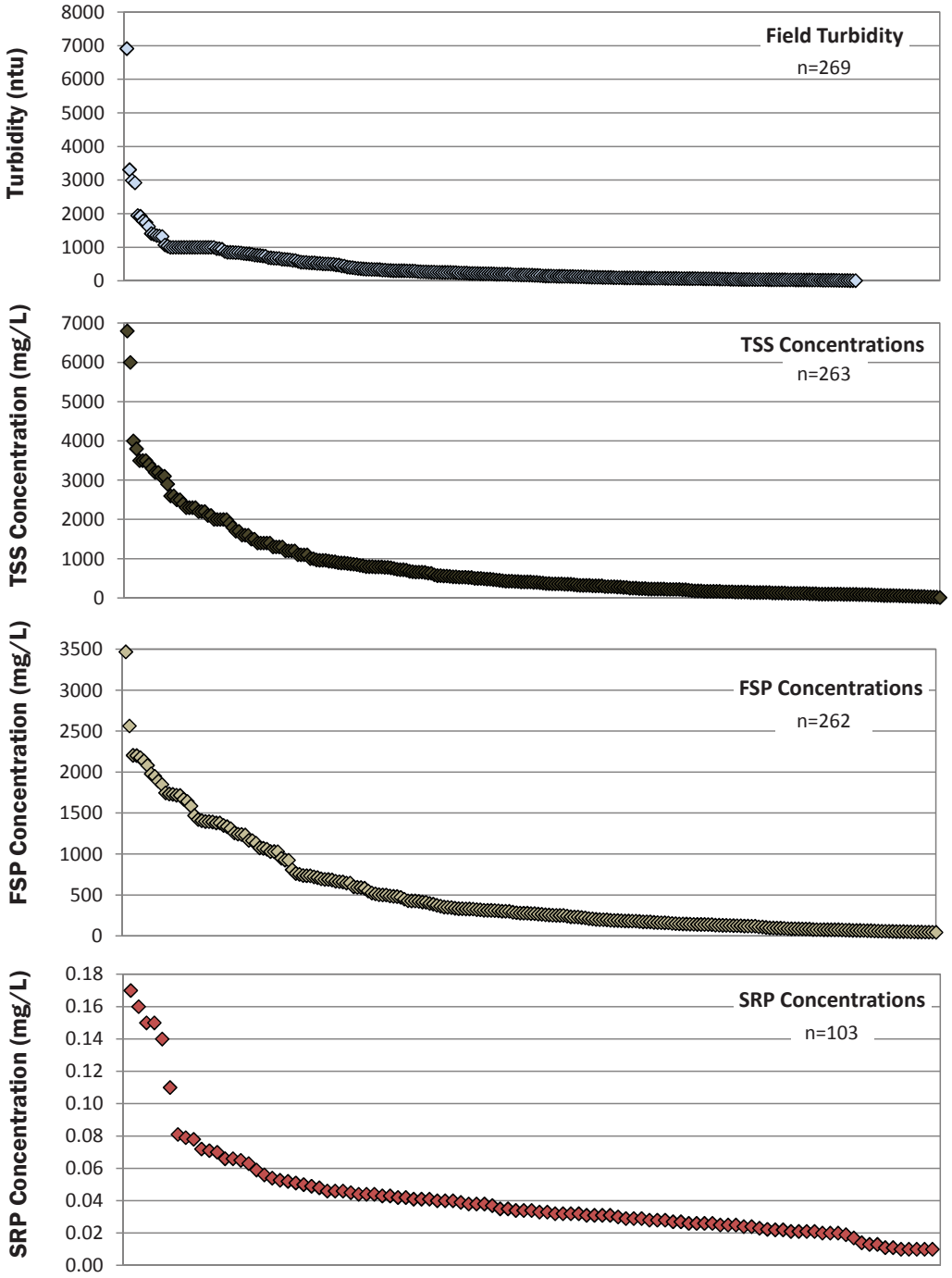
CONTROLLED EXPERIMENT CONCENTRATIONS

Figure 5.1 presents turbidity, FSP, TSS and SRP values obtained from the controlled experiments over the course of the study, ranked from highest concentration to lowest concentration. Figure 5.1 includes all road segments sampled over all observation periods and the number of observations for each pollutant is provided. The analysis of SRP concentrations was included starting in WY2010, and therefore there is less available SRP data compared to the other pollutants of concern.

TURBIDITY TO FSP CONCENTRATION

Figure 5.2 correlates the results from controlled experiment samples that were analyzed for turbidity in the field and then sent to the analytical laboratory for FSP concentration analysis. This strong correlation (R^2 = 0.924; n=238) suggests that field turbidity is a promising cost-effective and reliable proxy for FSP concentrations by mass (mg/L) for road-specific runoff samples. Other Tahoe Basin researchers have also found strong FSP (both mass and number of particles) to turbidity correlations in stormwater, streams, and land use data, but the slope of the curve can vary by source of FSP (Kayhanian et al. 2005; 2NDNATURE and NHC 2010a; Heyvaert et al. 2010). El Dorado County stormwater personnel have also found a strong FSP to turbidity relationship during their road monitoring efforts (R. Wigart pers. comm.). Additional data at higher FSP and turbidity values (> 1,000 NTU) and the standardization of analytical methods for both FSP and field turbidity would increase our confidence in using field turbidity as a reliable and cost effective proxy for FSP concentrations.

TAHOE BASIN CONTROLLED ROAD EXPERIMENTS



Range of measured pollutant concentrations from controlled experiments on 1ft² areas of moderate accumulation on road surfaces conducted from 2009 - 2011, ranked high to low. Over two years of data collection, it appears a representative distribution of expected 1ft² road conditions have been sampled.

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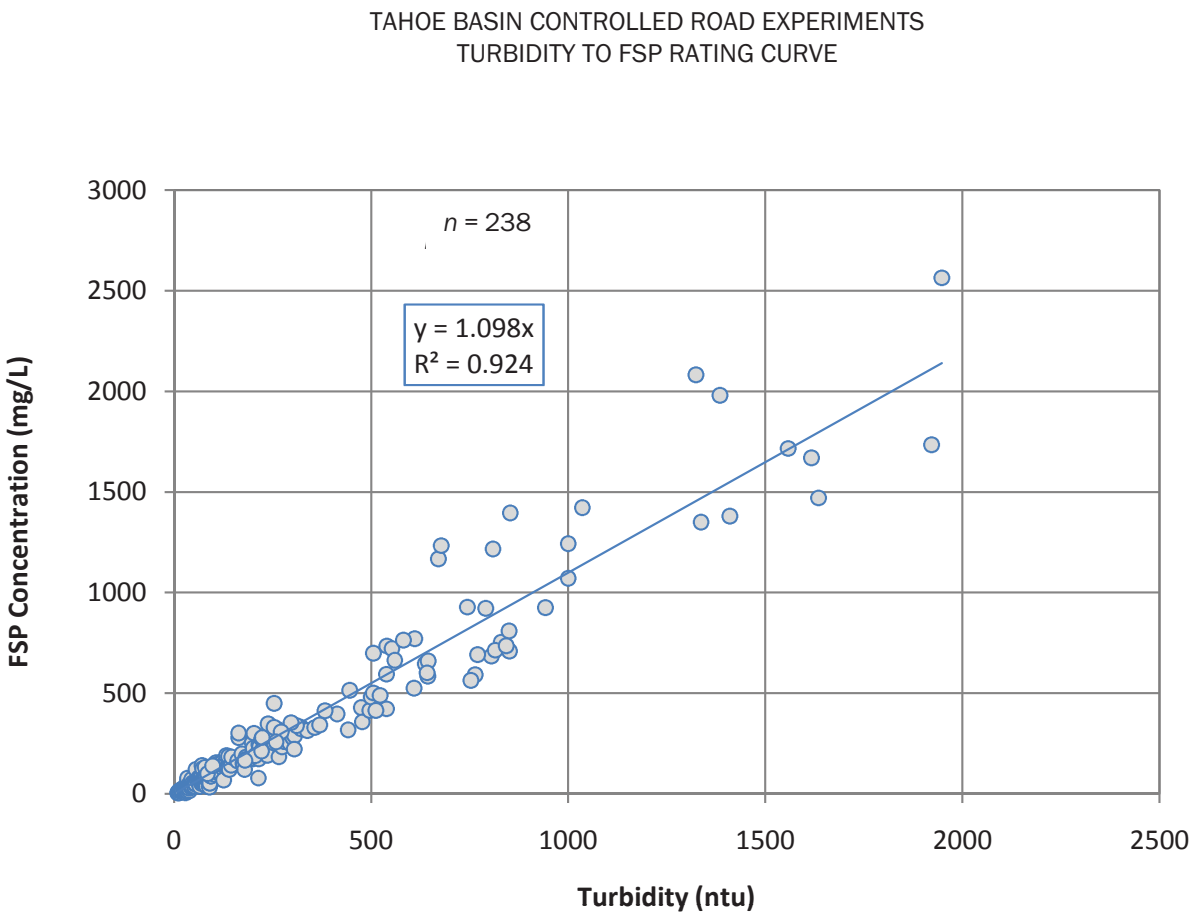
RANKED CONTROLLED EXPERIMENT WATER QUALITY DATA

FIGURE 5.1



Correlation plot of turbidity versus FSP concentration based on 238 controlled Tahoe Basin road experiments collected and analyzed in 2009 and 2010 (2NDNATURE and NHC 2010a).

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TURBIDITY V. FSP CONCENTRATION CORRELATION PLOT

FIGURE 5.2

SEASONAL VARIATIONS

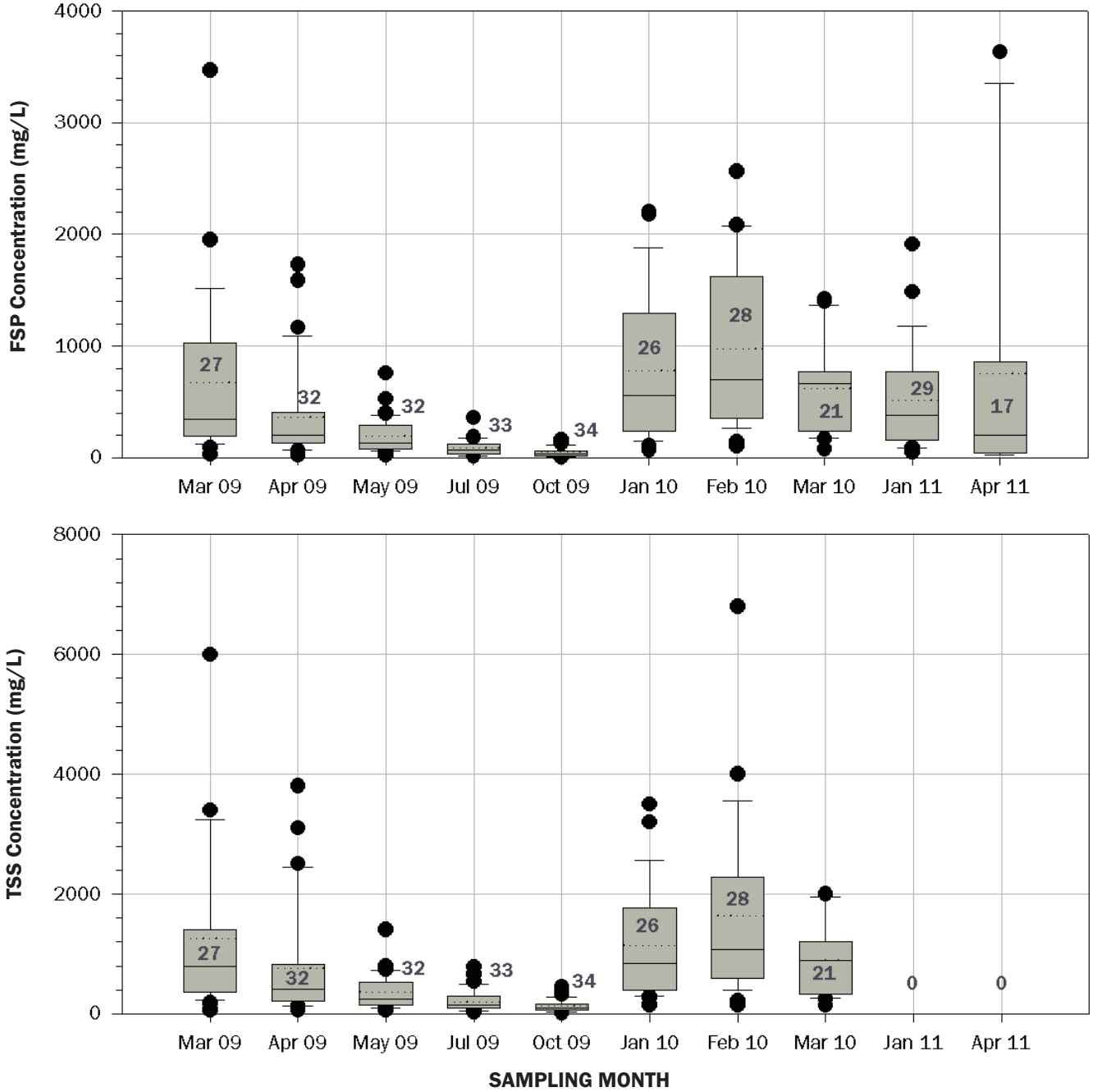
Figure 5.3 presents the FSP concentration range obtained from controlled experiments on the area of moderate accumulation for all road segments sampled during each observation period, demonstrating the extreme seasonal variability in FSP concentrations. Of the 315 controlled experiments conducted, which were equally distributed throughout the year, 77% of the observations (105 of 136 samples) that exceeded 300[3] mg/L FSP were observed during the winter months (January through March), and 32% of the observations (44 of 136 samples) exceeded 1,000 mg/L FSP during the same time frame. The 1,000 mg/L is used as the upper threshold, because road segments that exceeded 1,000 mg/L using the portable sampler possessed excessive amounts of fine sediment, the roads are in poor condition and should a runoff event occur it would be considered an extreme downslope water quality risk.

This seasonal trend of peak FSP concentration observed during the winter months aligns with seasonal road maintenance practices, when significant amounts of abrasives, a source of potential FSP, are applied to the road surface to provide traction and protect driver safety. It is likely that tire chains, plowing and other road surface impacts increase the rate of pavement degradation during the winter months as well. Abrasives used on Tahoe Basin roads contain some fraction of FSP prior to application, but it is assumed the greatest generation of FSP on winter roads is the pulverization of abrasives, pavement decay and other material transported to the road surface from vehicle traffic. In addition to an increased source of pollutants, the opportunity and effectiveness of street sweeping to remove abrasives and other material prior to accumulation and pulverization is intermittent and can be challenging given adverse weather conditions and icy road surfaces during the winter.

The maximum FSP concentrations and variability across sites significantly decreases from the winter months through the spring sampling periods (April and May) and summer sampling periods (July and October; see Figure 5.3). By summer, the measured FSP concentrations are reduced to <100 mg/L on nearly all roads sampled, regardless of the road condition prior to the runoff event. This finding is likely the combined result of: (1) warmer temperatures reducing the need for road abrasive applications, (2) jurisdictions having more opportunities to sweep given the length of time since the most recent winter storm and abrasive application, and (3) late spring/summer rain events mobilizing and essentially washing off the sediment accumulated on the road surface. There are some road segments where it is known that winter road abrasives were applied, but it has been confirmed from the jurisdiction that no sweeping actions were conducted at any point during the year. At these sites the measured FSP concentrations were reduced from > 1,000 mg/L during the winter to < 200 mg/L during summer and fall observations. These observations suggest that spring rain events can essentially wash road surfaces and effectively remove material and pollutants from the road surface, transporting them into the stormwater conveyance system. It is likely that high wind events and traffic passing can also transport FSP from the road surface to the shoulder or beyond.

[3] The FSP value of 300 mg/L is used a critical threshold, above which is considered a significant water quality risk of a road surface because a) 300 mg/L is the 60th percentile value given the existing 315 controlled road sampling data points; b) field observations of a road surface that results in a FSP concentration > 300 mg/L visibly appears to have an elevated amount of fine particles on the road surface; c) roads subjected to both road abrasive applications and high sweeping frequency have been observed to be consistently below 300 mg/L during winter observations, therefore indicating that FSP values below 300 mg/L on high risk roads are achievable during winter road conditions; and d) using the mixed urban catchment data obtained from this research, the mean FSP concentration is 128 mg/L and 300 mg/L is the 89th percentile, indicating 300 mg/L is relatively elevated given available data.

TAHOE BASIN CONTROLLED ROAD EXPERIMENTS



The strong seasonal pattern of FSP and TSS concentrations from road surfaces is demonstrated by the box and whisker plots of Tahoe Basin road FSP and TSS concentrations measured during the controlled experiments from WY2009-WY2011. In 2011, water quality samples were not submitted to the laboratory for analysis. FSP concentrations are determined using field turbidity results and the turbidity to FSP concentration rating curve shown in Figure 5.2. No TSS concentration data is available for those 2 observations periods.

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MEASURED FSP AND TSS CONCENTRATIONS BY SAMPLING MONTH

FIGURE 5.3

JURISDICTIONAL DIFFERENCES

FSP

The seasonal trends of FSP suggest that the winter and early spring road conditions provide the greatest opportunity to manage the risk to downslope water quality by local jurisdictions. During this time, roads have the greatest amount of pollutants following winter storm abrasive application and there is the greatest risk of pollutant transport into the stormwater system during the subsequent spring rains. Eight-six percent (or 44 of 51) of the samples that exceed a FSP concentration of 1000 mg/L (see Figure 5.3) were measured in the winter months. Table 5.1 provides the distribution of these 51 samples by jurisdiction in charge of road maintenance. The jurisdictions are ordered from left to right by increasing average annual abrasive application by lane mile (see Figure 4.3). There is an increasing trend that as a jurisdiction's abrasive application rate increases the frequency of samples >1000 mg/L in that jurisdiction increases, suggesting that abrasive application has a direct effect on the discrete observed FSP concentration on the road surface.

Table 5.1. Comparison by jurisdiction of total number of FSP samples that exceeded 1000 mg/L with the average annual abrasive application rate per lane mile (MT/mile/WY; see Chapter 4.3).

Jurisdiction	El Dorado County	NDOT	Washoe County	CSLT	Placer County	Caltrans	KGID
# of samples > 1000 mg/L FSP	1	6	1	1	13	16	13
Average annual abrasive application per lane mile (MT/mile/WY)	6.1	6.5	7.3	9.3	14.9	43.9	116.2

While increased FSP concentrations are to be expected during the winter months when the sources (i.e., abrasives) are the highest, road segments where low FSP concentrations are observed during the winter months provide insight into how to reduce FSP accumulation on the road surfaces. The research team conducted a closer examination of these 44 winter observations <300 mg/L FSP with respect to the specific road maintenance practices implemented at those road segments. While the exact chronology of practices conducted at the road segment prior to our observations are not maintained by the jurisdictions, the implementation of road maintenance practices that minimize abrasive applications and maximize sweeping frequency with more efficient sweepers were confirmed for the majority of the road segments where those 44 observations occurred.

- Fourteen of the 44 winter road segment observations <300 mg/L were conducted on lower risk roads where road abrasives are not typically applied and observations by field personnel confirmed no evidence of recent abrasive applications. Typically these are low sloped roads in residential areas with low traffic densities.
- Of the 9 winter observations where FSP <100 mg/L, 4 observations were on high risk roads (EI and VIL1, see Figures 3.2A-B) where road abrasives are frequently applied; however, these segments were subjected to frequent street sweeping using high-efficiency sweepers when conditions allowed.
- The lowest measured winter FSP concentration (28 mg/L) was observed in March 2009 on Highway 50 at the South Y in South Lake Tahoe (road segment EI, see Figure 3.2A and photo at right). During this time Caltrans was testing the use of a high efficiency regenerative air sweeper at this heavily trafficked intersection (L. Waters, pers. comm.) and multiple passes were observed by 2NDNATURE field personnel along the road segment prior to the controlled experiment.

EI Road Segment, March 2009: Lowest measured FSP Concentration (28 mg/L)

The upper graphic in Figure 5.4 presents the integration of the controlled experiment FSP concentration data from 5 winter observations (March 2009, January 2010, February 2010, March 2010 and January 2011) arranged from highest to lowest average FSP concentration by Tahoe Basin jurisdiction. Sampling sites where abrasive applications were unlikely or infrequent (low gradient residential roads with low traffic density) were removed from the dataset presented in Figure 5.4. There is a discernible trend in the maximum, average and minimum FSP concentration values observed across jurisdictions, although the distribution of road risk categories sampled for each jurisdiction is similar (see Figure 3.1).

TSS

The TSS concentrations from the controlled experiments show a similar seasonal and jurisdictional pattern to the FSP concentrations with peak values in the winter and reductions observed through the spring and into summer (see Figure 5.3). The two highest measured concentrations are observed in February 2010 (6800 mg/L) and March 2009 (6000 mg/L), and the monthly average TSS concentration during the winter months (January through March) is >800 mg/L. By the summer and early fall (July through October), the average monthly TSS concentration is <150 mg/L and there are frequent observations (11 samples, or 16%) of TSS concentrations <50 mg/L. Winter TSS concentrations from controlled experiments are provided on the bottom half of Figure 5.4 and indicate a jurisdictional trend similar to the FSP concentration data.

SRP

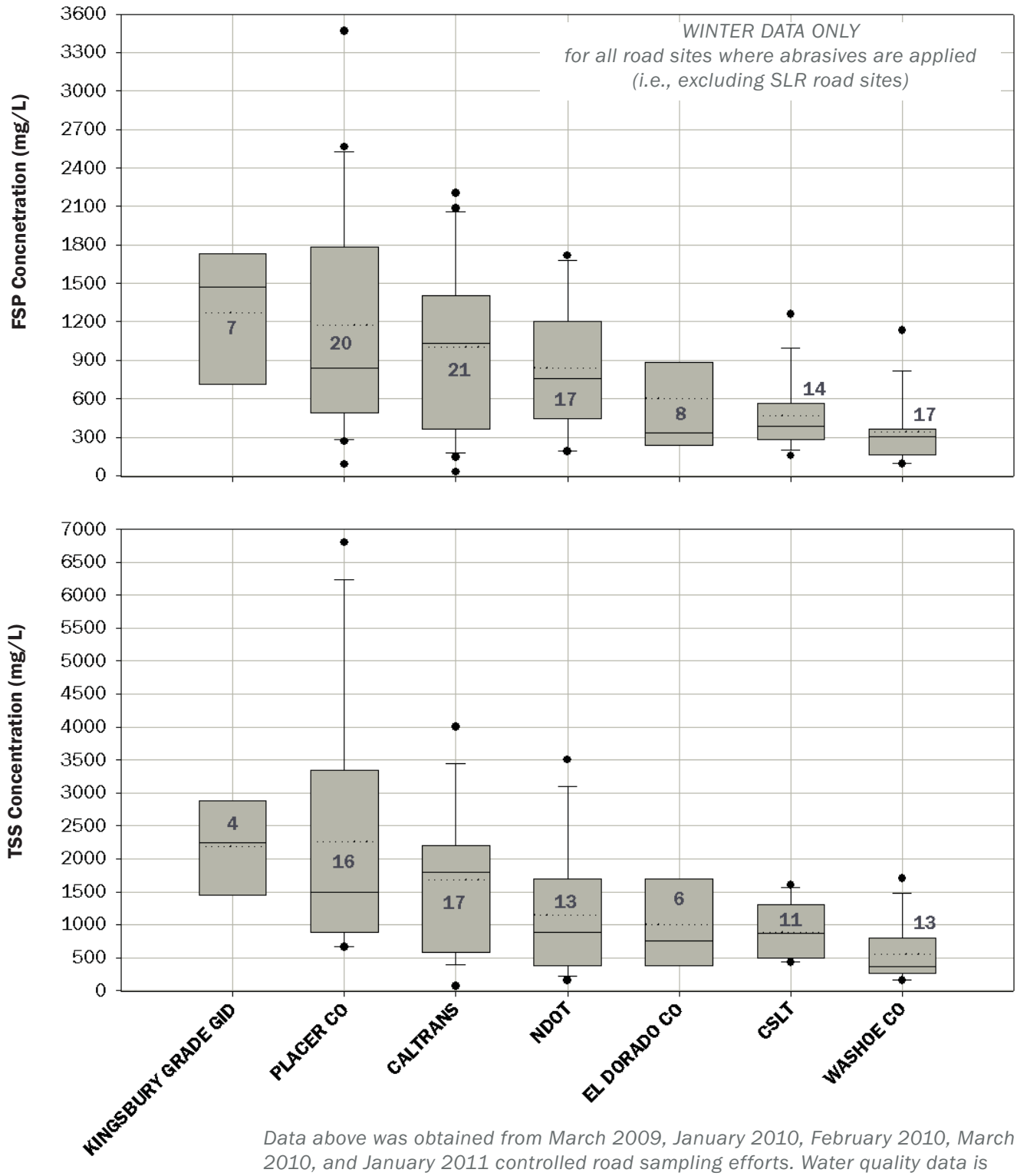
The SRP concentrations from 103 controlled experiments are plotted in a box and whisker plot by jurisdiction in Figure 5.5A. Given the limited SRP sampling, the SRP box and whisker plot shows all road segments for all observation periods (October 2009, January 2010, and February 2010). The data is arranged from highest to lowest average SRP concentration, resulting in a different jurisdiction order than shown in Figure 5.4, and demonstrates some variability but no significant difference in the SRP concentrations across jurisdictions.

Figure 5.5B illustrates that there is no correlation between SRP and FSP concentration, suggesting the factors influencing SRP concentrations on Tahoe Basin roads are different from the factors driving observed FSP concentrations. Perhaps more importantly is the concentrations of SRP measured from roads are significantly lower than those observed from other land uses. With a mean SRP of 0.04 mg/L for 103 samples, road SRP concentrations are over an order of magnitude lower than the SRP mean concentrations (0.6 mg/L) measured from a fertilized ball field in Incline Village (2NDNATURE 2007) and well below the Tahoe Regional Planning Agency surface water discharge standard for dissolved phosphorous (DP) of 0.1 mg/L (TRPA 2007).

Since the Lake Tahoe TMDL regulates total phosphorous (TP) and not the biologically available dissolved fraction (SRP), there is some interest in understanding the potential implications of the finding that roads are a low priority source of SRP relative to the potential of TP source loading from this land use. Given the extensive breadth of this data collection effort, TP was not analyzed in order to reduce analytical costs and therefore we have no consistent road specific data to make an inference of the expected TP loading from roads. However, the biogeochemical behavior of phosphorous species and existing Tahoe stormwater datasets can be used to infer two possible scenarios.

1. Using the compilation of stormwater data from 12 typical urban mixed land use Tahoe catchments (see Table C1 in 2NDNATURE 2006), the average ratio of SRP:TP was 0.12 ± 0.07. Applying this ratio to the SRP mean road concentration of 0.04 mg/L from this research yields an estimated TP concentration of 0.33 mg/L from roads. The watershed model used to support the TMDL (LRWQCB and NDEP 2010) estimated primary and secondary road EMCs as 1.98 mg/L and 0.588 mg/L, respectively. This tenuous comparison suggests TP loading from road surfaces may be lower than originally assumed; however road-specific TP

TAHOE BASIN CONTROLLED ROAD EXPERIMENTS



Data above was obtained from March 2009, January 2010, February 2010, March 2010, and January 2011 controlled road sampling efforts. Water quality data is presented by jurisdiction, ranked from left to right in order of decreasing mean concentration. In 2011, water quality samples were not submitted to the laboratory for analysis. FSP concentrations are determined using field turbidity results and the turbidity to FSP concentration rating curve shown in Figure 5.2. No TSS concentration data is available for those 2 observations periods.

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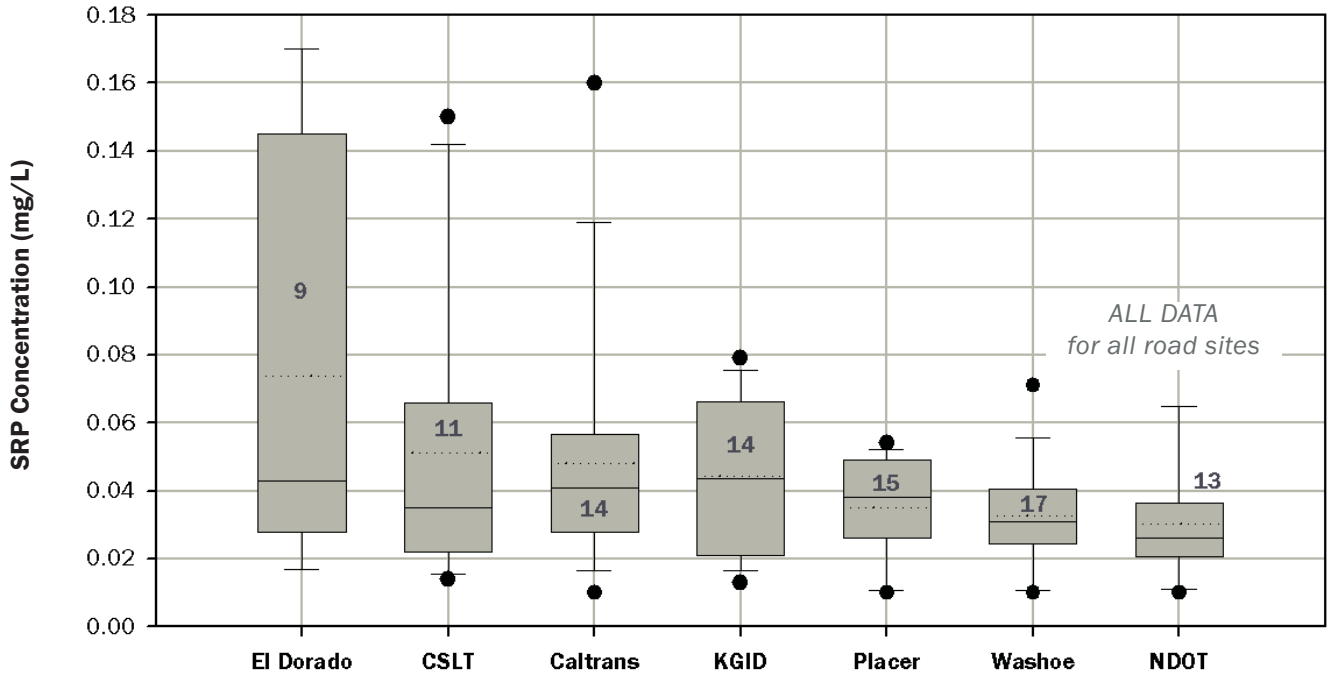
MEASURED FSP AND TSS CONCENTRATIONS BY JURISDICTION

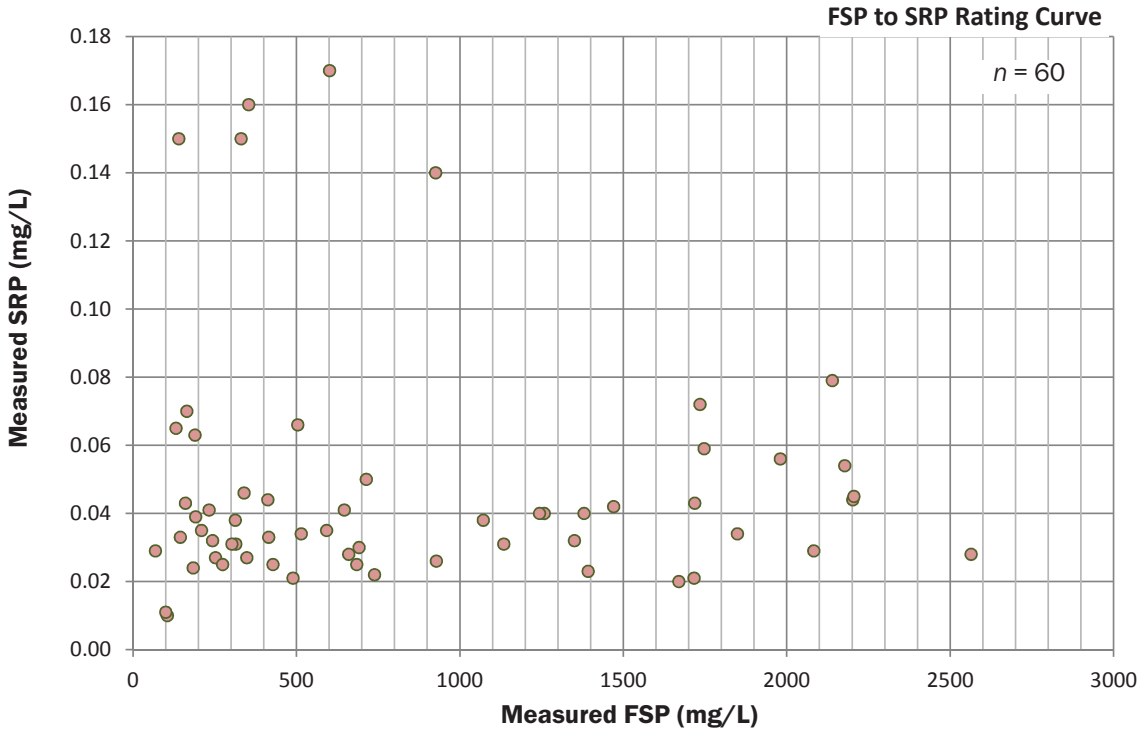
FIGURE 5.4

TAHOE BASIN CONTROLLED ROAD EXPERIMENTS

(A) Data above was obtained from October 2009, January 2010, and February 2010 controlled road sampling efforts. Water quality data is presented by jurisdiction, ranked from left to right in order of decreasing mean concentration.



(B) SRP concentrations are plotted against measured FSP concentrations for 60 samples where both data are available. The data shows no correlation between FSP and SRP, suggesting there are different factors influencing SRP concentrations in road surface runoff than those that affect FSP concentrations.



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MEASURED SRP CONCENTRATIONS

FIGURE 5.5

research is necessary prior to any recommendations to revise road TP CRCs in PLRM. If TP concentrations are consistent with the SRP findings that roads are not a significant source, then phosphorous source control efforts should be focused elsewhere (i.e. fertilizer reductions, car washing etc).

2. If this estimation approach is incorrect, and roads are a significant source of TP, it would be in the form of particulate phosphorous[4] (PP). Particulate phosphorous is bound to the small particles (i.e., FSP) and thus implementation strategies focused on reducing the amount of FSP available on road surfaces prior to stormwater runoff events would be equally effective at reducing PP and thus TP from this land use type.

ROAD POLLUTANT CONCENTRATIONS RELATIVE TO LAKE TAHOE TMDL LAND USE EMCS

Table 5.2 provides a comparison of the Lake Tahoe TMDL land use EMCs used in the Watershed Model (LRWQCB and NDEP 2010) to the mean concentrations of the sample datasets obtained using the portable simulator on Tahoe roads for each pollutant. This comparison has a number of limitations, but it does provide an initial evaluation of how Lake Tahoe TMDL EMCs align with a land use specific dataset. The greatest deviation is associated with the observed FSP concentrations on secondary roads being 4 times higher than the original Lake Tahoe TMDL EMC FSP values. The Lake Tahoe TMDL EMC values for residential and vegetated turf land uses are also provided in Table 5.2 to illustrate how average pollutant concentrations from road land uses compare to average pollutant concentrations across all urban land uses in the Tahoe Basin.

Table 5.2. FSP, TSS and SRP EMC values used by the watershed model (LRWQCB and NDEP 2010) by urban land use type. Mean concentrations obtained from this research using the portable simulator on impervious roads and two select CICU parking lots are provided for comparison. Note that the dissolved phosphorous (DP) and SRP numbers are not directly comparable as SRP is the biologically available fraction of DP.

Land use type	Watershed Model EMCs			WY09-WY11 Research Mean concentrations		
	FSP (mg/L)	TSS (mg/L)	DP (mg/L)	FSP (mg/L)	TSS (mg/L)	SRP (mg/L)
Primary roads	566	952	0.096	624	866	0.039
Secondary roads	89	150	0.144	434	767	0.044
Road spatial average*	164	276	0.136	464	783	0.043
CICU (Pervious and Impervious)	176	296	0.078	193	287	0.023
MFR (Pervious and Impervious)	92	150	0.144	Not evaluated		
SFR (Pervious and Impervious)	30	56	0.144			
Vegetated Turf	5	12	0.263			

The road spatial average* weights the primary and secondary road EMCs based on 110 miles of primary roads and 590 miles of secondary roads in the Tahoe Basin.

ROAD RAM DEVELOPMENT

The research contained herein contributed to the development of Road RAM and correlation of road condition scores to road segment FSP concentrations (mg/L) at time of observations. The insight and value of this research is detailed in the Road RAM Technical Document (2NDNATURE et al. 2010c) and not repeated herein. The portable

[4] TP = PP + SRP+ dissolved organic phosphorous (DOP) see Figure 2 (2NDNATURE 2006). It is reasonable to assume DOP source loading from roads would be extremely low, making PP the critical compound influencing TP concentrations from roads.

simulator was a critical component of the Road RAM field observation development, where the statistical significance of a series of rapid observations was tested to evaluate their capability to predict the FSP concentration measured by the simulator on the same 1ft^2 road surface. Road RAM (2NDNATURE et al. 2010c) is a complete standardized tool to rapidly determine and track road condition over time. Road condition is defined as the relative amount of FSP available on the road segment at the time of observation and is determined using a series of experimentally derived visual proxies. Table 5.3 presents the final categorical Road RAM to FSP concentration relationship and Figure 5.6 graphically presents the empirical equation. Figure 5.6 is a similar FSP to pollutant potential score relative to PLRMv1 Road Methodology (NHC et al. 2009a). This empirical equation allows a simple and reliable translation between Road RAM scores and road segment FSP concentrations.

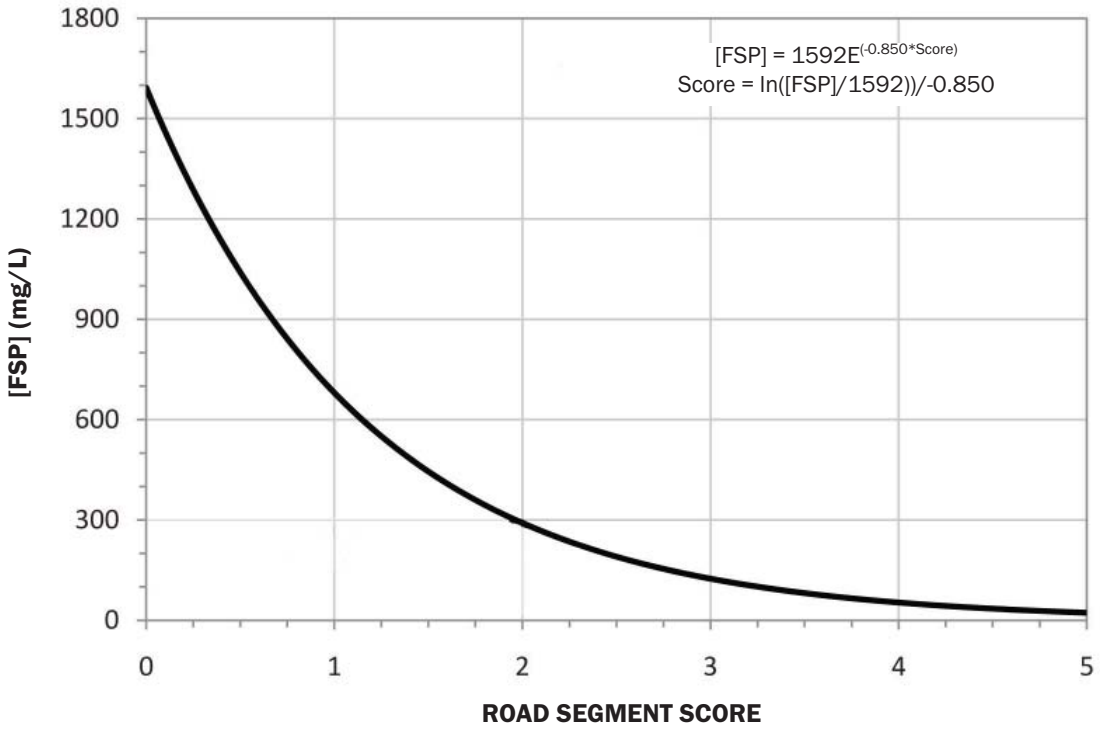
Table 5.3. Road RAM scores relative to road condition and relative risk to downslope water quality.

Road RAM Score	Condition	FSP Concentration (mg/L) Range
0 - 1.0	Poor	1,592-680
>1.0 - ≤ 2.0	Degraded	679-291
> 2.0 - ≤ 3.0	Fair	290-124
> 3.0 - ≤ 4.0	Acceptable	123-53
> 4.0 – 5.0	Desired	52-23

Each Road RAM score is correlated to an expected FSP concentration from the road segment if the segment were sampled in a manner consistent with the controlled experiments. The translation of road segment FSP concentrations to a 0-5 RAM score simplify communication of relative condition, while preserving the quantitative alignment to the concentrations of the pollutant of concern. Table 5.4 compares differences in Road RAM scores throughout the 0-5 range to the equivalent differences in FSP concentrations using the relationship shown in Figure 5.6. While the absolute FSP concentration differences vary depending upon the Road RAM score, the percent difference in the FSP concentrations is consistent, i.e., for every 0.1 change in Road RAM score there is a consistent 8.1% FSP concentration change. The smaller differences in absolute FSP concentrations at higher RAM scores (RAM >2 or FSP concentration <300 mg/L) are consistent with our ability to measure these differences in the field using the portable sampler. Much higher field precision (<8% error) is observed when there is less material on the road surface and RAM scores are above 2). Field sampling error significantly increases when the amount of material on the roadway is excessive, creating micro gullies and transport variability from the road surface to the sampler collection device. For simplicity's sake, road condition observation results are provided as Road RAM scores throughout this document. However, using Table 5.4 the reader can easily translate RAM scores to FSP concentrations.

The combination of the Road RAM visual proxies and controlled experiment data results were used to create a series of Basin-wide maps of road condition for 4 observations periods at the road segments monitored (Figure 5.7). Each symbol represents a specific road segment and the color designates the score range, consistent with Table 5.3. Similar to the seasonal trends shown in Figure 5.3, road conditions that minimize pollutant generation appear to be best during the summer observation period and worst during the winter observation period, where the overwhelming majority of the road segments have road condition scores deemed degraded or poor. Spatial variations during any particular observation period are also apparent. Any road segment score can be converted to an FSP concentration using the exponential equation presented in Figure 5.6. The Road RAM map outputs provide a simple communication tool to easily convey the time progression of relative road condition around the Tahoe Basin, and hopefully inform the prioritization of future actions to improve water quality from road surfaces.

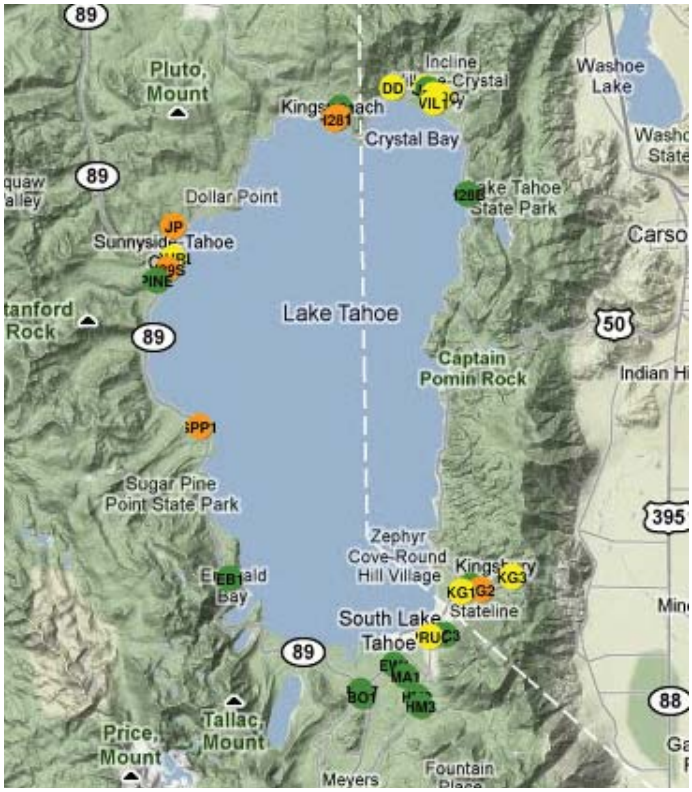
ROAD RAM SCORE TO FSP CONCENTRATION RELATIONSHIP



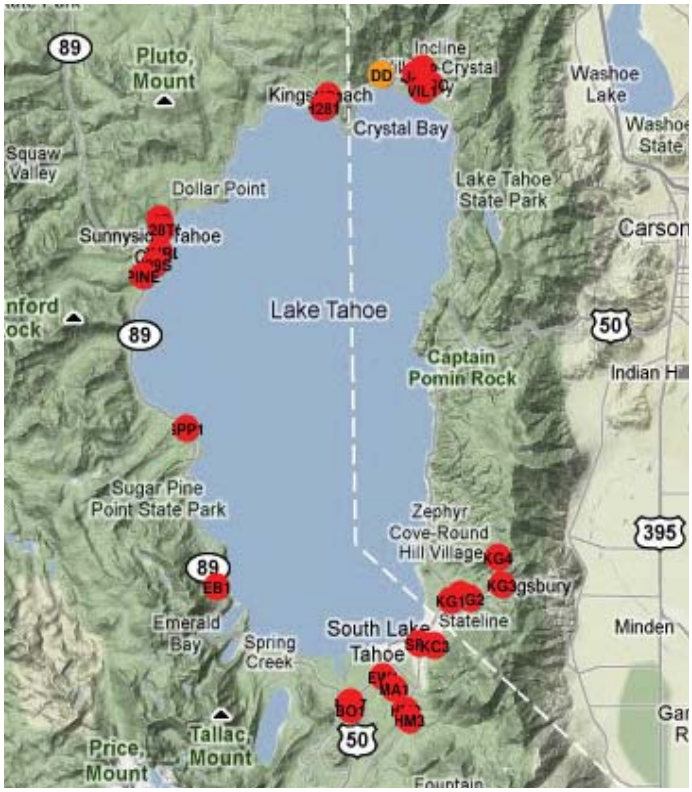
The road segment score represents the observed condition of the road segment at the time of observation. The road segment FSP concentration is converted to a road segment score by the Road RAM database using the same concentration to score relationship used in PLRMv1.

ROAD RAM ROAD SEGMENT CONDITION SCORES

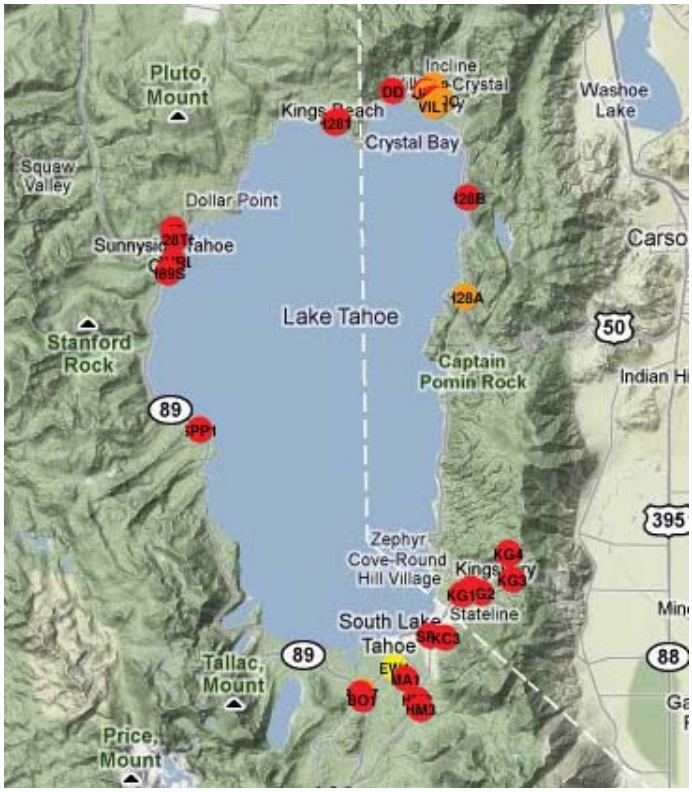
July 2009 Observation Period



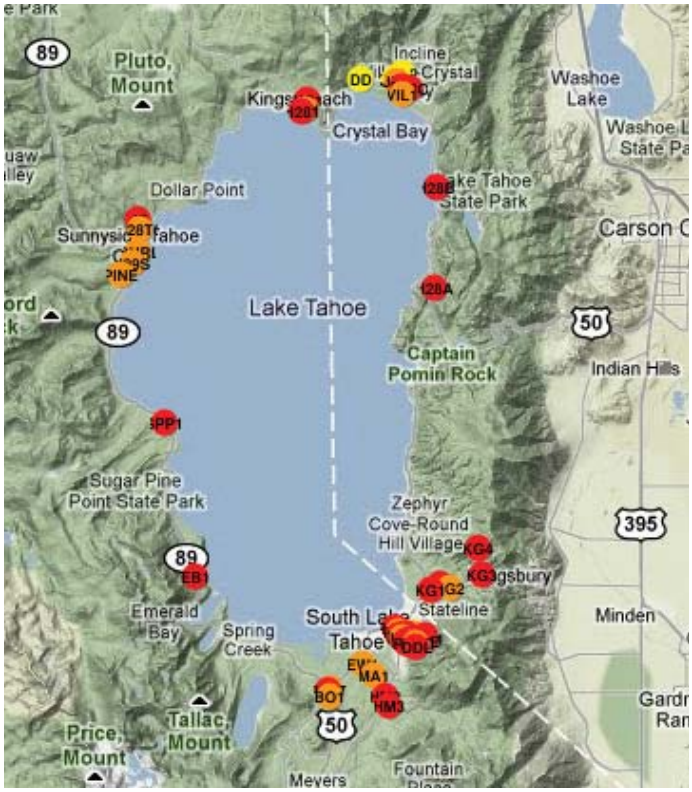
February 2010 Observation Period



January 2011 Observation Period



April 2011 Observation Period



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ROAD RAM ROAD SEGMENT CONDITION SCORES

FIGURE 5.7

Table 5.4. Comparison of differences in Road RAM scores to equivalent magnitude and percent differences in FSP concentrations. While the absolute FSP concentration difference on a ± 0.1 RAM score interval ranges from 130 mg/L to 2 mg/L as the expected FSP concentration decreases, the absolute deviation is consistently ± 8.1%.

Road RAM Score	FSP Concentration (mg/L)	FSP Concentration Difference	% Difference	Road RAM Score	FSP Concentration (mg/L)	FSP Concentration Difference	% Difference
0	1592	-	-	2.6	175	-15	-8.1%
0.1	1462	-130	-8.1%	2.7	160	-14	-8.1%
0.2	1343	-119	-8.1%	2.8	147	-13	-8.1%
0.3	1234	-109	-8.1%	2.9	135	-12	-8.1%
0.4	1133	-101	-8.1%	3	124	-11	-8.1%
0.5	1041	-92	-8.1%	3.1	114	-10	-8.1%
0.6	956	-85	-8.1%	3.2	105	-9	-8.1%
0.7	878	-78	-8.1%	3.3	96.3	-9	-8.1%
0.8	807	-72	-8.1%	3.4	88.5	-8	-8.1%
0.9	741	-66	-8.1%	3.5	81.3	-7	-8.1%
1	680	-60	-8.1%	3.6	74.6	-7	-8.1%
1.1	625	-55	-8.1%	3.7	68.6	-6	-8.1%
1.2	574	-51	-8.1%	3.8	63.0	-6	-8.1%
1.3	527	-47	-8.1%	3.9	57.8	-5	-8.1%
1.4	484	-43	-8.1%	4	53.1	-5	-8.1%
1.5	445	-39	-8.1%	4.1	48.8	-4	-8.1%
1.6	409	-36	-8.1%	4.2	44.8	-4	-8.1%
1.7	375	-33	-8.1%	4.3	41.2	-4	-8.1%
1.8	345	-31	-8.1%	4.4	37.8	-3	-8.1%
1.9	317	-28	-8.1%	4.5	34.7	-3	-8.1%
2	291	-26	-8.1%	4.6	31.9	-3	-8.1%
2.1	267	-24	-8.1%	4.7	29.3	-3	-8.1%
2.2	245	-22	-8.1%	4.8	26.9	-2	-8.1%
2.3	225	-20	-8.1%	4.9	24.7	-2	-8.1%
2.4	207	-18	-8.1%	5	22.7	-2	-8.1%
2.5	190	-17	-8.1%				

PLRMV1 CRC RANGE AND SHAPE

A CRC, or characteristic runoff concentration, is a runoff concentration for a pollutant of concern from a specific land use and associated land use condition over a range of stormwater runoff events and seasons. A CRC is similar in concept to an event mean concentration (EMC), but a CRC is calculated as the long-term pollutant load divided by the long-term runoff volume. For example, CRCs in PLRM are assumed to be representative of the pollutant load divided by the runoff volume generated by the continuous 18-year simulation that PLRMv1 currently executes. Conversely, EMCs attempt to characterize the average concentration in runoff for a specific event, which

typically lasts a few hours or days. In order to accurately quantify a CRC, the research would need to determine the volume weighted average of EMCs over multiple years for a particular site that captures a land use specific EMC across all event types for a specific condition. Multiple sites that cover a range of potential land use conditions would be necessary. Because this approach is cost, time and likely logistically prohibitive, various methods are used to compare our series of discrete measured pollutant concentrations on road surfaces appropriately to PLRMv1 CRC values.

The first comparison uses the complete dataset of measured road pollutant concentrations over the course of the research to evaluate the shape, minimum, and maximum values of current PLRM CRCs for road land uses. The shape of the exponential decay of the FSP CRC algorithm is presented in Figure 5.6. The measured FSP concentration values were obtained from 1ft^2 on the moderate accumulation area from 32 road segments during 10 observation periods for a range of meteorological conditions. The complete dataset (see Figure 5.1) is relevant to assess the range and exponential shape of CRCs in PLRM relative to road condition for the following reasons: 1) the series of road segments cumulatively represent the spatial range of observed road conditions across all jurisdictions in the Tahoe Basin; and 2) each road segment was sampled over a range of weather conditions during a 3-year period.

Table 5.5 compares these PLRM estimates to the values measured during road sampling for TSS, FSP and SRP concentrations. The results suggest the high bookend PLRM CRC values are within reason, while the PLRM minimum CRCs are within the range of measured concentration on Tahoe roadways. The high frequency of SRP samples measured at the minimum value (40 samples below 0.03 mg/L) suggests the analytical detection limit is too high to detect variations in the road SRP data. However, given comparisons of SRP concentrations on roads to other land uses in the Basin, it is likely not a stormwater monitoring priority to continue SRP sampling on road surfaces. Based on the available measured data, the PLRMv1 TSS, FSP and SRP CRCs appear to be representative of the observed range of concentrations from Tahoe roads.

Table 5.5. Comparison of PLRMv1 CRC values to measured concentrations for TSS, FSP and SRP collected during controlled experiments.

	TSS (mg/L)	FSP (mg/L)	SRP (mg/L)
PLRMv1 MAX CRC	1398	1014	0.16
Measured MAX concentration (n)	6800 (263)	3468 (262)	0.17 (103)
Frequency measured MAX > PLRMv1 MAX (n)	18% (51)	16% (43)	1% (1)
PLRMv1 MIN	63	22	0.03
Measured MIN concentration (n)	10 (263)	4 (262)	0.01 (103)
Frequency measured MIN < PLRMv1 MIN (n)	6% (16)	6% (16)	39% (40)

The CRC to road condition score) rating curves and equations for TSS, FSP, and SRP CRCs used in PLRMv1 (see Figure 2.1) show the inverse relationship between score and concentration (i.e., concentrations exponentially decline with an increase in road condition score on a 0-5 scale). The experimental field data in Figure 5.1 verifies that the exponential shape of the CRC to score relationships used in PLRMv1 for these pollutants is reasonable. This research finding also supports the FSP to score equation used in Road RAM (Figure 5.6).

CALCULATED AVERAGE FSP CONCENTRATION ESTIMATES

In order to compare observed road FSP concentration data and the PLRM predicted values for a specific road segment, we must ensure the observed data is expressed in a manner that is spatially and temporally comparable to a PLRM FSP CRC. Road RAM includes a spatial extrapolation technique to determine road condition (RAM score or FSP concentration) of a 10,000 ft^2 road segment based on visual observations in representative 1ft^2 areas (see *Road RAM Technical Document Chapter 9*; 2NDNATURE et al. 2010a). The road segment area is a standardized 10,000 ft^2 and the % area contribution of each accumulation category (high, moderate, low) is estimated for each road segment evaluated. The moderate accumulation area FSP concentration was measured using the simulator, and Road RAM visual proxies were used to predict the FSP concentration on the low and high areas of accumulation. The results are spatially weighted to estimate the road segment FSP concentration, a spatially comparable value to PLRM CRCs and these are the values shown for specific observation periods in Figure 5.7.

Road RAM temporal extrapolation techniques are used to compare a series of measured FSP concentration values at one road segment, which are concentrations representing discrete measurements at a specific location at a specific point in time, into a seasonally flow weighted concentration we believe to be comparable to PLRM FSP CRCs. Road RAM includes a temporal extrapolation technique to integrate a series of discrete observations at one road segment conducted over a water year and estimate the flow weighted annual FSP concentration or road condition (see *Road RAM Technical Document Chapter 8: Spatial and Temporal Extrapolation of Observations* (2NDNATURE et al. 2010a)). The weighting of FSP concentration data by season (Table 5.6) was informed by the seasonal road condition variations and the relative annual contribution of surface runoff in each season. Estimates of seasonal surface runoff from urban areas in the Tahoe Basin was derived from an analysis of long-term (18-year) time-series output of hourly surface runoff in EPA SWMM for representative PLRM scenarios. EQ 5.1 summarizes how the measured FSP concentration values were integrated to calculate volume weighted average FSP concentration at each road segment.

$$[FSP]average = [FSP]_{s/f} fRV_{s/f} + [FSP]_{w} fRV_{w} + [FSP]_{ws} fRV_{ws} + [FSP]_{ss} fRV_{ss} \qquad \text{EQ (5.1)}$$

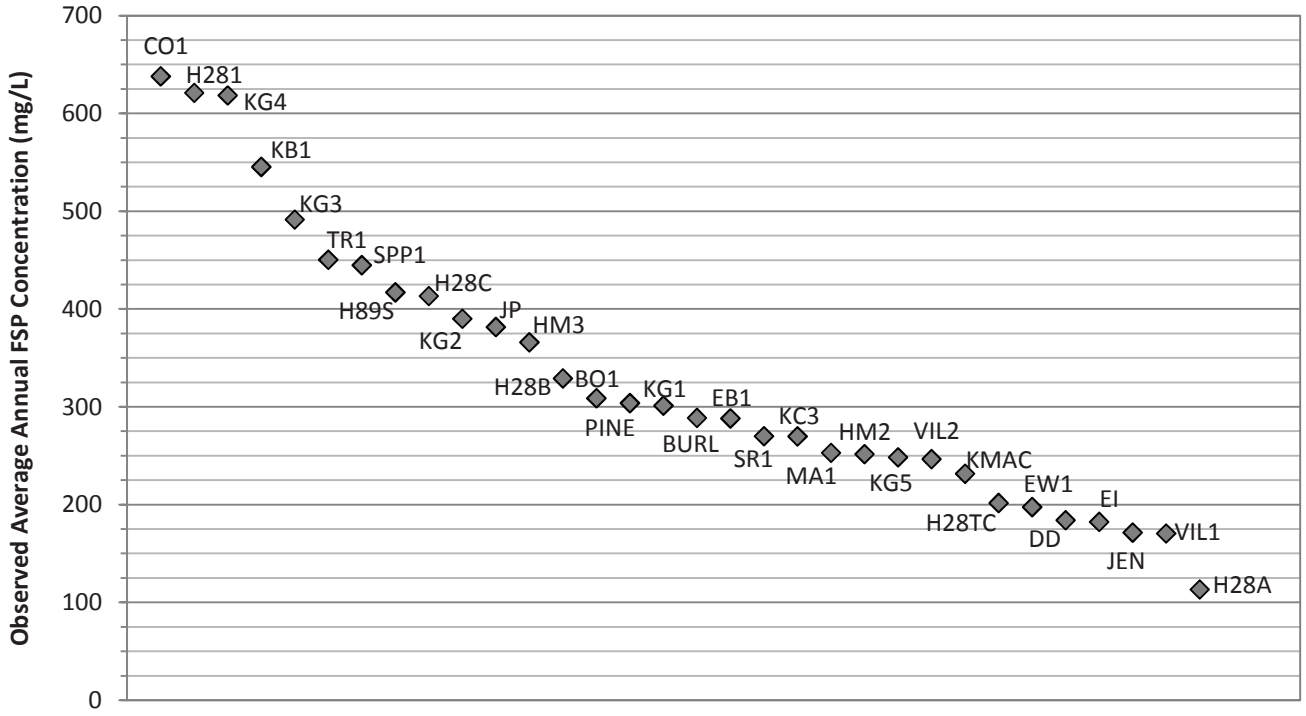
where [FSP] annual is assumed to be our best representation of an annual average FSP concentration given the available dataset, $[FSP]_i$ is the average FSP concentration of all observations made within the respective seasons and fRV_i is the fraction of the total average annual urban runoff volumes for each season indicated in Table 5.6.

Table 5.6. Temporal integration of discrete road condition observations to estimate the calculated volume weighted average FSP concentrations (slightly modified from Road RAM; 2NDNATURE et al. 2010a).

Season (months)	fRV_i
Summer/Fall (s/f: Aug-Dec)	20%
Winter (w: Jan-Feb)	20%
Late Winter/Early Spring (w/s: Mar-Apr)	40%
Spring/Summer (s/s: May-July)	20%

Using all available road segment data over 3 water years with the total number of observations per segment ranging from 5 to 10, the annual volume weighted observed FSP concentration is calculated per EQ 5.1 for the 32 road segments and plotted categorically from high to low in Figure 5.8. The 32 sites cumulatively represent a reasonable range of road risk types across all jurisdictions. The observed volume weighted average annual FSP concentrations range from 113 mg/L to 638 mg/L. Sixteen of the 32 sites had a calculated volume weighted FSP concentration > 300 mg/L and 31 of the 32 sites (66%) exceed the FSP EMC road average (164 mg/L) as determined from mixed catchment stormwater data (Gunter 2005) and used in the Watershed Model (see Table 5.2).

RANKED VOLUME WEIGHTED AVERAGE FSP CONCENTRATION



Ranking from high to low of the calculated volume weighted average road segment FSP concentration for the 32 road segments. Discrete road segment concentrations are temporally weighted based on the values presented in Table 5.5 to calculate an annual value.

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RANKED VOLUME WEIGHTED AVERAGE ROAD SEGMENT FSP CONCENTRATION

FIGURE 5.8

CALCULATED FSP CONCENTRATION LIMITATIONS

The calculated volume weighted average FSP concentrations are based on data generated using field observations with known limitations. The calculated values are generated using a number of spatial and temporal extrapolation techniques to integrate a series of discrete observations to estimate the volume weighted annual FSP concentration for specific road segments. Given the infeasibility of continuously sampling the stormwater runoff from a road segment over all event types for a number of years, we believe we provide a reasonable and appropriate approach to integrate the available series of temporally discrete FSP concentration measurements to compare to PLRMv1 CRCs predictions for the same road segments.

Figure 5.9 illustrates the time series of observed FSP concentration values and the calculated volume weighted average FSP value for a number of road segments included in the research. The actual fluctuation of FSP concentrations on the road surfaces are much more variable than the dataset represents and obviously the more frequent the road condition observations the better the temporal resolution of the dataset to estimate a volume weighted average concentration. The variability of road condition on daily or weekly timescales is significant during times when abrasives are applied or immediately following effective sweeping efforts. Controlled measurements of the amount of FSP on the road surface conducted immediately prior to and following sweeping efforts using a regenerative air sweeper in Washoe County suggested a 42% immediate reduction in the FSP on the road surface (NTCD 2011). The number of days since sweeping and/or abrasive applications on a specific road segment prior to the observed FSP concentration by field personnel can have a significant influence on the results. However, the research team was not able to obtain a chronology of the practices by the responsible jurisdictions to better understand the maintenance context prior to each of our observations. The sequence of happenings matters, such that the number of days since abrasive applications, sweeping efforts, snow hauls, runoff events, etc. and relative amount of traffic will result in a potentially different road condition. The calculated volume weighted averages presented herein assume that the general condition has been captured by the series of observations spanning WY09-WY11 for each road segment. The total precipitation for each of the water years 2009-2011 were above average (see Chapter 4.1) suggesting the road conditions during these winter months in the study may have been relatively worse than other years due to the increased frequency and amount of abrasive applications and reduced opportunity for sweeping.

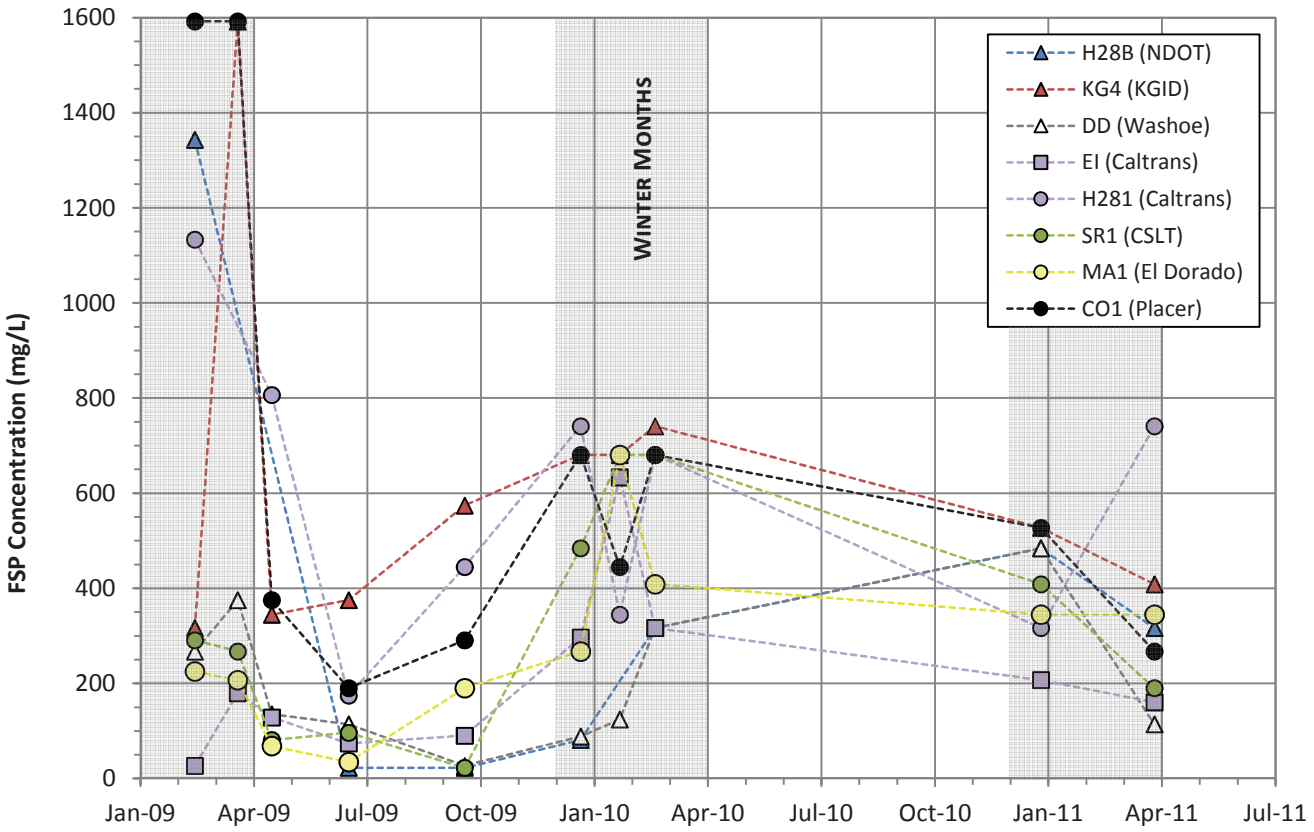
PLRM CRC PREDICTIONS COMPARED TO OBSERVED

PLRMv1 Road Methodology was used to predict the CRC for each road segment where seasonal observations had been made. We note that PLRM was not intended to predict the CRC for a specific road segment, but rather represent an average for a road risk type. A series of PLRM input assumptions were completed by the research team and compared to the calculated volume weighted average FSP concentrations. The analysis of each scenario yielded additional insight on how PLRM inputs drive expected road CRCs and how to best use PLRMv1 to compare predicted values to the calculated volume weighted FSP concentrations using the series of discrete observations. However, the obtainment of consistent observations over a range of water year types on roads maintained in a consistent manner (same road prescriptions across years) would greatly improve our ability to compare annual estimates of road FSP concentrations to PLRM CRC predictions.

PLRM SCENARIO A

Table 5.7 presents the PLRM inputs for each road segment grouped by jurisdiction. Road risk for each segment was determined using the March 2011 PLRM road risk layer, and road shoulder condition is representative of 2011 field observations. The abrasive strategy for all roads and all jurisdictions is set at minimal to remove the influence of one variable on the PLRM predictions. The sweeper type and sweeping frequency were informed by the

OBSERVED ROAD SEGMENT FSP CONCENTRATION TIME SERIES



Time series of observed road segment FSP concentrations for 8 road segments, representing each of the Tahoe Basin urban jurisdictions. For comparative purposes, road segments with the most frequent observations, greatest variability, and located in high traffic areas were selected for display. Caltrans site EI is also included because the March 2009 observation of 28 mg/L is the lowest observed winter FSP concentration at all sites from WY09-WY11 and according to Caltrans personnel (L. Waters pers. comm.) followed rigorous testing of a high efficiency sweeper at the South Y. Shading signifies winter season. Below the calculated volume weighted average road segment FSP concentration is provided for each site.

Site (Jurisdiction)	Calculated Average FSP Concentration (mg/L)
H28B (NDOT)	329
KG4 (KGID)	619
DD (Washoe)	184
EI (Caltrans)	182
H281 (Caltrans)	621
SR1 (CSLT)	270
MA1 (El Dorado)	253
CO1 (Placer)	638

Site	March 2011 Risk[1]	March 2011 Road Shoulder Condition[2]	Sweeper Type[3]	Sweeping Frequency[4]	PLRM FSP CRC (mg/L)	Calc [FSP] (mg/L)
Caltrans						
EB1	PLR/SHR	5	Broom	Often	208	288
EI	PHR	5	Vacuum	V. Frequent	348	182
H281	PHR	5	Broom	Frequent	472	621
H89S	PHR	1	Broom	Frequent	1010	417
SPP1	PLR/SHR	1	Broom	Frequent	472	445
CSLT						
BO1	SMR	1	Tandem	Often	204	309
EW1	SMR	1	Tandem	Often	204	198
KC3	PLR/SHR	4	Tandem	V. Frequent	229	270
SR1	PLR/SHR	5	Tandem	V. Frequent	200	270
El Dorado						
HM2	PLR/SHR	5	Regen	Frequent	194	252
HM3	SMR	5	Regen	Frequent	84	366
MA1	SMR	5	Regen	Frequent	84	253
KGID						
KG3	PLR/SHR	4	Broom	Rare	242	492
KG4	PLR/SHR	5	Broom	Rare	211	619
KG5	SLR	5	Broom	Rare	31	248
NDOT						
H28A	PMR	5	Vacuum	Frequent	235	113
H28B	PMR	5	Vacuum	Frequent	235	329
H28C	PHR	5	Vacuum	Frequent	376	364
KG1	PHR	5	Vacuum	Frequent	376	301
KG2	PHR	4	Vacuum	Frequent	432	390
Placer County						
BURL	SMR	4	Broom	Occasional	105	289
CO1	PLR/SHR	5	Broom	Often	208	638
JP	PLR/SHR	4	Broom	Often	239	382
KB1	PLR/SHR	5	Broom	Occasional	211	545
PINE	PLR/SHR	4	Broom	Often	239	304
TR1	SMR	5	Broom	Occasional	92	450
Washoe County						
DD	PLR/SHR	5	Vacuum	Occasional	189	184
JEN	SLR	5	Vacuum	Rare	29	172
KMAC	PLR/SHR	3	Vacuum	Occasional	268	232
VIL1	PMR	1	Vacuum	V. Frequent	491	171
VIL2	PMR	5	Vacuum	V. Frequent	217	247

[1] Combination of Type: P= primary road; S= secondary road and Risk: H= high risk; M= moderate risk; L= low risk
[2] Road Shoulder Condition: 1= erodible; 3= protected only; 4= stable only; 5= stable & protected
[3] Sweeper Type: Vacuum= High-efficiency vacuum-assisted (dustless); Regen= Regnerative air; Tandem= Tandem operation (mechanical broom + vacuum); Broom= Mechancical Broom
[4] Sweeping Frequency: Rare= 1-2 times summer only; Occasional= 1-2 times per season; Often= monthly winter & twice summer; Frequent= twice monthly winter & 2 times summer; V. Frequent= ASAP winter & monthly summer

COMPARISON OF **SCENARIO A** PLRM PREDICTED FSP CRCS TO CALCULATED VOLUME WEIGHTED AVERAGE FSP CONCENTRATIONS (WY09-WY11).

TABLE 5.7

jurisdiction's general road maintenance practice information provided (see Chapter 4.3), with site-specific adjustments based on the research team's observations throughout WY09-WY11.

Figures 5.10A-C presents the comparison between the calculated average FSP concentrations and the PLRM Scenario A predictions by jurisdiction, risk, and road shoulder condition, respectively. The solid line indicates agreement, below the line indicates PLRM CRC estimates are lower than the observed FSP concentration, and above the line indicates PLRM CRC values are higher. The dotted lines indicate a 20% difference, which is proposed as an aggressive target to judge the extent of deviations between observed and predicted values on a site-specific basis while recognizing the limitations in both estimates.

Of the 32 sites, 24 are outside of the 20% envelope. The most prevelant pattern of outliers is the frequent occurance of PLRM predictions lower than calculated FSP values for secondary road risk types (see Figure 5.10B), suggesting that secondary roads tend to accumulate more FSP than PLRM predicts. The secondary roads that fall below the line are frequently jurisdictions with relatively high annual abrasive application rates per road mile realtive to other jursidictions, namely Placer County and Kingbury Grade (see Figure 4. 3). For example, KG4 is a very steep residential road managed by KGID and is defined as a high risk secondary road. This road segment is heavily sanded but rarely swept, and measurements resulted in some of the highest discrete FSP concentrations during the study period (see photo at right). These findings led to a critical evaluation of the designation of road risk across jurisditions and PLRM Scenario B.

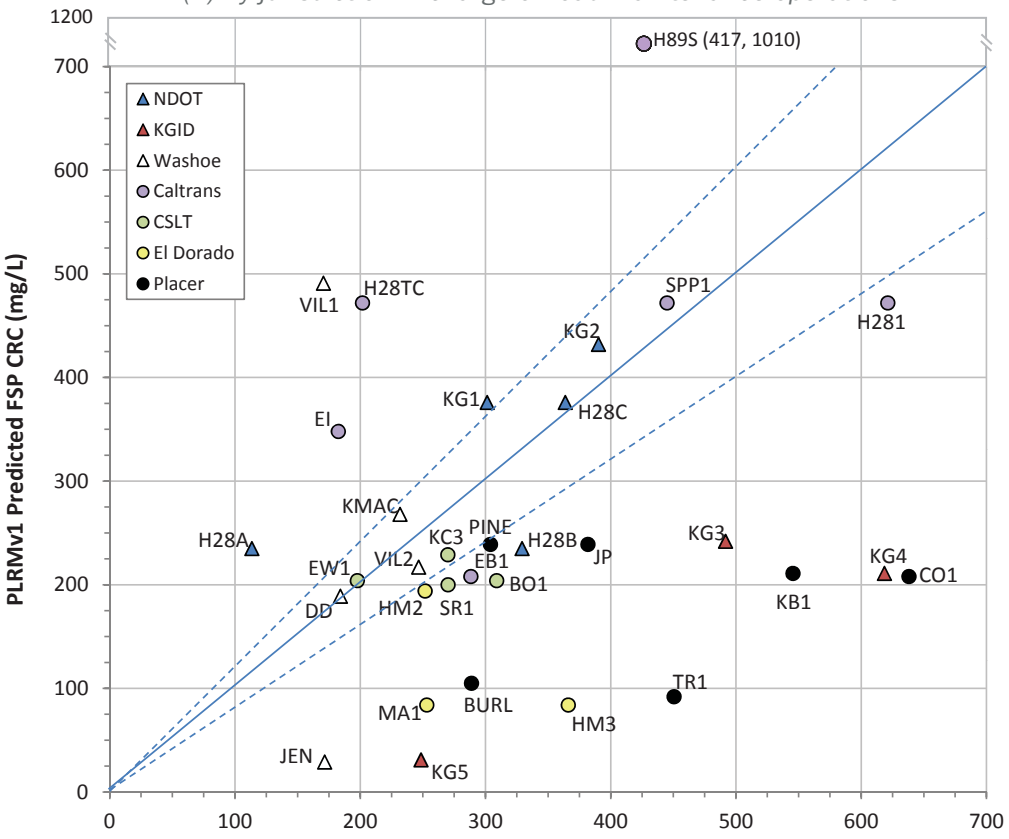
Road segment KG4 in April 2011. Note the significant accumulation of abrasives on the road surface and adjacent snow bank.

PLRM SCENARIO B

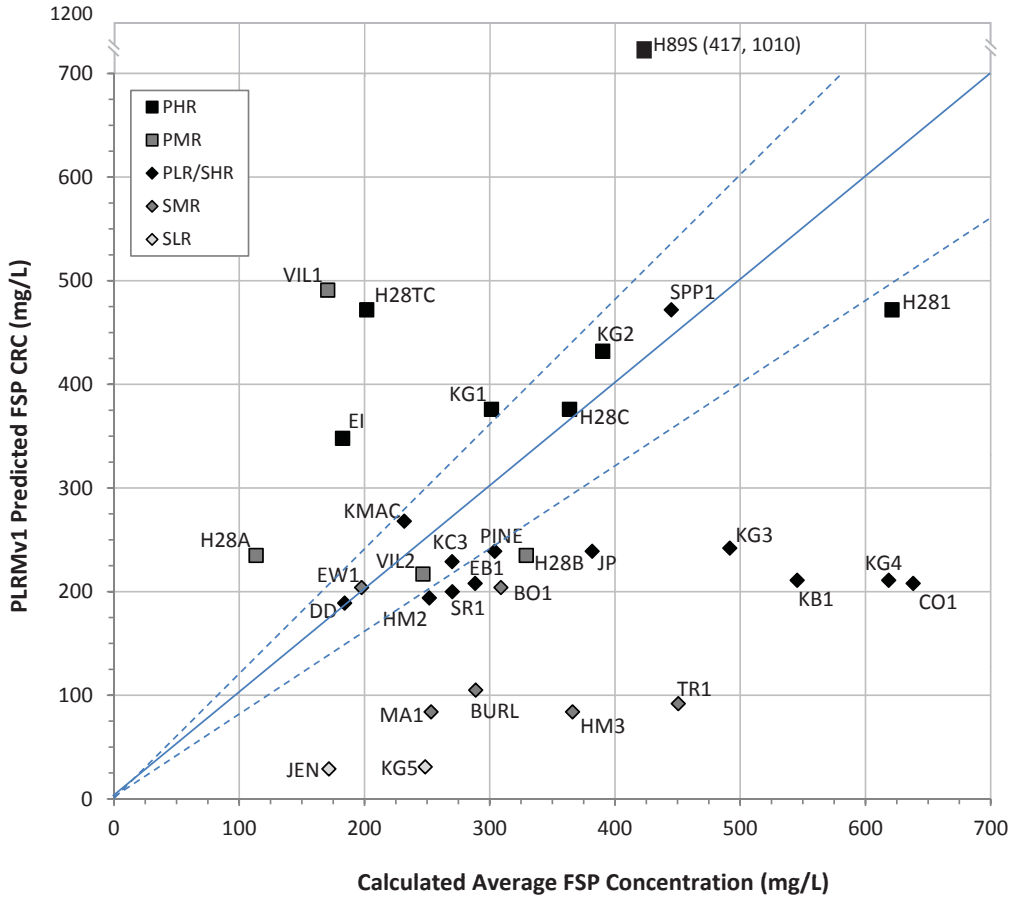
In PLRM Scenario B, we revise the March 2011 default road risk designations based on PLRM user guidance and our technical understanding of the road segment locations gained during this research. PLRMv1 categorizes roads based on road risk as a starting point of expected road condition based on the relative potential sources of pollutants (both abrasives applications and native road shoulder erosion). PLRMv1 essentially includes 5 different road risk types with incremental decreases in the initial CRC with a reduction in risk (PHR, PMR, PLR/SHR, SMR, and SLR). The expected road CRC is then further reduced in PLRM as result of source control and pollutant recovery actions conducted on the road segment. Through the application of PLRM and stormwater research (2NDNATURE and NHC 2010 and this research) it has been determined that across jurisdictions roads of the same risk type are not maintained using consistent techniques and a large deviation exists on the type, amount, frequency and spatial application of abrasives across jurisdictions in the Tahoe Basin (see Figure 4.4). PLRM user manual (NHC et al. 2009b) provides some guidance to critically assess the initial road risk designations included in PLRMv1 to improve the risk classification based on the jurisdiction's specific abrasive application procedures. We apply this guidance in PLRM Scenario B, along with our existing knowledge of the geographical context and observations of relative abrasive application by jurisdiction across sites. Additionally, we disregard the designation of primary or secondary road type. Rather, road risk was considered a continuum where the annual amount of abrasives applied relatively to all roads in the Tahoe Basin decreases incrementally from PHR to SLR. Based on information available and continued road segment observations over the 3 water years, the research team made assumptions for each jurisdiction based on the expected relative risk of their road networks and the specific roads included in the research. The exception to the jurisditional adjustments was the assignment of all sites located on the main arterial

SCENARIO A

(A) By jurisdiction in charge of road maintenance operations



(B) By road risk



See Table 5.7 for PLRM inputs for Scenario A.

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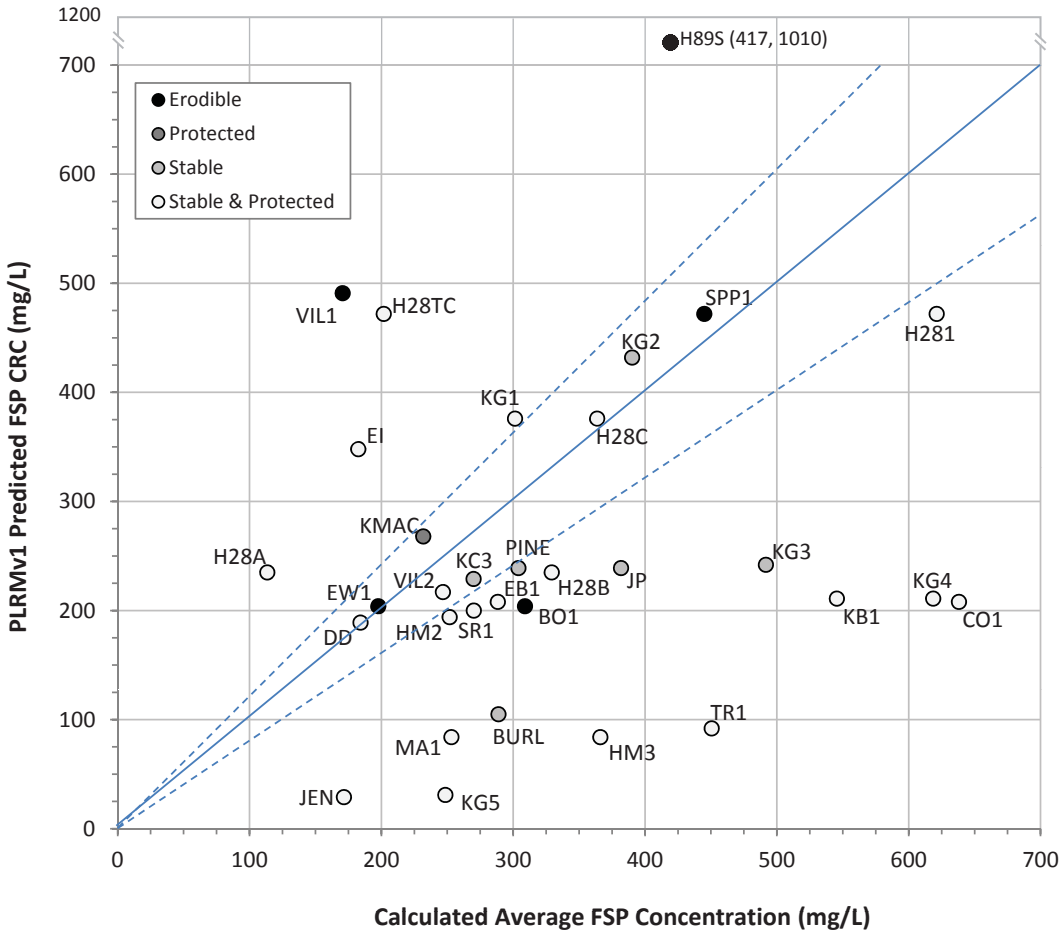
SCENARIO A: PLRM PREDICTED FSP CRCS TO CALCULATED VOLUME WEIGHTED AVERAGE FSP CONCENTRATIONS (WY09-WY11); PAGE 1 OF 2

FIGURE 5.10

SCENARIO A

(C) By road shoulder condition



See Table 5.7 for PLRM inputs for Scenario A.

SCENARIO A: PLRM PREDICTED FSP CRCS TO CALCULATED VOLUME WEIGHTED AVERAGE FSP CONCENTRATIONS (WY09-WY11); PAGE 2 OF 2

FIGURE 5.10

roads in the Basin (i.e., Highways 50, 89, 28, 207 and 267) as PHR regardless of jurisdiction as a result of the high amount of winter tourist traffic on these roads. Table 5.8 is organized by jurisidiction and includes the assumptions regarding juridisctional risk classifications. No other input modifications to PLRM are made from Scenario A. Figures 5.11A-C presents the comparison of the calculated volume weighted concentrations and PLRM Scenario B predictions by jurisdiction, risk and road shoulder condition, respectively. Of the 32 sites, 17 are outside of the 20% envelope, an improvement from Scenario A results.

PLRM SCENARIO C

The final adjustment to the PLRM inputs was the designation of all segments with stable and protected road shoulder condition. Scenario B (Figure 5.12A-C) shows no discernible trend with respect to road shoulder condition. This modification was tested because the controlled experiment data and Road RAM observations do not evaluate condition on pervious road shoulders so isolating PLRM predictions to just the impervious area may be a more robust comparison. No other changes were made to PLRM inputs in Scenario B (see Table 5.8) and the differences in the PLRM predictions in Scenario C are now limited to road risk type and pollutant recovery actions variations (see schematic on page 2.3). The removal of road shoulder condition reduced the predicted CRC for a number of segments and resulted in a slight improvement in agreement between predicted and calculated values (14 of 32 with a deviation > ± 20%). Scenario C exhibits a strong correlation between the predicted and calculated values (Kendall's tau of 0.5, significant above 99% confidence). In this case Kendall's tau, a ranked correlation coefficient, is used since the data show non-normal distributions (rather than Pearson's r which assumes normal distributions).

The comparisons between the PLRM predictions and calculated FSP concentrations are used to evaluate the relative effect of road characteristics on FSP concentrations.

ROAD SURFACE INTEGRITY

A number of road segments below the 1:1 line (higher calculated values than PLRMv1 predictions) are for roads with poor surface integrity. The research team has observed relatively elevated measured FSP concentrations on roads with high degree of cracking and pavement failure. HM3, BO1, and JP all have significant pavement cracking, and all three were observed to have a higher calculated average FSP concentration than predicted by PLRM (see Figure 5.12).

Road Segment HM3; Poor road surface integrity

Both discrete and average results suggest that maintaining road surface integrity can have a significant benefit to reducing the FSP generation of a road. Observations suggest poor road surface integrity may result in relatively elevated observed average FSP concentrations to: (1) decreased effectiveness of pollutant recovery actions as material cannot be effectively removed from the cracks using current sweeper technology, wind, traffic or any other mechanism besides wash off that transports FSP from the road surface to the shoulder; and (2) the elevated contribution of FSP locally from accelerated pavement degradation. Figure 5.13 presents the time series of observations from 3 of the road segments with poor integrity, illustrating the relatively elevated winter FSP concentrations (> 600 mg/L) for moderate to low risk roads, yet summer observations yield FSP concentrations <50 mg/L, suggesting road washoff during spring rains can effectively mine the cracks of stored material and transport pollutants downslope. Also included in Figure 5.13 is the time series data for site TR1, a poor integrity road that was repaved in Summer 2010, corresponding to a dramatic reduction in the subsequent winter observations in

Site	Adjusted Risk[1]	Sweeper Type	Sweeping Frequency	PLRM FSP CRC (mg/L)	Calc [FSP] (mg/L)	Points of Interest
Caltrans: Relatively high annual abrasive application and responsible for main arterial roads in Basin.						
EB1	PHR	Broom	Often	472	288	
EI	PHR	Vacuum	V. Frequent	348	182	One very low winter observation (28 mg/L) has significant influence on calculated FSP.
H281	PHR	Broom	Frequent	472	621	Main arterial road, PHR.
H28TC	PHR	Broom	Frequent	472	202	Main arterial road, PHR.
H89S	PHR	Broom	Frequent	1010	417	Main arterial road, PHR.
SPP1	PHR	Broom	Frequent	1010	445	
CSLT: Relatively moderate to low road abrasive application; No PHR roads						
BO1	SMR	Tandem	Often	204	309	Poor road surface integrity
EW1	PLR/SHR	Tandem	Often	462	198	Poor road surface integrity
KC3	PMR	Tandem	V. Frequent	324	270	Steep road.
SR1	PLR/SHR	Tandem	V. Frequent	200	270	High traffic density. Parking along road may affect sweeper's ability to sweep entire road width.
El Dorado: Relatively moderate to low road abrasive application; No PHR roads.						
HM2	PMR	Regen	Frequent	274	252	Located at intersection near school, high priority for abrasives.
HM3	PLR/SHR	Regen	Frequent	194	366	Poor road surface integrity.
MA1	PMR	Regen	Frequent	274	253	Located on dangerous curve, high priority for abrasives.
KGID: Relatively high annual abrasive application; High risk categories used						
KG3	PHR	Broom	Rare	548	492	Dangerous intersection.
KG4	PHR	Broom	Rare	477	619	Steep road.
KG5	PLR/SHR	Broom	Rare	211	248	
NDOT: Relatively moderate to low abrasive applications but responsible for arterial highways in Basin.						
H28A	PHR	Vacuum	Frequent	376	113	Main arterial road, PHR.
H28B	PHR	Vacuum	Frequent	376	329	Main arterial road, PHR. One very high concentration (>1,300mg/L) in LW/ES is influencing calculated FSP.
H28C	PHR	Vacuum	Frequent	376	364	Main arterial road, PHR.
KG1	PHR	Vacuum	Frequent	376	301	Main arterial road, PHR.
KG2	PHR	Vacuum	Frequent	432	390	Main arterial road, PHR.
Placer County: Relatively high annual abrasive application; High risk categories used.						
BURL	PMR	Broom	Occasional	342	289	
CO1	PHR	Broom	Often	472	638	
JP	PMR	Broom	Often	338	382	Poor road surface integrity.
KB1	PHR	Broom	Occasional	477	545	Steep road.
PINE	PMR	Broom	Often	338	304	
TR1	PMR	Broom	Occasional	477	450	Poor road surface integrity.
Washoe County: Relatively moderate to low abrasive applications; No PHR in jurisdiction						
DD	PLR/SHR	Vacuum	Occasional	189	184	Steep road.
JEN	SLR	Vacuum	Rare	29	172	
KMAC	PLR/SHR	Vacuum	Occasional	268	232	
VIL1	PMR	Vacuum	V. Frequent	491	171	High traffic density.
VIL2	PMR	Vacuum	V. Frequent	217	247	High traffic density.

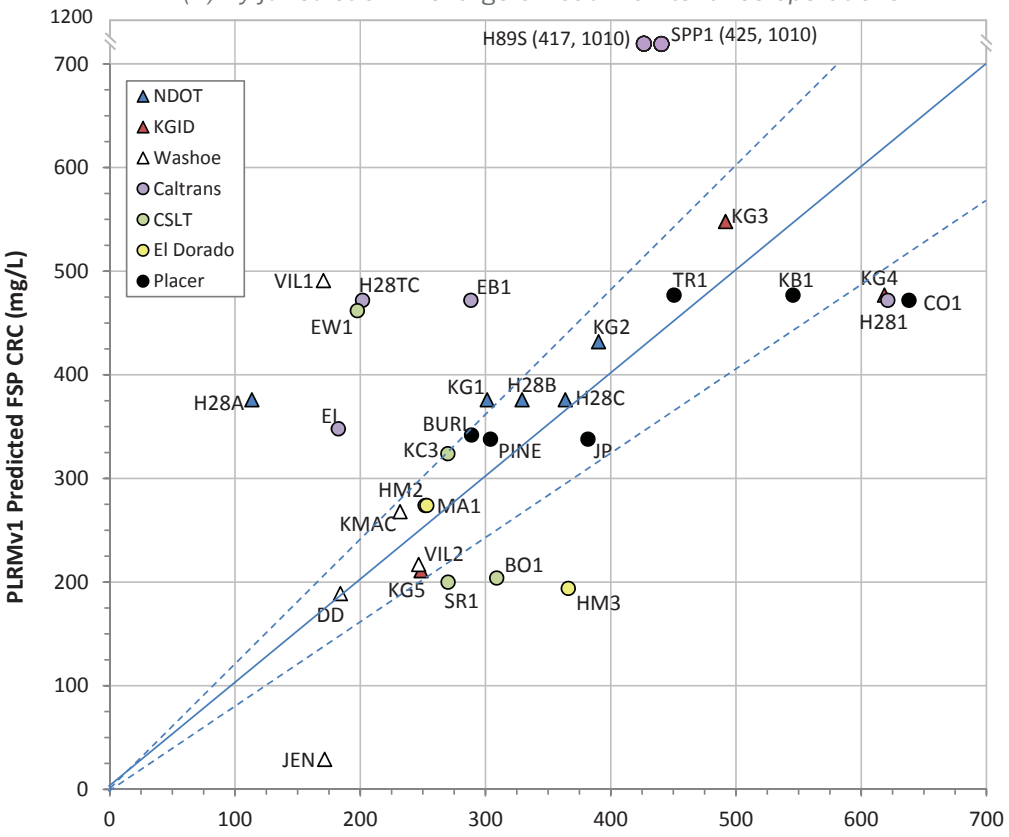
See Table 5.7 for footnotes. Note, road shoulder condition is unchanged from Scenario A; see Table 5.7 for road shoulder conditions by site.

COMPARISON OF **SCENARIO B** PLRM PREDICTED FSP CRCS TO CALCULATED VOLUME WEIGHTED AVERAGE FSP CONCENTRATIONS (WY09-WY11).

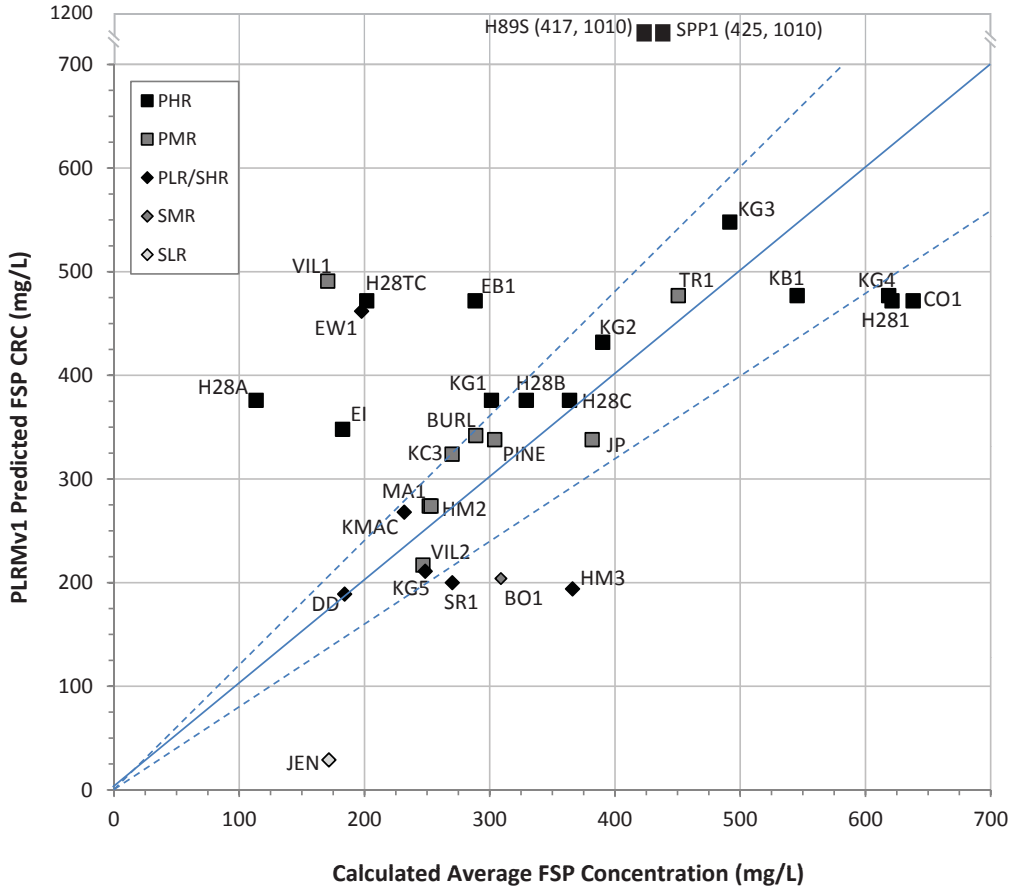
TABLE 5.8

SCENARIO B

(A) By jurisdiction in charge of road maintenance operations



(B) By road risk



See Table 5.8 for PLRM inputs for Scenario B.

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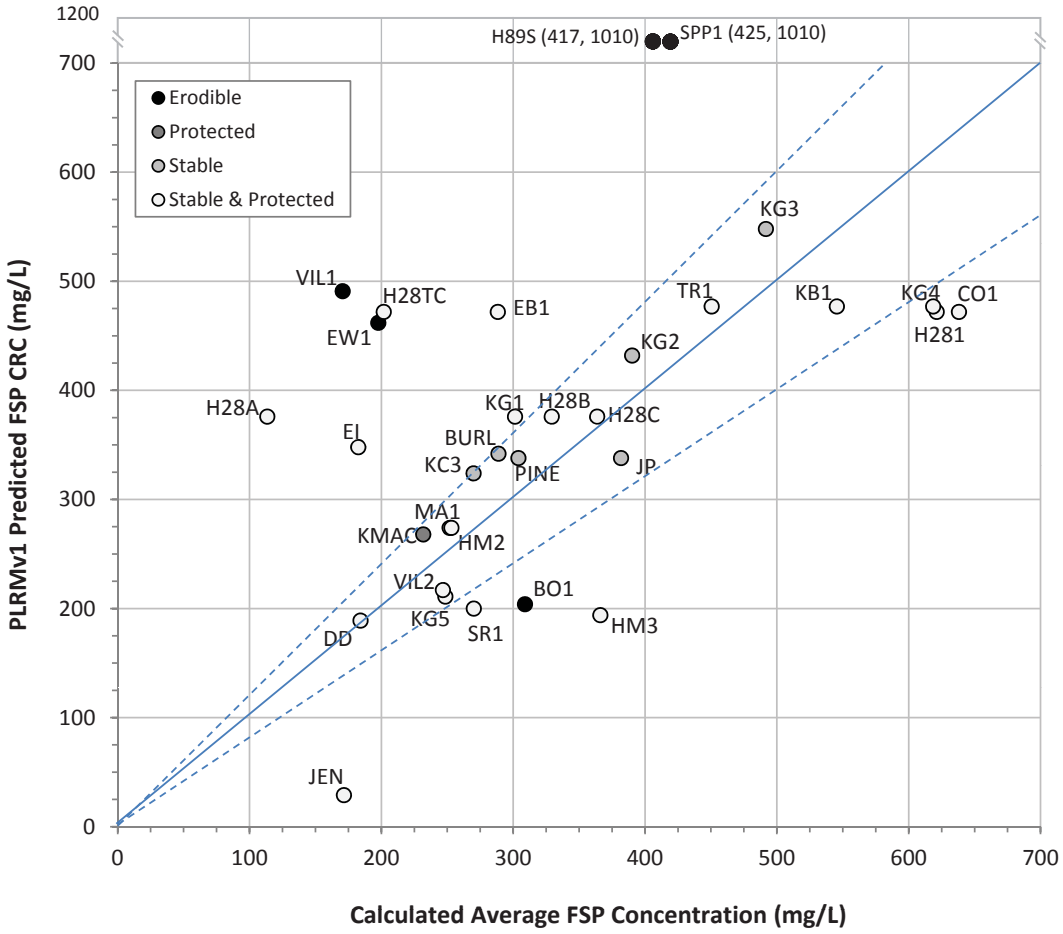
SCENARIO B: PLRM PREDICTED FSP CRCS TO CALCULATED VOLUME WEIGHTED AVERAGE FSP CONCENTRATIONS (WY09-WY11); PAGE 1 OF 2

FIGURE 5.11

SCENARIO B

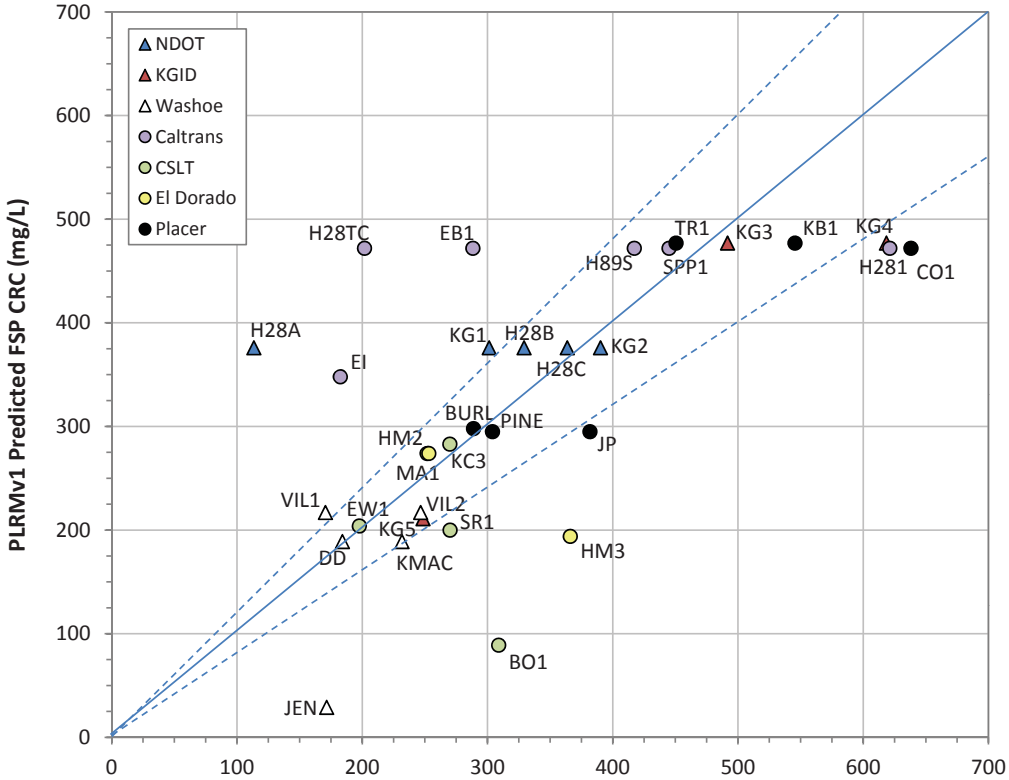
(C) By road shoulder condition



See Table 5.8 for PLRM inputs for Scenario B.

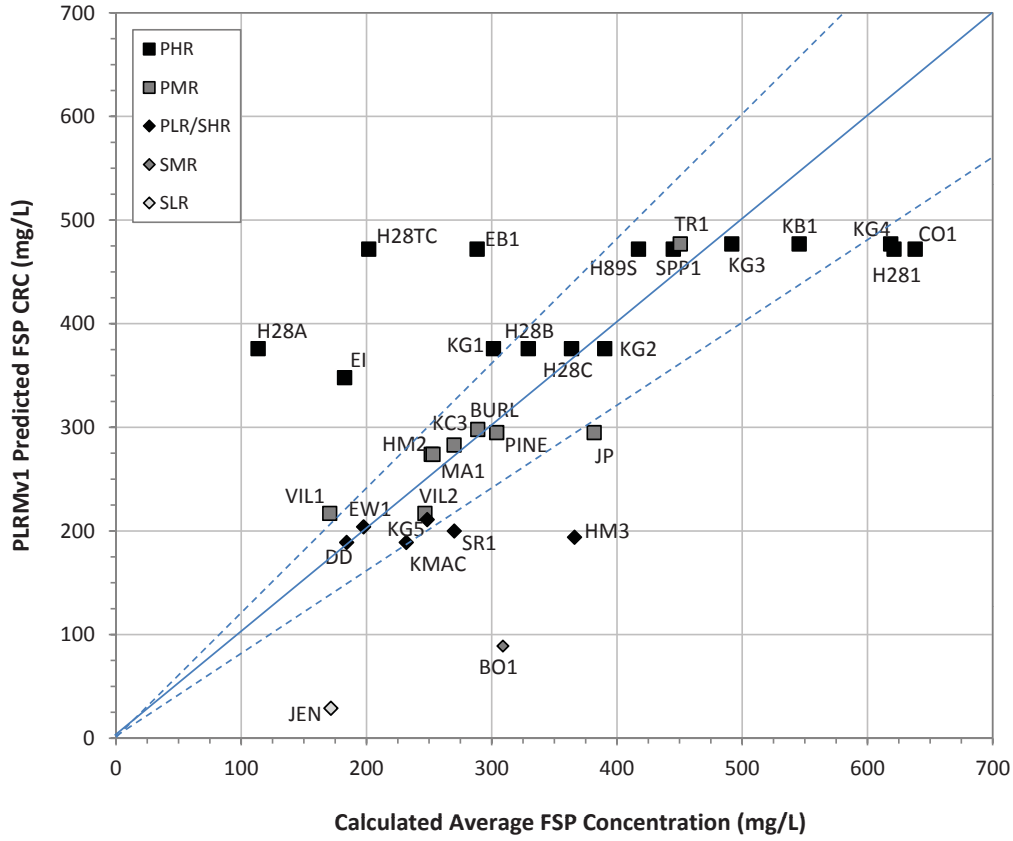
SCENARIO C

(A) By jurisdiction in charge of road maintenance operations



Kendall's tau = 0.51, suggesting a strong correlation, significant above 99% confidence.

(B) By road risk



PLRM inputs for Scenario C are the same as Scenario B, except all road shoulder conditions have been designated as stable and protected.

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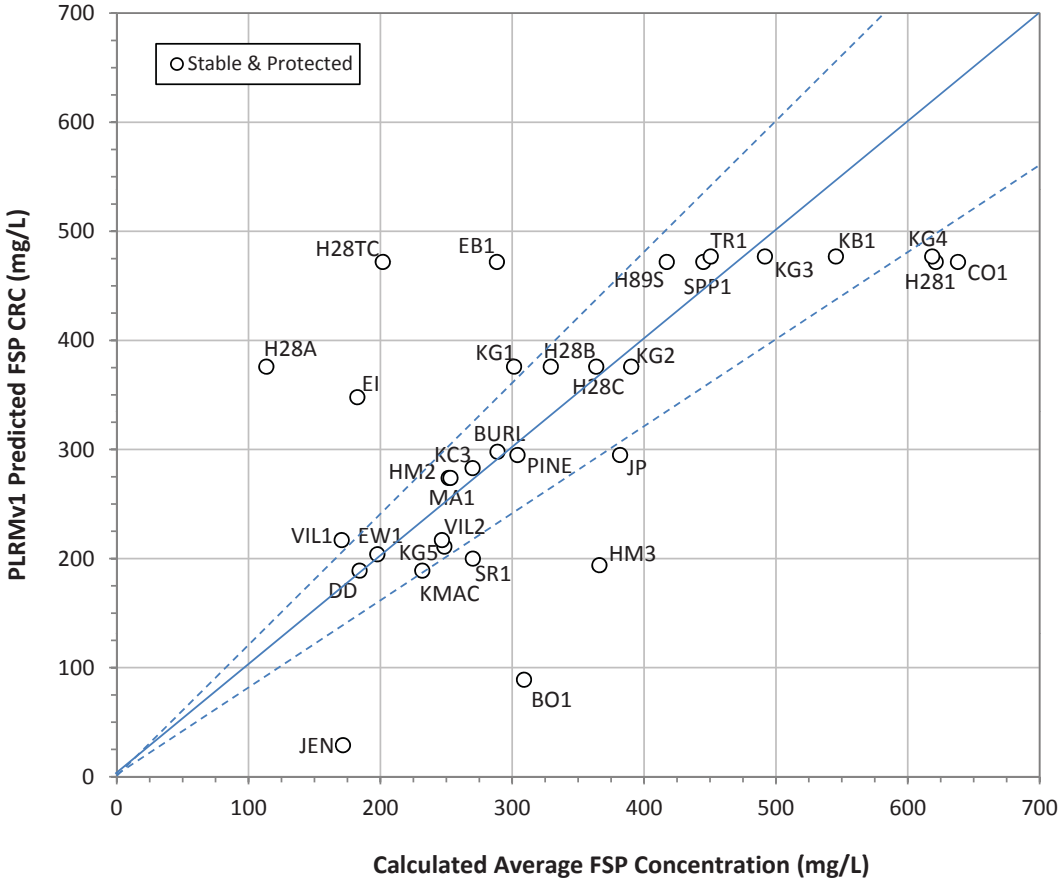
SCENARIO C: PLRM PREDICTED FSP CRCS TO CALCULATED VOLUME WEIGHTED AVERAGE FSP CONCENTRATIONS (WY09-WY11); PAGE 1 OF 2

FIGURE 5.12

SCENARIO C

(C) By road shoulder condition



PLRM inputs for Scenario C are the same as Scenario B, except all road shoulder conditions have been designated as stable and protected.

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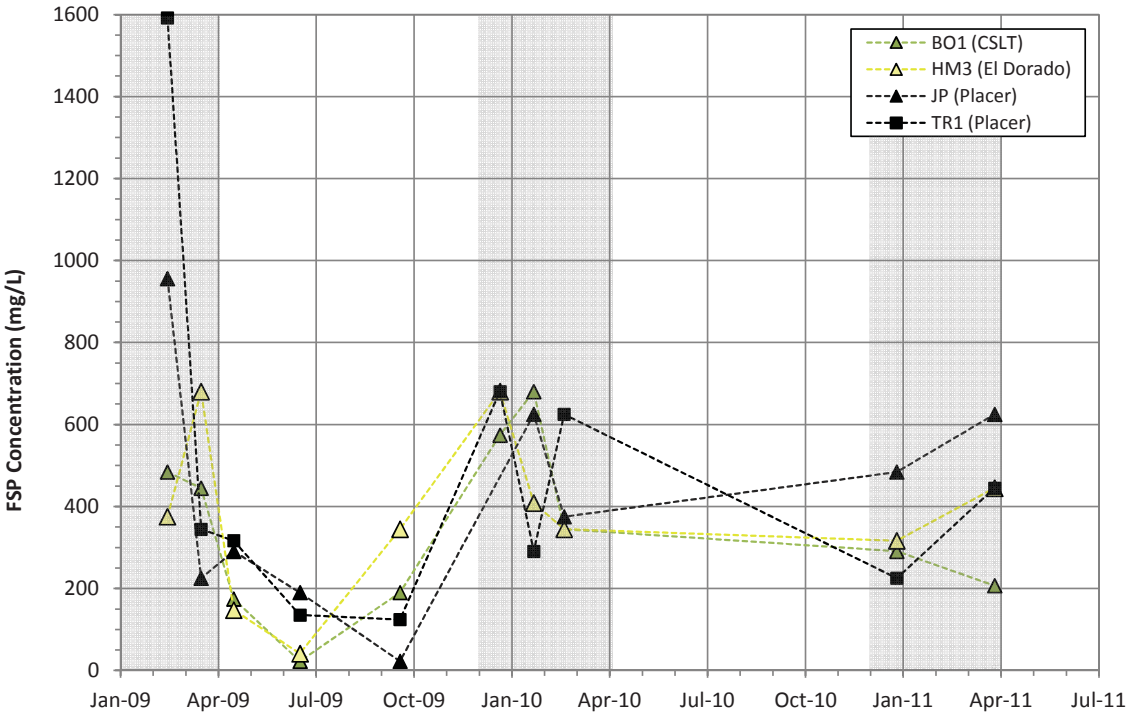
SCENARIO C: PLRM PREDICTED FSP CRCS TO CALCULATED VOLUME WEIGHTED AVERAGE FSP CONCENTRATIONS (WY09-WY11); PAGE 2 OF 2

FIGURE 5.12

OBSERVED ROAD SEGMENT FSP CONCENTRATION TIME SERIES AT SITES WITH POOR ROAD SURFACE INTEGRITY



Time series of observed road segment FSP concentrations for 3 road segments with poor road surface integrity, in addition to TR1, which was repaved in Summer 2010. Shading signifies winter season.

BO1

HM3

JP

TR1 March 2009

TR1 January 2011

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OBSERVED ROAD SEGMENT FSP CONCENTRATION TIME SERIES AT SITES WITH POOR ROAD SURFACE INTEGRITY

FIGURE 5.13

WY11 (from an average of 700 mg/L in previous winters to 225 mg/L in January 2011). Road surface integrity is not a factor included in PLRM to estimate average annual road condition, but visual and measured FSP accumulation on these road segments suggests poor road surface integrity can increase the downslope water risk.

SWEEPING EFFECTIVENESS

One outlier that persists throughout all PLRM scenarios is site EI, a Caltrans PHR road segment located at the South Y where high abrasive applications and very high traffic density exist. During the winter observations in 2009, Caltrans was rigorously testing a high efficiency sweeper and multiple passes were observed at the site prior to the lowest winter road segment FSP concentration measurement to date (28 mg/L; see Figure 5.4). This data point, combined with observations in Washoe County of good road conditions, where sweeping practices are consistently more frequent with high efficiency vacuum assist or regenerative air sweepers compared to other jurisdiction in the Tahoe Basin, supports the hypothesis that increased sweeping frequency with vacuum assist sweepers on roads that require frequent abrasive applications to protect driver safety can be maintained in a relatively good condition. While the direct cause and effect dataset does not exist, these data illustrate that relatively low (< 50 mg/L) FSP concentrations on a PHR road are achievable in the winter and based on the seasonal runoff volume distribution, low winter FSP concentrations are expected to result in a relatively lower amount of FSP transported into downslope stormwater.

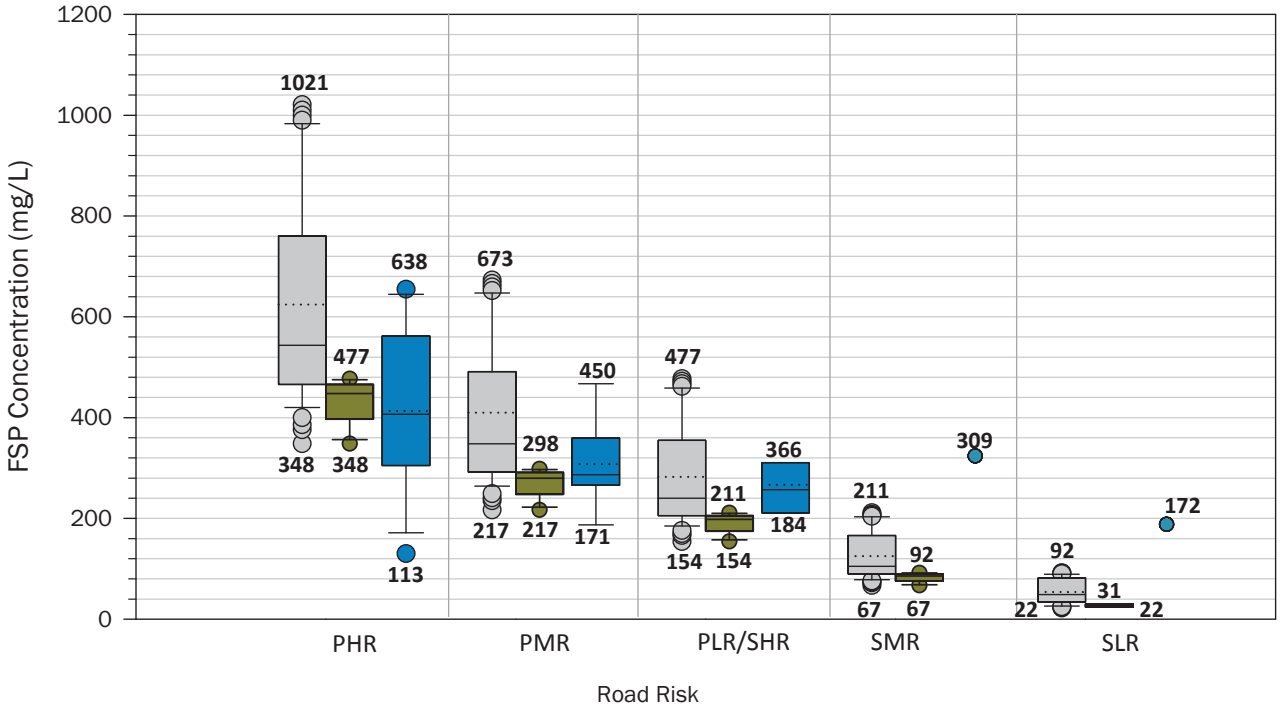
ROAD RISK AND ROAD SHOULDER CONDITION

Scenarios B and C improve the agreement between PLRM and calculated FSP values; however, with the adjustments to road risk, only two sites are designated as either SMR or SLR road segments. The implications of this upward shift of all of the roads to relatively moderate to high road risk is that even roads in residential neighborhoods with relatively low traffic were observed to have higher FSP concentrations than PLRM algorithms originally assumed. The population of road segments for this research were selected to ensure a range of potential risk across the Tahoe Basin, but these data suggest that the current spatial distribution of relatively low risk roads is lower than originally expected.

Given all of the limitations associated with the calculated volume weighted FSP value, we present a simple comparison of the potental PLRM FSP CRC range by road risk type for Scenario A, B and C and the observed FSP values. Figure 5.14 contains 3 box and whisker plots. The grey is the complete potential range of FSP CRCs used in Scenarios A and B. The green is the restricted range of potential FSP CRCs when the road shoulder condition is assumed to be stable and protected for all roads (Scenario C). The blue is the range of calculated FSP concentrations from the observed data. Figure 5.14 yields the following points:

- The PLRMv1 restriction that primary high risk (PHR) roads cannot have an FSP CRC lower than 348 mg/L is not representative of all observations. The calculated dataset indicates that primary high risk roads can potentially achieve average FSP concentrations approximately 65% lower than PLRMv1 currently allows and the mean calculated FSP concentration (396 mg/L) is below the 25th percentile of PLRMv1 CRCs for that risk category. Considering that WY09-W11 were relatively high snow winters (see Figure 4.4), the occurrence of some low discrete winter observations and volume-weighted FSP values below the PLRM minimum suggests that PLRM may need to accommodate even lower CRCs for high risk primary roads where more intensive source control and recovery actions are implemented.
- As discussed above and shown in Figure 5.12B, the WY09-WY11 volume weighted annual FSP concentrations for secondary moderate risk (SMR) and secondary low risk (SLR) roads are considerably higher than the current maximum FSP CRCs set by PLRMv1 for these road risk categories. This may

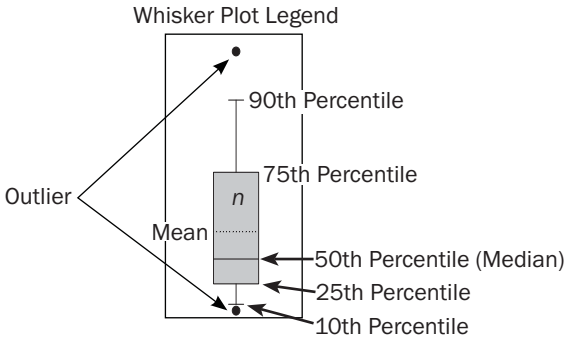
COMPARISON OF FSP CONCENTRATION RANGES



LEGEND

FSP Concentrations

- PLRMv1 (Scenario A/B)
- PLRM - Stable & Protected (Scenario C)
- Calculated Flow-Weighted Average (this research)



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COMPARISON OF FSP CONCENTRATION RANGES

FIGURE 5.14

- indicate that the PLRMv1 user guidelines for characterizing roads in the Tahoe Basin as secondary moderate risk and secondary low risk roads may need to be reevaluated and potentially adjusted.
- The impact of changes in road shoulder condition on the potential range of FSP CRCs for each risk type in PLRMv1 can be significant. Figure 5.14 shows how the ranges of FSP CRCs by road risk category are narrowed for stable and protected roads, significantly decreasing the maximum FSP CRC. The calculated FSP concentration ranges by risk category indicate a greater observed range than what is currently possible if PLRM predictions are restricted to only stable and protected values. While the data collection did not adequately address the contribution of material eroded from pervious road shoulders, this comparison illustrates the difficulty with adequately attributing incremental FSP CRC reductions to specific actions when our observations of road condition evaluate the integrated cumulative signal of many interrelated actions.

5.1.2 ROADWAY RESEARCH FINDINGS

1. This research (see Figure 5.2) supports other Tahoe Basin studies (Kayhanian et al. 2005; 2NDNATURE and NHC 2010a; Heyvaert et al. 2010; El Dorado County, R. Wigart pers. comm.) that suggest field turbidity may be a cost-effective and reliable proxy for FSP concentrations measured in stormwater and streams. Due to the relatively high FSP concentrations observed on roads, the development of consistent methods to obtain and translate field turbidity to FSP concentrations should be a future management priority to reduce monitoring costs while increasing the availability of data.
2. The average pollutant concentrations obtained from roadway sampling were 451 mg/L, 783 and 0.04 for FSP, TSS and SRP respectively. These concentrations can be compared to average samples collected in stormwater runoff from mixed land use catchments of 120 mg/L, 350, and 0.06 respectively (2NDNATURE 2006b, Gunter 2005, and data from this research in Chapter 6*)*. This comparison suggests that the average FSP and TSS concentrations from roads are significantly higher than the average mixed land use signal. In contrast, the average SRP concentration is slightly lower suggesting that roads may not be a primary source of SRP to catchment pollutant loads.
3. Research findings confirm both the range and shape of the road CRC values used in the PLRM v1 database (see Figure 2.1) are consistent with the calculated observed values. While discrete measurements using the portable simulator are not directly comparable to the PLRM CRC values given spatial and temporal differences, the range of measured values can provide insight into the general shape and maximum and minimum values used in PLRMv1. The measured FSP, TSS and SRP values (see Figure 5.1) show a similar distribution to the values used in PLRM (see Figure 2.1) demonstrating an exponential decay in concentrations as road condition improves, and the measured maximum and minimum values indicate that the PLRM minimum CRC values are achievable and the maximum CRC values are within reason when compared to discrete observations (see Table 5.5).
4. Roadway condition (as measured by the concentration of FSP obtained from the portable simulator and/or Road RAM) has a significant seasonal variability with the poorest road conditions consistently observed during winter months (see Figure 5.3). Given that the observed roadway conditions consistently improve at all road segments through the summer and fall, all available information suggests road condition is most sensitive and controllable from winter road maintenance practices (see Figure 5.4).
5. Road condition was periodically evaluated at 32 sites from the winter 2009 through summer 2011. The winter snowfall totals increased each of these years, yet the datasets identifying the total amount of road abrasives applied as reported by the jurisdictions (see Figure 4.4) and road condition both suggest a trend of

decreasing application of road abrasives and improved winter road condition for water quality (see Figures 5.9 and 5.13). The increased focus on roads as the primary source of FSP generation in the Tahoe Basin appears to have had a positive influence on road maintenance practices conducted for water quality protection. The co-occurrence of reduced abrasive application volumes and improved road conditions over the course of this research provide another piece of evidence to suggest road maintenance practices have a significant influence on winter road conditions.

6. PLRMv1 bounds anticipated runoff quality and achievable runoff quality through improvements in road conditions based on the concept of road risk, which in PLRMv1 allows a user to select from six different categories of road risk. Comparison of the volume weighted average FSP concentrations from this study indicates that the PLRMv1 guidelines for defining and categorizing road risk may be insufficient to reasonably capture differences in operational practices across jurisdictions in the Tahoe Basin. In order to better estimate road runoff quality across jurisdictions in the Tahoe Basin: 1) the concept of road risk would need to be modified to account for differences in operational practices across jurisdictions, or 2) jurisdictions would need to agree upon a standard set of operational practices that would be performed for specific types of roads and physiographic characteristics.

7. Comparisons of predicted and calculated FSP concentration ranges (see Figure 5.14) suggest that frequent street sweeping can provide greater FSP CRC reductions than currently allowed in PLRM. For example, the lowest calculated FSP concentrations were actually on high and moderate risk roads where high abrasive applications were coupled with frequent sweeping with high efficiency sweepers. Given the recent findings that improved road condition is a cost-effective pollutant load reduction strategy for Tahoe jurisdictions (2NDNATURE and NHC 2011B), additional research that is capable of defensibly testing and quantifying the cause and effect linkages between road maintenance prescriptions, subsequent road condition and associated stormwater FSP loads would be extremely beneficial for the Tahoe Basin.

8. Road surface integrity is not a factor included in PLRM v1, but there is anecdotal evidence that suggests poor road surface integrity can increase the downslope water quality risk. Moderate to low risk roads have relatively elevated winter FSP concentrations (>600 mg/L) due to material storage in pavement cracks, yet summer observations are <50 mg/L, suggesting road washoff during spring rains can effectively mine the cracks of stored material and transport pollutants downslope (see Figure 5.13). Pavement conditions are known to significantly affect the pickup performance of street cleaners (Sartor and Boyd 1972). Street sweepers have considerable difficulty effectively picking up particulate material from streets whose pavements are classified as poor, because lots of surface cracks and deep depressions allow material to accumulate where it cannot be recovered effectively by sweepers. The uneven surfaces that accompany poor pavement conditions make it difficult for the sweepers to operate effectively, especially the newer air machines that require a seal contact with the pavement. In order to realize the benefits of better sweeper pickup performance, proper pavement maintenance activities are needed to maintain a minimum pavement condition. In addition, all cracks should be sealed on a regular and ongoing basis. Future research is required to quantify the effect of road surface integrity on road FSP concentrations with perhaps particular attention to how road integrity influences the effectiveness of maintenance practices. Road surface integrity should be incorporated into future PLRM estimations of the effectiveness of sweeping.

9. The minimum and 25% percentile value of all calculated volume weighted FSP values were 113 and 243 mg/L, respectively. These data indicate that improved road conditions within the Tahoe Basin are achievable with improved water quality maintenance techniques. Spatial prioritization of roads with the greatest hydrologic connectivity to Lake Tahoe could be a useful exercise to identify road segments where improved road maintenance would provide the greatest FSP load reduction benefit.

10. Observations suggest that even roads where abrasives are not frequently applied can accumulate FSP as a result of tracking, road surface degradation or other mechanisms and thus continued observations of road condition and responsive recovery mechanisms when necessary are essential.

5.1.3 PLRM ROAD METHODOLOGY RECOMMENDATIONS

Future modifications to PLRM Road Methodology should consider the findings in the above section. Recognizing that there is currently no timeline set for completing improvements to PLRM, recommendations are separated below into: 1) upgrades to user manual guidance for PLRM v1; and 2) potential approaches for long-term improvements.

PLRM V1 USER MANUAL UPGRADES

The WY2009-WY2011 road condition research results presented within this report suggest that the current guidance provided in the PLRM user manual to determine road risk categories within a Tahoe Basin urban catchment may be too confining. Currently, the user begins with the default values for road risk provided in a GIS shapefile associated with the PLRM software, which is based on primary and secondary roads as designated by the Lake Tahoe TMDL land use layer. Current PLRM guidance does provide a list of potential factors that may justify adjustments to the default layer (e.g., bus routes, busy intersections, main access routes to ski resorts, etc.); however, there is no clearly defined mechanism for evaluating differences across road locations. This lack of explicit guidance can result in subjective designations that are not consistent across Tahoe Basin urban jurisdictions.

In the near term, pending resources to integrate the technical improvements recommended below, an upgraded PLRMv1 user manual could help to resolve existing confusion by users and increase the tool usability. However, while this research has identified additional factors which users should consider while designating road risk (provided below), no specific upgrades to the user manual are provided at this time. Prior to providing such guidance, frequent PLRM users should be included in a PLRM user workshop to elicit input on which sections of the current user manual lack clarity and to gain feedback on any suggested upgrades. Without such input, there is the danger that the supplemental PLRM guidance may not decrease the subjectivity of the user inputs and/or may result in a process that is overly burdensome for the user. In the meantime, in addition to the factors provided on pages 54-55 of the current PLRM User Manual (NHC et al. 2009B), this research identifies the following items which should be considered as the user evaluates road risk within their jurisdiction:

- Road risk categories should be considered a continuum ranging from most frequent abrasive applications (PHR) to no abrasive applications (SLR), and users should not be constrained by the TMDL land use designations of primary and secondary roads. Based on the monitoring results of this research, it is possible for smaller local roads in the Tahoe Basin, which are categorized in the default PLRM road risk layer as secondary roads, to exhibit very high FSP concentrations that will require the road to be assigned the classification of a primary road in PLRM.
- Jurisdictions should consider the total average annual abrasives applied per lane mile in their jurisdiction compared to the Tahoe Basin average (see Figure 4.3). Jurisdictions who apply significantly more abrasives than the Tahoe Basin average will likely have roads at the higher end of the risk continuum.
- Roads with minimal to no parking pressure on the road shoulder will likely be a lower risk than roads where parking pressure is higher. Note this criterion is different that the road shoulder condition, as it

looks at the density of cars parked on the road shoulder and not whether or not they are able to park there.

- Arterial neighborhood roads are likely to be in higher risk than neighborhood roads with fewer access points, due to higher local traffic and increased abrasive tracking from nearby high risk roads.
- In general, roads in closer proximity to higher risk roads will likely have an increased risk due to abrasive tracking.
- Significant shade on the road surface, particularly if the shade is present for a majority of the day, will likely increase abrasive application and therefore increase risk.

POTENTIAL APPROACHES FOR LONG-TERM IMPROVEMENTS

Funding for PLRM technical updates and improvements has been secured through a SNPLMA Round 12 research grant for 'Stormwater Tools Improvement Project' and an interagency agreement is currently being negotiated between the Bureau of Land Management and Environmental Protection Agency. Based on the lessons learned from this research, there are two potential approaches to the future structure of the PLRM Road Methodology: 1) allowing a user to define an expected condition of road and thus the expected CRC, which would be verified through subsequent assessments (e.g., Road RAM); or 2) improving the existing approach, which incrementally lowers the CRC for a specific type of road based on a set of user-defined actions. Based upon the structure and advantages and disadvantages of each approach described below, the user defined CRC approach is the preferred recommendation of the research team and technical advisory committee.

ROAD METHODOLOGY APPROACH #1 – USER DEFINED CRC (I.E., ROAD CONDITION)

While a number of limitations associated with the ability to use a series of spatially and temporally discrete observations exist and have been outlined above, there is an opportunity to utilize the available road specific condition assessment tools (i.e., portable simulator and Road RAM) to guide PLRM users to define their own pre- and post-project road condition and associated CRC. Below is the general approach to a user defined road condition.

- Jurisdictions would group roads by the road maintenance practices conducted on a specific network of roads using classification guidance in the Road RAM User Manual as a starting point (see STEP 3 of 2NDNATURE et al 2010). Based on this research, the inclusion of road surface integrity and/or pavement management actions may be considered as a component of road class. Jurisdictions would be required to have very detailed descriptions of the practices conducted that define each class.
- The PLRM user would assign each road class with an FSP CRC depending upon existing or future practices. The research herein would be used as an initial guide to recommend a range of acceptable CRCs for each jurisdiction based on WY09-WY12 practices.
- In the future, the jurisdictions would implement road condition assessment efforts to obtain a series of spatial and temporal observations on specific road classes (characterized by different road maintenance prescriptions) to calculate the flow weighted average FSP concentrations. By applying a number of the techniques developed and implemented under this research effort, jurisdictions could simultaneously test the effectiveness of innovative road maintenance practices implemented on a subset of roads and quantify the expected improved prescription FSP CRCs to inform PLRM inputs. As new road maintenance prescriptions are identified and implemented, this flexible approach allows the incorporation of these

practices directly into PLRM estimates if the appropriate effectiveness assessment has been performed. Sharing of the quantified FSP CRCs by jurisdictions implementing similar prescriptions or interested in similar improvements would be encouraged.

- Road shoulder condition as it relates to road shoulder erosion and/or the stormwater entrainment of FSP on the pervious road shoulder is not adequately addressed by the current field evaluation techniques, and the developers would need to identify a solution to ensure this is still incorporated. The approach to isolating the contribution/influence of road shoulder condition on the road class CRCs presented above would certainly be considered.
- The experimental design and guideline details to provide the jurisdictions with a standardized approach to assessment, data analysis and CRC determination from the data obtained would need to be developed and documented.

The main benefits of a condition based approach to the PLRM Road Methodology are the alignment between model inputs and observations that can be verified in the field, and the elimination of the need for PLRM developers to estimate the incremental benefit of individual actions on the long-term average road condition. The Crediting Program requires jurisdictions to conduct and submit annual verification reports to justify annual credit awards based on their commitments during catchment registration. The current recommended method for verification of road condition is the use of Road RAM or equivalent, thus providing a direct programmatic link between the estimation tool (PLRM), the condition verification tool (Road RAM) and the award of annual credits when these two conditions align. The downsides include the lack of current guidance on how a jurisdiction should determine the appropriate CRC for current and future road practices and the need of future road monitoring to inform and verify the model inputs. In addition, this approach does require more on the ground observations and time spent evaluating road conditions. However, given the cost-effective opportunity for jurisdictions to achieve long-term FSP load reductions as a result of road condition improvements (2NDNATURE and NHC 2011B), continued focus on the water quality effectiveness of road maintenance prescriptions in the Tahoe Basin is likely.

ROAD METHODOLOGY APPROACH #2 – IMPROVE ACTION-BASED CRC ESTIMATIONS

PLRMv1 adjusts CRCs from road land uses based on a set of user-defined actions, which reduce CRCs in the model assuming that user-defined actions improve water quality by either reducing the pollutant sources or increasing the sinks. Based on the research herein, the following modifications would be explored to better align PLRM Road Methodology with factors observed to influence the FSP CRCs.

- The current PLRM Road Methodology merges estimated rates of road abrasive applications and road shoulder erosion into one algorithm to calculate a pollutant potential score in PLRM, which is then translated into a CRC for each pollutant modeled. The current algorithm is challenging to validate because it blends different mechanisms of pollutant generation into one prediction of runoff quality (pollutant build-up and wash-off on the road surface is combined with road shoulder erosion). To improve future PLRM validation efforts the current algorithm could be revised to separately define actions and estimate pollutant generation from the road surface relative to pollutant generation from the road shoulder.
- Based on this research, the current PLRM algorithms may be under-predicting the observed variability of FSP generation based on the condition of the road surface and over-predicting FSP variability from the condition of the road shoulder (see Figure 5.14). Some of the observed variability in FSP generation is due to differences in operational practices among Tahoe jurisdictions, and this variability should be addressed by developing standardized and well-defined approaches to winter road operations (see next bullet). If

road shoulder condition contributions to pollutant loads are isolated in a future version of PLRM, the challenge of quantifying the contribution and ability to recover pollutants from pervious shoulders will remain. The findings and limitations regarding road shoulder condition should be critically assessed when revising the PLRM Road Methodology.

- The road risk approach could be refined or replaced by a more quantifiable classification system defining standards for road maintenance practices. Under this approach, each Tahoe urban jurisdiction would develop a road operations plan that defines specific maintenance practices and seasonal road operations to be performed for each class of roads in their jurisdiction, which would then be linked to the revised classification system. The classification system would estimate the pollutant potential from a road surface based on defined metrics such as abrasive application rates, abrasive types, and potentially other metrics.
- The ultimate effectiveness of FSP recovery from street sweeping and the resulting improvement to an FSP CRC in PLRM is a highly debated topic. Nevertheless, the effectiveness of street sweeping in PLRM algorithms should be revaluated to consider the following factors:
    - Effect of road surface integrity on sweeping effectiveness estimates.
    - Effect of road shoulder condition on sweeping effectiveness estimates.
    - Ability of sweepers other than “high-efficiency” sweepers to recover a greater fraction of FSP on the road surface relative to what PLRM currently predicts. For example, PLRM provides a very minor credit for the use of mechanical broom sweepers for FSP recovery. However, mechanical broom sweepers can operate more efficiently in adverse weather conditions and can potentially recover coarse road abrasives prior to pulverization by vehicle traffic.
    - Maximum recovery credit the PLRM currently allows for “high-efficiency” street sweepers. This recommendation is based on observations during this research. The lowest observed winter FSP concentration was measured at the high risk Caltrans site EI in March 2009, when Caltrans was testing the use of a high efficiency sweeper (see Figure 5.9).

The main advantages of continuing with an action-based approach to the PLRM Road Methodology are 1) user familiarity with the current approach; 2) ease of model use as model inputs can be readily defined with some certainty; and 3) a manageable system to link and track PLRM modeling assumptions with actual road maintenance practices. Furthermore, the action-based approach reinforces to PLRM users the concept that incremental water quality benefits can be realized with specific operational changes to road maintenance practices. The action-based approach presents a significant model calibration and validation challenge as it is extremely difficult to isolate and quantify through monitoring, with reasonable accuracy, the incremental CRC reduction associated with a specific action. The comparisons in this report of calculated volume weighted average runoff concentrations from observed data and PLRM CRCs illustrate the difficulty in adequately attributing incremental FSP CRC reductions to specific actions, because observations of road condition evaluate the cumulative water quality signal of many interrelated actions. Furthermore, the action-based approach is based on the premise that a defined action will improve the condition of a road by some defined degree, which in turn improves the runoff quality predicted by the PLRM. As discussed below, the ultimate effect on water quality is based on the condition of a road and not the actions that might degrade or improve the condition. Consequently, through the action-based approach PLRM will continue to infer expected road conditions, which may not be reflective of actual road conditions when actions performed are more or less efficient at improving road condition relative to a PLRM prediction.

5.2 PRIVATE PARCEL CRCS

5.2.1 PRIVATE PARCEL RESULTS

The primary focus of the private parcel CRC research was to test a variety of sampling techniques to identify viable methods for collecting data that would be consistent with and comparable to the water quality data described in Chapter 5.1. The 2NDNATURE team tested several different sampling techniques, and a discussion of their effectiveness is discussed below.

IMPERVIOUS SURFACES

Two of the 34 road segment sites selected for the controlled experiments and Road RAM observations were located in commercial parking lots, likely the worst case scenario for pollutant generation on private parcels. Table 5.9 provides the observation period and calculated average annual FSP concentration results for these two sites, located in Raley's parking lots in South Lake Tahoe (RSLT) and Incline Village (RIV). Similar to the road water quality results, the 2 commercial parking lots show seasonal trends, with the highest concentrations recorded in the winter months, and lowest concentrations recorded in the summer and fall.

Table 5.9. Commercial parking lot concentrations observed during WY09-WY11 roadway monitoring. Values presented include the observed FSP concentrations by observation period, the average annual concentration based on the seasonal weighting presented in Table 5.6, and the PLRM predicted FSP CRC for CICU impervious surfaces both in existing and improved conditions.

CICU Imp	April 2009	May 2009	July 2009	Oct 2009	Jan 2010	Feb 2010	Mar 2010	Jan 2011	Mar 2011	Ave Annual	PLRM Predicted CRCs	
											Existing	Improved
RIV	147	88.5	105	22.7	574	1040	878	878	680	**417**	187	129
RSLT	57.8	24.7	22.7	22.7	956	291	345	445	317	**218**		

Table 5.9 also presents the comparison of the PLRM predicted FSP CRC values for CICU impervious surfaces to the calculated average annual FSP concentration. While the data is limited, it does suggest that commercial parking lots have the potential to generate relatively high FSP concentrations. It is assumed that parking lots and driveways posses the highest potential FSP loading surface type within commercial or residential land uses. The CICU CRCs used in PLRM are expected to be commercial land use average that would include the contribution of relatively lower FSP generating surface types such as roofs and sidewalks, thus making the PLRM predicted CRCs in Table 5.9 reasonable. Similarly, source control efforts on private parcels should prioritize surfaces where cars transport and deposit FSP potentially accumulated elsewhere.

PERVIOUS SURFACES

The following provides a brief discussion of the pervious monitoring techniques tested during this research, including the pros, cons, and preliminary results when appropriate.

CONTROLLED EXPERIMENTS

The portable sampler was initially tested on pervious surfaces, in the hopes that the sampling methods could be standardize to reduce sampling variability and improve comparisons across land use types. However, as described in Chapter 3.1.3, there were several issues which resulted in our inability to control the volume applied and to

capture a standardized amount runoff from the portable simulator on pervious surfaces. Therefore a few other techniques were tested and are explained below.

PARTICLE GRAIN SIZE ANALYSIS

The collection of dry material from a 1 ft^2 area of exposed soil on a private parcel was tested because the technique could be done rapidly, allowing the collection of a large number of samples from a range of locations in a short amount of time. The sampling area can be standardized across all sites, and equivalent to the sampling area used for the controlled experiments on impervious surfaces. However, there were the following disadvantages that resulted in the data being inappropriate for comparisons to PLRM private parcel CRC values:

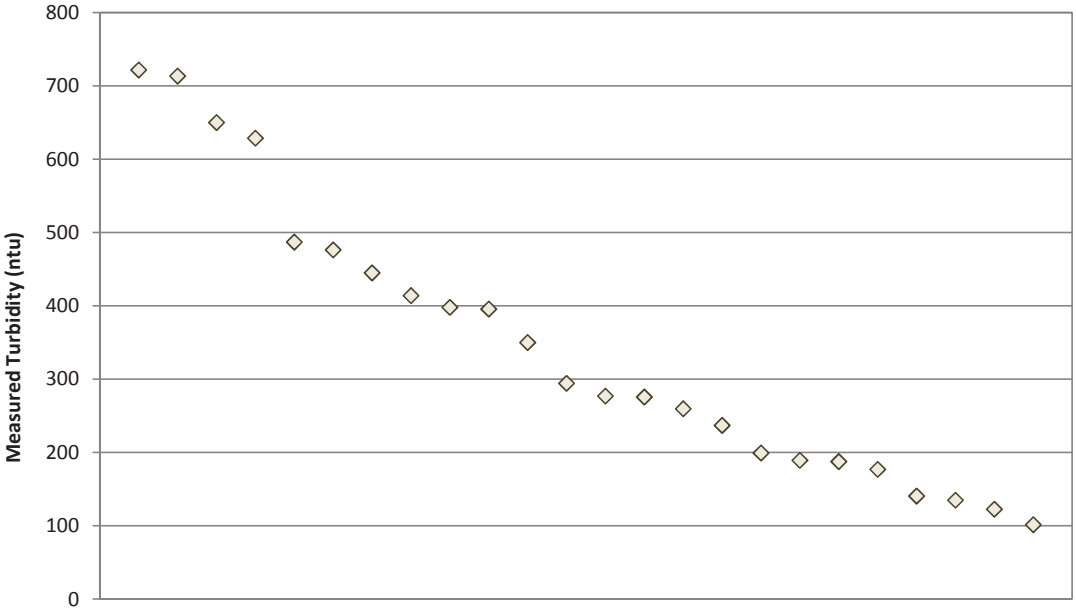
1. Particle grain size distribution is strongly dependent upon the fraction of coarse material present in the sample. All samples were sieved through a 2 mm mesh to standardize the volume and reduce the variability of the grain size distribution of the material submitted to the laboratory. However, the differences in the % of the sample < 16 μm covered a range of less than 15% making our confidence that we could detect differences across sites beyond our sampling error questionable.
2. The submission of the samples to the laboratory for analysis reduces the cost-effectiveness of the sampling technique, and the research team was unable to determine appropriate field observations that correlated to the particle size distribution results to reduce future analytical costs.
3. The collection of samples from exposed surfaces within a private parcel represent the worst case scenario for pollutant generation from a private parcel, whereas PLRM predicts a FSP concentration which integrates all surface types within all parcels of the same land use within a catchment. A technique for spatially weighting the distribution of surface types within a parcel would be necessary to make more suitable comparisons.

WATER QUALITY TURBIDITY TESTS

Similarly to the particle grain size analysis techniques, the water quality turbidity tests had a standardized sampling area that was equivalent to the controlled experiments. The water quality turbidity tests also aimed to address the first disadvantage listed above for the particle grain size analysis technique (the inability to correlate dry material sample results to water quality results). Figure 5.15 ranks the measured average turbidity concentrations of the 24 samples analyzed, and demonstrates the detection of a significant range of turbidity values across sites. Regardless, the turbidity results did not correlate with simple field observations of the relative compaction and/or visual relative degree of disturbance of the pervious surface samples. Disadvantages of this technique include:

1. Measured values shown in Figure 5.15 represent a single 1 ft^2 area within the entire private parcel, while PLRM predicts a parcel average FSP concentration. As shown with the road water quality data, a single 1x1 area is unlikely to represent the average of a larger area. The measured values would need to be spatially weighted based on % distribution within the parcel to be more comparable to PLRM predictions. This is similar to the discussion of the spatial integration of road controlled experiments on a 1ft^2 area to an entire road segment (10,000 ft^2) in Chapter 5.1.
2. Sampling technique is biased due to the collection of all material within a 1x1 square rather than the portable sampler that requires material to mobilized and transported into the sampler simulating a runoff microcosm. Sampling methods therefore assume 100% entrainment of the sediment in stormwater, when in reality the concentrations are likely to be significantly lower due to (1) infiltration through the subsurface and (2) particle capture as the runoff travels over vegetation, organic matter, etc within the parcel.

RANKED PRIVATE PARCEL PERVIOUS SURFACE TURBITY MEASUREMENTS



Range of 25 water quality turbidity measurements, ranked high to low, from pervious surfaces on private parcels representing a range of observed condition. While the measurements indicate a range of observed turbidity values, a meaningful statistical correlation of turbidity to simple field observations of relative compaction and/or degree of disturbance was not identified.

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3. Private parcel land use samples were collected in an area of exposed soil, which will preferentially bias the results towards higher concentrations. Areas with erosion control BMPs, such as vegetation, will have less erodible soil and therefore lower generation of FSP.

5.2.2 PRIVATE PARCEL RESEARCH FINDINGS

1. Realistically, the greatest influence on stormwater pollutant load reductions from private parcels will result from implementation of private parcel BMPs that infiltrate runoff volumes and provide effective source controls on site. Future research should prioritize evaluations of how to implement, maximize and maintain the effectiveness of private parcel infiltration BMPs over time.
    - Effective and well maintained infiltration BMPs will significantly minimize the runoff contributions from parcels before it enters the stormwater conveyance system, thereby reducing the necessary capacity and treatment capabilities of downstream treatment BMPs.
    - Effective source control actions will eliminate the introduction of pollutants into the stormwater system. The high number of observations of pervious and impervious surfaces of all land use types during this research suggests that TSS and FSP source control efforts on private land uses should target strategies that reduce the potential accumulation and subsequent transport from impervious surfaces and highly compacted pervious surfaces where cars frequently park, such as driveways and parking lots, particularly in the winter. Strategies that reduce the amount of FSP available on these surfaces prior to subsequent runoff events (such as sweeping and removal) will reduce the distributed contribution of the primary pollutant in stormwater from private land uses.
2. If future water quality monitoring of private land uses occurs, the data collection should focus on the concentrations emanating from the impervious and highly compacted pervious surfaces. These surfaces likely are the biggest influence on pollutant transport from private land uses, as a significant portion of the surface water flowing over pervious surfaces will be infiltrated and never reach the stormwater conveyance system. The portable simulator is a reasonable and repeatable device that can cost-effectively assist with the generation of a large impervious surface water quality dataset, but this effort demonstrates its limitations and poor field precision on even highly compacted pervious surfaces.
3. There are a myriad of challenges associated with cost-effectively sampling the runoff quality from a specific land use type. Ideally the isolated runoff from a series of discrete parcels of a specific land use type and condition could be collected and compared, but the ability to instrument and isolate specific land use types would be technically challenging if not impossible and would result in excessive instrumentation and monitoring cost. Given the objectives and the resources available for this effort, an appropriate cost effective technique to obtain water quality data from pervious surfaces adequate to compare to CRC values was, unfortunately, not identified.

5.3 ROAD SHOULDER INFILTRATION

5.3.1 ROAD SHOULDER RESULTS

COMPARISON TO CURRENT PLRM ALGORITHM

Table 5.10 compares measured K_{sat} to predicted K_{sat} using the PLRM[5] v1 algorithm. As shown in Table 5.10, field measurements of K_{sat} have significant variability across sites and Soil Survey Map Units. The current PLRM algorithms that combine hydrologic properties for a Soil Survey Map Unit and a land-use based compaction factor do not appear to provide an adequate method to estimate the variability observed in K_{sat}. Note that because road shoulders can be highly modified, the soil measured in the road shoulder may not be representative of the Soil Survey Map Unit defined in Table 5.10. This discrepancy may be influencing the interpretation of Table 5.10.

Table 5.10. Comparison of measured K_{sat} to current PLRM algorithm[4].

Map Unit	Texture of Soil Horizon Sampled	PLRM Unimpacted K_{sat} [in/hr]	PLRM Secondary Road K_{sat} [in/hr]	PLRM Primary Road K_{sat} [in/hr]	Field Measured Road Shoulder K_{sat} [in/hr]		
					Max	Min	Median
7172	Gravelly Medial Sandy Loam	5.0	1.5	1.0	13.00	1.00	2.17
7222	Very Cobbly Sandy Loam	3.8	1.1	0.8	12.50	2.33	7.42
7444	Loamy Coarse Sand	12.0	3.6	2.4	1.83	0.08	0.47
7421	Gravelly Loamy Coarse Sand	5.0	1.5	1.0	4.50	0.67	1.83
7491	Coarse Sandy Loam	1.6	0.5	0.3	9.33	0.17	1.25
7471	Loamy Coarse Sand	13.5	4.0	2.7	2.00	0.33	1.22

COMPARISON OF ROAD LAND USE TO MEASURED K_{SAT}

Table 5.11 compares measured K_{sat} for all sites by the type of road land use (secondary or primary road). As shown in Table 5.11, secondary roads have a higher average K_{sat} relative to primary roads and a much larger standard deviation. While additional data collection may be warranted to better assess the variability of K_{sat} for primary roads, it is likely that the variability of measured K_{sat} for secondary roads will remain larger because the condition of road shoulders is relatively uniform for primary roads.

Table 5.11. Road land use type and measured K_{sat}

Road Type	K_{sat} [in/hr]			Standard Deviation	# of Samples
	Max	Min	Ave		
Secondary	13.00	0.08	2.04	3.22	38
Primary	2.00	0.33	1.19	0.76	6

[5] A bug in PLRMv1 was discovered during this research. The values shown in Table 5.11 are the intended values that PLRM is supposed to estimate. Values derived from PLRM version 1.1 for Ksat will be slightly lower than those shown in Table 5.11.

COMPARISON OF COMPACTION MEASUREMENTS TO MEASURED KSAT

Figure 5.16A presents measurements of cone penetrometer depth and K_{sat}. No correlation across cone penetrometer depths with measured K_{sat} is apparent in Figure 5.16A. It should be noted that sites with relatively low cone penetrometer depths (less than two inches) had Ksat measurements below two inches/hour. Conversely, sites with relatively high cone penetrometer depths (greater than three inches) had Ksat measurements at or above two inches/hour. This result may indicate that while cone penetrometer depths cannot be used to infer Ksat for all soil conditions, it may be a useful measurement to quickly distinguish between highly compacted soils with lower Ksat and relatively undisturbed soils with higher Ksat.

COMPARISON OF ROAD SHOULDER CONDITION AND MEASURED KSAT

Table 5.12 compares the observed road shoulder condition defined using the PLRM Road Methodology with measured K_{sat}. While additional data collection may be warranted to increase the sample size to better assess the variability of K_{sat} with observed condition, the following points about the data presented in Table 5.12 are noted:

- Erodible road shoulders have the lowest variability in measured K_{sat}. This observation is likely due to all erodible road shoulders having some level of disturbance by definition, which diminishes the potential for high K_{sat} measurements.
- There is significant variability in measured K_{sat} for stable and stable and protected road shoulders. This observation may indicate that condition alone cannot be used to infer K_{sat} for stable and stable and protected road shoulders. In these cases, soil type may be the dominant factor influencing K_{sat} for road shoulders.

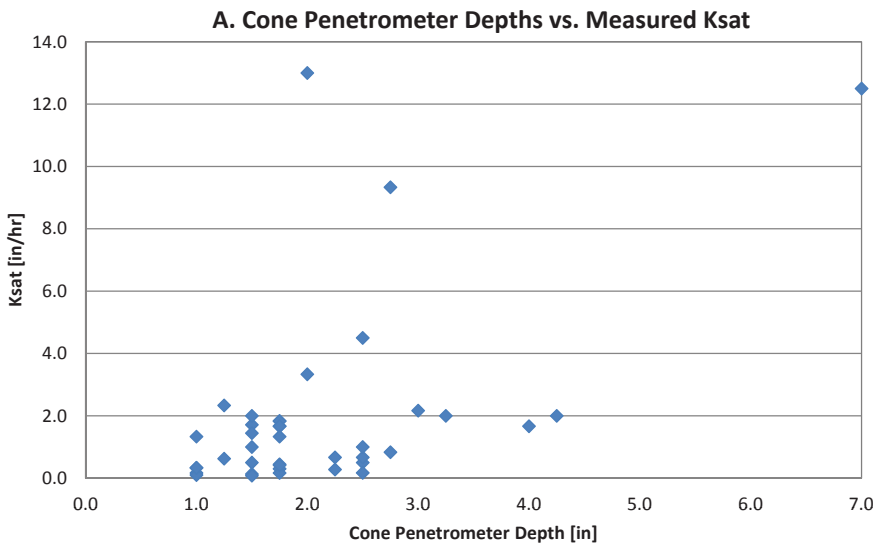
Table 5.12. Road shoulder condition and measured Ksat

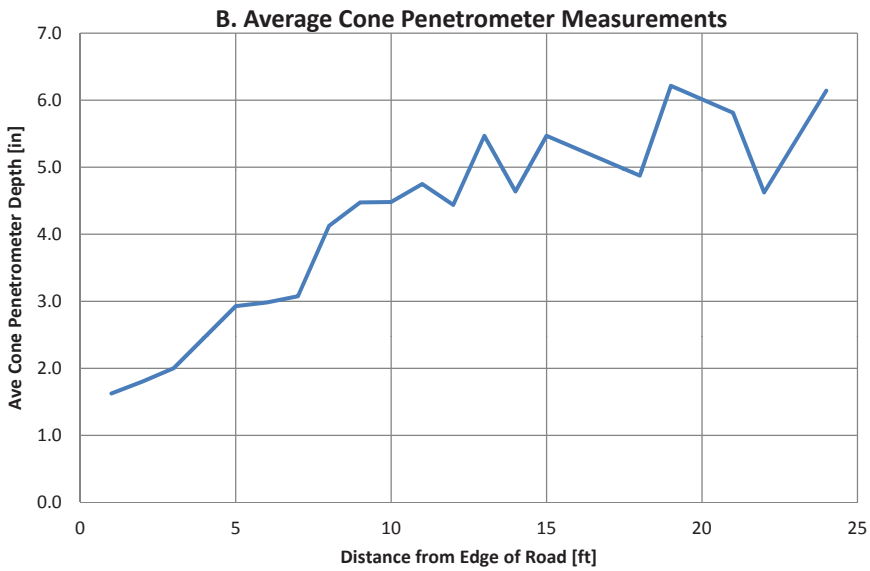
PLRM Road Shoulder Condition	K_{sat} [in/hr]			Standard Deviation	# Samples
	Max	Min	Ave		
Erodible	2.33	0.08	0.97	0.75	28
Stable Only	9.33	0.17	2.83	2.93	8
Stable and Protected	13.00	0.67	6.23	6.03	5

TRANSECTS

Figure 5.16B shows the average cone penetrometer depth for all transects as a function of distance from the edge of the road. Figure 5.16B demonstrates that average soil compaction decreases with distance from the edge of the road surface. Average cone penetrometer measurements had a relatively constant increase until a distance of roughly 12-15 feet from the edge of road. After about 15 feet from the edge of the road, average cone penetrometer measurements varied between 5 and 6 inches but did not demonstrate a trend of continued increase with distance from the edge of the road.

Table 5.13 summarizes statistics for measured K_{sat} within three to five feet of the edge of the road and 24 feet from the edge of the road. Three of the seven K_{sat} values measured at 24 feet from the edge of the road were too rapid to be within the range of accuracy for the CHP. These measurements were included in the analysis assuming a rate of 20 in/hr. As shown in Table 5.13, measured K_{sat} is notably higher with increased distance from the edge of the road.





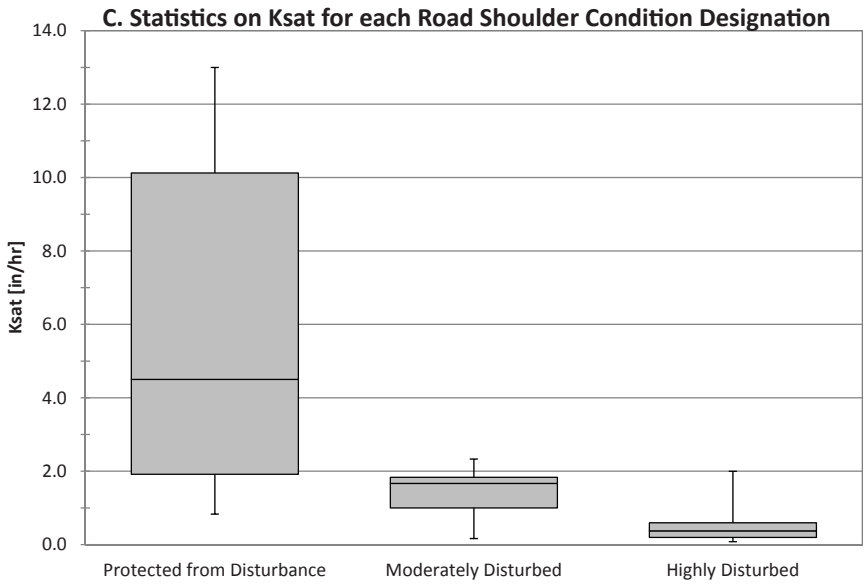


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FIGURE 5.16

Table 5.13. Transects and measured K_{sat}

Distance from Impervious [ft]	K_{sat} [in/hr]			Standard Deviation	# Samples
	Max	Min	Median		
3 or 5	9.33	0.33	1.83	3.10	7
24	20.00	9.50	14.67	4.27	7

5.3.2 ROAD SHOULDER INFILTRATION RESEARCH FINDINGS

Based on the results and interpretation presented above, a simple method was developed to categorize road shoulder condition at each road shoulder site to infer a default K_{sat} in PLRM. Road shoulder condition was defined as either: highly disturbed, moderately disturbed, or protected from disturbance, based on qualitative observations made in the field about the level of disturbance of the majority of the pervious portion of the road shoulder (see Appendix B for a decision tree to identify road shoulder condition).

Statistical results for road shoulders comparing the estimated condition with measured K_{sat} are shown in Figure 5.16C. For conditions defined as either highly disturbed or moderately disturbed, the measured K_{sat} in the road shoulder exhibits a relatively narrow range of values. Conversely, for the condition defined as protected from disturbance, a wide range of measured K_{sat} values was observed. These results appear to indicate the following:

- Road shoulder compaction is likely the primary factor influencing measured K_{sat} values in road shoulder soils with conditions observed as either highly disturbed or moderately disturbed. In these cases, soil type may not strongly influence measured K_{sat} values.
- For road shoulders observed in the protected from disturbance category, soil type is likely the primary factor influencing measured K_{sat} values. In this case, compaction estimates or visual observations of disturbance do not appear to provide strong correlations and cannot be used to infer K_{sat}.

CHAPTER 6. STORMWATER TREATMENT BMP RESEARCH

The stormwater treatment BMP research was conducted to obtain cost-effective hydrologic and water quality datasets from nine different treatment BMPs (termed SWTs in PLRM) within the Tahoe Basin in a manner that would allow comparisons of measured data to PLRM hydrologic predictions and inform the PLRMv1 CEC values particularly for FSP. Based on SWT type and key design attributes, PLRM predicts the average annual volume captured and treated by the SWT (treated flow) and the average annual volume not captured (bypass flow) (see schematic on page 2.6). Treated flow is assigned a CEC for each pollutant based on the type of SWT modeled. Bypassed flow retains the inflowing pollutant concentrations routed to the SWT at each time step, which is calculated by PLRM as the flow-weighted average of CRCs for land uses contributing to the SWT. The CEC values used within the PLRMv1 database (see Table 2.3) were determined using limited Tahoe specific data, particularly for fine sediment particles (FSP), which is the primary pollutant of concern. The results below compare PLRM predictions of SWT performance on event, seasonal and annual time steps for four SWTs for monitoring periods where confidence in the measured data was high. In addition, over 100 treated outflow samples were collected from the nine SWTs over the 3 water years and this data is used to compare measured pollutant concentrations in treated outflow to CEC values used in the PLRMv1.

6.1 SWT HYDROLOGY RESEARCH

6.1.1 COMPARISON OF OBSERVED VERSUS PREDICTED PERFORMANCE

The PLRM hydrology module (SWMM-based) predicts stormwater runoff from urbanized catchments and generates a time-series of surface runoff for an 18-year continuous simulation. At each time step in the simulation, surface runoff from contributing catchments may be routed to SWTs. Based on the user inputs of SWT type and key design attributes, PLRM predicts the average annual volume of water captured by the SWT over the 18-year simulation, where:

$$V_{CAP} = V_{ET} + V_{INF} + V_{OUT_T} \text{ (EQ 6.1)}$$

$$\%_{CAP} = V_{CAP} / V_{IN} \text{ (EQ 6.2)}$$

The captured volume (V_{CAP}) includes volume losses due to evapotranspiration (V_{ET}), infiltration (V_{INF}), and outflow through the treated outlet (V_{OUT_T}), and hydraulic capture ($\%_{CAP}$) is defined as the percent of the inflow volume (V_{IN}) treated by the SWT (V_{CAP}). The remaining volume not captured and treated by the SWT is considered bypass (V_{OUT_B}). Definitions for each variable are provided in Appendix C. Table 6.1 presents the PLRM average annual volume estimates for inflow, treated outflow, infiltration and evapotranspiration, and bypass, as well as the predicted % hydraulic capture for 5 SWTs monitored during this research. The PLRM models for each catchment and SWT were built using the information provided in Tables 3.4 and 3.5.

Table 6.1. PLRM average annual hydrology estimates (WY1989-WY2006).

BMP Type	Site	Inflow (ac-ft)	Treated Outflow (ac-ft)	Infiltration + ET (ac-ft)	Bypass Outflow (ac-ft)	Hydraulic Capture (%)
Dry Basin	Rocky Point	16.3	14.4	0.9	1.0	94%
	PA2	39.6	18.1	17.8	3.8	91%
Wet Basin	Osgood	39.4	24.8	0.5	14.1	64%
	Eloise	215.4	44.8	0.4	170.3	21%
	PA1	34.3	26.9	1.1	6.3	82%

Observed hydrologic performance in each SWT was calculating based on water balance equations developed from high resolution (15 min interval) water depth monitoring and detailed topographic surveys of each SWT, which including surveys of inlet and outlet structures that controlled surface water elevations in each SWT. All hydrologic monitoring data collection and the associated analysis methods are detailed in Chapters 3.1.4 and 3.2.1. Instrument failure and data gaps did occur during the monitoring effort, which limited the quality and extent of datasets that that were deemed appropriate to compare to predicted performance in PLRM. Of the 9 SWTs instrumented with depth recorders, three wet basins (Osgood, PA1 and Eloise) and two dry basins (PA2 and Rocky Point) resulted in reliable observed hydrologic data (Figures 6.1A-E). See Table 3.5 and Chapter 3.1.4 for a discussion of the difficulties in calibrating the depth gage data at the other SWTs.

For SWTs and time periods with reliable water depth datasets, observed calculations of hydrologic performance are compared to PLRM estimates of performance (Table 6.2). While Table 6.1 displays annual average PLRM estimates of hydrologic performance, Table 6.2 displays predicted performance from PLRM simulations on an annual and seasonal basis for time periods with reliable monitoring data during water years 2009 through 2011. The seasonal approach was taken to evaluate potential differences in observed and predicted performance from variable meteorological conditions in the Tahoe Basin and the associated differences in hydrologic responses, which include: 1) runoff generated by a mixture of rain and snowmelt (October- February); 2) runoff that includes a significant spring snowmelt component (March-May); and 3) runoff generated by rain events and thunderstorms (June-Sept). The categorization of seasons used by this research is consistent with the season definitions in the RWQCB NPDES permit monitoring requirements (LRWQCB 2011).

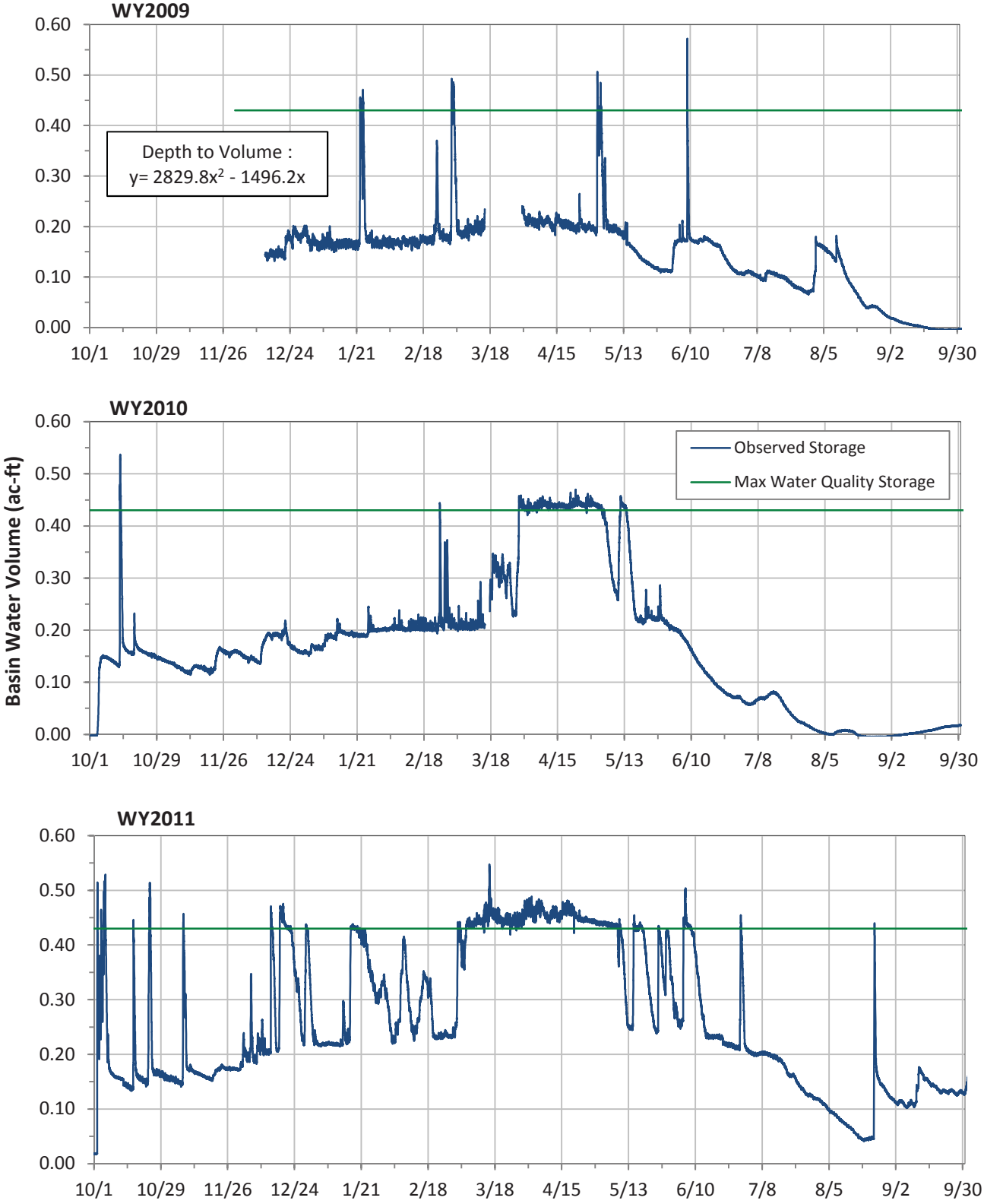
As discussed in Chapter 4.1 and shown in Figure 4.1, the 18-yr PLRM simulation (WY1989-WY2006) represents a range of dry, average and wet water years, while the water years monitored during this research represent one average year and two wet years, with total precipitation increasing in each year during the study from WY2009 to WY2011. Given the difference in the distribution of water year types between the two datasets, the use of standard PLRM outputs that present average annual SWT performance (see Table 6.1) to the observed seasonal estimates (see Table 6.2) is not an appropriate comparison. Therefore, post-processing of output generated by PLRM models was completed in SWMM (see Chapter 3.2.2) to predict the seasonal hydrologic performance of each SWT (see Table 6.2) to compare with the monitoring data, as discussed in more detail below.

LIMITATIONS ASSOCIATED WITH SWT MONITORING AND MODELING

Each SWT monitored during this research has known idiosyncrasies which complicated representations of SWT performance model through PLRM, as well as the calculations of observed hydrologic performance using the water balance equations. Site-specific issues include:

- Rocky Point Basin: The Rocky Point Basin is comprised of two dry basins that are connected via a culvert (see Figure 3.7E). Water levels were recorded in the south basin for this research, which due to the direct hydraulic connection between the two basins also represents water levels in the north basin. The outlet structures of both basins are identical and include a single orifice (treatment outlet) and concrete weir (bypass outlet). The north basin is used by the adjacent commercial properties for snow storage, which complicates the analysis of water level data because the stored snow may have artificially raised recorded water levels during the winter and spring. Furthermore, the single treatment orifice used to drain the basins (treatment outlet) was found to be clogged with debris on at least one occasion, which could have led to variable treatment performance and this variability adds uncertainty to the analysis of water level data and the modeled representations of performance in PLRM.

Osgood Basin Volume Time Series WY2009-WY2011



Frequency of Occurrence: Water Storage Above Outlet Elevation Resulting in Treated Outflow / Bypass Outflow

WY	Season		
	Fall/Winter	Spring	Summer
WY09	55% / 1%*	77% / 2% *	12% / 0%
WY10	46% / 0%	100% / 41%	7% / 0%
WY11	75% / 12%	100% / 83%	39% / 3%

* significant data gaps in observed volume time series

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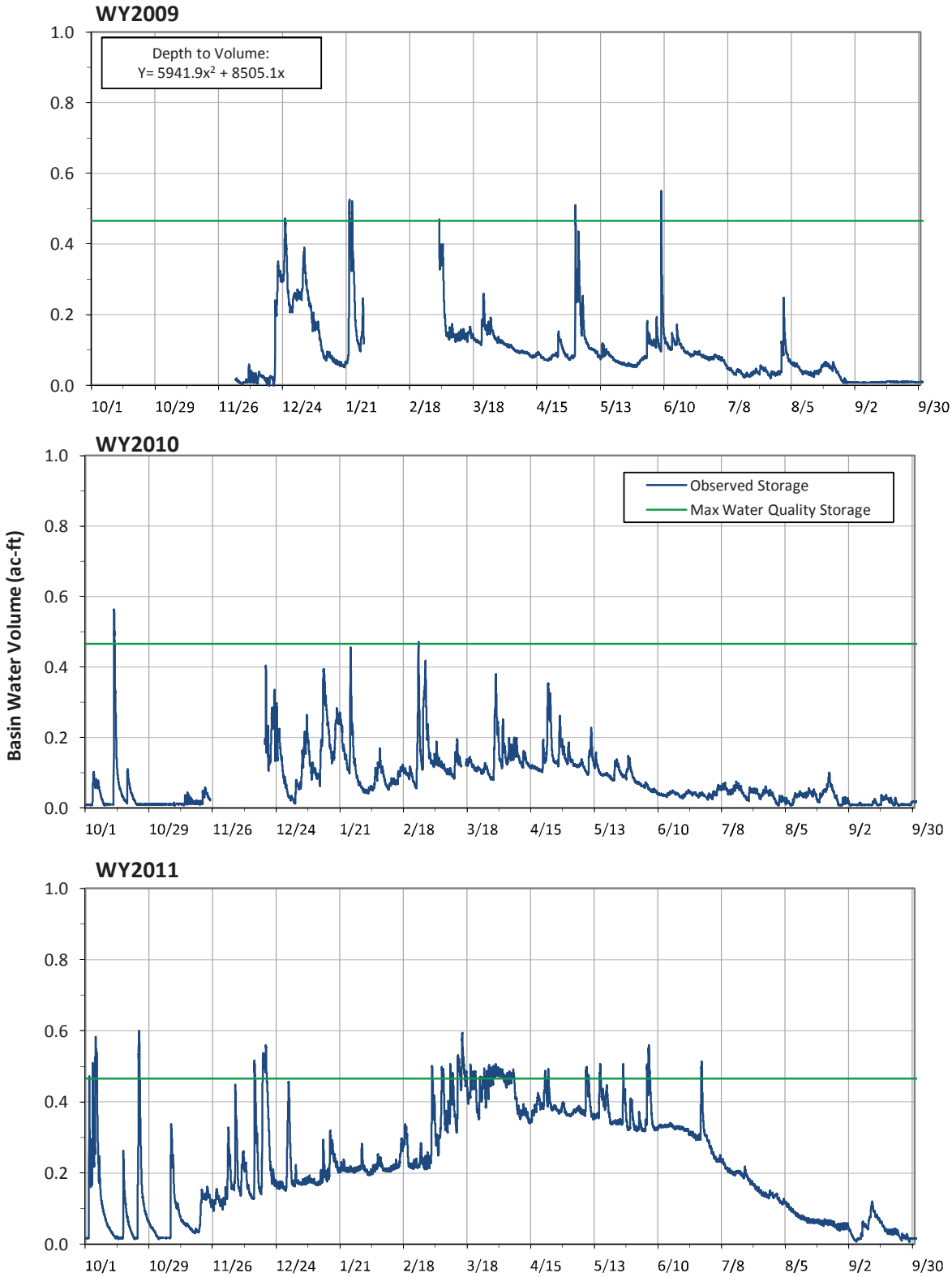
OSGOOD BASIN VOLUME TIME SERIES

FIGURE 6.1A

Park Avenue Upper Basin (PA1) Volume Time Series WY2009-WY2011



Frequency of Occurrence: Water Storage Above Outlet Elevation Resulting in Treated Outflow / Bypass Outflow

WY	Season		
	Fall/Winter	Spring	Summer
WY09	59% / 2%*	88% / 1%	32% / 1%
WY10	46% / 1%*	100% / 0%	2% / 0%
WY11	79% / 3%	100% / 33%	61% / 2%

* significant data gaps in observed volume time series

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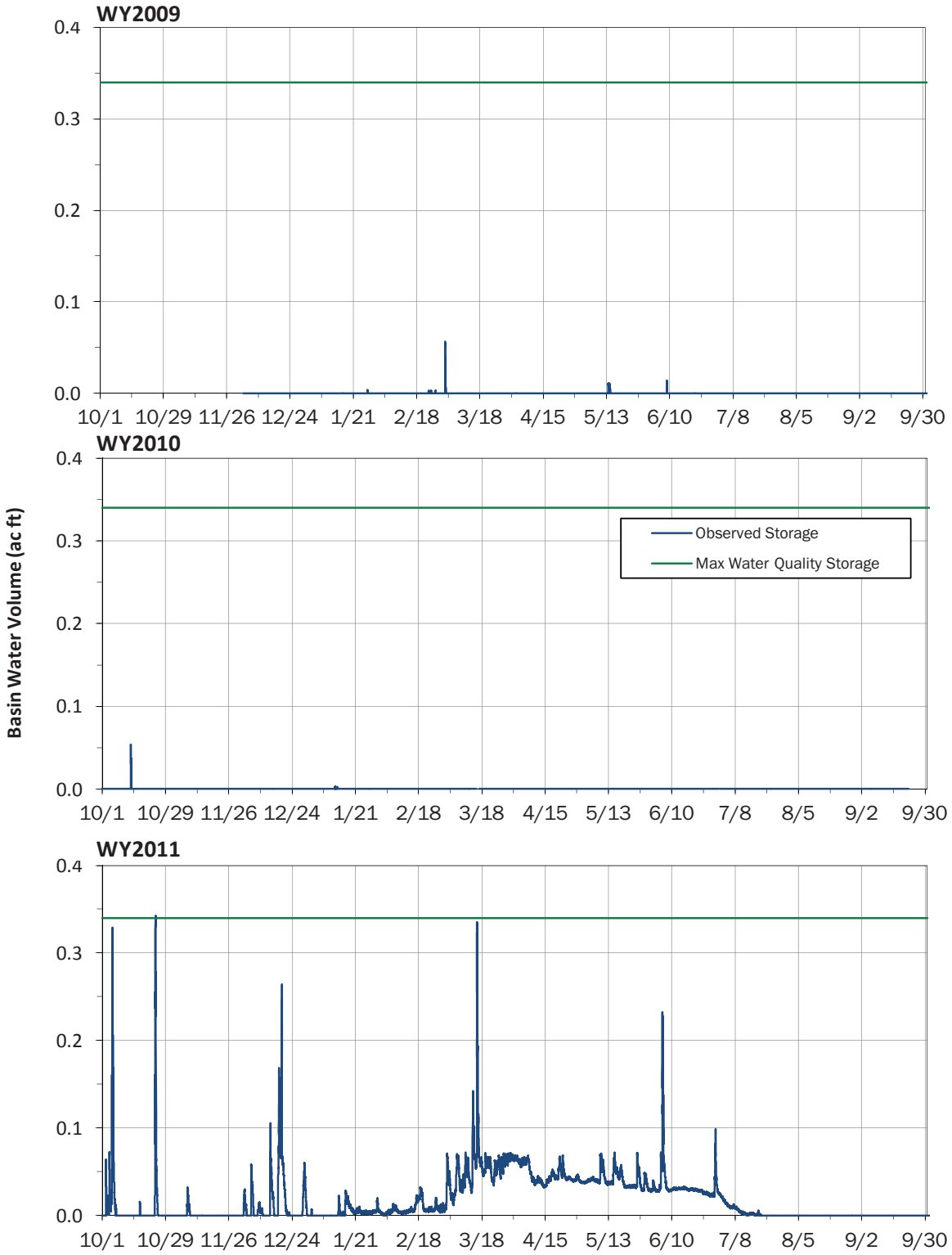
PA1 BASIN VOLUME TIME SERIES

FIGURE 6.1B

Park Avenue Lower Basin (PA2) Volume Time Series WY2009-WY2011



Frequency of Occurrence: Water Storage Above Outlet Elevation Resulting in Treated Outflow / Bypass Outflow

WY	Season		
	Fall/Winter	Spring	Summer
WY09	0% / 0%	0% / 0%	0% / 0%
WY10	0% / 0%	0% / 0%	0% / 0%
WY11	0% / 0%	0% / 0%	0% / 0%

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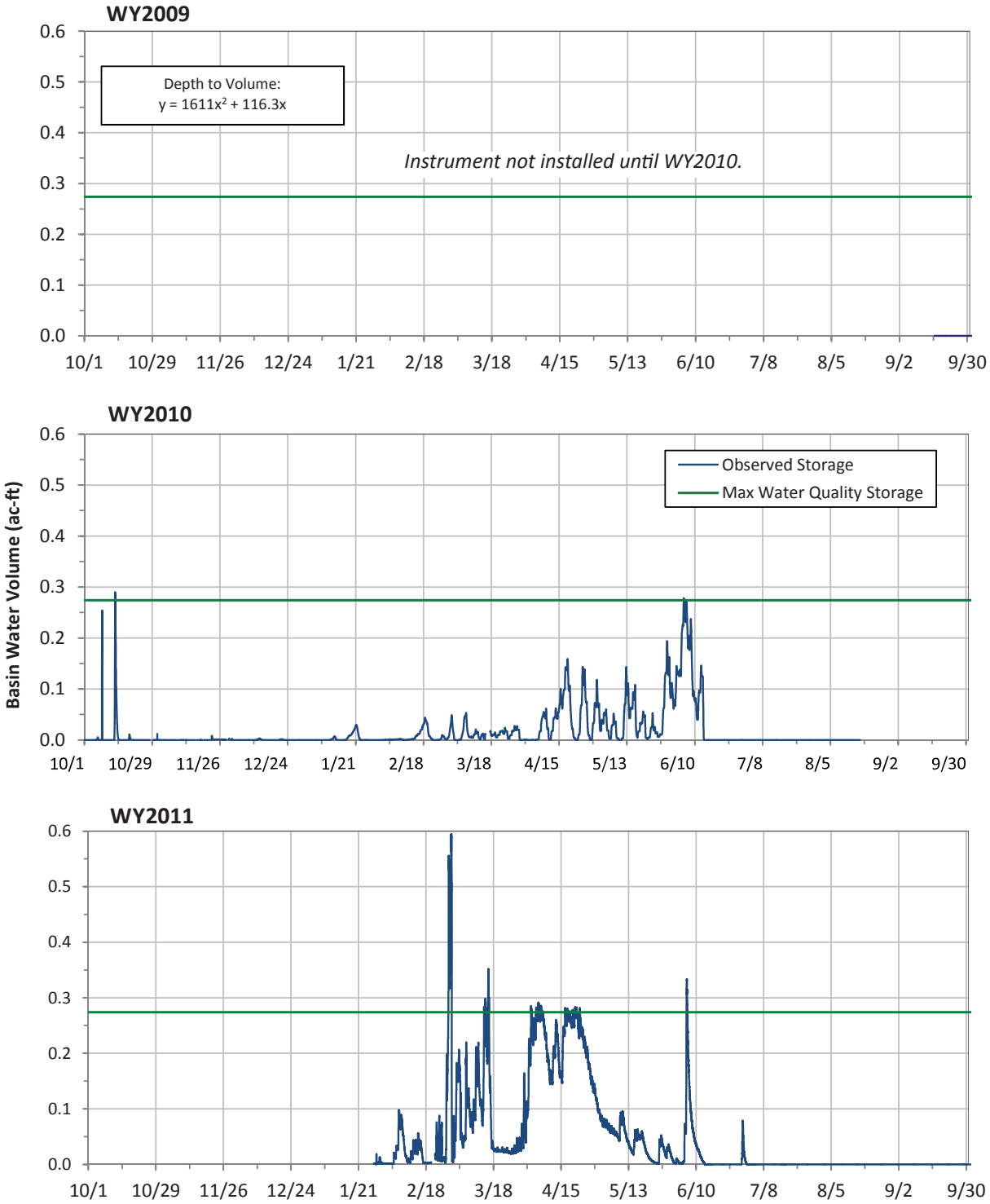
PA2 BASIN VOLUME TIME SERIES

FIGURE 6.1C

Rocky Point Basin Volume Time Series WY2009-WY2011



Frequency of Occurrence: Water Storage Above Outlet Elevation Resulting in Treated Outflow / Bypass Outflow

WY	Season		
	Fall/Winter	Spring	Summer
WY09	-	-	-
WY10	5% / 10%	50% / 0%	11% / 1%
WY11	41% / 5%*	91% / 3%	6% / 1%

* significant data gaps in observed volume time series

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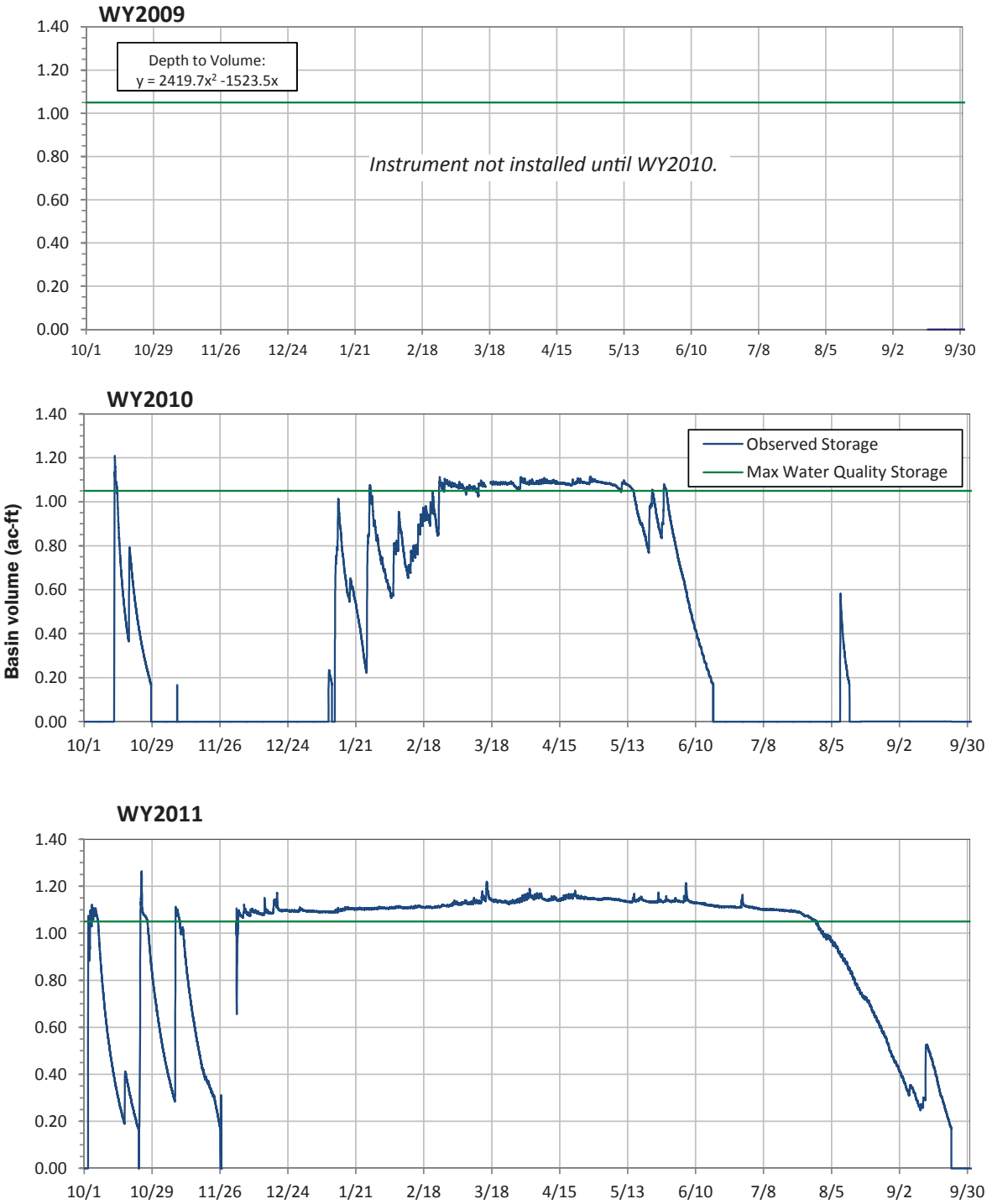
Eloise Basin Volume Time Series WY2009-WY2011



Frequency of Occurrence: Water Storage Above Outlet Elevation Resulting in Treated Outflow / Bypass Outflow

WY	Season		
	Fall/Winter	Spring	Summer
WY09	-	-	-
WY10	80% / 8%*	100% / 82%	44% / 0%*
WY11	83% / 68%	100% / 100%	73% / 50%

* significant data gaps in observed volume time series

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BMP Type	Site	Season	Start Date	Stop Date	# Days	Observed					PLRM Predicted				
						Inflow (ac-ft)	Treated (ac-ft)	Infiltration + ET (ac-ft)	Bypass (ac-ft)	Hydraulic Capture (%)	Inflow (ac-ft)	Treated (ac-ft)	Infiltration + ET (ac-ft)	Bypass (ac-ft)	Hydraulic Capture (%)
Dry Basin	Rocky Point	Spring WY11	01-Mar-11	31-May-11	92	40.4	38.9	0.2	0.9	96%	9.4	8.6	0.5	0.3	97%
		Summer WY11	01-Jun-11	30-Sep-11	122	3.5	2.9	0.0	0.3	82%	1.8	1.7	0.1	0.0	100%
	PA2	Fall/Winter WY11	01-Oct-10	28-Feb-11	151	2.2	0.0	2.2	0.0	100%	36.6	13.1	13.4	10.1	73%
		Spring WY11	01-Mar-11	31-May-11	92	3.0	0.0	3.0	0.0	100%	23.3	9.6	9.5	4.3	82%
		Summer WY11	01-Jun-11	30-Sep-11	122	1.5	0.0	1.5	0.0	100%	3.9	2.0	1.9	0.0	100%
Wet Basin	Osgood	Summer WY09	01-Jun-09	30-Sep-09	122	3.6	1.9	0.9	0.9	68%	2.6	2.0	0.0	0.6	78%
		Fall/Winter WY10	01-Oct-09	28-Feb-10	151	14.0	9.6	0.8	3.2	74%	23.4	13.5	0.3	9.6	59%
		Spring WY10	01-Mar-10	31-May-10	92	54.7	12.8	0.7	41.2	24%	11.7	10.6	0.1	1.1	91%
		Summer WY10	01-Jun-10	30-Sep-10	122	1.7	1.1	0.8	0.0	97%	1.0	1.0	0.0	0.0	100%
		Fall/Winter WY11	01-Oct-10	28-Feb-11	151	141.6	15.7	0.9	124.8	12%	40.9	14.8	0.1	25.9	37%
		Spring WY11	01-Mar-11	31-May-11	92	900.0	12.8	0.8	886.3	1%	22.4	14.3	0.1	8.0	64%
		Summer WY11	01-Jun-11	30-Sep-11	122	13.5	6.9	1.0	5.7	55%	5.8	2.7	0.0	3.1	47%
	Eloise	Fall/Winter WY10	09-Jan-10	28-Feb-10	51	16.7	7.9	3.0	5.6	64%	57.0	16.1	0.2	40.7	29%
		Spring WY10	01-Mar-10	31-May-10	92	89.9	52.6	4.4	33.1	63%	69.6	18.4	0.0	51.2	26%
		Fall/Winter WY11	01-Oct-10	28-Feb-11	151	250.5	73.4	6.5	170.8	32%	211.5	33.7	0.2	177.6	16%
		Spring WY11	01-Mar-11	31-May-11	92	662.5	69.0	4.5	588.9	11%	141.1	27.5	0.1	113.5	20%
		Summer WY11	01-Jun-11	30-Sep-11	122	200.0	45.0	5.9	150.0	25%	20.1	6.7	0.1	13.3	34%
	PA1	Fall/Winter WY09	03-Dec-08	28-Jan-09	57	9.6	5.6	0.9	3.0	67%	8.7	7.9	0.1	0.7	92%
		Spring WY09	01-Mar-09	31-May-09	92	15.0	13.3	1.6	0.5	98%	13.9	13.1	0.2	0.6	96%
		Summer WY09	01-Jun-09	30-Sep-09	122	9.0	6.5	2.1	0.4	93%	1.9	1.9	0.0	0.0	100%
		Fall/Winter WY10	01-Oct-09	28-Feb-10	151	14.3	9.9	2.0	2.5	82%	23.2	17.3	0.8	5.1	78%
		Spring WY10	01-Mar-10	31-May-10	92	16.6	15.1	1.6	0.0	99%	8.5	8.4	0.1	0.0	100%
		Summer WY10	01-Jun-10	30-Sep-10	122	2.3	0.4	2.0	0.0	94%	0.7	0.7	0.0	0.0	100%
		Fall/Winter WY11	01-Oct-10	28-Feb-11	151	50.2	20.0	2.5	27.5	44%	36.6	20.5	0.4	15.6	57%
		Spring WY11	01-Mar-11	31-May-11	92	95.3	15.5	2.0	77.8	18%	20.4	14.7	0.2	5.4	74%
		Summer WY11	1-Jun-11	30-Sep-11	122	25.0	13.3	2.5	9.6	60%	3.3	2.7	0.1	0.5	85%

SWT VOLUME COMPARISON: WY2009-WY2011 OBSERVED TO PLRM PREDICTIONS

TABLE 6.2

- Upper Park Avenue Basin (PA1): As documented by previous monitoring of the Park Avenue Basins (2NDNATURE 2008), the constructed elevation of the inlet junction box that routes flows from the Rocky Point drainage to PA1 (see Rocky Point inlet in Figure 3.7B) allows water to bypass the PA1 wet basin when water levels are elevated in PA1. During these conditions, the research team has observed backwatering of the inlet junction box from PA1, which results in (1) water draining from the PA1 wet basin through the inlet pipe and into the bypass pipe connected to the junction box and (2) diversion of Rocky Point catchment inflows to the bypass channel. This variable conveyance adds uncertainty to the analysis of water level data and the modeled representations of performance in PLRM.
- Lower Park Avenue Basin (PA2): 2NDNATURE (2008) documented the poor hydraulic connection at the Park Avenue Basins between the upper wet basin (PA1) and the lower dry basin (PA2). Over the course of monitoring (WY05-WY07; WY09-WY11), outflow at PA1 was frequently observed (70% of the year on average) while inflow at PA2 was observed only 15% of the year on average. NHC (2007) studied the causes for the observed losses in the storm drain pipe connecting PA1 discharge to PA2, which uses an inverted siphon design at a profile conflict with the Stateline Creek storm drain system. The results of the NHC study concluded that the losses were caused by gaps between the joints in the storm drain pipe connecting the two basins which allowed exfiltration into: 1) the Stateline Creek storm drain system, which discharges to the North Ditch; and 2) the soils surrounding the storm drain pipe. In 2010 the City of South Lake Tahoe attempted repairs to the storm drain system to eliminate the observed hydraulic connection to the Stateline Creek storm drain system. The repairs appear to have improved the connection between the two basins based on water level data recorded in water year 2011. However, losses are still occurring in the storm drain system that would require direct PLRM calibration to observed data. Therefore, comparisons of observed PA2 data to PLRM estimates of hydrologic performance would not be meaningful and are not used for this purpose.
- Osgood Basin: The drainage area to the wet basin includes a notable amount of forested uplands, which includes a large stream environment zone (Keller Creek Drainage). During periods of spring snowmelt runoff, especially in above average water years, the tributary forested uplands input a significant baseflow to Osgood Basin. PLRMv1 was designed to model surface runoff from developed lands and does not attempt to model runoff generated from forested areas during saturated conditions that generated baseflow. The baseflow component of the basin complicates the comparison and analysis of water level data and the modeled representations of performance in PLRM. In addition to this complication, a bypass pipe located near the inlet of the Osgood pretreatment settling basin can be opened to bypass the SWT and directly discharge runoff to the outlet. Anecdotal evidence suggests that the gate to the bypass pipe was intermittently open during monitoring; however researchers were unable to obtain documentation of the frequency and duration of bypass flow adding uncertainty to water budget estimates.
- Eloise Basin: Similar to the situation at Osgood Basin, Eloise Basin includes a significant baseflow component, complicating the comparison of water level data and PLRM modeled performance. The catchment area (281 acres) presented in Table 3.4 includes only the urban area modeled in PLRM, while the total catchment area is over 560 acres and includes a significant forested upland component (NHC 2007). This area likely contributes baseflow regularly to Eloise Basin, even during below average water years. Furthermore Eloise Basin was not constructed with a low flow treated orifice(s) in the outlet structure. However, over the course of the last 25 years the outlet structure, which is a corrugated metal pipe, has gradually corroded and currently allows water to leak out the structure. This outflow is difficult to measure in the field and adds uncertainty to water budget estimates.

In addition to the site specific complications noted above, little to no maintenance has occurred in these SWTs over the past several years (see Table 3.5). Furthermore, if/when maintenance activities are performed there is typically no documentation of the actions taken. Lack of maintenance can result in the gradual decrease in volume capacity, reduced infiltration rates, and lowering of treatment outflow rates due to blocked orifices. The lack of consistent maintenance, and documentation of maintenance actions when they do occur, leads to variable hydrologic performance that is difficult to quantify and accurately track. In addition, it is extremely challenging to quantify the pollutant load reduction benefit of a SWT that is not in desired operational condition. This variability adds uncertainty to the analysis of water level data and the modeled representations of performance in PLRM.

INFLOW, TREATED AND BYPASS VOLUMES

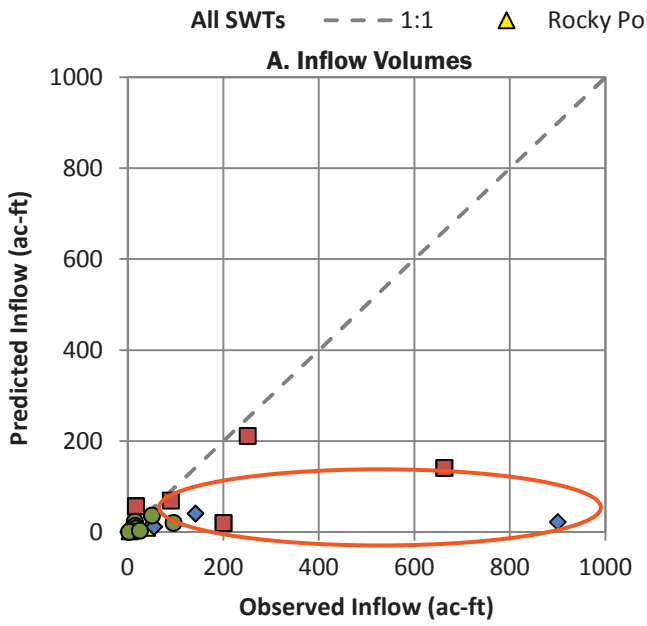
Figure 6.2 presents correlation plots of observed versus predicted values for inflow volume, treated volume, bypass volume, and hydraulic capture for all seasons (n=23) shown in Table 6.2 for Rocky Point, Osgood, Eloise, and PA1.

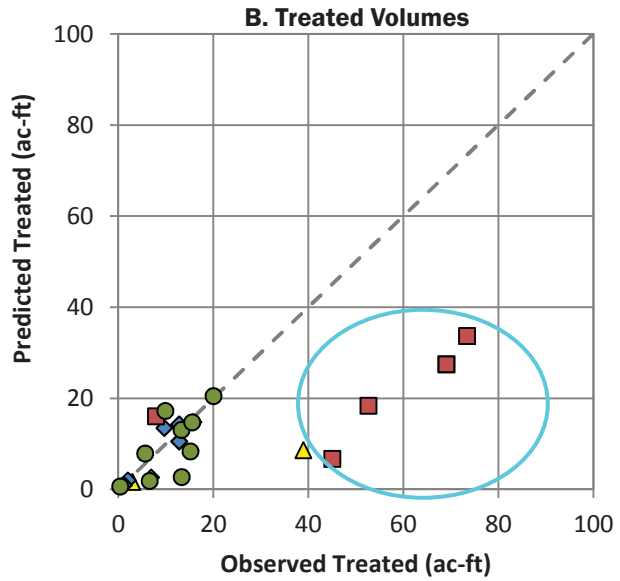
The inflow, bypass, and hydraulic capture data indicate a number of the observed values are significantly higher than the corresponding PLRM estimates (see Figures 6.2A, C-D). The higher observed values occurred during the extremely wet seasons of Spring 2010, Fall/Winter 2011, Spring WY11, and Summer WY11, when a significant baseflow component was present at the monitored wet basins. As discussed in Chapter 4.1, during the 3 water years of research, each year was successively wetter than the last. Table 6.3 shows the increasing trend in total precipitation, along with the concurrent increasing trend in observed inflow volumes to each SWT. Time series of observed storage supports this finding, as all basins were at or above the maximum water quality storage capacity more frequently in WY2011 than in previous years (see summary tables in Figures 6.1A-E). PLRM does not model baseflow within the current hydrology module, and therefore PLRM algorithms do not estimate increased inflows due to elevated groundwater during wet seasons, explaining the significant outliers shown in Figures 6.2A. Increased inflow also causes higher bypassed volumes and reduced hydraulic capture (see EQ 6.1 & 6.2), explaining the discrepancies in Figure 6.2C-D as well.

Review of Figure 6.2B indicates a very strong correlation between the observed and predicted treated outflow volumes (Pearson's r of 0.73, significant above 99% confidence). Treated outflow volumes are a critical metric with regards to PLRM modeling of pollutant load reductions and the general alignment between observed and predicted values suggest PLRM models the treatment volumes of SWTs reasonably well. The treated outflow outliers in Figure 6.2B are Eloise Basin and Rocky Point, where observed values are higher than predicted. The differences for Eloise can be attributed to the continual increase in baseflow contributions from forested upland area above catchment modeled by PLRM. Observed seasonal average baseflow inputs are estimated to range from 0.1 to 0.5 cfs in WY2010 for the fall/winter and spring, respectively, and 0.9 to 3.0 cfs in WY2011. As mentioned above, PLRM does not attempt to model baseflow generated from forested areas during saturated conditions and therefore the PLRM predictions are lower than the observed volumes, which include this contribution. At Rocky Point, the use of the north basin for snow storage during winter months may artificially raise the recorded water levels when the basin is inundated, resulting in a higher observed frequency of treated outflow (and therefore higher observed treated outflow volumes) than is actually occurring.

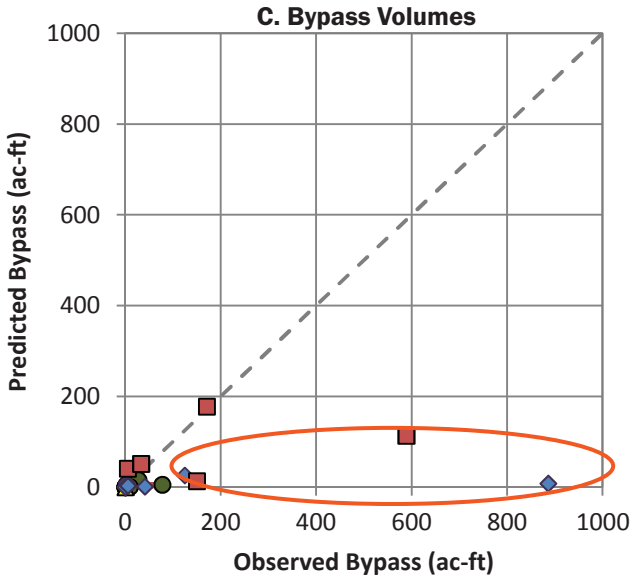
SWT Seasonal Hydrologic Comparisons

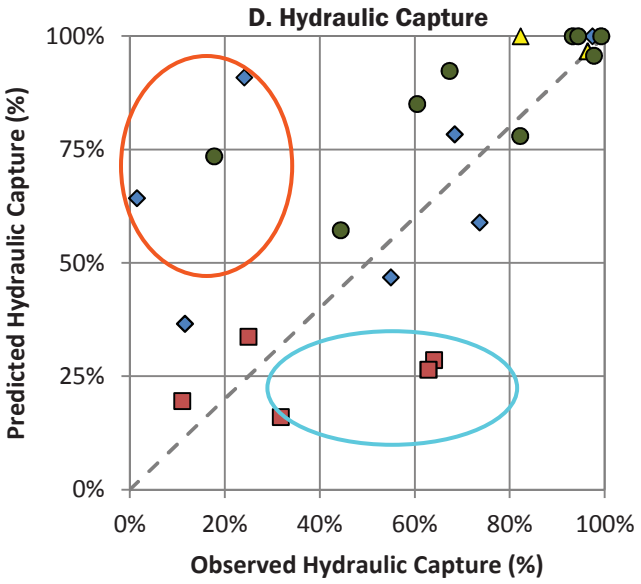
All seasons presented in Table 6.2





Note very strong correlation between observed and predicted volumes (Pearson's r=0.73, significant above 99% confidence).





Circled points indicate wet seasons (Spring WY10, All Seasons in WY11) in locations known to have high seasonal groundwater elevations (e.g., Osgood and Eloise Basins). The significant baseflow signal increases observed inflow volumes, resulting in higher bypass volumes and decreased hydraulic capture performance (red circles). In Eloise Basin, the baseflow inflow rates are roughly equivalent to the treated outflow rates, resulting in higher treated volumes and therefore higher than predicted hydraulic capture (light blue circles).

Inflow Volume = Treated +Bypass + Infiltration + Evapotranspiration
Hydraulic Capture = (Inflow - Bypass) / Inflow

Table 6.3. WY09-WY11 comparison of total precipitation and observed SWT inflow volumes.

		Water Year	WY2009	WY2010	WY2011
		Water Year Type	Average	Wet	Wet
		Total Precipitation (in) (% increase over previous year)	27.2	37.9	45.0
SWT Type	**SWT**	**Catchment Area (acres)**	**Inflow Volume (ac-ft) (% increase over previous year)**		
Dry Basin	PA2	n/a	0.1	6.6	63.8
Wet Basin	Osgood	341.6	30.3	78.2	1070
	Eloise	280.8[1]	n/a	163	1550
	PA1	224.6	31.9	31.2	168

[1] This is the total urban area of the catchment modeled in PLRM. The actual area draining to Eloise Basin is significantly higher (560 acres; NHC 2007) and has a significant forested upland component.

Previous groundwater monitoring at Eloise Basin (2NDNATURE 2006) has measured nearly a 7 ft increase in the local groundwater elevation from fall to the spring peak of snowmelt runoff, which places the groundwater table above the bottom of the Eloise Basin. That research (2NDNATURE 2006) was conducted during WY04 and WY05, which were a dry year following 2 average years and a wet year, respectively (see Figure 4.1). Other local groundwater monitoring in the Park Avenue Basins (2NDNATURE 2008) in WY06 (a wet year) and WY07 (a dry year) show increases in the groundwater elevation on the order of 4 ft with a 1.5 to 2 ft separation between the basin bottom and the highest groundwater elevation. The differences in fluctuations in groundwater levels for these two basins, in combination with the much higher forested upland area in the Eloise and Osgood catchments compared to Park Avenue (see Table 3.4, and footnote in Table 6.3) likely explains why observed inflow volumes at Eloise and Osgood Basins were much higher relative to PA1 (see Table 6.3) in WY10 and WY11.

Figure 6.3 presents data for the periods of time when baseflow inputs are suspected to be negligible to compare PLRM and measured hydrology metrics. While the number of data points used in the correlation plots is limited (n=9), the alignment between observed and predicted inflow and bypass volumes and hydraulic capture greatly improves. All data show very strong correlations between observed and predicted volumes significant above 95% confidence (see Figure 6.3). Future efforts to compare PLRM and measured hydrology must consider potential baseflow inputs that will not be included in PLRM predictions.

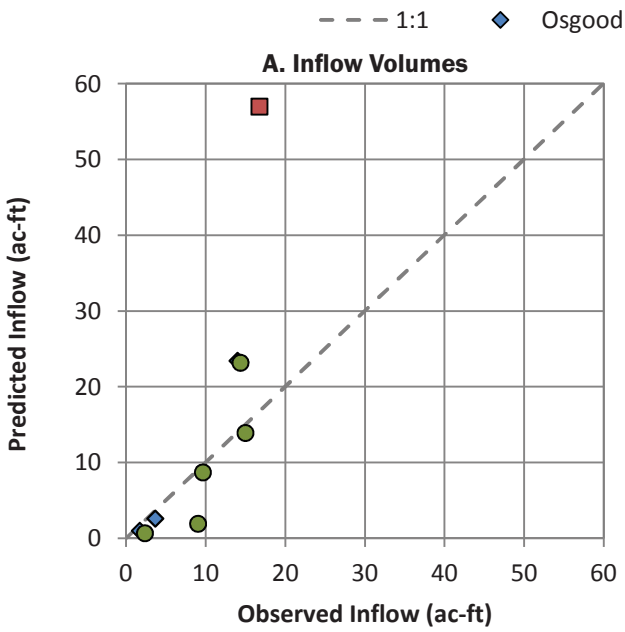
EVAPOTRANSPIRATION AND INFILTRATION VOLUMES

Figure 6.4 compares observed to predicted infiltration + evapotranspiration seasonal volumes in Table 6.2. Evapotranspiration is estimated using the surface area of the detained water, which varies with water surface area predicted from depth-area relationships, and standard monthly evapotranspiration rates for areas in the vicinity of the Tahoe Basin (www.cimis.water.ca.gov). Estimated evaporation volumes are a necessary variable to compare to PLRM performance estimates for wet basins, but in comparison to other loss terms, evapotranspiration volumes on a seasonal scale are negligible. Therefore, the differences between observed and predicted values shown in Figure 6.4 are assumed to be primarily due to differences in infiltration volume estimates. PLRM v1 does not estimate infiltration from wet basins. However, calculations of observed infiltration suggest that wet basins do infiltrate water volumes on a seasonal time scale, and future PLRM modifications may need to consider this factor. A previous water budget analysis on Eloise Basin suggested that infiltration occurred through the sides of the basin, rather than the basin bottom (2NDNATURE 2006).

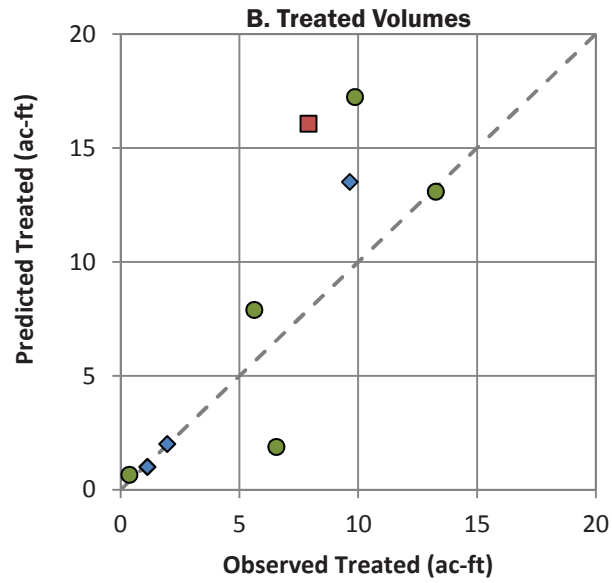
The observed time series of storage was used to calculate seasonal infiltration rates for each of the five SWTs with reliable water level data using the methodology described in Chapter 3.2.1. For each SWT, there was a strong

SWT Seasonal Hydrologic Comparisons

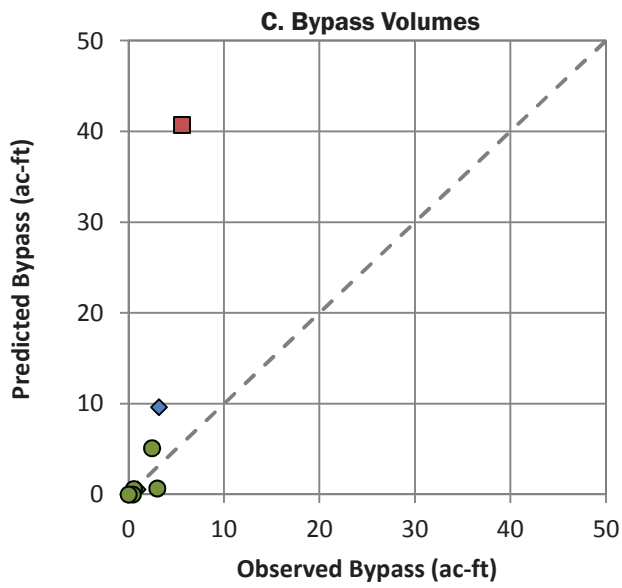
Seasons when baseflow is negligable



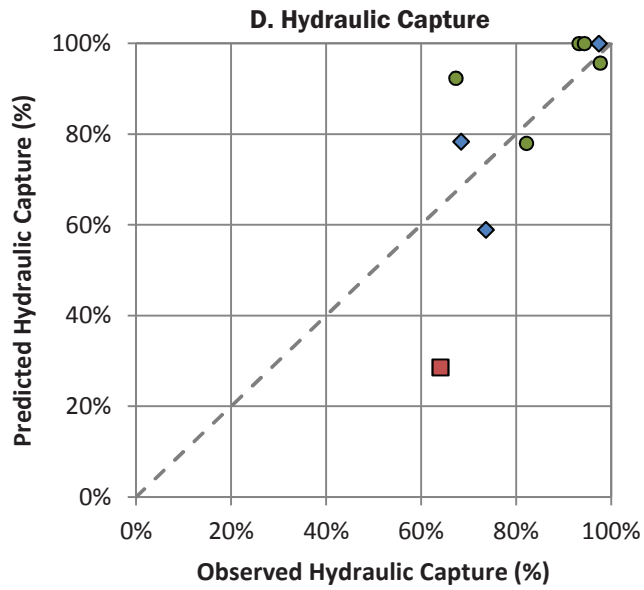
Very strong correlation between observed and predicted volumes (Pearson's r=0.78, significant above 98% confidence).



Very strong correlation between observed and predicted volumes (Pearson's r=0.83, significant above 99% confidence).



Very strong correlation between observed and predicted volumes (Pearson's r=0.85, significant above 99% confidence).



Very strong correlation between observed and predicted volumes (Pearson's r=0.73, significant above 95% confidence).

Seasons included are
Fall/Winter WY09
Spring WY09
Summer WY09
Fall/Winter WY10
Summer WY10
see Table 6.2

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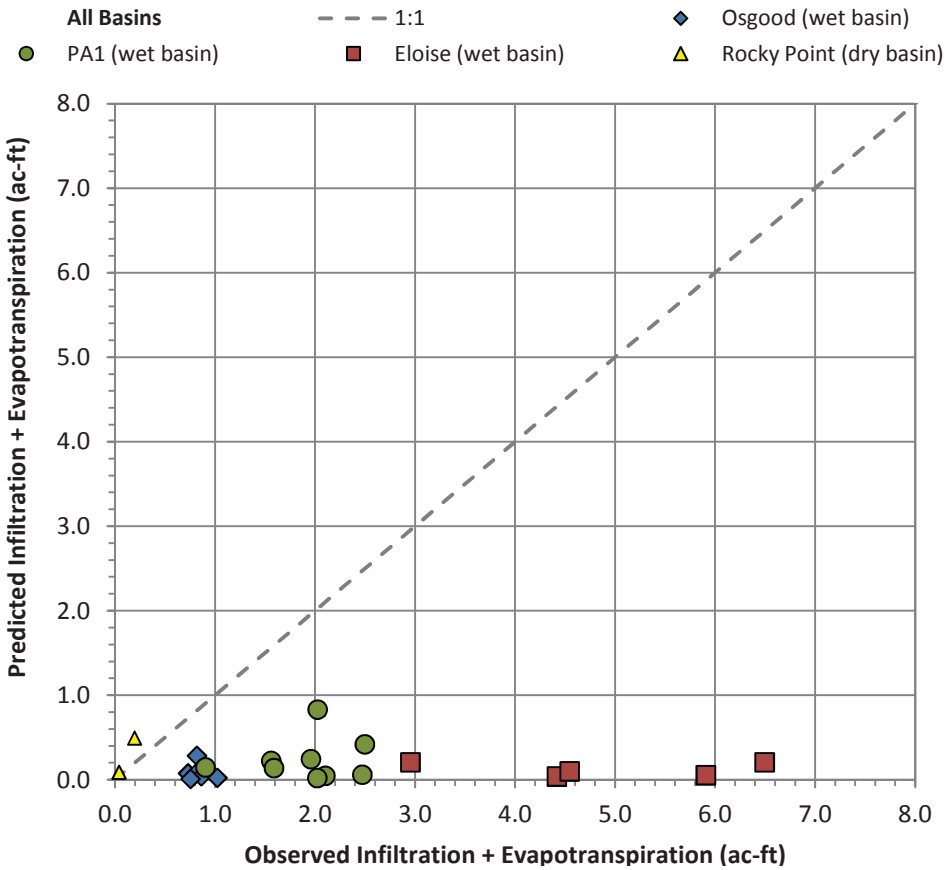
SWT SEASONAL HYDROLOGIC COMPARIONS; NEGLIGIBLE BASEFLOW

FIGURE 6.3

SWT Seasonal Infiltration + ET Comparisons

All seasons presented in Table 6.2



Observed and predicted seasonal infiltration and evapotranspiration volumes based on data shown in Table 6.2. Evapotranspiration volumes are negligible in comparison to infiltration volumes on seasonal time scales. Limited dry basin data (yellow triangles) show general agreement, while wet basin data show higher observed values relative to PLRM predictions. PLRM assumes infiltration does not occur in wet basins; however observations during WY09-WY11 suggest otherwise.

seasonal difference in the observed infiltration rates with spring/early summer typically at least 50% lower than the late summer/ fall rates (Table 6.4). This difference is expected as result of soil saturation, increased shallow groundwater table elevations in the spring, and the concurrent reduction in the amount of separation between the bottom of a basin the groundwater elevation. The seasonal rates estimated in Table 6.4 were averaged to determine the average annual infiltration rate for each SWT. Note that winter infiltration rates were difficult to calculate using the water budget analysis given the flashy hydrology of winter rain and rain on snow events, and the frequency of basin water depths above the treated outflow elevation.

Table 6.4. Average seasonal and annual infiltration rates calculated using the water budget analysis. For purposes of this analysis, spring/early summer is defined as April-July, and late summer/early fall is August-November.

SWT Type	SWT	# of data points		Observed infiltration rate (in/hr)		Observed average annual infiltration rate(in/hr)	Range of PLRM Recommended Infiltration Rates (in/hr)
		Spring/ Early Summer	Late Summer/ Fall	Spring/ Early Summer	Spring/ Early Summer		
Dry Basins	PA2	3	16	0.19	0.26	0.23	0.05 – 0.50
	Rocky Point	4	8	0.07	0.20	0.14	
Wet Basins	Osgood	2	4	0.01	0.02	0.02	n/a
	PA1	5	11	0.05	0.15	0.10	
	Eloise	1	11	0.05	0.10	0.08	

Observations indicate that the dry basins monitored had average annual infiltration rates on the order of 0.14 to 0.23 in/hr and seasonal rates ranging from 0.07 to 0.26 in/hr (see Table 6.4). PLRMv1 recommends a range of 0.05 - 0.50 in/hr for dry basins. While this research is limited to observations of two dry basins in South Lake Tahoe, CA over a period of roughly three water years, the available data suggest the range of infiltration rates recommended by PLRMv1 for dry basins is reasonable.

Observations indicate that the wet basins monitored had average annual infiltration rates ranging from 0.02 to 0.10 in/hr and seasonal rates ranging from 0.01 to 0.15 in/ hr (see Table 6.4). These estimated infiltration volumes contributed as much as 5-10% of the annual water loss from a wet basin (see Table 6.2). While this research is limited to observations of three wet basins in South Lake Tahoe, CA over a period of roughly three water years, the available data suggests that future improvements to PLRM should consider incorporating an algorithm that simulates infiltration in wet basins, at least on a seasonal time scale.

6.1.2 USING DISCRETE MEASUREMENTS TO INFORM INFILTRATION RATE INPUT TO PLRM

In addition to the comparison of observed and predicted volume estimates, this research included a series of discrete infiltration rate measurements using a constant head permeameter (CHP) (NRCS 2010; 2NDNATURE et al. 2010) to inform recommendations on how discrete CHP measurements could be used to infer appropriate PLRM inputs for average annual infiltration rates in SWTs. Despite calculated observations of infiltration in wet basins from the water level data, CHP measurements were not conducted in wet basins due to the sustained inundation of these SWTs, and therefore only dry basin data is available.

The CHP data are compared to the seasonal and annual infiltration rates calculated from the water budgets for each dry basin (see Table 6.4). As expected, CHP measurements varied spatially and seasonally within each SWT. Therefore, each SWT evaluation included multiple CHP measurements that collectively represented the different surface types and relative inundation frequencies of different infiltration surfaces within the SWT and at different

times of year. Figure 6.5 presents these CHP values for each SWT compared to the measured seasonal infiltration rates for the respective SWT using the data in Table 6.4.

While the data is limited, it does provide a preliminary numerical relationship to convert CHP measurements to a seasonal infiltration rate for dry basins. Given both the seasonal variability of the CHP measurements and the seasonal differences in observed infiltration rates, it is recommended that multiple measurements are made across different seasons for the dry basin of interest to determine the appropriate average annual infiltration rates required for input to PLRM. One approach may be 4 discrete CHP observations (consisting of multiple CHP measurements that collectively spatially represent the SWT infiltration conditions that are then averaged) conducted every 3 months for one year. The rating curve equation in Figure 6.5 would be used convert to 4 seasonal infiltration rates that are averaged to obtain an average annual infiltration rate estimate for PLRM. This approach would provide an estimate of the average annual infiltration rate for the observed year only. The caveat of this approach is that the infiltration rate of an SWT that accepts urban stormwater in the Tahoe Basin will decline over time without maintenance (see Chapter 6.1.3 below). We recommend that the user consider the both the time since last maintenance prior to the discrete CHP measurements and the anticipated frequency of maintenance within the SWT when determining a representative average annual infiltration rate over the 18-year PLRM simulation. As discussed below, observations from this research suggest dry basin SWT infiltration rates might notably decline within a few years of treating typical Tahoe Basin urban stormwater.

6.1.3 OBSERVED DECLINE IN SWT INFILTRATION RATE

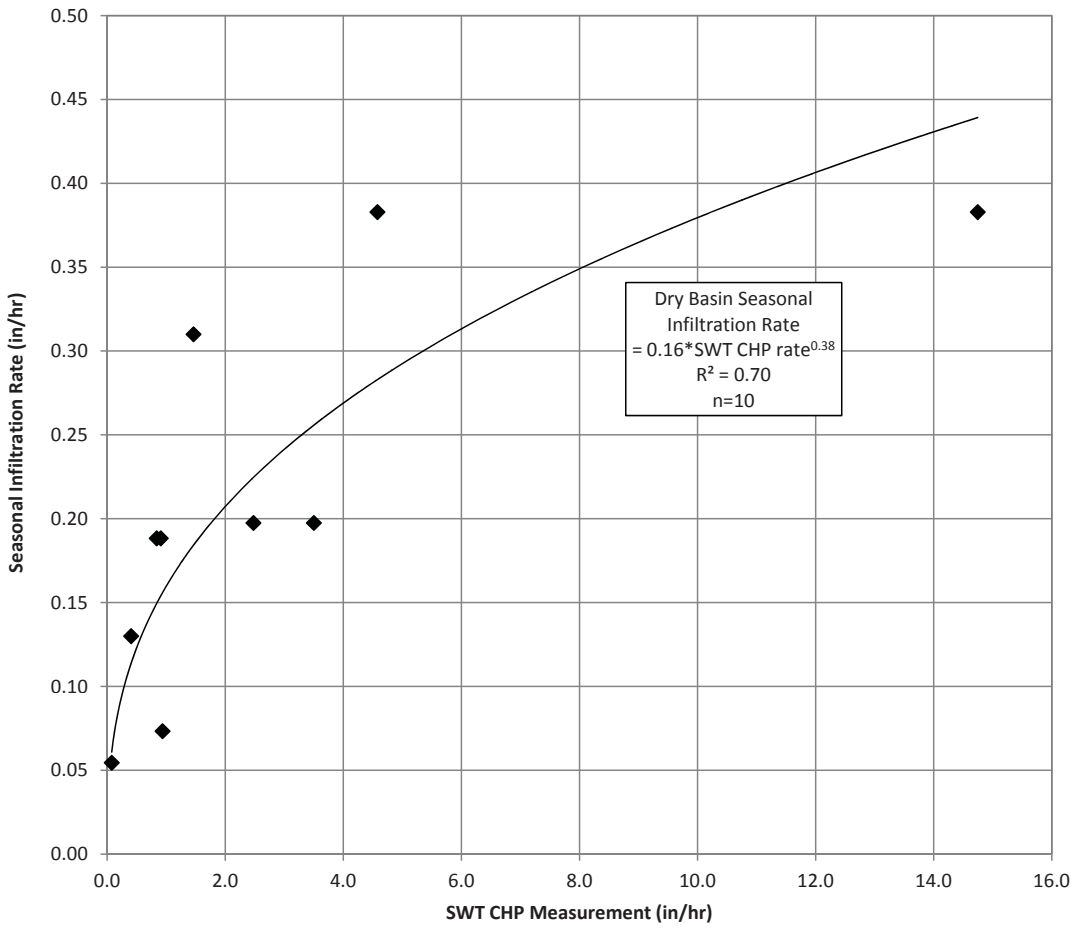
PLRM user guidance suggests the selection of an infiltration rate for a dry basin or infiltration basin that represents the average condition of the SWT facility over the long-term. In reality the infiltration rate of an SWT facility will vary over time based on the amount of pollutant loading and maintenance performed.

Layer of fine material accumulation in upper cell of PA2 following sustained inundation in Spring WY11.

Observations of the lower Park Avenue Basin (PA2) over the past 5 water years suggest that the decline in infiltration rate can occur fairly rapidly. Prior to Spring 2011, sustained inundation in PA2 had not been observed (see Figure 6.1C and 2N 2008) and any events that did inundate the dry basin were rapidly infiltrated. Modifications by the City of South Lake Tahoe to improve conveyance from PA1 to PA2 and the above normal 2011 water year notably increased the amount of observed stormwater routed to PA2 in the WY2011. The design of PA2 includes a rock weir that creates separate detention cells in the basin (see Figure 3.7C). Site observations and water level data suggested that the upper cell of the dry basin was inundated 57% of the time in WY2011, which is a significant increase relative to prior years monitored (Table 6.5). Following sustained inundation in the spring of 2011, field personnel observed a layer of fine material caking the basin surface in the upper cell of the dry basin (see photo at right). Coincidently, calculated observation of seasonal infiltration rates declined by 45% from WY10 to WY11 in the upper cell of the dry basin (see Table 6.5). The rapid decline in infiltration rates from a single water year, albeit one with a notable volume of stormwater discharged to the dry basin, was an unexpected result. This finding likely further highlights the need for frequent SWT maintenance to preserve desired infiltration rates.

Discrete CHP and seasonal infiltration rate comparisons

Dry Basins



SWT CHP measurement values are a spatially weighted series of discrete measurements taken throughout the dry basin, which collectively represent the different surface types and relative inundation frequencies of different infiltration surfaces within the SWT. SWT seasonal infiltration rates are shown in Table 6.4. Seasons are defined as Spring/Early Summer (April - July) and Late Summer/Early Fall (August - November).

While the above data is limited, it does provide a preliminary numerical relationship to convert CHP measurements to a seasonal infiltration rate for dry basins. Given both the seasonal variability of the CHP measurements and the seasonal differences in observed infiltration rates, it is recommended that multiple measurements are made over an annual time period for the dry basin of interest to determine the appropriate average annual infiltration rates required for input to PLRM. A potential approach could include 4 discrete SWT CHP observations conducted every 3 months for one year, which are converted to 4 seasonal infiltration rates and averaged to obtain an average annual infiltration rate. This approach would provide an estimate of the average annual infiltration rate for the observed year only and would potentially need to be adjusted to inform the long-term PLRM input of the SWT average annual infiltration rate.

Table 6.5. PA2 changes in measured infiltration rates from the water budget analysis compared to frequency of inundation within the basin based on the water level time series data. WY06 and WY07 data from previous 2NDNATURE (2008) research.

Water Year	Frequency of Inundation (% WY)	Average Annual Infiltration Rate (in/hr)
WY2006	4%	0.65
WY2007	0%	0.48
WY2009	0%	0.31
WY2010	0%	0.31
WY2011	57%	0.14

In Table 6.6 the CHP measurement time series is presented for the upper and lower cells of PA2. Prior to 2011, there is little difference in the observations made in the two cells. However, following sustained inundation of the first cell in 2011 there is a marked deviation between the measured CHP values. CHP measurements in the upper cell significantly decline while measurements made in the lower cell remain high. These results are consistent with the differences in infiltration rates measured using the water budget analysis (see Table 6.5).

Table 6.6. Comparison of CHP measurements in upper and lower cells of PA2.

Water Year	PA2 Upper Cell CHP Measurement (in/hr)		PA2 Lower Cell CHP Measurements (in/hr)	
	Summer	Fall	Summer	Fall
WY2009	-	14.74	-	11.53
WY2010	1.62	3.69	3.69	-
WY2011	1.98	3.50	>20	9.93

While similar datasets are not available to evaluate the potential decline in infiltration rates in wet basins, anecdotal evidence suggests that these basins were previously capable infiltrating greater volumes than they can currently. The photos below provide a visual time series of the progression of wetland vegetation development in PA1 from April 2005 to August 2011. This increasing presence of wetland vegetation suggests a higher percentage of organic material and fine-grained sediment at the basin bottom, which will likely decrease the infiltration capacity of the soil. Similar to PA1, Osgood and Eloise Basins are currently dominated by wetland vegetation. Using a simple assumption that each wet basin had an initial benchmark infiltration rate at time of construction of 0.25 in/hr, we estimate the potential reduction of the initial infiltration rate to those observed during this research (Table 6.7). We suspect the 0.25 in/hr benchmark infiltration rate is within the range of newly constructed basins in Tahoe soils with no developed wetland vegetation community. However, discrete measurements taken directly following construction or maintenance actions to restore basin infiltration are needed to improve this estimate.

Progression of wetland vegetation development in the Upper Park Avenue Basin (PA1) over the years: April 2005; September 2005, and August 2011.

Table 6.7. Simple assumptions of potential SWT infiltration rate decline.

SWT	Year Constructed	Assumed Infiltration Rate at Construction (in/hr)	WY2011 Observed Infiltration Rate (in/hr)	Total Rate Loss (in/hr)	% Performance Decline
Eloise	1990	0.25	0.08	0.22	74%
Osgood	1997	0.25	0.02	0.28	94%
PA1	2001	0.25	0.10	0.21	68%

6.1.4 SWT HYDROLOGY FINDINGS AND RECOMMENDATIONS

- A comparison of 23 seasonal estimates generated from 3 water years of SWT hydrology data collection to PLRM predictions indicate a very strong correlation (significant above 99% confidence) between measured and modeled treated outflow volumes across a range of hydrologic conditions experienced by dry and wet basins (see Figure 6.2B). Given that treated outflow is the most critical hydrology metric used to adjust pollutant loads as a result of SWT construction, this is a very valuable finding.
- Calculations from observed water level data confirms that baseflow can significantly influence the hydrologic performance of SWTs in the Tahoe Basin during wetter water years and runoff periods, and this influence is strongest in wet basins with large forested tributary areas. The current PLRM hydrology module was not developed to simulate baseflow, and during times of high seasonal groundwater the model will likely underestimate actual inflow and therefore overestimate the hydraulic capture performance of the SWT. PLRM was designed to be a relatively simple tool to predict potential pollutant load reductions from stormwater quality improvement projects in the Tahoe Basin over a long-term continuous simulation. The inclusion of additional algorithms that would accurately model seasonal baseflow on a site-specific basis would greatly increase the complexity of the model for the PLRM user, and therefore this potential improvement is not recommended. Furthermore, SWT designs that include large amounts of commingled forested runoff with urban stormwater runoff are discouraged, as the increased input of forested runoff to an SWT likely affects the hydraulic capture performance of an SWT.
- Future improvement to PLRM should consider allowing a user to define a baseflow component for a modeled SWT facility. To avoid significantly increasing the modeling complexity of PLRM, the recommended approach would allow a user to specify in the SWT editor the average monthly baseflow to the SWT facility. An internal PLRM refinement to this user input could then vary the monthly average baseflow during the long-term continuous simulation based on a statistical analysis of total precipitation for the water year being simulated. The PLRM algorithm would reduce average monthly baseflow when simulating below normal water years and would increase average monthly baseflow when simulating above normal water years.
- Despite the baseflow issue described above, the comparison of SWT hydrology data generated from three water years of data collection to PLRM predictions of performance illustrates reasonable agreement between measured and modeled performance across a range of hydrologic conditions (see Figure 6.2B). When the modeled to measured hydrologic comparisons are limited to seasons when baseflow is negligible, the alignment between measured and modeled hydrologic performance greatly improves (Figure 6.3). Given that PLRM estimates of treated flow and hydraulic capture are critical metrics used to estimate pollutant load reductions resulting from SWT implementation, this is an encouraging finding.
- PLRM algorithms include static rates of infiltration and flow through treatment outlets over the long-term continuous simulation. These static rates assume that SWTs are maintained over time to ensure

continued function at some standard level of performance. However, as noted in this research, consistent maintenance of SWTs in the Tahoe Basin is lacking (see Chapter 3.1.4 and Table 3.5). This research team has been monitoring SWTs in the Tahoe Basin for over a decade and to date maintenance of SWTs to restore function and preserve condition over time is not generally occurring. There is limited evidence from this research of rapid declines (up to 50%) in infiltration rates due to trapping of particulates at the basin surface in as little as 1-2 years. Furthermore, frequent clogging of low-flow treatment outlets for SWTs with heavy pollutant loads was observed during this research, which notably altered the hydrologic performance of the SWT relative to predicted performance. In order for SWTs to consistently achieve the pollutant load reductions predicted by PLRM, inspections and maintenance actions appear to be necessary on a frequent basis.

- Available data has been used to convert discrete CHP measurements to a seasonal SWT infiltration rate in dry basins. More data collection is necessary to refine this relationship. However, based on limited set of observations, the suggested range of average annual infiltration rates (0.05-0.50 in/hr) in PLRMv1 for dry basins appears reasonable.
- PLRMv1 does not allow for the simulation of infiltration in wet basins. Based on the results of this research, seasonal infiltration in wet basins may be an important factor in the overall water balance for wet basins. Should future versions of PLRM include infiltration in wet basins, a range of 0.01 to 0.10 in/hr is recommended.
- To ensure that modeled estimates of performance are reasonable, user inputs for PLRM should reflect a strong understanding of the hydrologic function of an SWT based on actual observations and measurements taken after construction of the SWT and not rely upon design specifications. SWT design and function is frequently more complicated than can be readily modeled in PLRM. Therefore, users of the PLRM will typically need a strong understanding of actual SWT function and the PLRM algorithms to develop a reasonable model representation. Future improvements to PLRM should consider allowing a PLRM user to input customized stage-discharge relationships for SWTs and potentially include more than one treatment or bypass outlet structure.

6.2 CHARACTERISTIC EFFLUENT CONCENTRATIONS (CEC)

The SWT sampling effort included inlet and outlet comparisons across a range of events to inform our understanding of pollutant treatment capabilities, particularly for FSP. Water quality data to inform PLRMv1 CECs are constrained to the quality of treated outflow from each SWT (see schematic on page 2.6). Resource limitations and data collection challenges result in a prioritization of SWTs for instrumentation and sampling to inform the CECs. Please refer to the SWT sampling methods section (Chapter 3.1.4) for details, but the majority of effluent samples have been obtained from a series of dry and wet basins over the past three water years. The figures and tables below include the results for all 4 pollutants evaluated (FSP, TSS, TP and SRP), but in an effort to keep the results section concise, we focus discussions on FSP due to the minimal amount of previous stormwater data available for this priority pollutant of concern.

6.2.1 EVENT CONCENTRATION REDUCTIONS

Passive samplers were installed in each dry and wet basin as inlet and outlet pairs set at the same elevations to sample the same time period of rising water in an SWT. The experimental design is based on the assumption that during a specific runoff event, the inlet/outlet pairs of passive samples will collect pre and post treatment water

quality samples (see Figures 3.9A-B). Figures 6.6A-E present the pollutant concentrations obtained for each inlet and outlet pair for three dry basins and three wet basins. Samples that fall below the 1:1 line suggest pollutant concentration reductions as a result of treatment. It must be noted that some of the outlet samplers were installed above the treated outlet elevation in an SWT, and therefore Figure 6.6A-E includes both samples inferred to represent both treated and bypass flows. No grab sample data, which is discussed later, are included in the inlet and outlet data comparisons presented in Figure 6.6A-E.

Of the 85 inlet/outlet pairs analyzed for FSP, 68 or 80% of the samples collected at the outlet indicated an FSP concentration reduction. The frequency of FSP concentration reductions was more common in wet basins than dry basins. These simple concentration comparisons indicate that in addition to volume reductions, wet and dry basins do provide some removal of the mass of FSP in stormwater, which is likely attributable to particle settling and adherence onto vegetation. FSP concentration reductions as a result of treatment appear to be much more reliable when inlet concentrations are less than 300mg/L, which is particularly evident at PA1 (Figure 6.6D).

Given the available data, the average urban mixed catchment concentration (inflow to SWTs sampled) was 128 mg/L FSP and the average SWT effluent was 41.5 mg/L FSP (Table 6.8). Since PLRM assigns a static effluent concentration to treated volumes, a comparison of the effluent concentrations as a function of inflowing water quality suggests that the treatment capability of wet and dry basins is influenced by the FSP incoming concentrations. The average effluent SWT FSP concentration is 26 mg/L and treatment is more reliable when the inflowing stormwater is below 100 mg/L FSP, but the effluent is over 200 mg/L when the inflowing FSP concentration is > 300 mg/L (see Table 6.8). These findings support the assumption that effective pollutant source control actions in the catchment will reduce the concentrations and loads of pollutants delivered to public stormwater treatment systems, thereby increasing their effectiveness and duration of adequate performance prior to maintenance needs. The implications of these findings to inform future PLRM modeling of SWT treatment capabilities is addressed in the recommendation sections below.

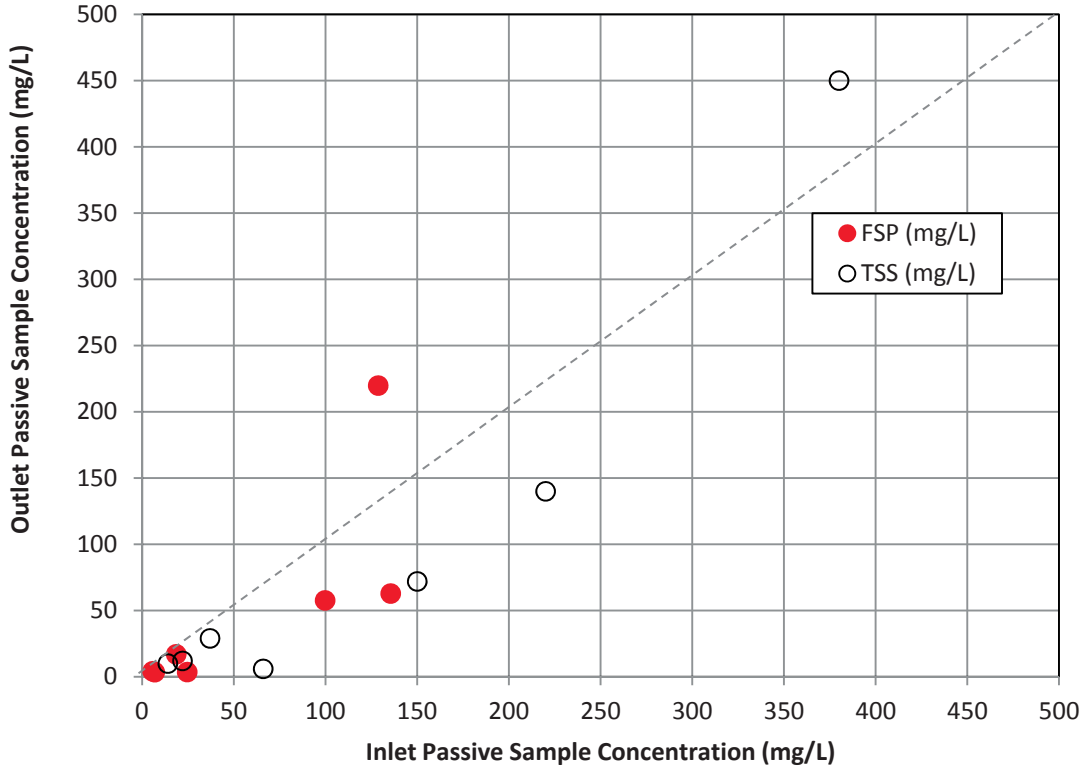
Table 6.8. Mean, standard deviation and n values for metrics of interest generated from the SWT water quality dataset. Values include samples collected from wet and dry basins as well as treated and bypass volumes as presented in Figures 6.6A-E.

	Mean	St Dev	*n*
Catchment (SWT inflow) FSP (mg/L)	129	156	*95*
SWT effluent FSP (mg/L)	41.5	76.0	*153*
SWT effluent FSP when inflow FSP < 100 mg/L	26.3	30.2	*55*
SWT effluent FSP when inflow FSP > 300 mg/L	204	177	*14*

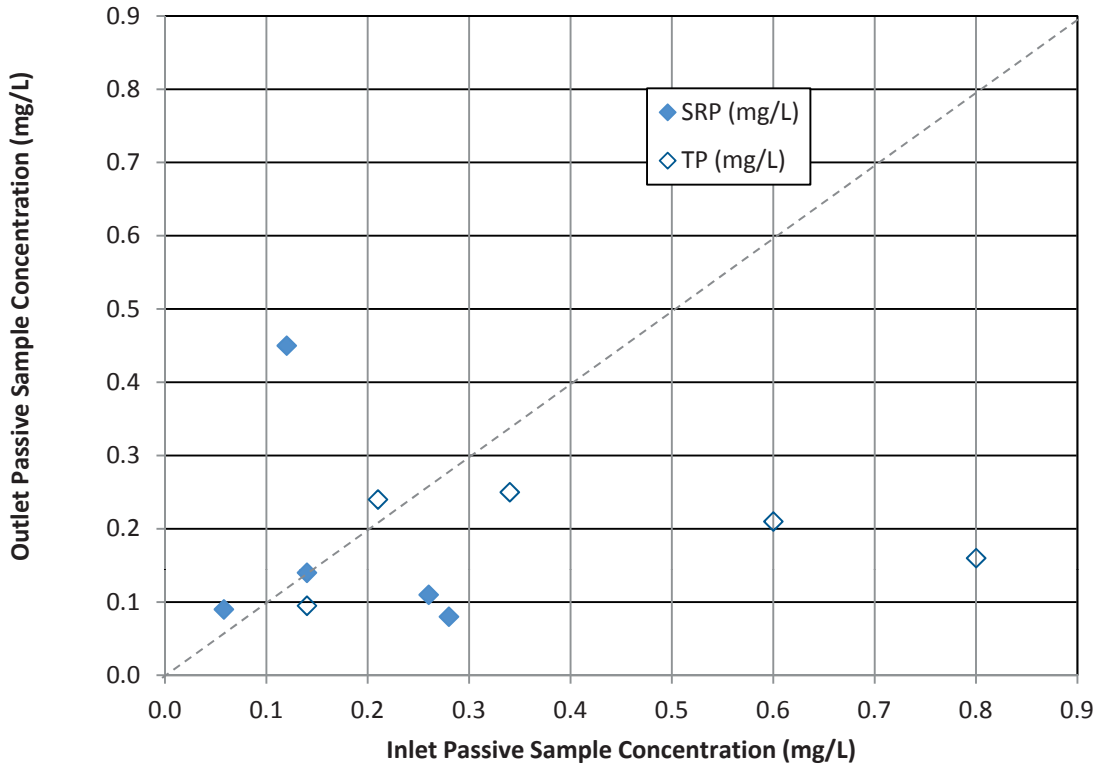
6.2.2 SEASONAL SWT OUTFLOW CONCENTRATIONS

Figure 6.7 illustrates the treated and bypassed FSP sample concentrations for dry and wet basins by collection month. The data show relatively elevated outflow concentrations (> 150 mg/L FSP) during high intensity summer and winter rain events compared to the winter and spring events. These findings are consistent with an array of other stormwater research findings that document relatively higher pollutant concentrations measured during intense summer and fall rains compared to snowmelt runoff or other low intensity rain events that do not have the same pollutant transport capacity. While higher intensity summer and winter rain events will produce larger peak flows in stormwater runoff that can influence treatment performance, the data appear to suggest that achievable effluent FSP concentrations for dry and wet basins may be linked to the inflowing concentrations of FSP.

Blue Lakes; Dry Basin



Treated n = 7
Bypass n = 0



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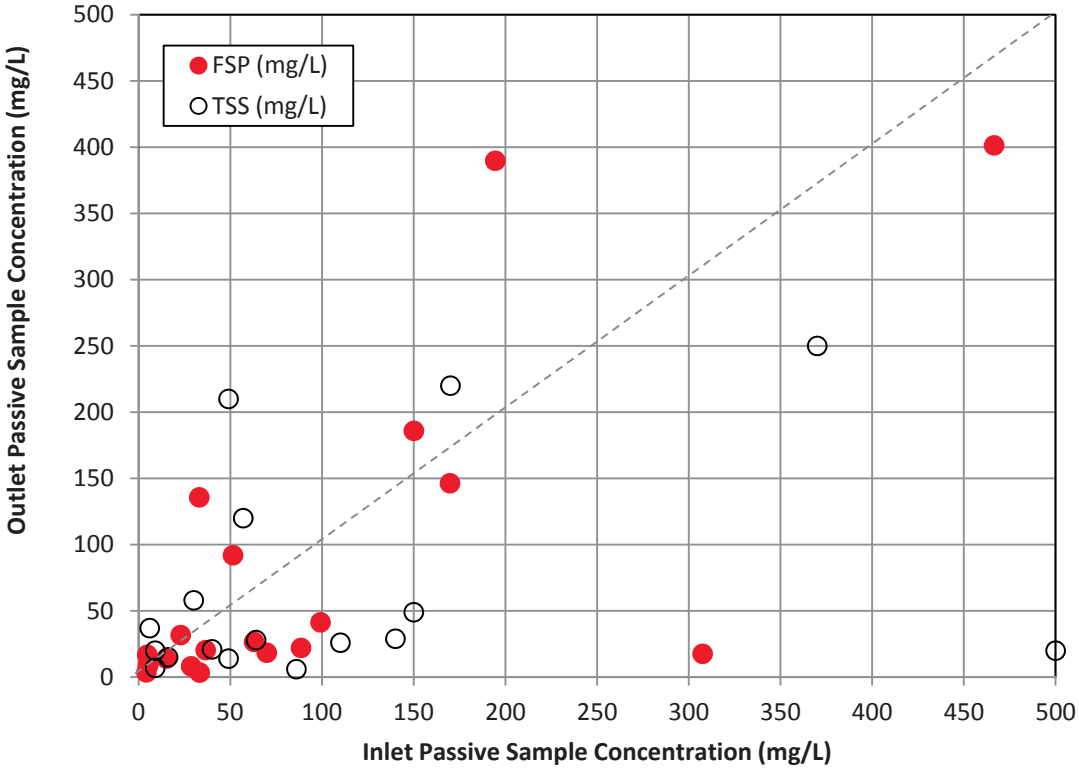
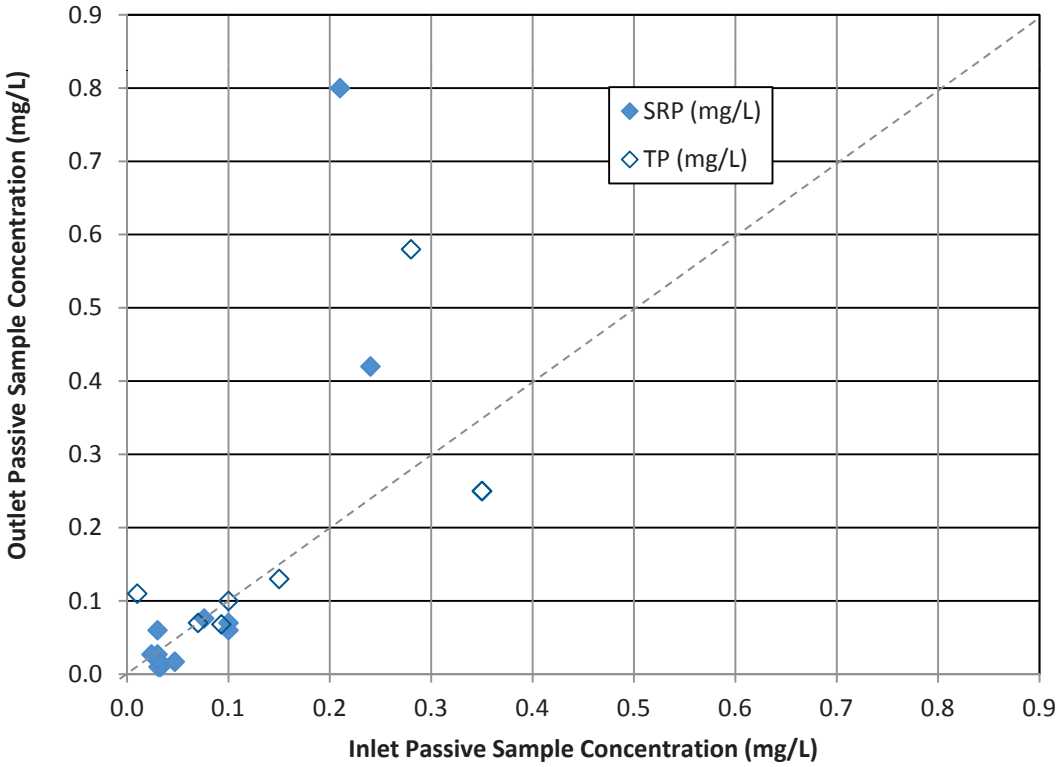
INLET/OUTLET CONCENTRATION COMPARISON: BLUE LAKES

FIGURE 6.6A

Rocky Point; Dry Basin



Treated n = 19
Bypass n = 0



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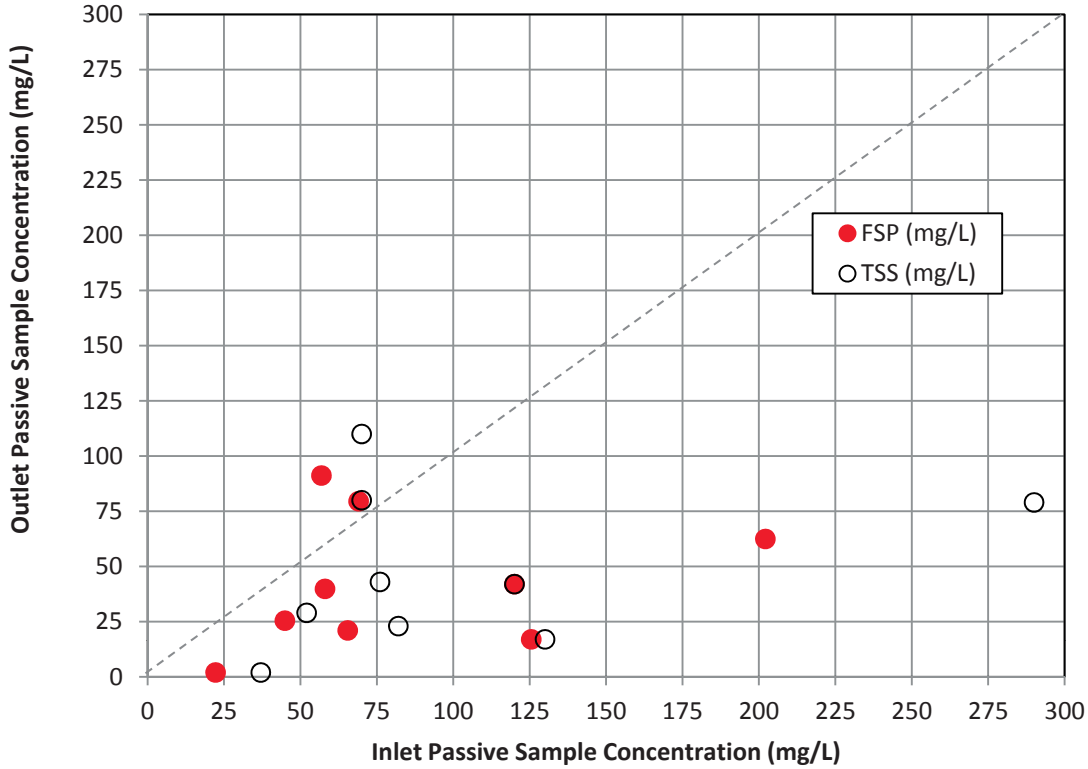
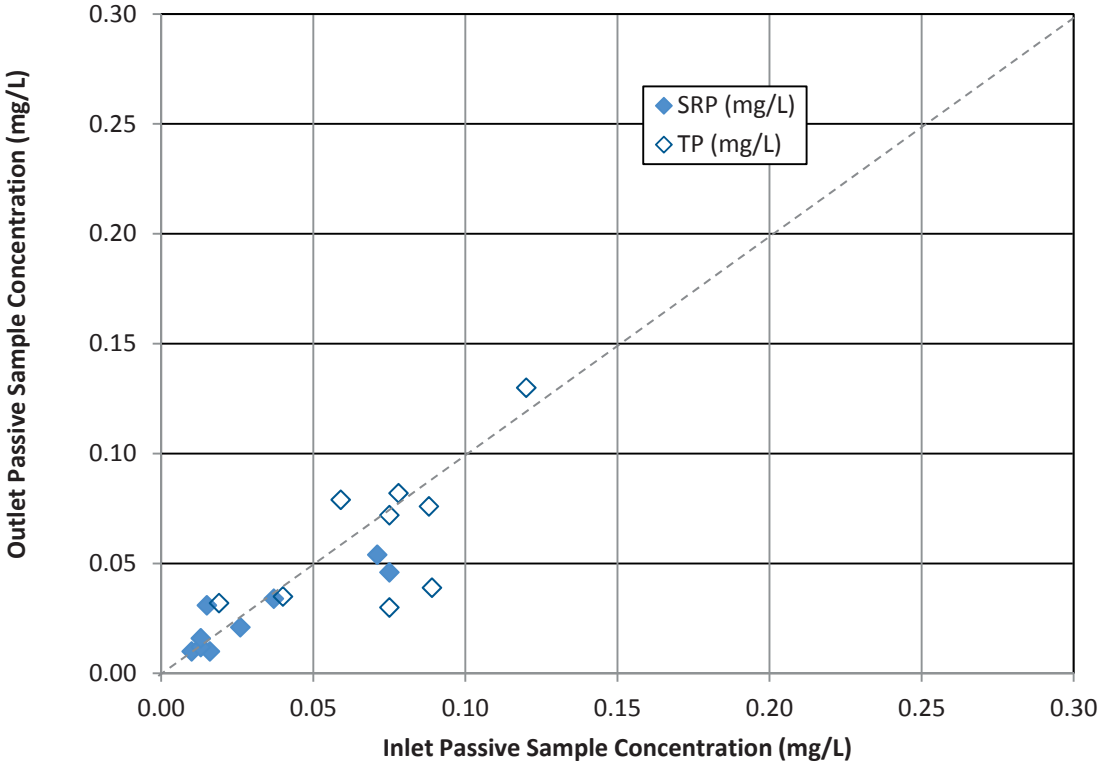
INLET/OUTLET CONCENTRATION COMPARISON: ROCKY POINT

FIGURE 6.6B

Eloise; Wet Basin



Treated n = 0
Bypass n = 9



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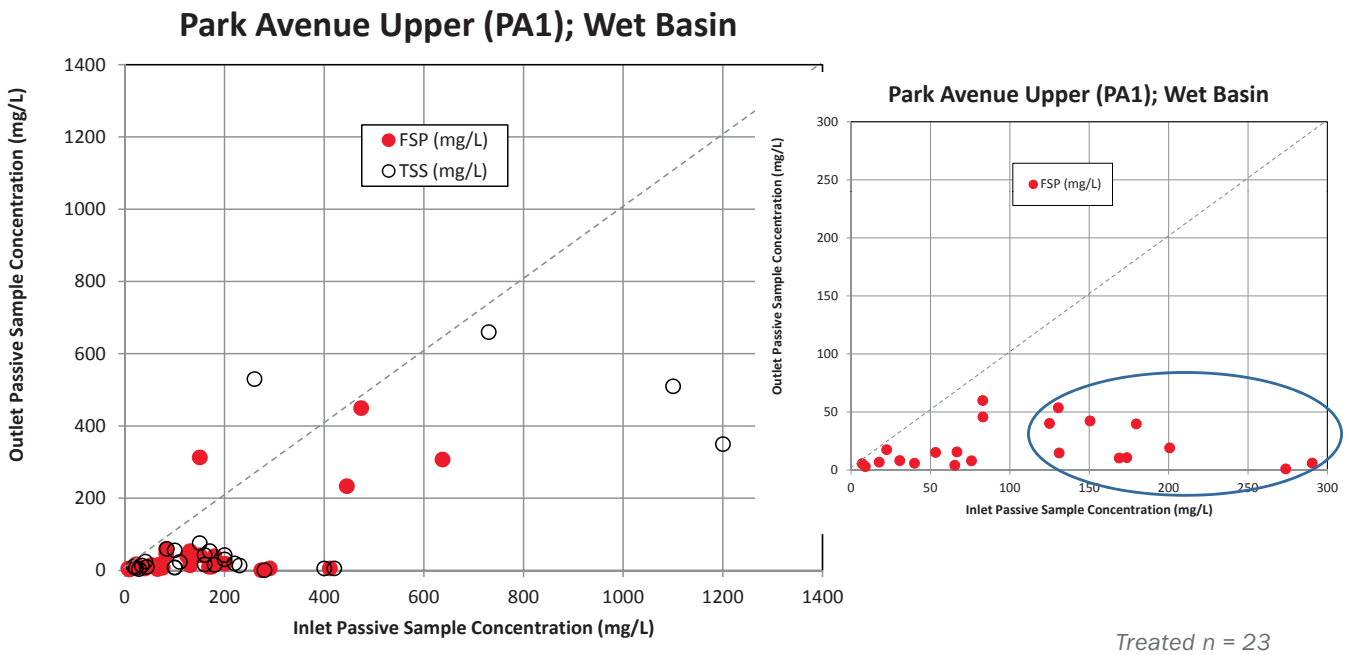
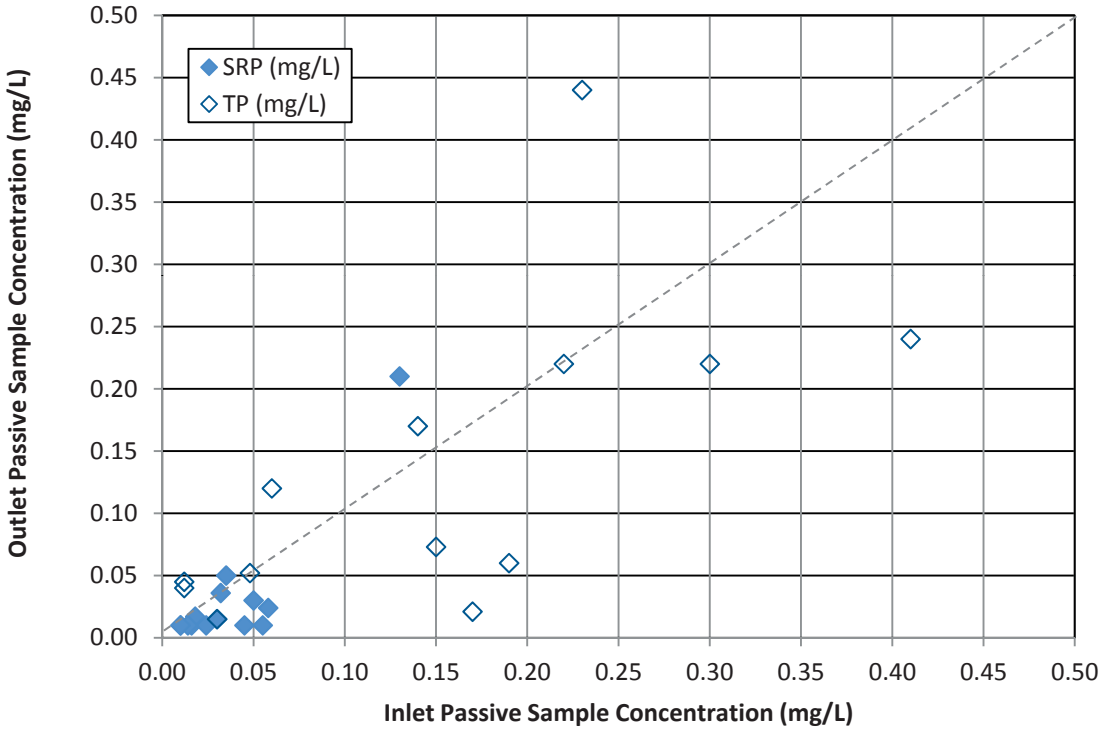
INLET/OUTLET CONCENTRATION COMPARISON: ELOISE

FIGURE 6.6C



Treated n = 23
Bypass n = 4



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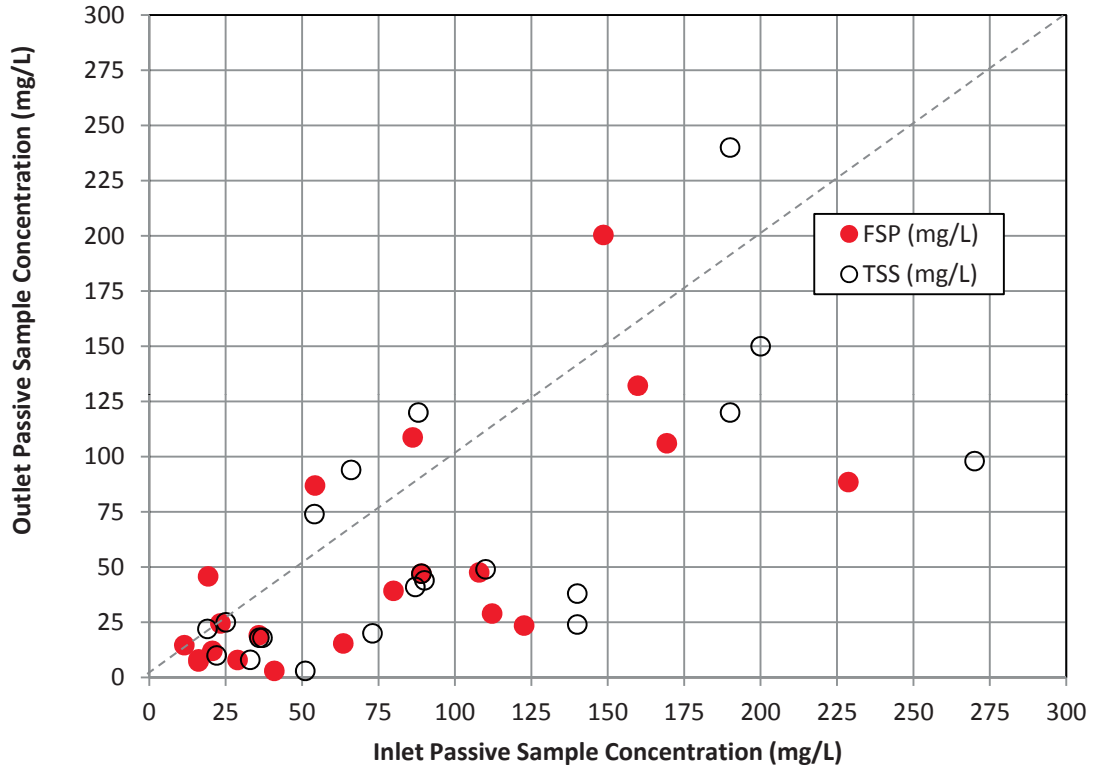
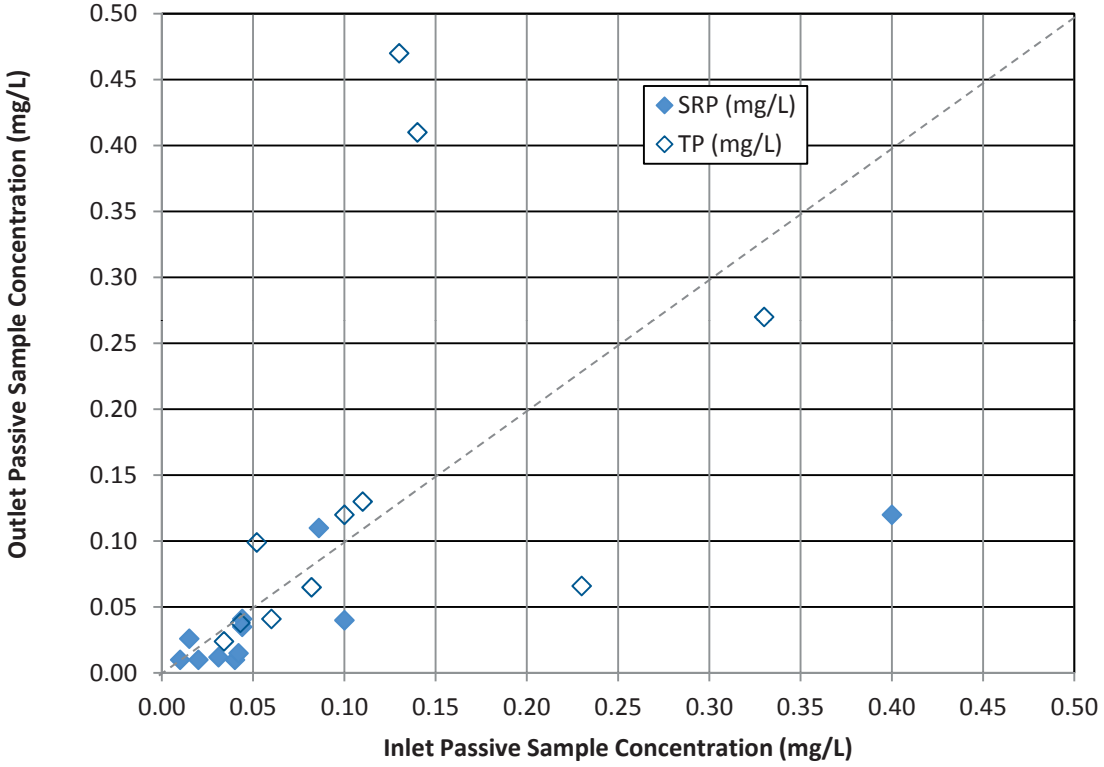
INLET/OUTLET CONCENTRATION COMPARISON: PARK AVENUE

FIGURE 6.6D

Osgood; Wet Basin



Treated n = 13
Bypass n = 13



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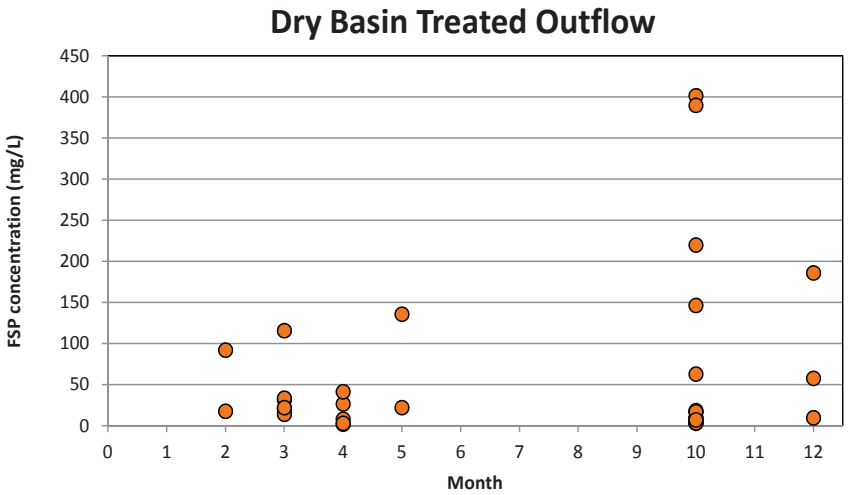
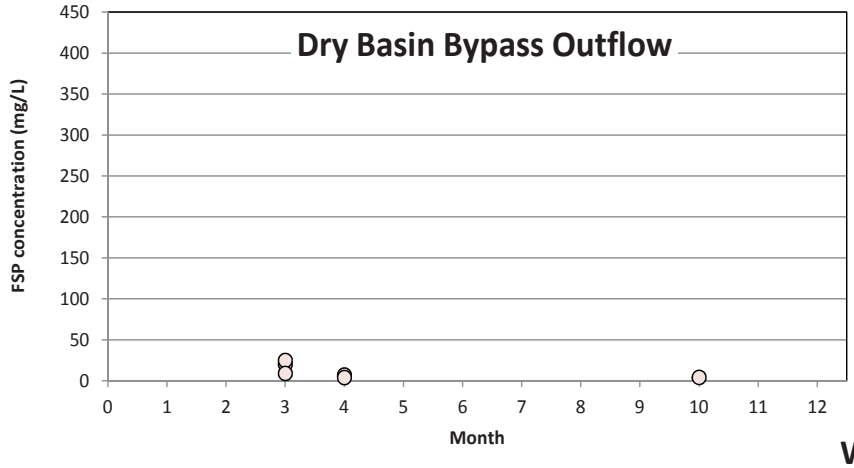
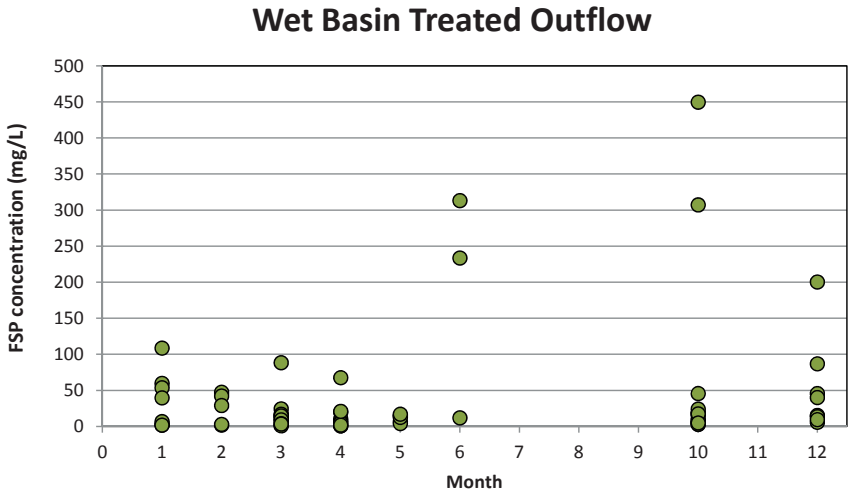
INLET/OUTLET CONCENTRATION COMPARISON: OSGOOD

FIGURE 6.6E

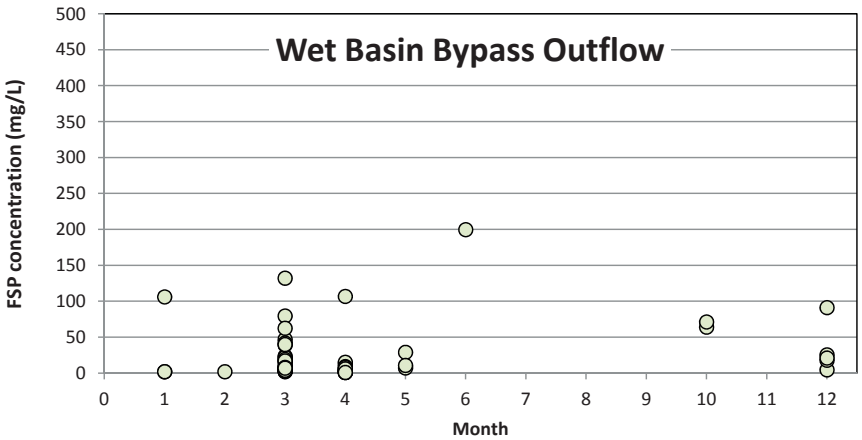


Of the 34 treated samples collected from dry basins, 15 were obtained via grab.





Of the 64 treated samples collected from wet basins, 34 were obtained via grab.



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FSP TREATED AND BYPASS MONTHLY CONCENTRATIONS

FIGURE 6.7

6.2.3 COMPARISON OF MEASURED CONCENTRATIONS WITH PLRMV1 CEC VALUES

PLRMv1 currently assigns a static CEC value to all treated effluent volumes for each pollutant modeled based on the type of SWT facility modeled. This research obtained the largest dataset to date of dry basin and wet basin performance estimates for reducing pollutant concentration in stormwater runoff in the Tahoe Basin to compare with PLRMv1 CEC values. The overall sampling approach was designed to cost-effectively produce a dataset that captures the range of treated effluent pollutant concentrations across SWT sites and event types (i.e., summer thunderstorms, winter rain, rain on snow, and snowmelt) in order to infer the most representative CECs for wet and dry basins. While automatic sampling techniques may have produced a dataset with greater resolution and diversity of possible effluent concentrations, these techniques are extremely costly, and had they been implemented under this research, high resolution data collection would have been limited to a single SWT for two water years. The more cost-effective passive sampling technique combined with limited grab sampling was chosen in order to increase the spatial and temporal range of the dataset resulting in over 30 sampled events at three different wet basins and over 20 events at two dry basins.

It is worth noting that monitoring of flow-based cartridge filters with the same cost-effective passive sampling techniques used for dry and wet basins was not feasible, and therefore automated instrumentation had to be used to estimate treatment performance. The one cartridge filter included in the study proved to be extremely challenging to instrument properly due to backwater and high moisture content in the subsurface vault and the monitoring effort produced a very limited dataset. Data from the monitored cartridge filter is presented in Table 6.9, but additional effluent data from cartridge filters is necessary prior to evaluating the representativeness of the PLRMv1 CEC values for this type of SWT facility.

Over the three year period, treated outflow was sampled using both the passive samplers and grab sampling to capture concentrations during the rising limb, falling limb and peak of the event hydrographs and we believe the wet and dry basin dataset in hand provides a representative range of hydrograph characteristics across sites and event types. Evaluations of the grab sample timing indicate that that the majority of the grab samples were collected on the falling limb of the respective event hydrograph. The treated outflow samples are nearly an even split with 43% collected via grab sampling for the dry basins and 53% collected via grab from the wet basins (see Figure 6.7). Grab samples are an opportunistic sampling approach, which require site visits by field personnel during an event, and can result in sample collection anywhere on the storm hydrograph. In comparison, a passive sampler reliably collects a discrete sample on the rising limb of a storm at the same water level of SWT inundation across all events. The first flush phenomena that results in higher pollutant concentrations during the rising limb of an event hydrograph has been well documented in streams (Stubblefield et al. 2006) and urban stormwater (Bertand-Krajewski et al. 1998, CWP 2005). Thus, we expect sample concentrations collected from passive samplers on the rising limbs to be higher on a relative basis when compared to grab samples collected on the falling limbs of an event hydrograph. Quantitative comparison of passive and grab samples from all sites (using the non-parametric Mann-Whitney U statistic) shows that passive sample means are significantly higher (95% confidence) in the dry basins, while the same difference cannot be distinguished in the wet basins. These results were greatly influenced by the summer thunderstorms that infrequently resulted in treated outflow from wet basins during the study period, but rarely resulted in treated outflow (and thus were not sampled) at the subject dry basins (see Figure 6.7).

Given the potential sampling biases associated with the sampling design and our desire to determine a single average annual treated outflow concentration for dry and wet basins from the measured data to compare with PLRMv1 CEC estimates, the following approach was implemented and results verified using an objective statistical technique. All of the treated samples (grab and passive) were integrated by season and key statistical metrics for

WET BASIN TREATED OUTFLOW

	SRP (mg/L)	DP (mg/L)	TP (mg/L)	TSS (mg/L)	FSP (mg/L)
	Fall/Winter (Oct 1- Feb 28)				
mean	0.04	0.04	0.16	59.5	48.8
median	0.02	0.04	0.12	28.0	16.5
stdev	0.05	0.03	0.13	103.2	91.4
n	26	26	26	36	36
	Spring (Mar 1- May 31)				
mean	0.01	0.02	0.03	17.4	15.0
median	0.01	0.01	0.03	14.0	10.6
stdev	0.01	0.01	0.01	20.9	19.2
n	13	4	4	28	28
	Summer (June 1- Sept 30)				
mean	-	-	-	403	186
median	-	-	-	530	234
stdev	-	-	-	339	156
n	0	0	0	3	3

DRY BASIN TREATED OUTFLOW

	SRP (mg/L)	DP (mg/L)	TP (mg/L)	TSS (mg/L)	FSP (mg/L)
	Fall/Winter (Oct 1- Feb 28)				
mean	0.18	0.20	0.19	125	80.2
median	0.09	0.11	0.17	26.0	17.0
stdev	0.22	0.26	0.13	187	122
n	14	14	14	21	21
	Spring (Mar 1- May 31)				
mean	0.02	0.03	0.08	51.0	36.6
median	0.02	0.02	0.07	28.0	22.1
stdev	0.24	0.28	0.13	210	136
n	11	11	11	16	16
	Summer (June 1- Sept 30)				
mean	-	-	-	-	-
median	-	-	-	-	-
stdev	-	-	-	-	-
n	0	0	0	0	0

CARTRIDGE FILTER TREATED OUTFLOW

	SRP (mg/L)	DP (mg/L)	TP (mg/L)	TSS (mg/L)	FSP (mg/L)
	Fall/Winter (Oct 1- Feb 28)				
mean	0.02	0.02	0.06	40.3	22.3
median	0.02	0.02	0.06	28.0	21.4
stdev	-	-	-	27.6	15.4
n	1	1	1	3	3
	Spring (Mar 1- May 31)				
mean	0.01	0.02	0.06	43.8	34.9
median	0.01	0.02	0.05	48.0	17.0
stdev	0.001	0.01	0.01	28.6	31.7
n	3	3	3	5	5
	Summer (June 1- Sept 30)				
mean	-	-	-	65.0	54.1
median	-	-	-	-	-
stdev	-	-	-	-	-
n	0	0	0	1	1

wet basins, dry basins and cartridge filter samples and are provided in Table 6.9. The PLRM long-term simulation was used to determine the relative seasonal contribution of the average annual total urban runoff (Table 6.10). The seasonal runoff volume contributions were used to calculate a weighted mean and median for each pollutant of concern (Table 6.11) and compared to PLRMv1 CEC values by SWT type. EQ 6.3 summarizes how the seasonal FSP concentration values were integrated to calculate volume weighted average FSP concentration for wet and dry basins:

$$[FSP]average = [FSP]_{f/w} fRV_{f/w} + [FSP]_{spr} fRV_{spr} + [FSP]_{sum} fRV_{sum} \qquad \text{EQ (6.3)}$$

where [FSP] average is assumed to be our best representation of a flow-weighted annual average FSP concentration given the available dataset, $[FSP]_i$ is the average FSP concentration of all observations made within the respective seasons (see Table 6.9), and fRV_i is the fraction of the total average annual urban runoff volumes for each season indicated in Table 6.10.

Table 6.10. Average annual seasonal contribution to total urban runoff volumes as simulated by PLRM. These season designations are consistent with the NPDES permit stormwater monitoring reporting requirements (LRWQCB 2011).

Season	% of WY
Fall/Winter (Oct 1- Feb 28)	53%
Spring (Mar 1- May 31)	40%
Summer (June 1- Sept 30)	7%

By definition, a CEC is the long-term flow weighted concentration of all treated outflow discharged from a specific SWT type maintained in acceptable condition over an 18 year period. While the dataset used to estimate the values in Table 6.11 is limited, we do believe the dataset captures the range of potential event types, seasons, and pollutant loading conditions for the water years sampled. However, given the higher frequency of occurrence and relative ease of sampling snowmelt runoff event types, we believe the timing of the sample collection is likely to bias the existing dataset towards a higher number of low flow and low concentrations samples. While episodic high intensity rain events can transport substantially greater pollutant loads, they are more infrequent and therefore more challenging to sample, particularly using grab sampling techniques. Therefore, the flow weighted mean obtained from a representative dataset is assumed to be the most representative value to compare to PLRM CECs, rather than the median that can disproportionately reduce the influence of the higher concentration events on estimates of CECs during the monitoring period. The seasonal flow weighting approach incorporates greater importance of fall and spring seasonal concentrations on the annual stormwater loads. Thus, we recommend the most representative measured concentrations are the volume weighted seasonal means; highlighted in red in Table 6.11.

In order to assess the reasonableness of the volume weighted mean concentrations measured during this research (see Table 6.11), we employed a bootstrap resampling method. Since it is infeasible to sample the event mean concentration of all runoff events, we must obtain a subset of the population of possible events. The bootstrap analysis provides a measure of the variability of the mean we have computed from our sample by constructing a number of sample populations of the observed dataset (and of equal size to the observed dataset), each of which is obtained by random sampling with replacement from the original dataset. We resampled the wet and dry basin datasets 10,000 times for each pollutant to create a distribution of mean values from which we can estimate a confidence interval of the mean. The output of the bootstrap analysis is expressed as the range of the 95% confidence interval of the mean concentration. As presented in Table 6.11, all of the flow weighted means fall

WET BASIN

	SRP (mg/L)	TP (mg/L)	DIN (mg/L)	TN (mg/L)	TSS (mg/L)	FSP (mg/L)
	PLRM v1 CEC					
	0.04	0.10	0.10	0.10	10	10
	WY09-11 data					
volume weighted mean	**0.03**	**0.10**	NA	NA	**67**	**45**
volume weighted median	0.01	0.08	NA	NA	58	29
n	*39*	*30*	*NA*	*NA*	*67*	*67*
	Bootstrap Results					
bootstrap mean	0.03	0.14	NA	NA	57	41
95% confidence interval	0.02 - 0.05	0.10 - 0.20	NA	NA	33 - 115	25 - 75
bootstrap simulations	10,000	10,000	NA	NA	10,000	10,000

DRY BASIN

	SRP (mg/L)	TP (mg/L)	DIN (mg/L)	TN (mg/L)	TSS (mg/L)	FSP (mg/L)
	PLRM v 1 CEC					
	0.05	0.16	0.10	0.10	25	25
	WY09-11 data					
volume weighted mean	**0.10**	**0.13**	NA	NA	**87**	**57**
volume weighted median	0.06	0.12	NA	NA	25	18
n	*24*	*20*	*NA*	*NA*	*34*	*34*
	Bootstrap Results					
bootstrap mean	0.11	0.16	NA	NA	96	63
95% confidence interval	0.06 - 0.43	0.12 - 0.25	NA	NA	54 - 190	36 - 125
bootstrap simulations	10,000	10,000	NA	NA	10,000	10,000

within the bootstrapped 95% confidence intervals. These results indicate that we are 95% sure that the actual volume weighted mean is within the range of possible means that would be calculated for the entire event population, given the distributional characteristics of our dataset. In addition, the seasonal weighted average annual means for TSS and FSP are within 15% of the bootstrap means for TSS and FSP, which given the information available confirms these are the best estimations of the CECs using the measured datasets.

Comparing to PLRMv1 values, both the wet basin and dry basin TP and SRP CEC values currently fall within the 95% confidence range and are very similar to the volume weighted means generated with this dataset. In contrast, the PLRMv1 TSS and FSP CEC values for both wet and dry basins are lower than the minimum values of the 95% confidence interval (see Table 6.11). Given that this is the best available data on wet and dry basin treated outflow quality in the Tahoe Basin, it suggests that the TSS and FSP PLRMv1 CEC values are potentially too low relative to Tahoe Basin stormwater conditions. However, any recommendations for refining PLRM CECs for wet and dry basins should consider the following limitations of the dataset.

- The data was obtained from three increasingly wet water years. The winters were characterized by above average snowfall, which as explained in Chapter 5 could have potentially resulted in greater delivery of FSP from increased road abrasive use relative to normal or below normal water years. Additionally, greater annual volumes of runoff were sampled during the study relative to what would be expected during an average water year, which can reduce SWT treatment performance for TSS and FSP.
- As discussed in Chapter 6.1 when evaluating the limitations of SWT hydrology observations, there was a general lack of maintenance performed on the SWTs monitored for this study. Therefore, it is likely that each of the SWTs monitored was not performing at its highest achievable treatment condition and thus the observed treated water quality might be better if regular maintenance was implemented. Regardless of this point, we believe the data is representative of the general performance of most current SWTs in the Tahoe Basin, which typically receive infrequent water quality maintenance.
- The flow weighted mean for dry basins does not include any summer samples from high intensity and short duration rain events that typically have relatively high concentrations, thus biasing the dry basin population to the more frequent event types with lower pollutant concentrations.

Assuming the PLRM SWT module is not modified and continues to assign a static CEC for all treated outflow by SWT type, and based on the limitations and considerations above, we present recommended revisions to the PLRM CEC values (Table 6.12) assuming minimal SWT maintenance for water quality is performed. Each value presented in Table 6.12 falls between the minimum value of the 95% confidence interval and the volume weighted mean measured and considers the fact that the majority of data was obtained from wet water years. The recommended CEC revisions are intended to reflect our current understanding of SWT function and commitment to maintenance in the Tahoe Basin.

Table 6.12. Recommended revisions to PLRM TSS and FSP CECs for wet basins and dry basins in the Tahoe Basin.

SWT Type	Current PLRM TSS CEC (mg/L)	Recommended TSS CEC (mg/L)	TSS Rationale	Current PLRM FSP CEC (mg/L)	Recommended FSP CEC (mg/L)	FSP Rationale
WET BASIN	10	40	Minimum of 95% interval: 33 mg/L Volume weighted mean: 67 mg/L	10	30	Minimum of 95% interval: 25 mg/L Volume weighted mean: 45 mg/L
DRY BASIN	25	60	Minimum of 95% interval: 54 mg/L Volume weighted mean: 87 mg/L	25	40	Minimum of 95% interval: 36 mg/L Volume weighted mean: 57 mg/L

6.2.4 CEC FINDINGS AND RECOMMENDATIONS

- PLRMv1 currently assigns a static CEC value to all treated effluent volumes for each pollutant modeled based on the type of SWT facility modeled. Results suggest the treatment capability to achieve effluent FSP concentrations similar to the recommended FSP CECs in Table 6.12 are limited when inflow concentrations are relatively elevated (> 300 mg/L). The results of the data analysis suggest that future revisions to PLRM should consider developing a linkage between achievable effluent concentrations, especially for FSP, to inflowing concentrations while maintaining limits on the maximum achievable quality of treatment runoff. It is likely that PLRMv1 is currently overestimating treatment performance for SWTs where influent pollutant concentration are consistently high (e.g., greater than 300 mg/L; see Table 6.8). Effective pollutant source control actions implemented in catchments tributary to an SWT will reduce influent pollutant concentrations and thereby improve the treatment performance of the SWT.
- Volume weighted means of treated outflow quality were calculated for comparison to current PLRM CEC values for TSS, FSP, TP and SRP. A bootstrapping statistical technique was conducted on the raw datasets to define the 95% confidence interval within which we expect the actual long-term volume weighted mean to exist. The TP and SRP results were similar to PLRM CEC values and do not appear to require modification. However, the TSS and FSP estimates of treated effluent quality derived from this research were 3 to 4 times higher than the PLRMv1 CEC values for both wet and dry basins. Recommended revisions to the current PLRM TSS and FSP CECs for wet and dry basins are provided in Table 6.12. These relatively higher CEC values for FSP and TSS may be more appropriate estimates of achievable effluent quality from wet basins and dry basins given typical Tahoe Basin maintenance practices. Anecdotal evidence obtained from this research (see Chapter 3.1.4 and Table 3.5) and previous research efforts suggests that SWTs in the Tahoe Basin are generally not maintained to the level of maintenance assumed over the 18 year time period of simulation in PLRMv1.
- The continuation of long-term monitoring and sampling of treated outflow would be extremely valuable to increase the population of data across water year types and hopefully characterize improvements in treated effluent water quality as SWT maintenance actions likely increase in the Tahoe Basin as part of the Lake Tahoe TMDL implementation process. The inclusion of other SWT types modeled in PLRM using defensible and consistent data collection techniques would be also address key data gaps. The re-evaluation of efforts similar to this research on 5 year intervals would provide Tahoe specific stormwater quality data that would continue to inform and improve PLRM estimates of pollutant load reductions.

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Attachment D

Pilot Catchment Validation Study: Lake Tahoe Basin (June 2012)

PILOT CATCHMENT VALIDATION STUDY: LAKE TAHOE BASIN

Final Report: June 2012. Funded by Army Corps of Engineers Sacramento District.

2NDNATURE ecosystem science + design / nhc

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LIST OF TERMS

2N	2NDNATURE, LLC
BMP RAM	Best Management Practice Maintenance Rapid Assessment Methodology; Tool for Tahoe Basin urban stormwater community to determine relative condition of an urban stormwater BMP.
CICU	Commercial/Industrial/Communications/Utilities; Land use designated in Tahoe Basin TMDL.
CRC	Characteristic Runoff Concentration; Representative concentration for a pollutant of concern in runoff from a specific land use and associated land use condition in PLRM.
Crediting Program	Lake Tahoe Clarity Crediting Program; Tahoe Basin program that defines system to track and evaluate pollutant load reductions and related credits within context of TMDL by urban catchment.
CSLT	City of South Lake Tahoe; Tahoe Basin urban jurisdiction responsible for Osgood catchment operations and maintenance
DCIA	Directly Connected Impervious Area; Impervious surfaces draining through a direct hydraulic connection to a surface water drainage system.
FSP	Fine Sediment Particle; Mass fraction of TSS concentration <16µm.
LRWQCB	Lahontan Regional Water Quality Control Board; California regulatory agency overseeing Tahoe Basin TMDL implementation.
MFR	Multi-Family Residential; Land use designated in Tahoe Basin TMDL.
NDEP	Nevada Division of Environmental Protection; Nevada regulatory agency overseeing Tahoe Basin TMDL implementation.
NTCD	Nevada Tahoe Conservation District; Local Tahoe Basin research agency
PLRM	Pollutant Load Reduction Model; Tool for Tahoe Basin urban stormwater community to estimate pollutant load reductions associated with catchment-scale water quality improvement actions.
Road RAM	Road Rapid Assessment Methodology; Tool for Tahoe Basin urban stormwater community to determine the condition of impervious road surfaces.
Road Class	Road RAM term that categorizes roads based on the combination of pollutant control and recovery practices employed on a particular road throughout the year.
Road Risk	PLRM term that incorporates road characteristics to describe relative risk of pollutant generation and transport downslope from impervious road surfaces.
SFR	Single Family Residential; Land use designated in Tahoe Basin TMDL.
SNPLMA	Southern Nevada Public Land Management Act; Tahoe Basin research funding source
SWMM	Storm Water Management Model; EPA-developed dynamic rainfall-runoff simulation model used for single event and long term (continuous) simulation of surface hydrology quantity from primarily urban/suburban areas.
SWT	Stormwater Treatment Facility; Treatment BMP designed to reduce urban stormwater volumes and/or pollutant concentrations from a concentrated stormwater flow path.
TMDL	Tahoe Basin Total Maximum Daily Load; Implementation plan that establishes pollutant load reduction allocations for urban stormwater to improve Lake Tahoe clarity.
TSS	Total Suspended Sediment; Mass of sediment contained in a known volume of water.
USACE	US Army Corps of Engineers; Tahoe Basin research funding source
WY	Water Year; Hydrology term defining a twelve month period from October 1st to September 30th.

CHAPTER 1. EXECUTIVE SUMMARY

The *Pilot Catchment Validation Study* was funded by the US Army Corps of Engineers (USACE) to develop, test and refine stormwater sampling protocols, Pollutant Load Reduction Model (PLRM; NHC et al. 2009a) modeling techniques, and data analysis approaches to facilitate a catchment scale comparison of pollutant load observations with PLRM predictions. This research is the initial effort to explore a few key questions regarding stormwater tools that are intended to support the implementation of the Lake Tahoe TMDL (LRWQCB and NDEP 2010):

1. Are PLRM predictions of stormwater runoff volumes and fine sediment particle (FSP; <16μm) loads on a catchment scale reasonable when compared to measured values at the outlet of an urban catchment?
2. Is the catchment FSP loading signal sensitive to changes in road condition on a seasonal and annual basis?
3. Are Road Rapid Assessment Methodology (Road RAM; 2NDNATURE et al. 2010c) scores reflective of actual road maintenance practices, and can RAM scores be predicted based on these practices?

The resources to achieve the objectives outlined above were extremely limited and this was intentionally an initial effort that would, hopefully, be built upon using additional funding sources. Therefore, to maximize the information and findings from this research the Osgood catchment in South Lake Tahoe, CA (see Figure 3.1) was selected as the study site. The Osgood catchment was determined to be the most cost-effective site to test and develop these protocols because the researchers are very familiar with the site; another related stormwater research effort was being simultaneously conducted there; and a number of the methods and necessary site data could be shared between the two efforts. The technical report detailing the results of that other research, titled *Focused Stormwater Quality Monitoring to Inform Assumptions & Evaluate Predictive Capabilities of Existing Tools* (2NDNATURE and NHC 2012), is being released concurrently with this document. Similar data collection and analysis techniques were used for both efforts to evaluate existing stormwater tools, and background information on the tools and associated algorithms are not repeated within this report.

This research data collection focused on (1) documentation of the actual road maintenance practices implemented by the City of South Lake Tahoe (CSLT; the responsible jurisdiction) within the catchment; (2) road condition tracking using Road RAM observations at 20 road segments located throughout the catchment and representing a range of road attributes; (3) continuous flow and turbidity monitoring at the catchment outlet (i.e., inlet to the Osgood wet basin, see Figure 3.2); and (4) treatment BMP condition tracking of the pre-treatment settling basin (forebay) immediately upstream of the monitoring site. While this dataset is too limited to provide recommendations for future tool improvements at this time, this research has improved our understanding of how to manage, analyze and report both monitored and PLRM generated datasets to ensure future validation efforts are as representative and informative as possible.

Subsequent to initiation of this *Pilot Catchment Validation Study,* 2N and NHC were awarded a SNPLMA Round 11 research grant in November of 2011 to build upon this research. Two additional urban catchments have been selected for instrumentation and monitoring from March 1, 2012 to February 28, 2013 and then compared to PLRM predictions. The instrumentation, data management, modeling approach and data analysis lessons learned from this effort have been invaluable to ensure the future research results in accurate stormwater data and reliable PLRM predictions to make informed comparisons and conduct model validation. The key findings and recommendations from this *Pilot Catchment Validation Study* include:

1. In general, the limited data show initial alignment between measured and PLRM predicted values for road FSP concentrations (see Tables 5.4 and 5.5) and catchment inflow volumes (see Table 5.8); however, the following issues need to be addressed in order to improve comparability:

- Continuous stormwater monitoring is challenging, especially in the freeze/thaw conditions of the Tahoe climate and in locations of intermittent flow. The research team faced a myriad of issues in the selection, calibration and maintenance of the installed turbidity equipment. The USACE resources provided the opportunity to test multiple approaches and configurations and identify the techniques necessary to obtain reliable turbidity and stormwater FSP data. Improved instrumentation and rigorous QA/QC protocols have been identified to ensure any future instrument issues are quickly resolved.
- In WY2011 there was a consistent and significant baseflow contribution from the Keller Canyon catchment (see Figure 3.1). PLRM was not designed to accommodate baseflow into the hydrologic estimates, which makes alignment of measured and modeled runoff volumes challenging during very wet spring conditions when baseflow is significant. The SNPLMA Round 11 funded research has expanded the monitoring study to include two additional catchments. In part, these catchments have been selected because they are not suspected to have a significant baseflow component, even in wet years.

2. To test the sensitivity of the overall catchment water quality signal to changes in road conditions, we compared our discrete Road RAM observations to the continuous turbidity time series measured at the catchment outlet. While the WY2011 instrumentation challenges preclude an in-depth analysis, the limited outlet monitoring data have a lower measured catchment FSP concentration than the comparable spatially averaged road FSP concentration based on Road RAM observations (see Table 5.6). This result follows our assumptions that dilution of the road FSP signal will occur when commingled with water from other “cleaner” land uses. Future data collection will address the following:
   - If we desire to evaluate the potential signal of road conditions on catchment water quality, we must constrain the inherent influence hydrologic variability has on catchment FSP loads. We need to account for all other potential FSP sources and sinks within the catchment, including actions that would result in capture and removal of material generated by the roads prior to delivery to the monitoring station. The research team will work with jurisdictions to document treatment BMP maintenance practices and the estimated FSP mass recovered from the system.
   - This research struggled through the iterative process of defining and delineating road class with CSLT personnel. In the process of changes in road class, the initial road segment selection no longer provided at least 3 road segments by class for precision analysis. Future catchment monitoring will inevitably include periodic changes to road class, and researchers must be cognizant to adjust road segments included in observations accordingly.
3. Great improvements have been made on defining and coordinating the documentation of road maintenance practices by the responsible jurisdiction. The research team and CSLT developed initial jurisdiction-wide definitions of road class and improved the documentation of catchment road maintenance practices. Future data collection and analysis will address the following:
   - Protocols will be refined to document the actual road maintenance practices conducted within the catchment, including the total amount of abrasives applied, total number of miles swept per day, number of passes per road per day, and total amount of FSP recovered. This improved documentation will increase our confidence that actions are conducted consistently each time, such that we can reduce some uncertainty in our analyses and comparisons.
   - Following the completion of the SNPLMA Round 11 field data collection effort, a statistical analysis will be conducted to evaluate the ability to predict road condition (i.e., FSP concentration and corresponding Road RAM score) as a result of prior sequential happenings, namely road maintenance practices, runoff events and other weather variables. 2NDNATURE (2012) has demonstrated the ability to predict road condition using an extensive road condition dataset obtained by the Nevada Tahoe

Conservation District (NTCD) in Washoe County (NTCD and DRI 2011 and 2NDNATURE 2012 *in prep*), and the inclusion of the WY2012 data will allow a similar analysis on the road networks within the monitored catchments.

CHAPTER 2. RESEARCH BACKGROUND

Recently a suite of Tahoe Basin urban stormwater management tools has been developed and adopted by the Lake Clarity Crediting Program (Crediting Program; LRWQCB and NDEP 2009) to support the implementation and tracking of pollutant load reduction actions associated with the Lake Tahoe TMDL. The Lake Tahoe TMDL analysis has identified that fine sediment particles (<16µm; FSP) are the primary pollutant of concern impacting lake clarity and stormwater runoff originating in urban areas is estimated to contribute 72% of the annual FSP pollutant load to Lake Tahoe (LRWQCB and NDEP 2010). The Crediting Program recommends the use of the Pollutant Load Reduction Model (PLRM; NHC et al. 2009a), Road Rapid Assessment Methodology (Road RAM; 2NDNATURE et al. 2010c) and Best Management Practice Maintenance Rapid Assessment Methodology (BMP RAM; 2NDNATURE et al. 2009a) by local jurisdictions and regulators to estimate and track urban load reductions over time. The Crediting Program directs urban jurisdictions to estimate annual load reductions using distinct urban catchments to preserve the physical mass balance concept that annual pollutant loading to Lake Tahoe is the sum of distinct input points (i.e., urban catchment outlets). The Lake Tahoe TMDL and Crediting Program are committed to the use of these tools to manage the Lake Tahoe TMDL Clarity Challenge into the future, yet a number of key questions and potential tool improvements remain. This research has been funded to provide catchment-scale, on-the-ground verification of tool inputs and outputs to validate the tool interactions.

2.1 RESEARCH FUNDING AND RELATED EFFORTS

In 2010 the US Army Corps of Engineers (USACE) funded 2NDNATURE (2N) and Northwest Hydraulic Consultants (NHC) to conduct this research, titled *Pilot Catchment Validation Study*, and test the integration of the urban stormwater management tools on a single urban catchment for WY2011. The primary objective of this *Pilot Catchment Validation Study* was to develop, test and refine data collection protocols, PLRM modeling techniques, and data analysis approaches to facilitate a catchment scale comparison of pollutant load observations with PLRM predictions.

The resources for this research to achieve the objectives outlined in the scope were limited, so Osgood Basin in South Lake Tahoe, CA was selected to complete the *Pilot Catchment Validation Study*. Osgood Basin was a cost-effective site to test and develop these protocols because the researchers are intimately familiar with the site; another related stormwater research effort was being simultaneously conducted there; and a number of the methods and necessary site data could be shared between the two research efforts. The technical report detailing the results of that other research, titled *Focused Stormwater Quality Monitoring to Inform Assumptions & Evaluate Predictive Capabilities of Existing Tools* (2NDNATURE and NHC 2012), is being released concurrently with this document.

In November 2011, 2NDNATURE and NHC were awarded a SNPLMA Round 11 research grant to build upon this *Pilot Catchment Validation Study*. An additional 2 urban catchments have been selected for instrumentation, PLRM modeling and analysis from March 1, 2012 to February 28, 2013. The instrumentation, data management, modeling approach and data analysis lessons learned from this USACE-funded effort have been invaluable to ensure the future research results in accurate stormwater data and reliable PLRM predictions to make informed comparisons and conduct model validation.

2.2 TOOL OVERVIEW

The *Focused Stormwater Quality Monitoring to Inform Assumptions & Evaluate Predictive Capabilities of Existing Tools Technical Report* (2NDNATURE and NHC 2012) provides a simple overview of the PLRM and Road RAM

approaches and the key components of each tool addressed by the objectives of this research and therefore are not repeated here.

2.3 RESEARCH OBJECTIVES

The primary goal of this monitoring is to define protocols and initiate the collection of a catchment-specific empirical dataset to validate PLRM with the intention that future research would benefit from these instrumentation, data collection, management, and analysis efforts. Similarly, we experimented with and defined the appropriate approach to obtain PLRM FSP concentration and SWMM hydrology on a discrete time scale that is directly comparable to measured data. While the dataset generated from this effort is limited, the intent was to identify how best to implement the stormwater tools and collect, manage and analyze data from an urban catchment. The research data collection, management, and analysis methods are presented in Chapter 3. The location where the specific objective has been addressed in the technical report is provided for easy reference.

1. Obtain cost-effective high resolution hydrologic and sediment loading data from one urban catchment to compare measured catchment runoff and FSP data with PLRM predictions. These data will be combined with future catchment datasets to validate and recommend PLRM refinements as necessary (Chapter 5.2).

2. Provide data to test the hypothesis that urban catchment FSP loading (at an SWT inlet) is influenced by (i.e., sensitive to) road conditions on a seasonal and annual basis (Chapter 5.1).

3. Collaborate with the responsible jurisdiction to improve documentation of operational practices conducted within a specific catchment being monitored. Critical practices include chronology of road and Treatment BMP maintenance actions. The road practice actions to be documented include abrasive type, abrasive application rates, frequency and distribution; and sweeper type, sweeper speed, sweeping frequency and distribution (Chapter 4). Treatment BMP maintenance includes frequency of maintenance, type of maintenance performed (vactoring, vegetation removal, etc.), and estimated mass of material recovered, when applicable.

4. Obtain data to verify and inform our ability to predict Road RAM scores based on road maintenance practices and test if Road RAM scores reflect road maintenance actions that reduce sources and/or increase sinks of FSP. The results from objective #4 will inform future PLRM and Road RAM improvements to improve consistency and alignment of these two critical stormwater tools (Chapter 5.1).

CHAPTER 3. PILOT CATCHMENT MONITORING METHODS

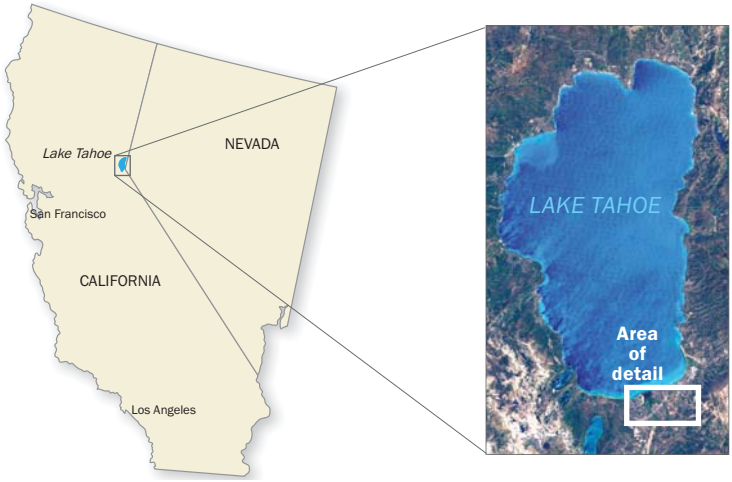
A data collection plan (2NDNATURE and NHC 2011) was finalized in April 2011 and includes details on the research objectives, site selection process, data collection strategy, and data analysis and management protocols. The plan is included as Appendix A, and below we provide a brief synopsis of the key data collection, management, and analysis methods.

3.1 CATCHMENT CHARACTERISTICS

This research integrates a number of reliable and cost-effective stormwater monitoring techniques to constrain, sample and model urban pollutant generation (particularly from roads) in the Osgood Basin catchment. Catchment details are provided in Figure 3.1 and Table 3.1. The stormwater generated within the catchment as delineated in Figure 3.1 is routed into the Osgood Basin through a pre-treatment settling basin prior to discharge to the wet basin. The water quality monitoring described below was conducted at the outlet of the settling basin (Figure 3.2).

Table 3.1. Osgood catchment summary.

Location	South Lake Tahoe, CA	
Total Area (ac)	342	
Impervious Area (%, ac)	23% (77 acres)	
Average Slope (%)	9%	
Sub-Catchments	**Bijou Park**	**Keller Canyon**
Total Area (ac)	148	194
Impervious Area (%, ac)	32% (47 acres)	16% (30 acres)
Land Use Distribution		
Primary Roads	3%	
Secondary Roads	11%	
Commercial Industrial Communications Utilities (CICU)	4%	
Multi-Family Residential (MFR)	14%	
Single Family Residential (SFR)	25%	
Unimpacted Vegetation (EP 1-5)	43%	
Catchment Soils		
Dominant Soil Type	Cassenai; Cagwin Rock	
Private Parcels (% TRPA Certification		
CICU	27%	
MFR	21%	
SFR	20%	



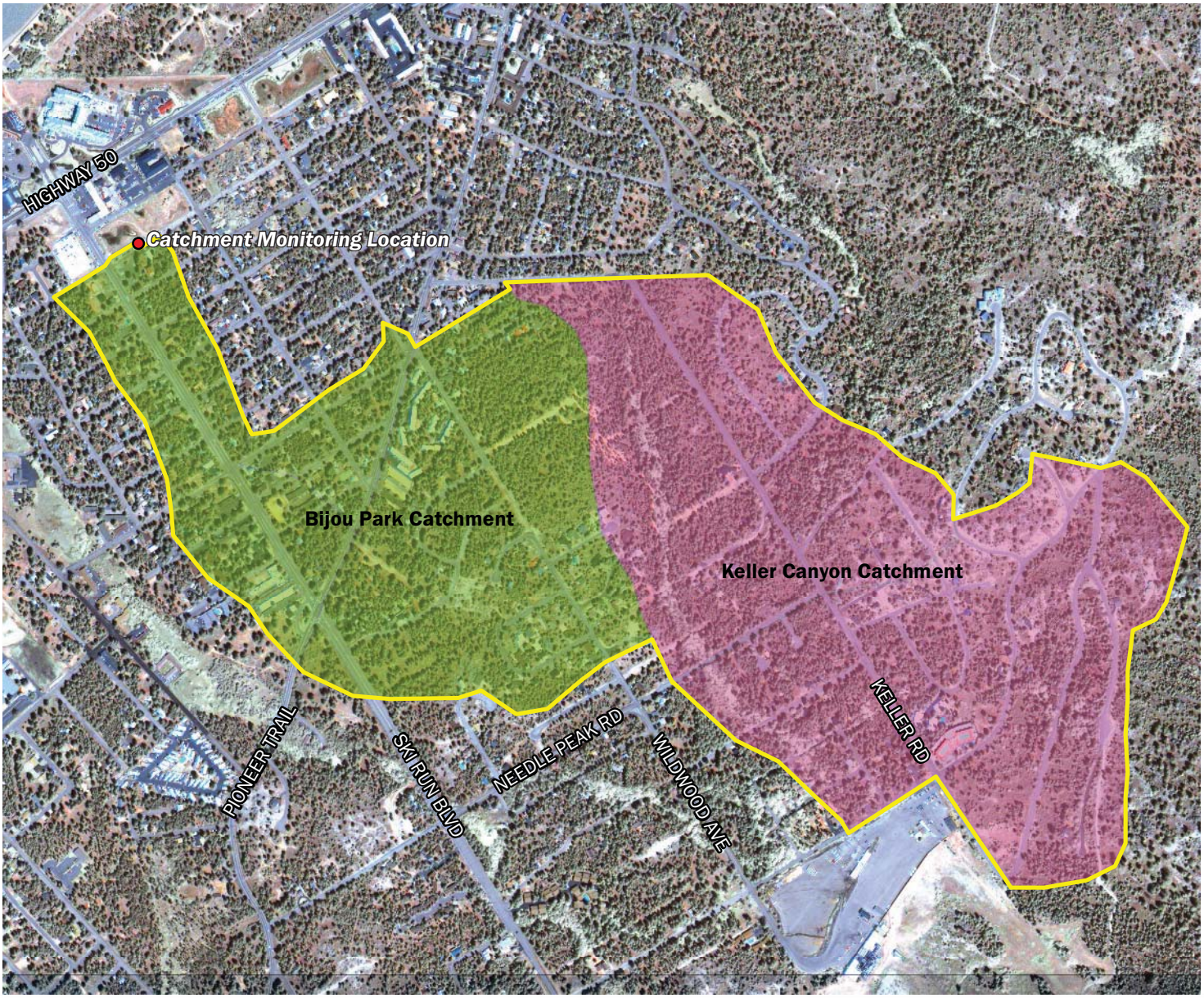


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Figure 3.1. Osgood Catchment Loacation Map

Feet
0 300 600 1,200
N

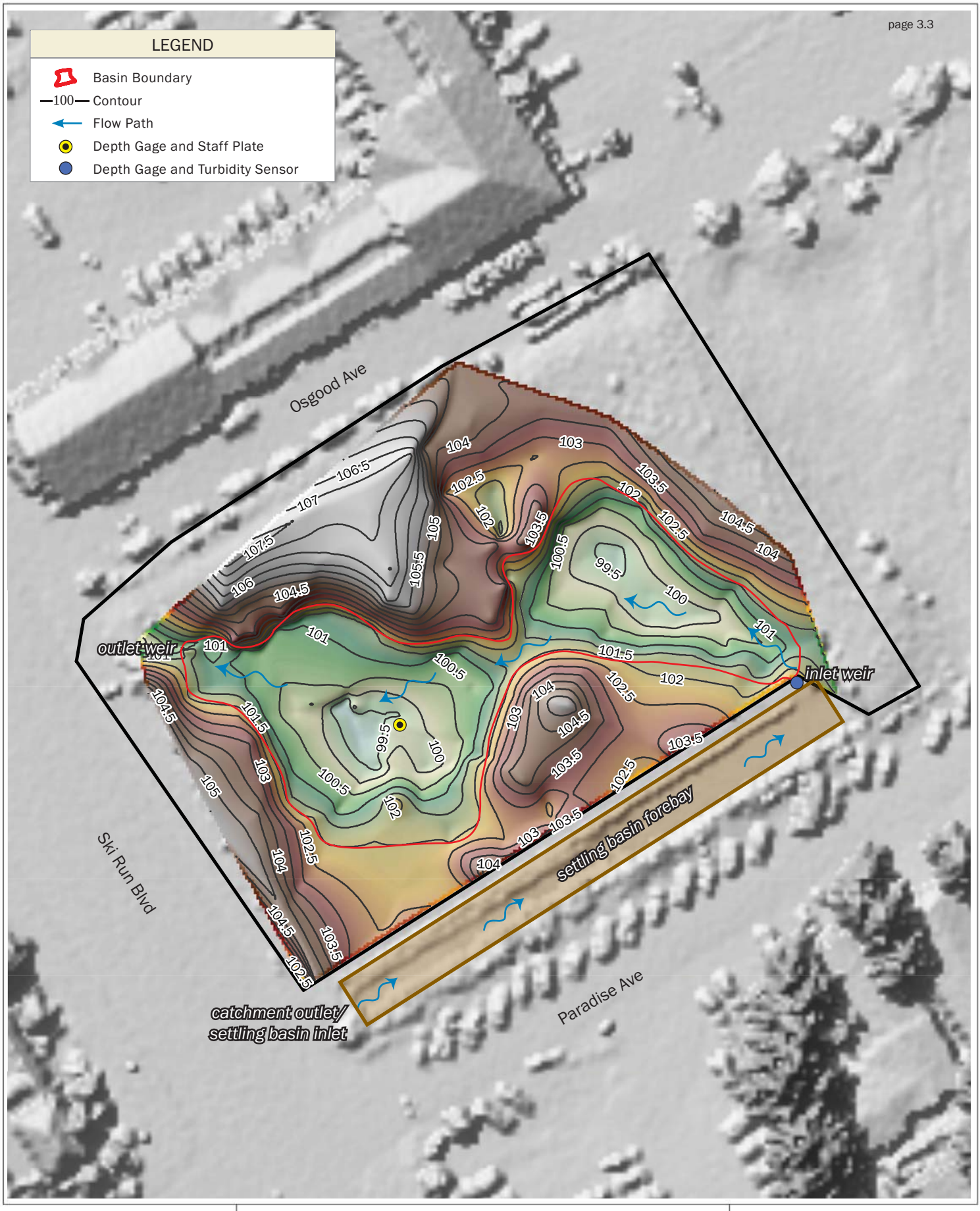

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Figure 3.2. Osgood Settling Basin and Wet Basin Site Map Shaded topographic contours of Osgood Basin plotted over a 2010 LiDAR data. Elevations values are in feet, with a contour interval of 0.5 feet. Elevation is relative to 0ft on staff plate within basin where: 0ft staff = 100ft elevation

Feet
0 15 30 60
N

3.2 CATCHMENT MONITORING

It is assumed that the road network within an urban catchment can have a significant influence on the FSP loading generated within the catchment. Therefore, road condition tracking using Road RAM provides critical data to test this hypothesis. The catchment water quality signal was monitored using high-resolution turbidity and flow monitoring at the Osgood Basin inlet and sediment accumulation surveys of the pre-treatment settling basin located at the upstream end of the Osgood Basin inlet (see Figure 3.2).

ROAD CONDITION TRACKING

Key road attributes of the 8.3 road miles in Osgood catchment were mapped by 2NDNATURE and NHC personnel and are summarized in Table 3.2. The following provides a brief description of each road attribute and the mapping methods:

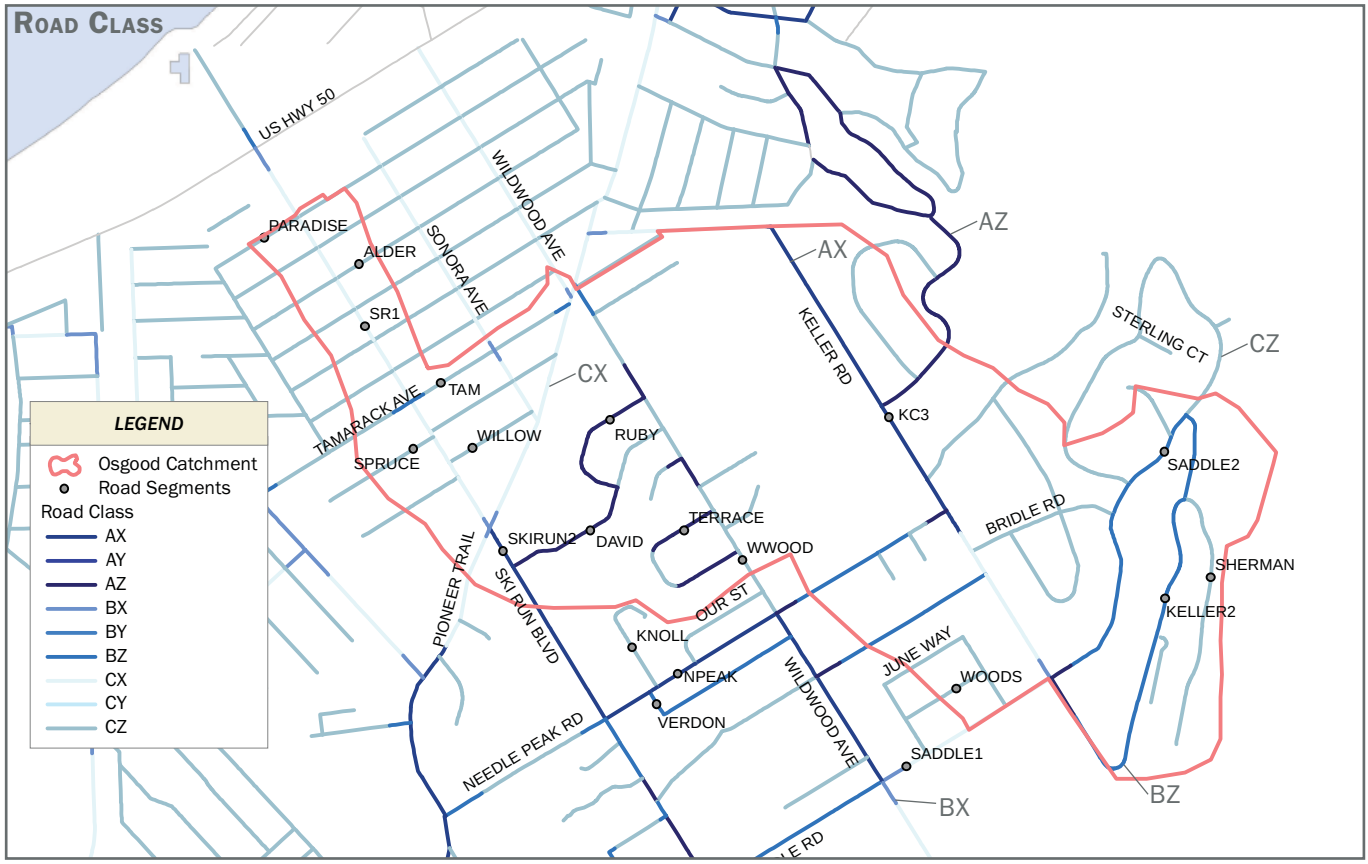
- Road Class is the combination of pollutant control practices employed on a particular road throughout the year (Road RAM; 2NDNATURE et al. 2010c). 2N personnel worked closely with CSLT public works and street personnel to map the abrasive application priority (A, B or C) and sweeping effectiveness (X, Y, Z) for all roads within the Osgood catchment based on the typical maintenance practices (see Chapter 4 for more details).
- Road Risk is a proxy for the relative likelihood of pollutant generation and transport downslope from a road (PLRM; NHC et al. 2009a). NHC updated the default PLRM road risk layer for roads within the CSLT with input from CSLT personnel in March 2011, and the shapefile is available on the TIIMS website (http://www.tiims.org/TIIMS-Sub-Sites/PLRM/docs-downloads.aspx).
- Road Surface Integrity is the quality of road pavement with respect to cracks, fissures, etc. (Road RAM; 2NDNATURE et al. 2010c). 2N field personnel mapped the road surface integrity of the lower half of the Osgood catchment according to Road RAM STEP 2 protocols described in the *Road RAM User Manual* (2NDNATURE et al. 2010d).
- Road Shoulder Condition characterizes the source control efforts to reduce road shoulder and primary flow path erosion along the side of the roadway (PLRM; NHC et al. 2009a). With funding from SNPLMA Grant PO23, NHC field personnel mapped road shoulder condition, road shoulder connectivity, and road shoulder compaction throughout the Tahoe Basin. The March 2011 shapefile is available on the TIIMS website (http://www.tiims.org/TIIMS-Sub-Sites/PLRM/docs-downloads.aspx).
- Road Shoulder Connectivity defines the degree of hydraulic connection between the road surface and surface water resource (PLRM; NHC et al. 2009a).
- Road Shoulder Compaction describes the degree to which the road shoulder has been disturbed by vehicular and pedestrian traffic (PLRM; NHC et al. 2009a).

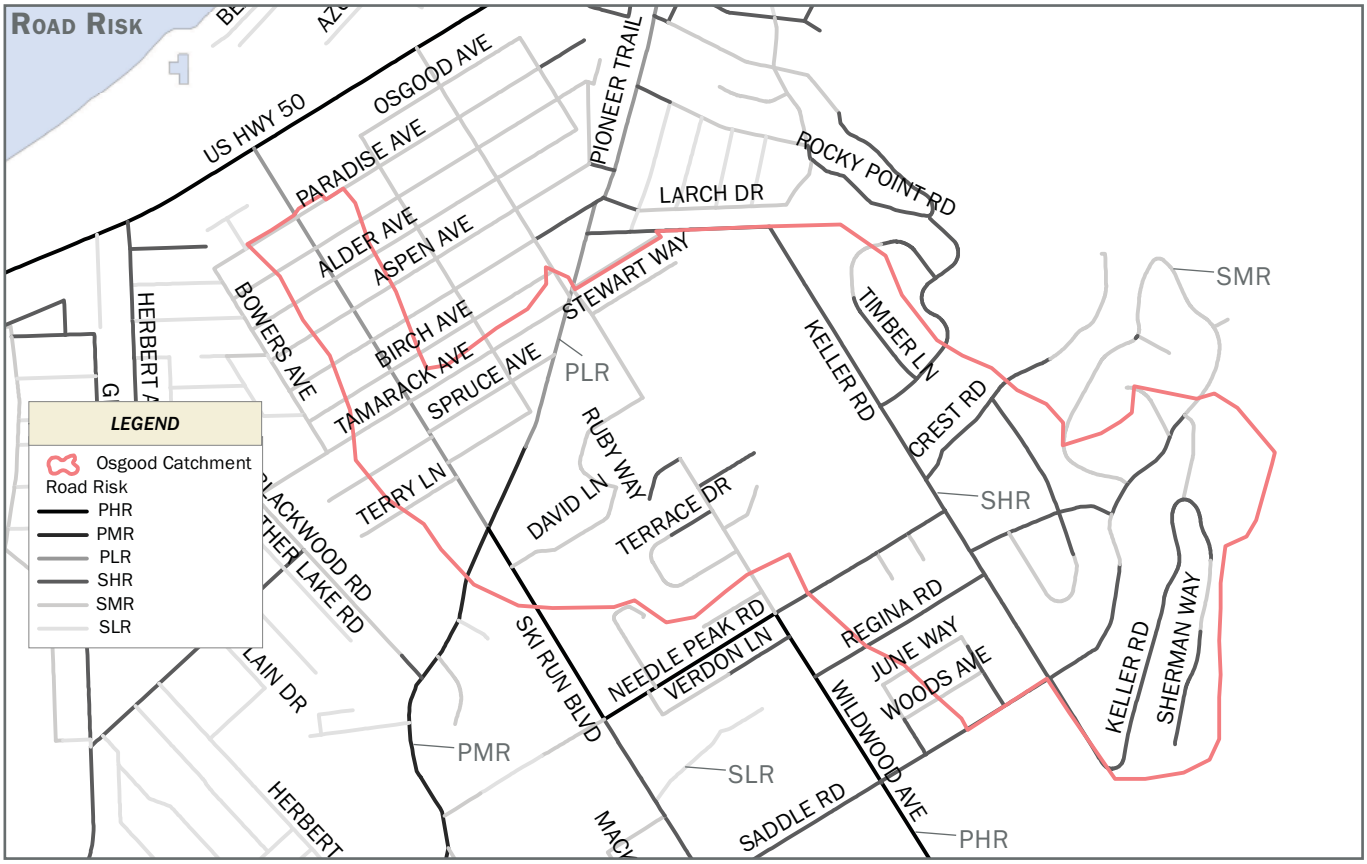
Table 3.2. Osgood catchment road attribute summary by road miles and number of road segments. Road surface integrity was not mapped for the entire catchment. Road shoulder condition, connectivity and compaction are all mapped for both sides of the road.

Road Attribute		Catchment Miles	% of Catchment	# Road Segments
Road Class	AX	0.6	7.2%	3
	AY	0	0%	-
	AZ	0.9	10.8%	3
	BX	0.1	1.2%	1
	BY	0	0%	-
	BZ	1.4	16.9%	3
	CX	1.4	16.9%	1
	CY	0	0%	-
	CZ	3.9	47.0%	9
Road Risk	PHR	0.1	1.2%	2
	PMR	0	0%	-
	PLR	0.8	9.5%	1
	SHR	4.5	53.6%	5
	SMR	1.9	22.6%	12
	SLR	1.1	13.1%	0
Road Surface Integrity	Poor	0.6	7.2%	1
	Moderate	2.4	28.9%	7
	Good	0.7	8.4%	1
	n/a	4.6	55.4%	8
Road Shoulder Condition	Erodible	2.8	18.2%	7
	Protected	0	0%	-
	Stable	6.5	42.2%	18
	Stable & Protected	6.1	39.6%	15
Road Shoulder Connectivity	DCIA	13.2	85.7%	33
	ICIA	2.2	14.3%	7
Road Shoulder Compaction	High	9.9	64.7%	27
	Moderate	4.5	29.4%	6
	Protected	0.9	5.9%	7

Following Road RAM guidance (2NDNATURE et al. 2010d), 20 road segments were selected based on the distribution of road class throughout the Osgood catchment (Figure 3.3). Four monitoring locations are outside the catchment boundary but included to ensure the respective road class is representatively sampled. Catchment road class is defined relative to the practices throughout the CSLT jurisdiction and therefore these road segments are representative of the conditions within the catchment. Table 3.2 includes the number of road segments per road attribute category.

2N personnel conducted Road RAM STEP 4B field observations at each of the 20 road segments a total of 7 times during WY2011: 1 fall observation (10/14/10), 1 winter observation (1/22/11), 2 late winter/early spring observations (4/6/11; 4/20/11), 2 spring observations (5/19/11; 6/22/11), and 1 summer observation (8/17/11).





Road class and road risk labels are provided in maps to improve differentiation of attribute colors.

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OSGOOD CATCHMENT ROAD ATTRIBUTES AND ROAD SEGMENT LOCATIONS

FIGURE 3.3

CATCHMENT WATER QUALITY MONITORING

This research aimed to identify and refine methods for continuous turbidity monitoring in an intermittent flow environment. High resolution turbidity monitoring is common in systems with perennial flow, but there are a myriad of challenges associated with both automated level and turbidity monitoring in conditions that are periodically dry and when temperatures dip below freezing. Previous issues encountered by both this research team and others in the Tahoe Basin include: (1) complete instrument failure due to exposed instruments in freezing conditions, where moisture can freeze within the instrument and disrupt the instrument mechanism; (2) the loss of instrument calibration due to intermittent exposure to air leading to inaccurate readings when the instrument is reintroduced to water; and (3) inaccurate turbidity readings due to scratching of the turbidity sensor from wiper operation in dry conditions. This instrument damage can be extremely costly and result in excessive data loss. 2NDNATURE field personnel built upon this previous knowledge to identify instruments that would function properly in this intermittent, freeze/thaw conditions. The final instrument configuration selected was a Campbell Scientific CR510 datalogger, Druck level transducer and Campbell Scientific OBS-3 turbidity meter, where the turbidity meter was programmed to only collect data when the level transducer registered a water depth greater than 0 inches to avoid turbidity sensor damage from wiper operation in dry conditions. A secondary data logging program was run simultaneously to measure the datalogger battery level to QA/QC that any data gaps were due to the lack of flow and not power loss of the instruments.

Using the resources from this effort and in coordination with the CSLT, a v-notch weir (see photo to right) was constructed at the inlet of the Osgood Basin in February 2011. The instruments were also installed at this time to continuously (10-minute interval) monitor the stormwater inflowing to the wet basin from the settling basin, but only to record data when inflow was occurring. The depth time series data was converted to 10 min discharge (Q, cfs) using a hydraulic discharge equation for flow over a 90° v-notch weir (EQ1) and 5 ft rectangular weir (EQ2).

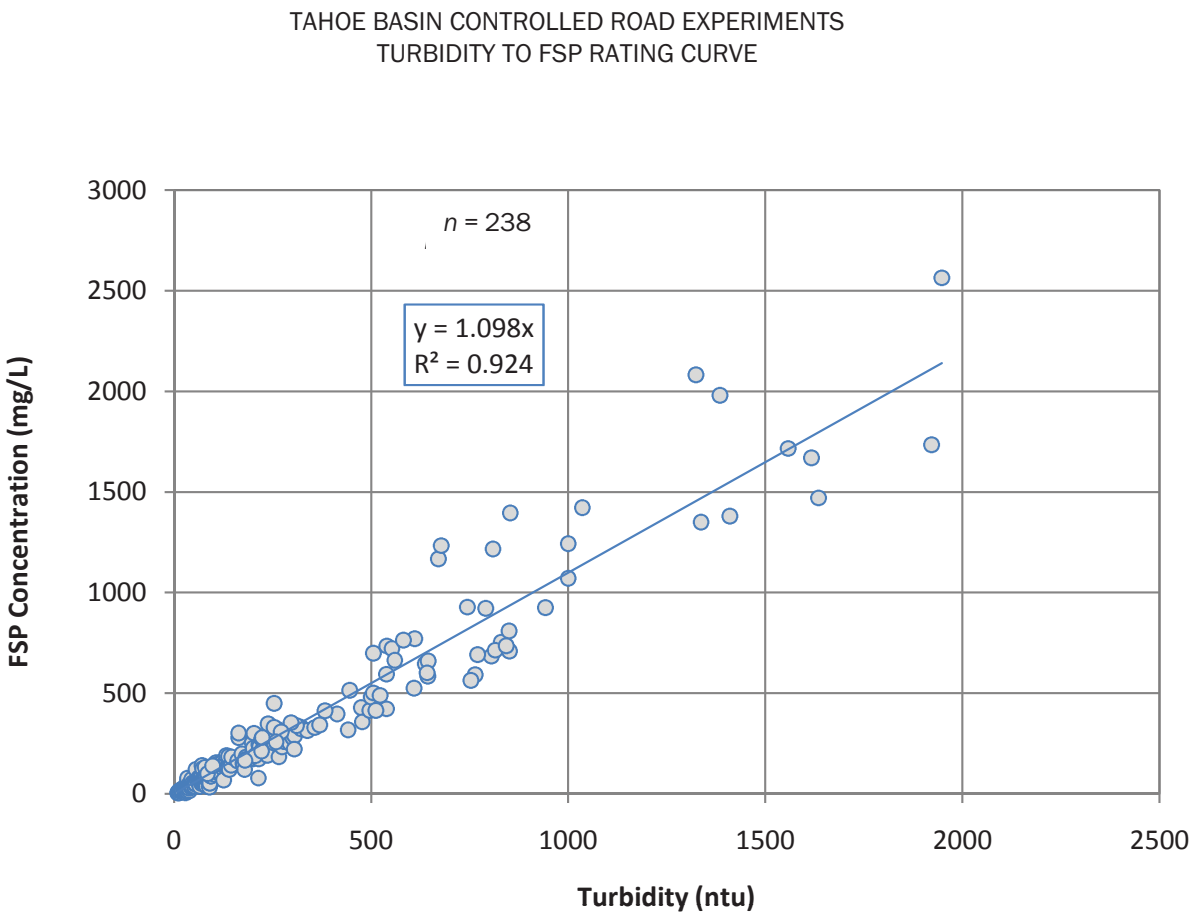
90 degree notch weir and 5 ft rectangular weir installed at the Osgood Basin inlet.

$$90^{\circ}\text{ V-notch weir: } Q\ (cfs) = 2.48 * H_v^{2.5} \qquad \text{EQ (3.1)}$$

$$\text{5ft Rectangular weir: } Q\ (cfs) = 3.33 * 5 * H_r^{1.5} \qquad \text{EQ (3.2)}$$

where H_v is the water depth in the v-notch as recorded by the level transducer up to a maximum depth of 0.83 ft and H_r is the water depth in the rectangular weir, which is equivalent to the water depth as recorded by the level transducer less the height of the v-notch weir (0.83 ft). The turbidity time series is converted to FSP concentrations using the turbidity to FSP concentration rating curves that have been developed by the research team from this and other urban catchment monitoring sites (Figure 3.4). The discharge and FSP concentration data are used to quantify the Osgood catchment effluent stormwater volumes and FSP loads observed, which are compared to PLRM and SWMM predictions for the same time period.

While the instruments were in place from February through June 2011, there were numerous issues calibrating and maintaining the level recorder to ensure high quality data collection. A new Campbell Scientific level transducer has been installed for water year 2012, and instrument calibration and testing occurred through the winter to ensure that the instruments were ready to collect data during the critical spring snowmelt. Calibration has included periodic manual flow measurements to verify the hydraulic discharge equations above (see EQ 3.1 and 3.2), periodic turbidity spot measurements to verify the instrument turbidity readings, and occasional submission of water quality grab samples to the analytical laboratory for TSS and percent grain size distribution analysis.



Correlation plot of turbidity versus FSP concentration based on 238 controlled Tahoe Basin road experiments collected and analyzed in 2009 and 2010 (2NDNATURE and NHC 2010a).

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TURBIDITY V. FSP CONCENTRATION CORRELATION PLOT

FIGURE 3.4

TREATMENT BMP CONDITION

Simple field surveys were conducted to estimate the amount of material retained within the settling basin during the time of observation. 2NDNATURE performed material accumulation surveys in October 2010 and April 2011 to estimate the amount of sediment stored in the 200' long pre-treatment settling basin and track changes over time. Fifteen (15) transects were established between the inlet and outlet of the settling basin, and estimates of the depth of material on the basin floor were estimated using a stadia road at 3 points along each transect. The total volume of material was estimated, with each measurement representing one-third of the 20' long transect and each transect representing 15% (or approximately 13 feet) of the forebay. These back-of-the-envelope estimates are used to track the effectiveness of the basin to settle sediment prior to discharge to the wet basin.

3.3 PLRM PREDICTIONS

In order to compare PLRM predictions to observed catchment volumes and FSP loads, a PLRM input file is run using the EPA's Storm Water Management Model (SWMM) on a discrete time scale using available meteorology from the time period of interest.

SWMM HYDROLOGY ESTIMATES

PLRM uses SWMM to execute a long-term continuous simulation of stormwater runoff defined through user inputs describing land use conditions, including: pollutant source controls, hydrologic source controls, and stormwater treatment facilities. PLRM output is reported as average annual values based on the results of the entire 18-year continuous simulation (1989-2006). Detailed analysis of the results from the continuous simulation generated by PLRM can be accomplished by running the PLRM input file directly in SWMM and post-processing the time-series outputs generated by SWMM. Running a PLRM model directly in SWMM allows for assessment of output on any time scale, which is useful when comparing modeled output to collected field data.

PLRM INPUTS

The PLRM inputs for the Osgood Basin catchment are summarized in Table 3.1. Input data for each PLRM model was developed using: GIS data and reconnaissance level field assessments of drainage conditions. The following described the key steps and methods used to develop PLRM inputs.

1. GIS data was queried to develop input data for each PLRM catchment within a model (e.g., land use distribution, soil distribution, and average slope). The processes and algorithms used to develop the input data are described in the PLRM Applications Guide (NHC et al. 2010). The following GIS datasets were used:
   a. *TMDL Land Use GIS Layer*: The layer can be downloaded from the LRWQCB website at http://www.waterboards.ca.gov/lahontan/water_issues/programs/tmdl/lake_tahoe/index.shtml
   b. *2006 Tahoe Basin Soil Survey*: The layer can be downloaded from the Natural Resources Conservation Service (NRCS) website for Soil Survey Symbol = CA693 at http://soildatamart.nrcs.usda.gov/Survey.aspx?State=CA
   c. *PLRM Road Risk Layer*: See page 3.2 for details.
   d. *PLRM Road Shoulder Conditions Layer*: See page 3.2 for details.
2. Reconnaissance level field inspections were used to validate PLRM inputs derived from the GIS data listed above and to inform PLRM input parameters that cannot be developed from a GIS analysis, including the impervious area connectivity of CICU, SFR, and MFR land uses. The amount of impervious area associated

with SFR, MFR, and CICU land uses that is directly connected impervious area (DCIA) was estimated through field inspection. Note that a GIS layer is not available for this PLRM input.

3. Information on the degree of private property BMP implementation, as of 2011, was received from CSLT. This information was post-processed in GIS to estimate the percentage of private property BMP compliance by land use within each modeled drainage catchment.
4. The publicly available version of the PLRM includes a meteorological record that extends to water year 2006. In order to compare modeled output to field data collected in water years 2009 through 2011, the meteorological record of the PLRM database was extended. The process was completed as follows:
   a. Precipitation and temperature data were downloaded from the NRCS website for the Fallen Leaf and Hagan's Meadow SnoTel gages, which are the two SnoTel gages used in PLRM to generate meteorological data for simulations within the area of interest.
   b. The data was quality assured and added to the PLRM database for the two SnoTel gages.
   c. The PLRM meteorological algorithms were re-run to generate a new time series of meteorological data that extended through water year 2011 for the developed models.
5. In addition to extended the SnoTel meteorological record through water year 2011, short-duration (10 minute) meteorological data was collected by the City of South Lake Tahoe within the Osgood catchment (CSLT Fire Station weather station) during the monitoring study.

POST-PROCESSING OUTPUT FROM SWMM SIMULATIONS

Running a PLRM model directly in SWMM allows for assessment of output at any time scale, which is useful when comparing modeled output to collected field data for specific time periods. To assess time-series output the following process was used:

1. The PLRM program develops an input file that is run by SWMM ("tempSwmm.inp"). This input file was run directly in SWMM to provide access to the time-series output generated by SWMM.
   a. The file "tempSwmm.inp" was saved to a new directory. For a specific PLRM Project and PLRM Scenario, this file is located in the folder: C:\Program Files\PLRM\Projects\Project1\Scenario1.
   b. The "tempSwmm.inp" was opened and run in SWMM version 5.0.014, with the simulation period revised to extend through water year 2011. Note that version 5.0.014 is the specific version of SWMM that PLRM runs. Running a PLRM input file in a different version of SWMM may not generate comparable output relative to that reported by PLRM.
2. The SWMM time-series output was extracted from the program at specific points of interest (e.g., catchment outfalls, SWT treatment junctions, etc.) by using the "Report" functions.
3. The time-series output was imported into Microsoft Excel and analyzed for specific time-periods against available monitoring data collected during the research effort.

PLRM CATCHMENT FSP CONCENTRATION

PLRM estimates runoff concentrations from a catchment at each time step in a simulation as the product of land use specific CRCs and stormwater runoff as shown in the following equation for FSP.

$$Catchment\ FSP\ Concentration\ \left(\frac{mg}{L}\right)_i = \frac{(CRC_{LU_1} \times RV_{LU_1})_i + (CRC_{LU_2} \times RV_{LU_2})_i + (CRC_{LU_X} \times RV_{LU_X})_i}{(RV_{Total})_i} \quad \text{EQ (3.3)}$$

where:

i = time step in the simulation
CRC = characteristic runoff concentration for a specific land use (LU) and land use condition
RV = stormwater runoff volume of a specific land use (LU) during time step in the simulation

By definition, CRCs are static values that do not vary during a PLRM simulation for each defined land use and land use condition. However, the volume of stormwater runoff generated by each land use and the relative proportion of stormwater runoff generated among modeled land uses can vary at each time step. Therefore, estimated catchment runoff concentration for a particular pollutant will vary during a PLRM simulation as stormwater runoff varies among land uses during the simulation, but this level of technical detail is not presented to the user in the currently available PLRM output reports. To estimate an average annual catchment concentration for a particular pollutant predicted by PLRM, a user can divide the average annual pollutant loading reported by the average annual surface runoff reported.

3.4 CATCHMENT MONITORING METHOD RECOMMENDATIONS

Based on one water year of monitoring in the Osgood catchment during the *Pilot Catchment Validation Study*, the following adjustments to the monitoring methods will be made for the SNPLMA-funded research:

1. Ensure adequate spatial representation of road segments by road class included in periodic road condition observations. This effort struggled through the iterative process of defining and delineating road class with the responsible jurisdiction. In the process of changes in road class, the initial segment selection for observations no longer provided at least 3 road segments by class. Future catchment monitoring will inevitably include periodic changes to road class, and researchers must be cognizant to adjust road segments included in observations accordingly.

2. Given the objective to obtain catchment data to adequately test the hypothesis that road condition has an influence on catchment water quality, our data collection and information sharing with the local jurisdiction must include any actions that would result in capture and removal of material generated by the roads prior to delivery to the monitoring station. Future coordination will include documentation of any road surfacing projects and the periodic evaluation of the condition of treatment BMPs that are assumed to have an influence on FSP fate and transport within the catchment, including records of vactor removal of this material from the system.

3. As expected, the instrumentation selection, calibration and programming required significant effort to obtain reliable continuous turbidity in an intermittent stormwater flow environment. The USACE resources provided the opportunity to test multiple approaches and configurations and identify the techniques necessary to obtain reliable turbidity and stormwater FSP data. The recommended instrumentation is FTS H2 Axiom datalogger with dual com ports; Campbell Scientific CS450 SDI pressure transducer; and FTS DTS-12 turbidity sensor.

4. Continued instrument QA/QC is critical for automated equipment. Manual flow and turbidity measurements across the range of observed values are necessary to ensure data accuracy. Additionally, the occasional submission of grab samples to the laboratory for analysis of TSS and grain size distribution will continue to inform the turbidity to FSP rating curve shown in Figure 3.4. Given that the current rating curve has fewer data points at higher turbidity values, future sample submission to the laboratory for FSP analysis will focus on turbidity values measured in the field at greater than 200 ntu. The threshold will continue to be refined based on the data in hand and the range above which data is relatively limited. In general this is a much more focused and effective sample submission strategy to minimize analytical costs while increasing statistical confidence in a data generated rating curve. The amount of time required on site is significant to minimize instrument failure and associated data gaps.

5. Detailed assessment of PLRM using monitored data for the purpose of improving and refining model algorithms requires the use of site specific meteorological data (temperature and precipitation data). PLRM output generated using the SnoTel dataset, which is the basis of the current PLRM model, was evaluated against PLRM output generated using short-term meteorological data collected in the project area. The results of the analysis highlighted the following limitations of the SnoTel dataset for modeling runoff responses on a site specific and event basis:

    - Summer thunderstorms that occur at a specific stormwater monitoring location in the Tahoe Basin may not occur with the same intensity or duration at the SnoTel gage used by PLRM to predict the meteorological time series. Consequently, PLRM may misrepresent runoff responses from summer thunderstorms.

    - SnoTel data is reported in one hour increments. While this time step is appropriate for the objective of predicting average annual pollutant loading in PLRM over a long-term simulation, it is too coarse a time step to compare and evaluate PLRM predictions of runoff with detailed fluctuations in stormwater runoff collected from research efforts.

    - PLRM algorithms use the temperature recorded at the higher elevation SnotTel gage and a temperature lapse rate to predict the temperature at the modeled location and associated elevation. However, the temperature algorithms don't always correctly predict the type of event at the monitoring location (snow vs. rain). Consequently, the runoff response may not be correctly predicted for a specific event when temperatures at the monitoring location are close to the transition point between rain and snow.

    Data gaps, due to city-wide power losses and instrument malfunction, resulted in inconsistent local weather data from CSLT Fire Station weather station. If site-specific, event-based PLRM simulations are a research priority going forward, this existing data limitation will need to be addressed.

CHAPTER 4. ENVIRONMENTAL SETTINGS

This research focused on data collection and analysis of catchment pollution generation and stormwater quality. In order to appropriately place the data and findings obtained into the context necessary to compare hydrology and water quality monitoring data across water years or to inform average annual PLRM predictions, it is critical to constrain the drivers that inherently influenced the data obtained. The primary uncontrollable system driver is the weather conditions where daily, seasonal and water year meteorological variations introduce variability into hydrologic, water quality and land use condition observations. Another influence on the spatial and temporal results of the roadway research is the jurisdictional road maintenance practices, which are hypothesized to have a high influence on the relative amount of sediment (and FSP) available on a road surface in the Tahoe Basin.

4.1 WATER YEAR CONTEXT

The *Focused Stormwater Quality Monitoring to Inform Assumptions & Evaluate Predictive Capabilities of Existing Tools Technical Report* (2NDNATURE and NHC 2012) provides a frequency analysis of historic water year total precipitation in order to put monitored water years for specific data collection efforts into context. Based on the methodology and findings described in Section 4.1 of that technical report, WY2011 was a wet year with a total of 45.0 inches of precipitation, relative to the average annual of 31.6 in/year. The impacts of the relatively high annual total precipitation were exacerbated by the fact that the preceding two water years (WY09 and WY10) were an average and a wet year. Given the precipitation context of WY2011, we expect road conditions to be relatively poorer and stormwater pollutant loading to be relatively higher than most years.

4.2 OSGOOD CATCHMENT ROAD MAINTENANCE PRACTICES, WY2011

Table 4.1 summarizes the general CSLT road maintenance practices; however, this data does not provide temporal or spatial-specific data with which to evaluate road segment condition results by observation period. Improved record-keeping of actual road maintenance actions implemented at specific locations will allow informed effectiveness evaluations of road maintenance prescriptions and future research has identified this as critical need to link road condition and catchment water quality to the differences in road maintenance prescriptions.

Table 4.1. Summary of CSLT road maintenance practices, including key components of their abrasive application and pollutant recovery practices are provided.

Abrasive Application			Pollutant Recovery			
Spreader Equipment	**Abrasive Type**	**Lane Miles where applied (% of Jurisdiction)**	**Action Types**	**Sweeper Equipment**	**Frequency**	**Location**
Monroe Spreader + Plow	Eagle Valley Basin Volcanic Cinders; Huck Salt	52 miles (20%)	Sweeping	Tymco (regen air); Athey Mechanical Broom	Winter – Event-Based; Summer – 2x	All Roads

For the pilot catchment-scale research in the Osgood catchment, 2N personnel worked closely with CSLT public works and street maintenance personnel to develop a data management system to track the daily abrasive application and street sweeping events within the catchment. Following the Road RAM STEP 3 protocols in the Road RAM User Manual (2NDNATURE et al. 2010d), abrasive application priority and sweeping effectiveness were defined and mapped in the Osgood catchment (see Figure 3.2).

Abrasive application categories are defined as:

- Intensive (A): Highly trafficked, steep roads where abrasives are applied during every storm and frequently multiple times during one storm event. These include roads where abrasives are applied by both CSLT and Heavenly Ski Resort.
- Moderate (B): Minimally trafficked steeper roads in the upper watershed where abrasives area applied during most storms, but typically only one time per storm event. These include roads where abrasives are applied only by CSLT.
- Rarely to Never (C): Flat roads in the lower watershed as well as minimally trafficked flatter roads in the upper watershed. Abrasives may be applied during extreme events, but typically these roads are low priority and only targeted after the other roads have been sanded.

Sweeping effectiveness categories are defined as:

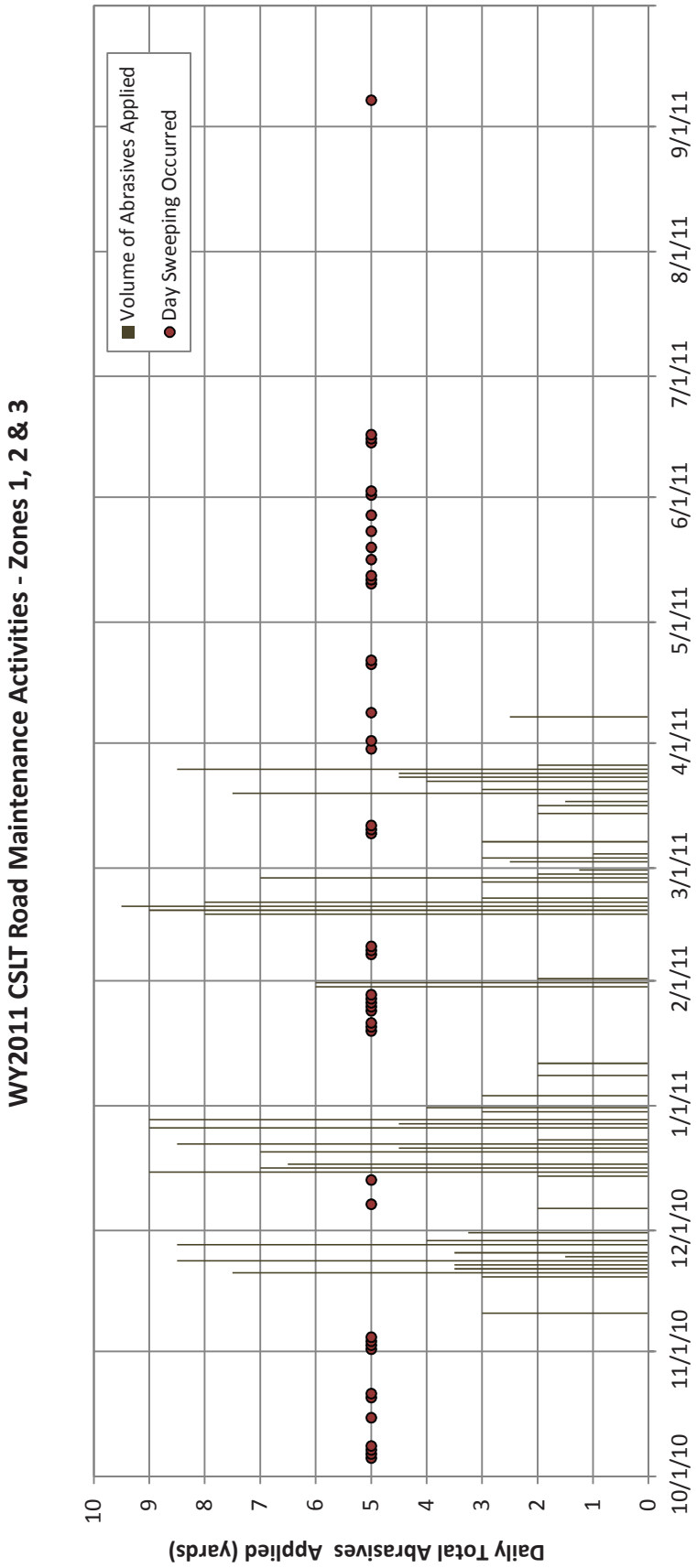
- Intensive (X): Priority roads where CSLT targets sweeping activities as conditions allow during the winter months. These include highly trafficked roads, such as Ski Run Boulevard, Pioneer Trail, and the main thoroughfares to Heavenly Ski Resort.
- Rarely to Never (Z): Less-trafficked roads where sweeping activities occur in the winter months as resources allow, but are typically targeted during the biannual jurisdiction-wide sweeping in the summer and fall.

CSLT street maintenance activities are managed by zones and the Osgood catchment is located within the Stateline (Zone 1), Heavenly (Zone 2), and Bijou (Zone 3) Zones. Abrasive application is tracked on a daily basis by the yards of abrasives applied per zone. Sweeping activities are also tracked daily by sweeper type, cubic yards of material recovered, and street locations swept. The chronology of abrasive applications and sweeping actions are documented by (1) abrasive application and sweeping logs completed by maintenance personnel, (2) QA/QC of logs by supervising manager, and (3) data entry into standardized data management system by stormwater personnel. This information was transferred to 2N on a regular basis via email and allowed the comparison of abrasives and sweeping actions to the observed road condition of specific segments as determined by Road RAM. Figure 4.1 provides a time series of the road maintenance activities conducted within the Osgood catchment during WY2011.

4.3 ROAD MAINTENANCE DOCUMENTATION FINDINGS AND RECOMMENDATIONS

Great improvements have been made on defining and coordinating the documentation of road maintenance practices by the responsible jurisdiction. The research team and CSLT developed initial jurisdiction-wide definitions of road class and improved the documentation of road maintenance practices conducted within the monitored catchment. While this level of detail is an improvement over previous documentation, there are still a number of improvements the research team and collaborating jurisdiction (CSLT) are working to resolve:

1. The CSLT sanding and sweeping routes do not directly correspond to the Osgood catchment boundaries. Therefore a spatial weighting based on the % of zone miles within the catchment was necessary to translate information by CSLT zones to Osgood catchment data. 2NDNATURE is working with CSLT personnel to develop more quantitative metrics, discussed below, to refine our spatial understanding of road maintenance activities without burdening the street maintenance personnel with excessive data management tasks.



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WY2011 CSLT ROAD MAINTENANCE: OSGOOD CATCHMENT

FIGURE 4.1

2. Specific locations and rates of abrasive application are not currently tracked. Given the designation of abrasive application categories described above, the total abrasives applied by zone are likely not applied evenly throughout the sanding zone. Based on the distribution of abrasive application priority categories, application rates per road mile were estimated. As monitoring continues in WY2012, 2N is collaborating with CSLT staff to improve the application rate estimations, including refining the spatial distribution of abrasive application during light, moderate and heavy storm events based on maintenance personnel expertise and estimating the application rate from the Monroe spreader based on vehicle speed.

3. Sweeping routes are not specifically tracked by street personnel. Sweeping logs include the general area and streets where the sweeper is operated, but the total number of miles swept per day, the specific stretches of a road swept, or the number of times a road is swept within one day is not tracked. Additionally, the yards of material removed is categorized as cinders, dirt, pine needles, etc., but the total amount of FSP recovered is not quantified. Given the lack of specific data, 2N personnel estimated the frequency of sweeping within the Osgood catchment, but cannot provide a specific chronology nor estimate the FSP removed by CSLT sweepers. CSLT is planning to install GPS monitors on their street sweepers in summer 2012, which will greatly improve our ability to quantify the number of miles swept, the number of passes made per road segment, and other details regarding the frequency of sweeping and correlate these metrics to observed road condition and volume of material recovered.

4. CSLT is currently training field personnel to implement Road RAM throughout the jurisdiction and ideally this additional verification will increase our confidence that actions are conducted consistently each time they are performed within the catchment, such that we can reduce some uncertainty in our analyses and comparisons.

5. Given the existing time and economical constraints facing local jurisdictions, 2NDNATURE has been working with CSLT to define the preferred road maintenance data to be tracked without being overly burdensome on CSLT staff. The following list provides the preferred list of metrics to be defined within the catchment:

    a. Specific locations of event abrasive application.

    b. Daily total mass of abrasives applied per road mile per road class.

    c. Daily miles of road swept and specific locations of sweeping by sweeper type.

    d. Mass of FSP recovered per mile swept by sweeper type.

CHAPTER 5. DATA ANALYSIS APPROACH AND RESULTS

The pilot catchment verification research focused on developing data collection and analysis techniques to obtain data appropriate to compare measured catchment FSP loads on seasonal and annual time scales with PLRM predictions for the same time periods. The instrumentation challenges limited the amount of reliable flow and turbidity data obtained during this effort. Throughout this report we present some critical findings related to data collection, data management and data analysis lessons learned and recommended improvements, but the dataset at this time is too limited to make any definitive conclusions regarding model performance or the role of roads on catchment water quality. These interpretations will be made following the completion of the subsequent catchment scale monitoring funded by SNPLMA Round 11 that will result in a complete water year of data obtained from at least two urban catchments. That technical report is currently scheduled for release in late 2013.

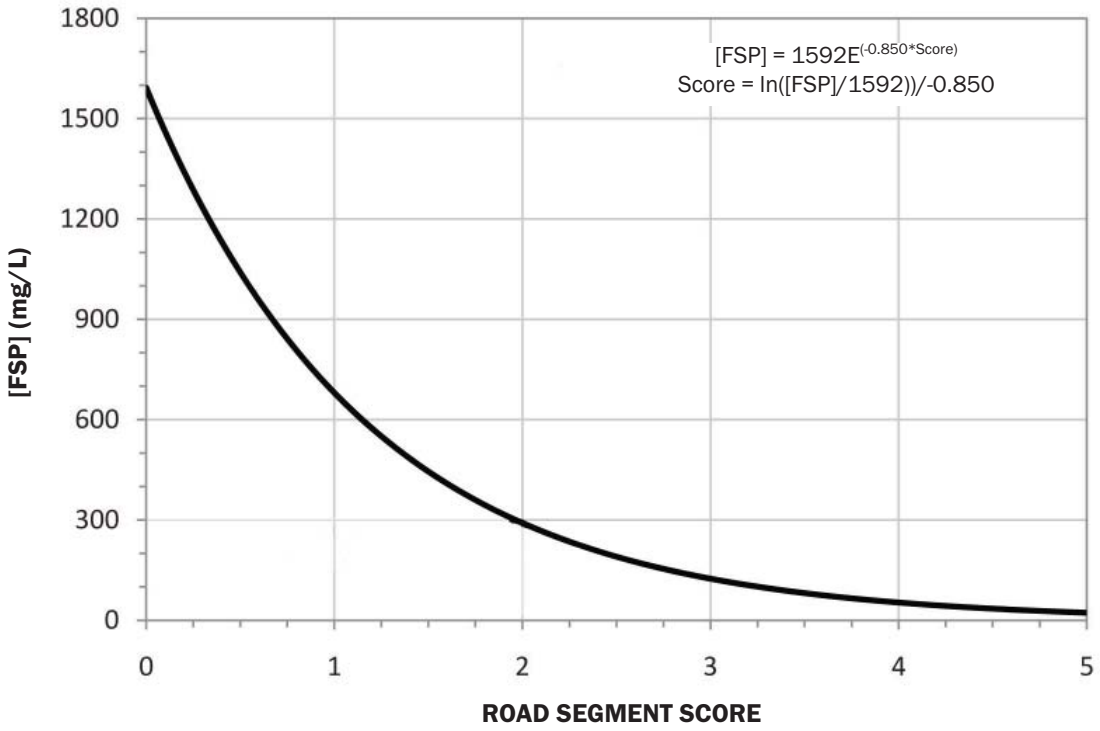
5.1 ROADWAY EVALUATIONS

The Road RAM tool provides spatial extrapolation and temporal integration methods to integrate a series of discrete road condition observations into volume-weighted average conditions (and associated FSP concentrations) for an urban catchment. These average catchment road conditions as determined from a strategic Road RAM sampling design can be compared to PLRM predictions of the integrated road network FSP concentration from a specific catchment.

COMPARISON OF ROAD RAM SCORES TO FSP CONCENTRATIONS

Each Road RAM score is correlated to an expected FSP concentration from the road segment if the segment were sampled in a manner consistent with the controlled experiments. The translation of road segment FSP concentrations to a 0-5 RAM score simplify communication of relative condition, while preserving the quantitative alignment to the concentrations of the pollutant of concern. Table 5.1 compares differences in Road RAM scores throughout the 0-5 range to the equivalent differences in FSP concentrations using the relationship shown in Figure 5.1. While the absolute FSP concentration differences vary depending upon the Road RAM score, the percent difference in the FSP concentrations is consistent, i.e., for every 0.1 change in Road RAM score there is a consistent 8.1% FSP concentration change. The smaller differences in absolute FSP concentrations at higher RAM scores (RAM >2 or FSP concentration <300 mg/L) are consistent with our ability to measure these differences in the field using the portable sampler. Much higher field precision (<8% error) is observed when there is less material on the road surface and RAM scores are above 2). Field sampling error significantly increases when the amount of material on the roadway is excessive, creating micro gullies and transport variability from the road surface to the sampler collection device. For simplicity's sake, road condition observation results are provided as Road RAM scores throughout this document. However, using Table 5.1 the reader can easily translate RAM scores to FSP concentrations.

ROAD RAM SCORE TO FSP CONCENTRATION RELATIONSHIP



The road segment score represents the observed condition of the road segment at the time of observation. The road segment FSP concentration is converted to a road segment score by the Road RAM database using the same concentration to score relationship used in PLRMv1. See PLRM Road Methodology in PLRM Model Development Document (NHC et al. 2009a) and the Road RAM Technical Document (2NDNATURE et al. 2010c) for more information on how this relationship was derived and validated.

Table 5.1. Comparison of differences in Road RAM scores to equivalent magnitude and percent differences in FSP concentrations. While the absolute FSP concentration difference on a ± 0.1 RAM score interval ranges from 130 mg/L to 2 mg/L as the expected FSP concentration decreases, the absolute deviation is consistently ± 8.1%.

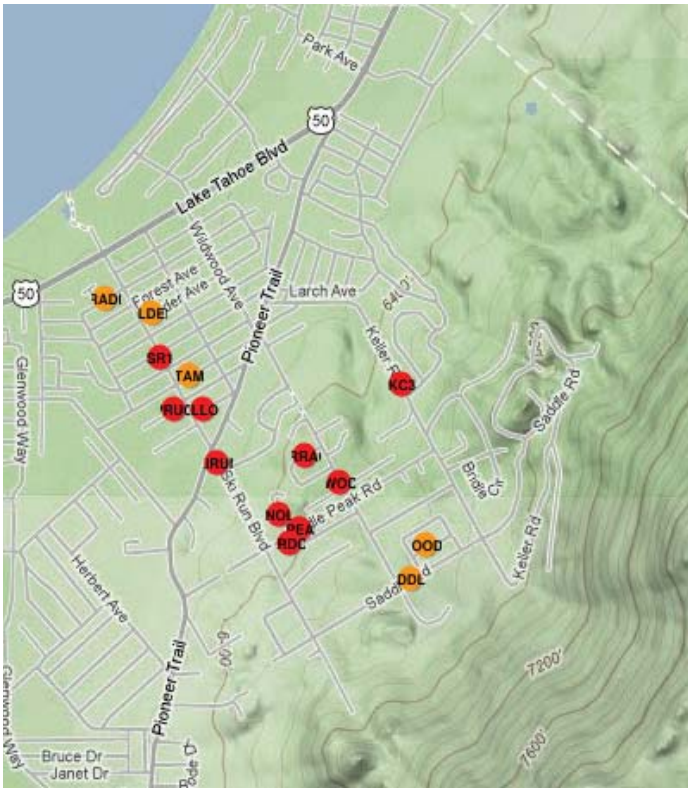
Road RAM Score	FSP Concentration (mg/L)	FSP Concentration Difference	% Difference	Road RAM Score	FSP Concentration (mg/L)	FSP Concentration Difference	% Difference
0	1592	-	-	2.6	175	-15	-8.1%
0.1	1462	-130	-8.1%	2.7	160	-14	-8.1%
0.2	1343	-119	-8.1%	2.8	147	-13	-8.1%
0.3	1234	-109	-8.1%	2.9	135	-12	-8.1%
0.4	1133	-101	-8.1%	3	124	-11	-8.1%
0.5	1041	-92	-8.1%	3.1	114	-10	-8.1%
0.6	956	-85	-8.1%	3.2	105	-9	-8.1%
0.7	878	-78	-8.1%	3.3	96.3	-9	-8.1%
0.8	807	-72	-8.1%	3.4	88.5	-8	-8.1%
0.9	741	-66	-8.1%	3.5	81.3	-7	-8.1%
1	680	-60	-8.1%	3.6	74.6	-7	-8.1%
1.1	625	-55	-8.1%	3.7	68.6	-6	-8.1%
1.2	574	-51	-8.1%	3.8	63.0	-6	-8.1%
1.3	527	-47	-8.1%	3.9	57.8	-5	-8.1%
1.4	484	-43	-8.1%	4	53.1	-5	-8.1%
1.5	445	-39	-8.1%	4.1	48.8	-4	-8.1%
1.6	409	-36	-8.1%	4.2	44.8	-4	-8.1%
1.7	375	-33	-8.1%	4.3	41.2	-4	-8.1%
1.8	345	-31	-8.1%	4.4	37.8	-3	-8.1%
1.9	317	-28	-8.1%	4.5	34.7	-3	-8.1%
2	291	-26	-8.1%	4.6	31.9	-3	-8.1%
2.1	267	-24	-8.1%	4.7	29.3	-3	-8.1%
2.2	245	-22	-8.1%	4.8	26.9	-2	-8.1%
2.3	225	-20	-8.1%	4.9	24.7	-2	-8.1%
2.4	207	-18	-8.1%	5	22.7	-2	-8.1%
2.5	190	-17	-8.1%				

WY2011 ROAD CONDITION RESULTS

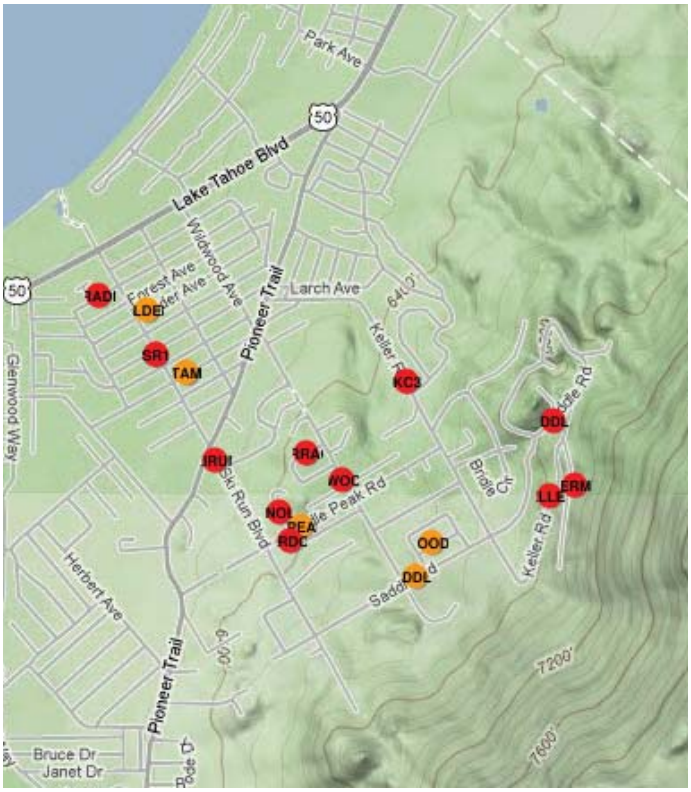
Road condition observations were conducted during a total of 7 Road RAM observation periods within the Osgood catchment during WY2011. Consistent with previous findings (2NDNATURE and NHC 2009; 2012), there is a strong seasonal variation in road conditions as illustrated by the road segment scores for 4 observation periods (Figure 5.2). The research team coordinated with the CSLT stormwater engineers to define and delineate six road classes within the Osgood catchment (see Figure 3.3 and Chapter 4.2). The series of road segment scores obtained for each observation period are used to determine the Road RAM score for each road class. Figure 5.3 presents the

WY2011 OSGOOD CATCHMENT ROAD SEGMENT CONDITION SCORES

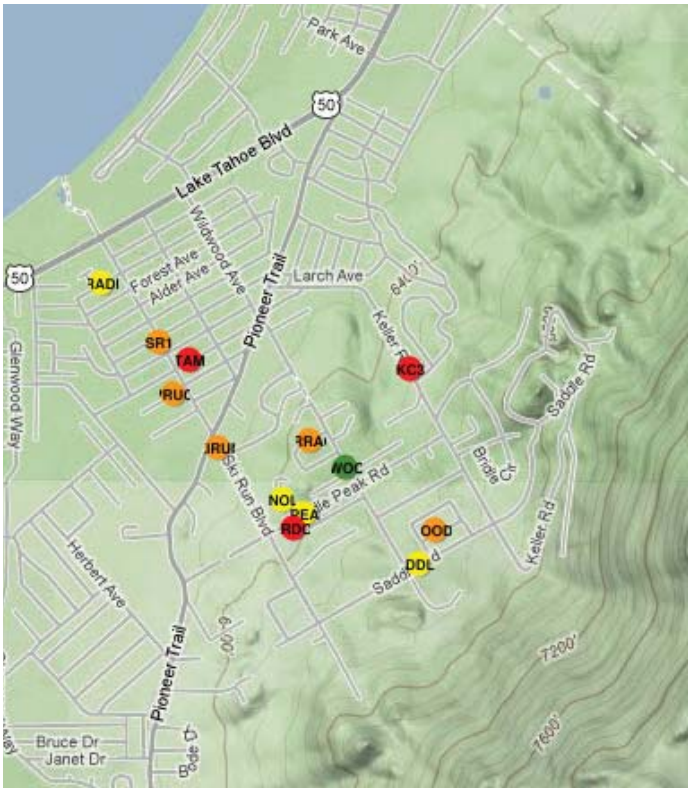
Fall/Winter: 1/22/11 Observation Period



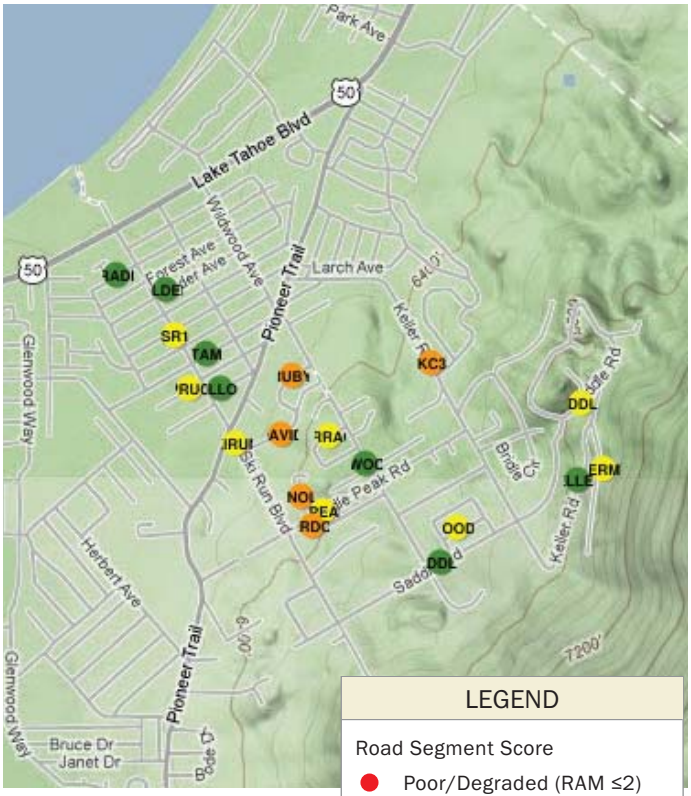
Late Winter/Early Spring: 4/20/11 Observation Period



Spring: 6/22/11 Observation Period



Summer: 8/17/11 Observation Period



LEGEND

Road Segment Score

- Poor/Degraded (RAM ≤2)
- Fair (2< RAM ≤3)
- Acceptable (3< RAM ≤4)
- Desired (RAM >4)

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May 2011 discrete road segment condition scores and those scores translated to Road RAM scores by road class, providing us with a simple, visual tool to communicate the relative downslope water quality risk posed by roads throughout the catchment.

Road classes are defined by specific road maintenance practices and can be categorically ranked based on the expected road condition. Road class AZ represents relatively high FSP sources (increased abrasive application amount and frequency) and relatively low FSP sinks (infrequent sweeping with a less efficient sweeper), while CX represents relatively low FSP sources (reduced abrasive application) and relatively high FSP sinks (frequent sweeping with a higher efficiency sweeper). Table 5.2 presents the average Road RAM scores by road class for each observation period in the Osgood catchment. Road class is presented in order of expected road condition, from worst to best based on the relative FSP sources and sinks associated with road maintenance practices provided in Chapter 4. In general, road condition observations follow the expected ranking of road class. Since the delineation of road class was iterative with CSLT through this research, the road segment population initially selected only resulted in one road for road classes BX and CX, which limits these conclusions.

Table 5.2. WY2011 Osgood catchment average road condition scores by road class. Road classes are ordered from expected worst to best condition based on the relative FSP sources and sinks. The WY2011 volume-weighted average scores for each road class are determined using the seasonal weighting shown in Table 5.6 of the *Focused Stormwater Quality Monitoring to Inform Assumptions & Evaluate Predictive Capabilities of Existing Tools Technical Report* (2NDNATURE and NHC 2012). The WY2011 volume-weighted average FSP concentration is calculated using the exponential equation included in Road RAM (see Figure 5.1).

Observation Period (Season)	Road Class (# road segments)					
	AZ (3)	BZ (3)	AX (3)	CZ (9)	BX (1)	CX (1)
10/14/10 (Summer/Fall)	-	4.5	2.9	2.9	2.7	3.0
1/22/11 (Winter)	1.8	1.4	1.6	1.8	2.1	1.6
4/6/11 (Late Winter/Early Spring)	1.7	1.5	1.5	1.8	2.0	1.3
4/20/11 (Late Winter/Early Spring)	1.1	1.6	2.2	1.9	1.9	2.5
5/19/11 (Spring/Summer)	1.2	1.5	2.0	2.7	2.8	2.6
6/22/11 (Spring/Summer)	2.6	1.4	2.5	2.6	3.9	2.3
8/17/11 (Summer/Fall)	2.6	3.2	3.1	4.0	4.6	3.8
WY2011 Volume-Weighted Average Score	**1.7**	**1.7**	**2.0**	**2.1**	**2.4**	**2.0**
WY2011 Volume-Weighted Average FSP (mg/L)	**373**	**374**	**294**	**257**	**215**	**284**

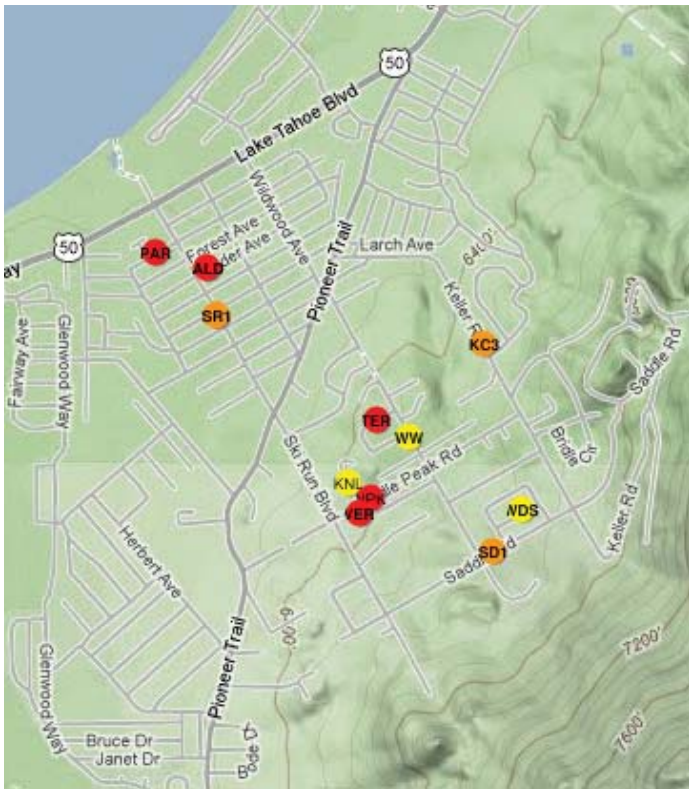
The process of documenting actual jurisdiction road maintenance practices and defining road classes is expected to be an iterative process and one critical guide of appropriate classification is the standard deviation of the road segment scores for segments of the same class. *Chapter 8 Road RAM Technical Document* (2NDNATURE et al. 2010c) provides guidance to evaluate road class categories and improve the definitions of road maintenance actions over time. In general, the target standard deviation of road segment observations by road class is ±0.5 RAM score, with a range up to ±1.0 depending on the applications of the tool. The research team calculated the observed minimum, maximum and average standard deviations by road class for WY2011 in the Osgood catchment (Table 5.3). The SNPLMA Round 11 Catchment research includes a second catchment within the CSLT jurisdiction, and 2NDNATURE will continue to improve road classification and calculate observation standard deviations by road class to improve our understanding of the relationship between observed road condition scores and implemented road maintenance practices on the jurisdiction-scale.

LEGEND

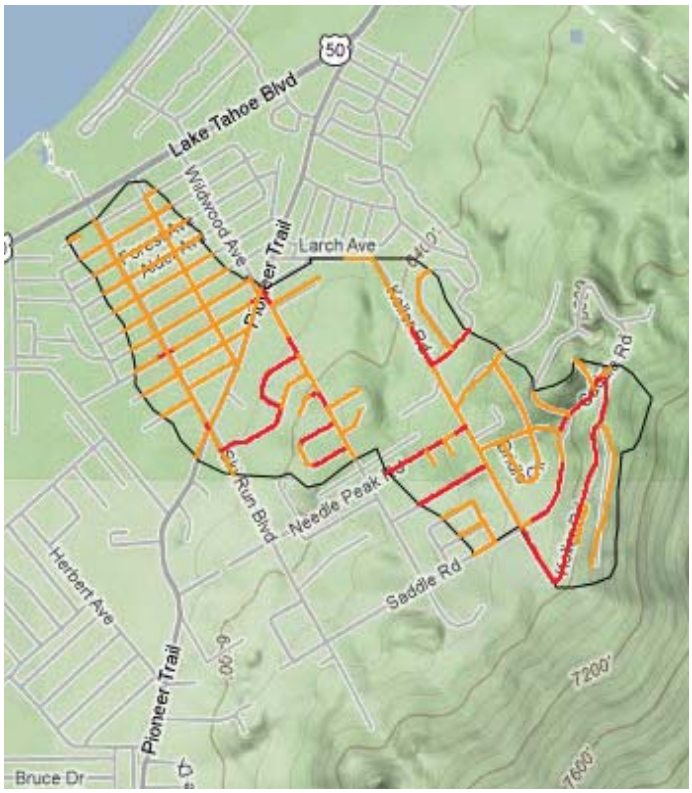
Road Segment Score

- Poor/Degraded (RAM ≤2)
- Fair (2< RAM ≤3)
- Acceptable (3< RAM ≤4)
- Desired (RAM >4)

Discrete Road Segment Scores



Road Class Scores



Discrete road segment condition scores are extrapolated to Road RAM scores by road class. For all road segments of the same road class (e.g., AX, AY, AZ, etc.), the condition scores are averaged and that average score is applied to all roads of that road class within the catchment (see catchment road class map in bottom half of Figure 3.3).

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MAY 2011 OSGOOD CATCHMENT ROAD SEGMENT AND ROAD CLASS CONDITION SCORES

FIGURE 5.3

Table 5.3. Standard deviation of observed road segment scores by road class.

Osgood Catchment Road Class (# road segments)	WY2011 Osgood Catchment Standard Deviations		
	Minimum	Maximum	Average
AX (3)	0.1	0.9	0.5
AZ (3)	0.2	0.5	0.4
BX (1)	-	-	-
BZ (3)	0.4	1.3	0.8
CX (1)	-	-	-
CZ (9)	0.3	1.0	0.7

ROAD MAINTENANCE PRACTICES AND ROAD CONDITION

The SNPLMA Round 11 research will integrate this road condition data with the WY2012 dataset from this and the other CSLT catchment instrumented and conduct a multivariate statistical analysis to test the hypothesis that observed road condition (as determined by Road RAM) is sensitive to road maintenance practices. Similar to the statistical analysis 2NDNATURE conducted on an extensive road condition dataset obtained by the Nevada Tahoe Conservation District (NTCD), 2NDNATURE will quantify a number of metrics from the road maintenance dataset provided by CSLT such as number of sweeps prior, number of days since last sweep, number of days since last abrasive application, number of days since last rain event, etc. relative to the date of Road RAM observations. 2NDNATURE (2012) has demonstrated the ability to predict road condition using the NTCD dataset and the inclusion of the WY2012 data will allow a similar analysis on the road networks within the monitored catchments.

ROAD CONDITION COMPARED TO PLRM PREDICTIONS

Since PLRM estimates the flow weighted average FSP concentration of road risk categories present within a catchment over a long-term simulation to predict a characteristic runoff concentration (CRC) from roads, the most effective way to compare Road RAM observations to the PLRM predictions is to use each tool to determine an volume-weighted average catchment roadway FSP concentration or CRC. We must keep in mind that WY2011 had above average snow fall and therefore we expect road condition to be worse than PLRM would predict. The series of WY2011 Road RAM road class observations for each observation period (see Table 5.2) are spatially weighted (see Table 3.2) to calculate a catchment road condition score. These discrete temporal observations are integrated into a single volume-weighted average FSP concentration for the Osgood catchment of 295mg/L for WY2011 (Table 5.4).

Table 5.4. WY2011 Osgood catchment Road RAM results. For each observation period, Road RAM scores are spatially weighted based on the % distribution of the road class within the catchment (see Table 3.2) to determine the catchment road condition score. Each observation catchment score is converted to FSP concentration using the score to FSP concentration exponential relationship that is used in both Road RAM and PLRM (see Figure 5.1). The discrete catchment scores are integrated using a seasonal weighting based on the seasonal contribution of total urban runoff (see Table 5.6 of 2NDNATURE and NHC 2012) to calculate a WY2011 average catchment road condition score and FSP concentration.

Observation Period (Season)	Osgood Catchment	
	Score	FSP (mg/L)
10/14/10 (Summer/Fall)	3.1*	119*
1/22/11 (Winter)	1.7	380
4/6/11 (Late Winter/Early Spring)	1.6	406
4/20/11 (Late Winter/Early Spring)	1.8	342
5/19/11 (Spring/Summer)	2.1	262
6/22/11 (Spring/Summer)	2.3	232
8/17/11 (Summer/Fall)	3.5	81.7
WY2011 Volume-Weighted Average	**2.0**	**295**

*denotes estimated values due to insufficient data for all road classes.

Using the PLRM Road Methodology, the publicly available road risk and road shoulder condition GIS layers (www.tiims.org) and road maintenance practice information provided by CSLT (see Figure 3.3, Chapter 4.2, and Table 5.6 of the *Focused Stormwater Quality Monitoring to Inform Assumptions & Evaluate Predictive Capabilities of Existing Tools Technical Report (*2NDNATURE and NHC 2012a)), the PLRM volume-weighted average catchment road CRC is predicted to be 184 mg/L (Table 5.5) equating to a catchment score of 2.5.

Table 5.5. PLRM volume-weighted average road FSP CRC prediction for the Osgood catchment. The PLRM Road Methodology predicts road risk FSP CRCs based on the distribution of road shoulder condition and jurisdiction road maintenance practices. Road FSP CRC values are spatially weighted based on the % distribution of road risk within the catchment to determine the catchment predicted road FSP CRC. This CRC is converted to a predicted catchment road condition score using the relationship presented in Figure 5.1.

Time Period	Road FSP CRC (mg/L) (% of catchment road miles)						Osgood Catchment	
	PHR (1.4%)	PMR (0.0%)	PLR (8.9%)	SHR (40.7%)	SMR (46.4%)	SLR (0.4%)	Road FSP CRC (mg/L)	Score
Predicted Volume-Weighted Average	520	-	200	237	135	89	184	2.5

The WY2011 observed catchment road FSP concentration is 111 mg/L (or 0.5 RAM score) higher than the volume-weighted average road FSP CRC predicted by PLRM, and given that WY2011 was above average, we find the alignment very reasonable. However, the following limitations likely contribute to the differences between Road RAM and PLRM:

- An accurate depiction of road class requires consistent maintenance practices on the roads within a specific class. Currently the resolution of detail on the amount and timing of abrasive application and the tracking of the specific locations, number of passes and operational sweeping consistency cannot verify that the practices are consistent. The research team is collaborating with the jurisdictions to improve this consistency and communication.
- The catchment Road RAM estimates are based on a number of spatial and temporal integration techniques that assume a reasonable mass balance and incorporate best professional judgment.

- PLRMv1 FSP CRCs are determined for each road risk type within the catchment, rather than road class used by Road RAM. CRCs by risk are static numbers that do not vary seasonally or across water year types.

5.2 MEASURED CATCHMENT FSP LOADING TO PLRM PREDICTIONS

This research implemented and refined high resolution data collection techniques at the inlet of the Osgood Basin to measure the FSP loading rate (grams per second; g/s) from the catchment over time. The integration of this loading rate over seasonal or annual time frames will provide measured data to compare to PLRM catchment FSP load predictions. This pilot effort was implemented specifically to test and refine new protocols and given these challenges, there is a limited amount of reliable FSP loading data to compare to PLRM predictions. While the analysis below is not sufficient to make any conclusions with respect to PLRM performance, the process and techniques used represent significant progress towards providing a framework to manage, analyze and report catchment monitoring data and PLRM predictions to allow future catchment validation.

CATCHMENT FSP CONCENTRATION COMPARISON TO ROAD CONCENTRATIONS

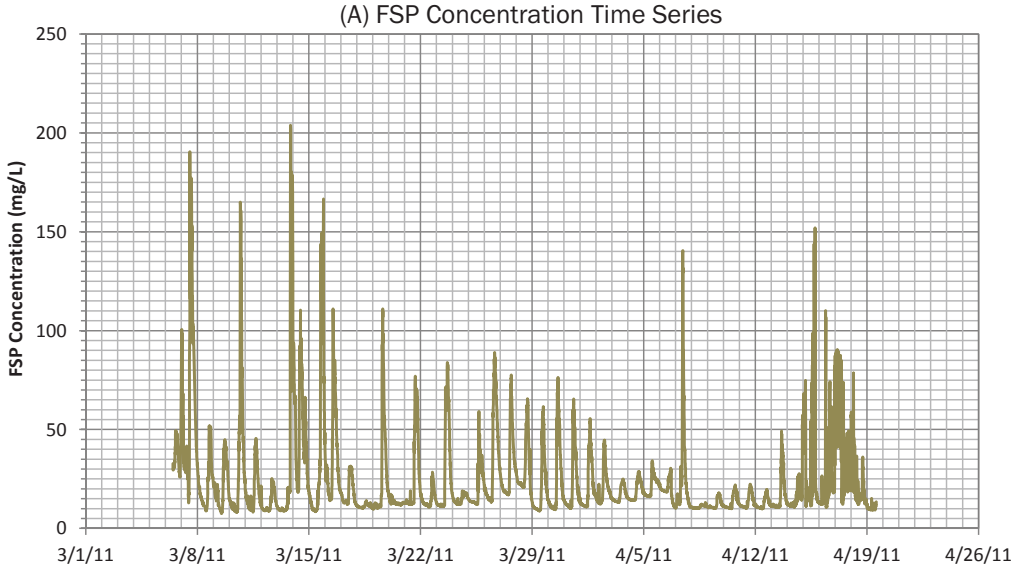
Given the instrument difficulties, the time period from March 6 to April 19, 2011 had the most reliable depth and turbidity data and was therefore selected for comparisons. The high-resolution (10-minute) turbidity time series was converted to FSP concentration (Figure 5.4A) using the best available stormwater turbidity to FSP concentration rating curve shown in Figure 3.4.

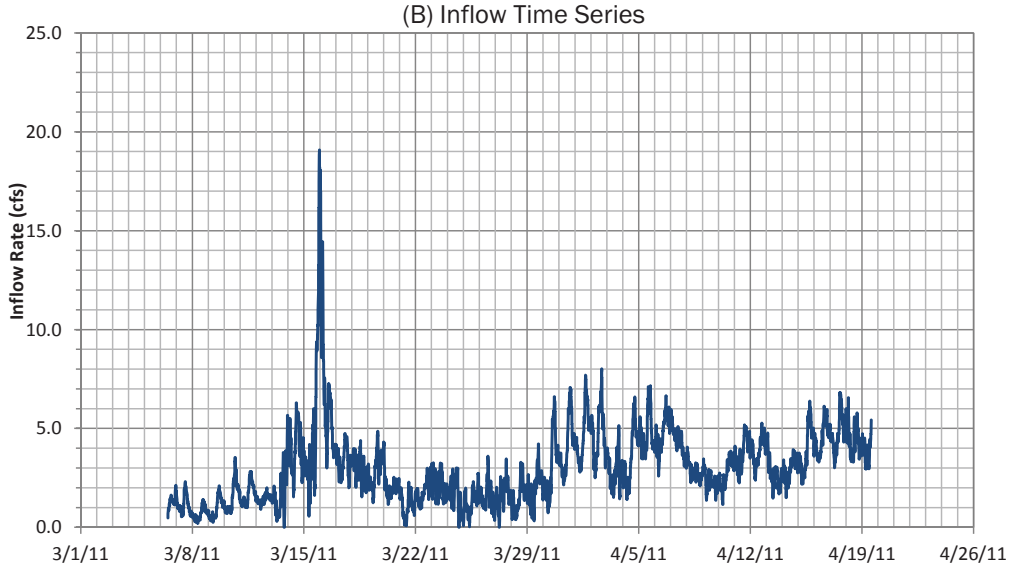
The catchment FSP concentrations are compared to the catchment road FSP concentrations estimated based on road condition observations for time periods when simultaneous data is available (Table 5.6). As expected, the measured average FSP catchment concentration is over 4 times lower than the calculated road FSP concentration. There are a number of potential influences including: (1) signal dilution from the significant baseflow contribution from the Keller Canyon subcatchment (see Figure 3.1) due to an above average water year and saturated soil conditions (see 2NDNATURE and NHC (2012) for a more in-depth discussion of this finding); (2) signal dilution due to “cleaner” water contributions from other land uses (SFR, MFR, etc.) that have much lower FSP concentrations than roads; (3) FSP removal by the settling basin (see Figure 3.2) located upstream of the monitoring station; (4) FSP capture by DIs and sediment traps located throughout the catchment and subsequent manual vactor removal by regular maintenance operations; and (5) a likely lag in delivery of road generated material to the monitoring location resulting in some storage in the conveyance system en route to the bottom of the catchment. As we continue to obtain catchment information and data to test the hypothesis that road condition can have a significant influence on catchment FSP loading, we must consider and constrain the fate and transport of road generated FSP on the catchment road network as it migrates to the catchment outfall where monitoring is conducted. We must also collect reliable data during drier conditions when the baseflow signal is expected to be negligible. These considerations must be incorporated into our data collection and data analysis approaches in the future.

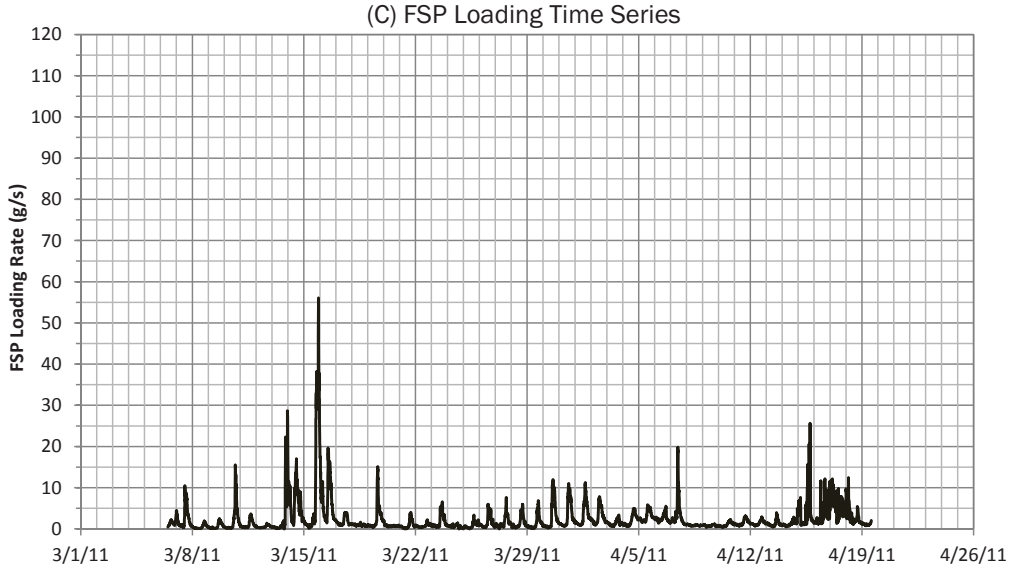
Table 5.6. Comparison of Spring 2011 Osgood catchment FSP concentrations. Observed catchment road FSP concentration for April 6, 2011 (see Table 5.4) is compared to the average daily FSP concentration measured April 7, 2011 (see Figure 5.4A) during the first significant runoff event following the road condition observations.

Observation period	Observed average road [FSP] (mg/L)	Observed runoff date	Daily average measured inlet [FSP] (mg/L)
4/6/11 (Late Winter/Early Spring)	406	4/7/2011	82.6

SPRING 2011 OSGOOD CATCHMENT MONITORING







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SPRING 2011 OSGOOD CATCHMENT MONITORING DATA

FIGURE 5.4

SETTLING BASIN FSP RETENTION

2N field personnel performed 2 surveys to estimate the amount of sediment delivered to the site but removed by the settling basin. The volume of material within the basin was quantified based on transect surveys in October 2010 and April 2011, and converted to mass using a standard density of 1.7g/ml[1] (Table 5.7). Assuming the rate of accumulation is evenly distributed over the time period between observations, these two data points suggest an accumulation rate of 0.57 MT per month or 0.85 MT every 6 weeks (the event duration).

At the onset of the study, the research team assumed that the settling basin primarily captures coarse sediment and debris and therefore was not a significant FSP sink in the overall catchment signal. Visual observations, however, suggest a surprisingly high distribution of powder-like material within the basin during dry conditions (see photo at right). Given these observations and rapid field geotechnical clay content tests, we estimate 20% of the material retained is FSP and that 0.15 MT of FSP delivered by the catchment is retained by the settling basin during a 6 week time period. However, to more appropriately constrain this estimate, sediment samples from the settling basin should be collected and submitted to an analytical laboratory for particle grain size analysis. Additionally, the settling basin is not regularly cleaned and while the research team requested maintenance of this treatment BMP by the CSLT prior to monitoring, but to our knowledge none was performed.

Sediment accumulation in Osgood settling basin, December 2011

Table 5.7. Sediment accumulation estimates in Osgood settling basin. Volume of material is converted to mass using a standard density of 1.7g/ml and assumed to contain 20% FSP.

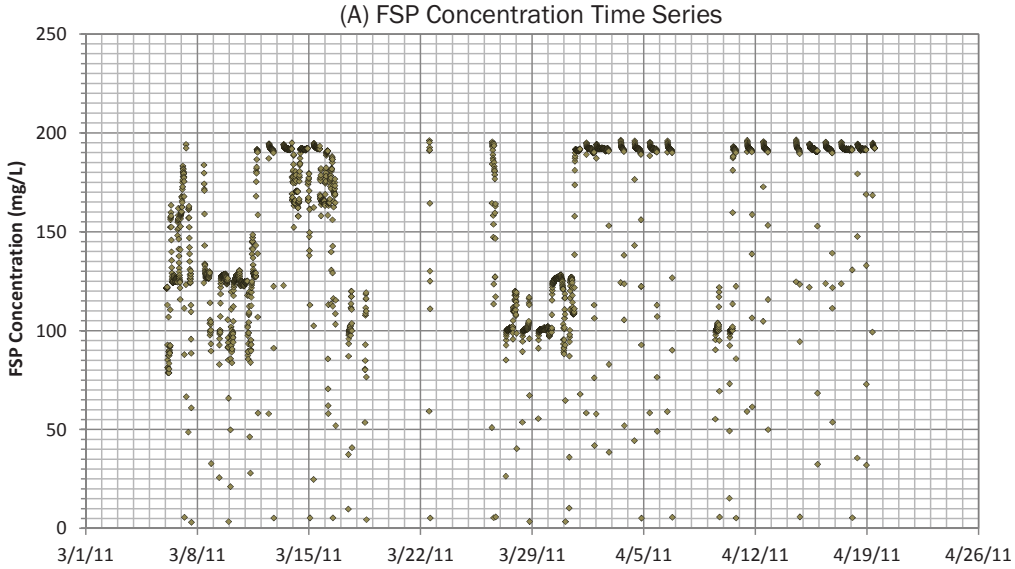
Date	Volume of material (cu-ft)	Mass of material (MT)	Estimated mass of FSP (MT)
10/13/10	351	16.9	3.38
4/20/11	447	20.3	4.06

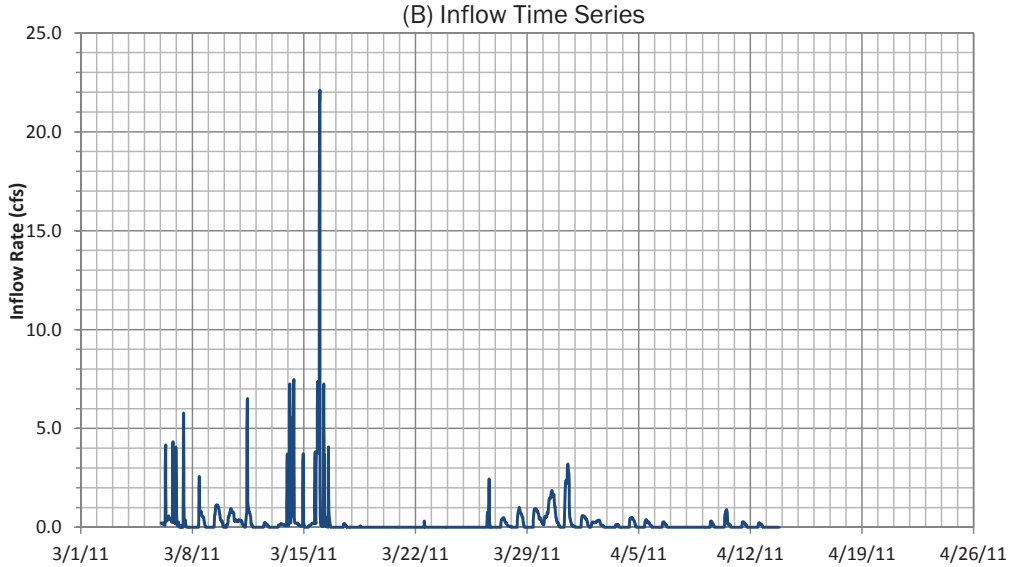
MEASURED CATCHMENT FSP LOADING

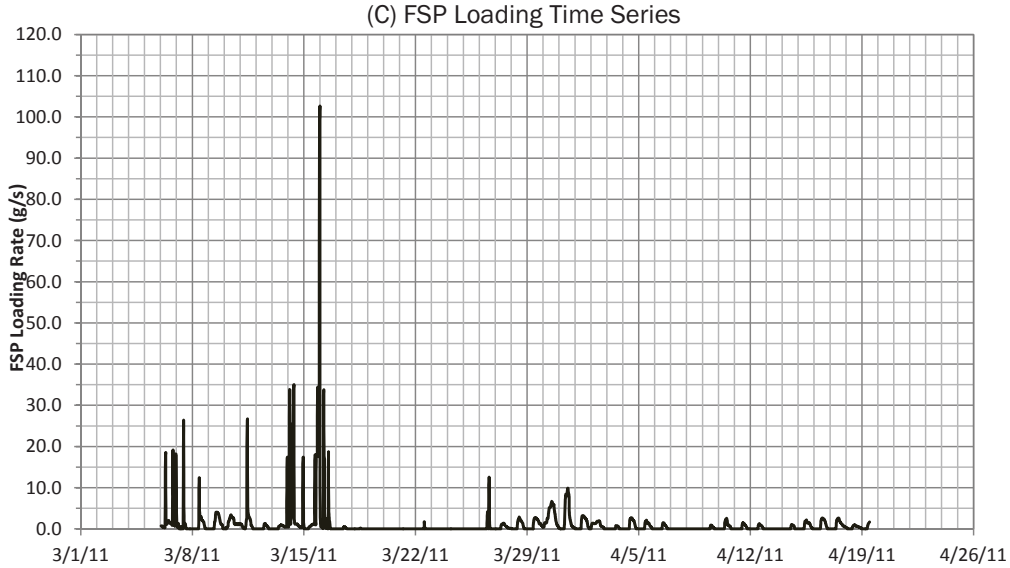
The measured FSP concentration time series from March 6 – April 19 is multiplied by the discharge time series to calculate the FSP loading rate (g/s) at the inlet to Osgood Basin (see Figure 5.4). PLRM FSP loading rates are the product of 10-min SWMM inflow predictions and PLRM catchment FSP concentrations generated for the same period (Figure 5.5). Table 5.8 compares the flow weighted average catchment FSP concentrations, total inflow volume, and total FSP load for the measured and predicted approaches.

[1] This bulk density of dry silt value has been used for volume to mass conversions in previous research (2NDNATURE et al. 2010c, 2NDNATURE and NHC 2012, etc.), and is therefore used here in order to remain consistent with previous calculations.

SPRING 2011 OSGOOD CATCHMENT PLRM PREDICTIONS







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SPRING 2011 OSGOOD CATCHMENT PLRM PREDICTIONS

FIGURE 5.5

Table 5.8. Spring 2011 measured and predicted Osgood catchment FSP concentrations, inflow volumes, and FSP loads from March 6 to April 19, 2011.

Catchment Metric	Measured value	PLRM predicted value	Adjusted measured value[1]
Flow weighted average FSP concentration (mg/L)	24.5	63.6	144
Total inflow volume (ac-ft)	259	22.4	29.3
Total FSP load (MT)	8.8	4.2	5.2

[1] Adjustments include: constant baseflow of 4 cfs and 11.5 mg/L removed from measured volume and load, and addition of 0.15 MT to FSP load based on the estimated FSP retained by settling basin.

The initial comparison suggests a significantly higher measured inflow volume (259 ac ft) than predicted by PLRM (22.4 ac ft). 2NDNATURE and NHC (2012) identified a significant baseflow contribution to the Osgood catchment from the Keller Canyon catchment (see Figure 3.1) in WY2010 and WY2011. Three consecutive years of increasingly higher precipitation and the wet WY2011 suggest the Keller Canyon catchment flow contribution was significant from March 6-April 19, 2011. Based on measured values during time periods assumed to be dominated by baseflow (i.e., nighttime with no measured precipitation), we estimate a constant baseflow contribution from the ephemeral springs in Keller Canyon of 4 cfs and average baseflow FSP concentration of 11.5 mg/L over the time period and adjust the measured values accordingly. Assuming FSP load is equally distributed during the Spring 2011 six week period, the FSP mass captured by the settling basin (0.15 MT every 6 weeks) is added to the adjusted FSP load to provide a more accurate comparison between PLRM and measured values.

With the removal of the baseflow component from the measured values, the predicted and measure total inflow volumes during the monitored event are similar, suggesting reasonable alignment between the SWMM modeling and the measured hydrology data. The comparison of FSP concentrations and total FSP load indicate higher measured values than predicted, with is consistent with the higher observed catchment road FSP concentration (see Table 5.4) compared to the predicted volume-weighted average road FSP CRC predicted by PLRM (see Figure 5.5).

5.3 DATA ANALYSIS AND REPORTING FINDINGS AND RECOMMENDATIONS

Despite the limited data collection, the USACE-funded research has provided a number of critical data management and data analysis techniques that will improve the results of the SNPLMA-funded monitoring in at least 2 urban catchments from March 1, 2012 through February 28, 2013. The following summarizes the key findings and recommendations for the subsequent research effort:

1. Comparisons of observed WY2011 (measured using Road RAM) and PLRM road condition predictions are reasonably close with average catchment scores of 2.0 (295 mg/L FSP) and 2.5 (184 mg/L FSP), respectively. Given the relatively high winter snow fall in WY2011, the relatively worse observed WY2011 conditions compared to PLRM are expected.

2. Following the completion of the SNPLMA Round 11 field data collection effort, a statistical analysis will be conducted to evaluate the ability to predict road condition (Road RAM score) as a result of prior sequential happenings, namely road maintenance practices and weather variables.

3. Comparisons of measured and predicted catchment volumes, FSP concentrations and loads must ensure the consideration and constraint of any sources or sinks that may not be included in the approaches. In the Osgood catchment, the estimated baseflow volume contribution from the Keller Canyon catchment

and the removal of FSP by the settling basin prior to the monitoring station was included in the adjusted measured values. Stormwater monitoring and treatment performance evaluations of SWTs retrofitted in built environments is complex, and a theoretical understanding of the sources and sinks on the measured or modeled signal is critical. The SNPLMA Round 11 funded research has expanded the monitoring study to include two additional catchments for WY2012 monitoring. In part, these catchments have been selected because they are not suspected to have a significant baseflow component, even in wet years. Future data collection will also include sediment sample analysis to quantify the FSP mass captured by the catchment treatment BMPs and removed during subsequent maintenance actions.

4. The stormwater volume alignment is challenging during very wet spring conditions when baseflow is determined to be a significant contribution. PLRM was not designed to accommodate baseflow, and as documented by 2NDNATURE and NHC (2012), this is significant source of surface water the spring of 2011 in particular. The baseflow contribution from the Keller Canyon was estimated based on a limited dataset and was not confirmed by field measurements. Continued catchment monitoring that provides similar water quality datasets for below average years, where baseflow is not expected to have as significant of a role will improve the quality of comparisons between monitored data and PLRM predictions.

5. While the comparisons between measured and predicted values are too limited to draw any conclusions regarding PLRM performance, this effort has greatly improved our understanding of how to manage, analyze and report both monitored and PLRM generated datasets to ensure future PLRM validation efforts are as representative and informative as possible. All of these lessons learned will continue to be incorporated into the ongoing SNPLMA Round 11 work to provide a complete water year to inform PLRM performance on short time scales on specific catchments.

6. Given the complexity of data collection, management, and analysis of the Osgood catchment, the SNPMLA Round 11 funded research will focus on two additional catchments that are expected to have fewer monitoring and hydrologic routing issues. Data collection in the Pasadena catchment within the CSLT jurisdiction (Figure 5.6) and the Central Incline Village catchment in Washoe County (Figure 5.7) began March 1, 2012 and employs the recommendations provided herein. Monitoring within the Osgood catchment is continuing, however data analysis of this site will be a lower priority given the challenges associated with this site that have been documented throughout this report.

2NDNATURE LLC
www.2ndnaturellc.com

Figure 5.6 Pasadena Catchment Location Map

Feet
0 125 250 500

N

2NDNATURE LLC
www.2ndnaturellc.com

Figure 5.7. Central Incline Village Catchment Location Map

Feet
0 255 510 1,020
N

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Attachment E

Crediting Program Support Services – Recommendations Memorandum and Project Report (December 2011)

RECOMMENDATIONS MEMORANDUM & PROJECT REPORT

CREDITING PROGRAM SUPPORT SERVICES

Prepared by
Environmental Incentives, LLC

12/23/2011

INTERNAL AGENCY DOCUMENT

Environmental Incentives

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I. SUMMARY

The Lake Clarity Crediting Program (Crediting Program) motivates effective action to improve Lake Tahoe clarity by tracking pollutant load reductions and enabling urban jurisdictions flexibility to most efficiently meet load reduction targets. The Crediting Program is systematically improved through a structured decision process to ensure 1) operational efficiencies reduce administrative costs, and 2) new scientific information enables jurisdictions to maximize the load reduction achieved at least possible cost. The decision process is capped with an Executive Decision Meeting where action is taken.

This summary presents recommendations for improving the Crediting Program, divided into two categories: those that require an executive-level discussion and consent items that are not expected to require executive engagement. It also presents a preview of substantial topics that are anticipated to come to executives' attention over the next year.

A Tahoe Total Maximum Daily Load (TMDL) executive action meeting held on September 8, 2011 resulted in three actions based on the recommendations presented. Additional context for these decisions is provided in the following section and Executive Action Meeting Report 2011.[1]

Key Terms

Crediting Program Handbook (Handbook) – The document that defines the Lake Clarity Crediting Program and protocols for calculating load reductions. Many of the recommendations in this memo are related to changes in the technical guidance section of the Handbook.

Catchment Credit Schedule (CCS) – The form and related technical guidance which jurisdictions use to document calculations and establish performance standards for catchments generating load reductions.

I. The executive action process will use a recommendation briefing and a public process with consensus expected between Lahontan and NDEP executives.
II. The TMDL baseline cutoff date was not changed, however urban jurisdictions can petition to have projects excluded from baseline on a case-by-case basis.
III. The Crediting Program Handbook v1.0 was conceptually adopted and has since been incorporated into agency policy and CA permits.

RECOMMENDATIONS FOR DISCUSSION

I. DEFINE EXECUTIVE DECISION PROCESS

Step 3.9 in the Handbook on page 3-12 describes the executive decision process. This recommendation proposes to provide clarifying detail.

Recommendation

- **Decision Process:** Decisions are by consensus of the program partner agency executives
- **Program Partners:** Water Board, NDEP
- **Program Advisors:** US EPA, TRPA and urban jurisdictions
- **Forum:** Annual meeting of program partners and program advisors with all parties expected to review program improvement recommendations and communicate major issues or changes in advance of meeting

[1] Environmental Incentives 2011. Crediting Program Executive Action Meeting Report 2011. https://environmentalincentives.centraldesktop.com/home/viewfile?guid=144324025366251D0CF25591C2105EDC4F6DB74C6&id=14769719.

Rationale

This decision process is structured to provide a streamlined and nimble process that will not overload staff with excessive effort but will provide executives the context needed to make decisions that are informed by key stakeholders. This decision process will enable the Crediting Program to smoothly incorporate new scientific findings, program performance information and stakeholder input to enhance the viability of the program over the Lake Tahoe TMDL implementation period.

Issues to Address

- TRPA inclusion as a program partner rather than a program advisor may be considered. This is not recommended because technical capability and regulatory authority are concentrated with Water Board and NDEP, the EPA designates at each State. The Water Board and NDEP are mission-focused on water quality, maintain responsibility for enforcement of the Clean Water Act, and are the primary motivators for jurisdictions to achieve load reduction targets.
- Jurisdictions may wish to participate as program advisors during the executive decision process. These organizations are engaged deeply in the Crediting Program and are often the source of program improvement recommendations. They are also consulted formally in a stakeholder meeting during development of the recommendations memo. Participation in the executive decision process will increase the difficulty for regulatory entity to make decisions in the timeframes necessary to efficiently maintain the Crediting Program. If the collaborative benefits of including regulated entities outweigh the costs in slower decision making; a representative of the regulated entities could be designated as a program advisor.

II. ADJUST BASELINE CUTOFF DATE

The City of South Lake Tahoe (CSLT) submitted an official Program Improvement Recommendation and compelling backup documentation to justify a change to the cutoff date for projects. This cutoff date is important to CSLT and other jurisdictions because projects completed before this date are included in the TMDL baseline and receive substantially less credit than those that are completed after the cutoff date.

Recommendation

- **Adjust baseline cutoff date** from October 2004 to May 1, 2004 in all sections of the Handbook.[2] Sections include: Chapter 0, Chapter 1, and CCS Technical Guidance & Instructions: Section E.

Rationale

CSLT reviewed rainfall and runoff data and found that very little stormwater flowed through projects built during the construction season of 2004. TMDL staff concludes that it is not necessary to include the effects of this runoff in the baseline loading condition.

This adjustment will demonstrate regulators' desire to work with jurisdictions by making a change that helps jurisdictions get the most possible credit for their actions. This demonstration comes at little cost to the Crediting Program because it impacts only a few projects built on the cusp of the baseline.

A cutoff date of May 1, 2004 is appropriate because it is often uncertain if a project is completed exactly by the October 15 grading deadline. The lack of certainty comes from (1) deadline waivers or penalties paid for late project closure and (2) need for administrative time to finish billing and close contracts. Typically no construction occurs during the winter (October-April) and this time can function as a grace period for tying up loose ends on projects that may have been completed on the cusp of the baseline period.

[2] All references to Handbook pages are to version 0.99. Pagination is expected to shift in version 1.0.

III. ADOPT HANDBOOK WITH ADJUSTMENTS

After reviewing all recommendations including consent items, executives can officially adopt the Handbook for use with Memoranda of Agreement and stormwater permits.

Recommendation

- **Adopt Handbook v1.0** based on recommended changes to previously reviewed version 0.99. This adoption will be subject to review of the final document via email in late September 2011.

Rationale

Adjustments to the Handbook are focused on clarity and usability enhancements based on the experience of urban jurisdictions which have pilot tested the program over the last 18 months. Major concepts in version 0.99, such as use of models to estimate expected loading and use of condition assessment tools to award ongoing credit are not changing.

CONSENT ITEMS

The following recommendations should be reviewed by executives but do not require discussion at the executive decision meeting unless called out for discussion by executives.

A) STORMWATER RUN ON GUIDANCE

Expand the technical guidance in Section B of the CCS Technical Guidance & Instructions on page TT-14 of the Handbook for dealing with stormwater from other jurisdictions that runs on to a registered catchment. This guidance will explain a well-though-out approach to delineate the catchment, model runoff and distribute credit.

Rationale: Most jurisdictions have asked for this guidance so that they can use best practices and minimize time spent recreating an approach.

B) RUNOFF VOLUME TRACKING

Add runoff volume to CCS Section F as a parameter to track.

Rationale: This change focuses implementers on reducing this aspect of the pollutants and is consistent with the Stormwater Quality Improvement Committee (SWQIC) preferred design approach. This parameter is already calculated by the Pollutant Load Reduction Model (PLRM) and would require a negligible amount of extra time to record.

Additional Considerations: Until the Accounting & Tracking Tool is updated, this parameter will only be recorded in the CCS. A tool integration effort is currently underway and should be able to incorporate the runoff volume parameter by the end of 2012.

C) CATCHMENT CONNECTIVITY CONSISTENCY

Provide additional guidance to increase consistency and reduce uncertainty among jurisdictions in estimates of catchment connectivity to surface waters. This addition is recommended for Section D of the CCS Technical Guidance & Instructions on page TT-26 of the Handbook.

Rationale: Catchment connectivity identifies the fraction of loading leaving a catchment, and is modeled in PLRM, that is expected reach surface waters and the lake. This guidance has been requested by some of the jurisdictions. The proposed approach is focused on simply binning similar catchments, but still allows jurisdictions some freedom to select the numeric connectivity percentage within the bins. Jurisdictions

who feel the guidance is not helpful can select a different connectivity as long as they take the time to provide a clear rationale for their choice.

Additional Considerations: The topic of jurisdictional baseline calculations is under some debate by jurisdictions; however the targeted nature of this change to the Handbook minimizes the controversy related to this aspect of connectivity. Urban jurisdictions which define more technically rigorous approaches will be allowed to use their approach provided that they provide documentation and show calculations and assumptions in the CCS Memo.

D) CATCHMENT DISCONNECTION

Make changes in the CCS to allow changes in catchment connectivity between Baseline and Expected conditions of a catchment. These changes are recommended for Chapter 1, page 1-4 and Sections D & E of the CCS Technical Guidance & Instructions on page TT-26 and 29.

Rationale: This change focuses jurisdictions on a strategy to hydrologically disconnect catchments, increasing infiltration that may occur between the outlet of a catchment and surface waters. This strategy shows potential for substantial load reduction.

Additional Considerations: This change cannot be quantified by the standard tool for load calculations (PLRM), so there will be less consistency among jurisdictions in the estimated benefit of this strategy.

E) STANDARD TOOL ISSUES

Add a "known issues" text box to the technical guidance for each standard stormwater tool. For example: the BMP Rapid Assessment Methodology (RAM) database crashes catastrophically when saved on a network drive and then moved to a new location. Recommended Handbook locations for these changes are:

BMP RAM - Appendix C, page C-4

Road RAM – Appendix C, page C-7

PLRM – CCS Technical Guidance & Instructions, page TT-26

Rationale: Informs users of potentially time-consuming issues and reduces possible frustration.

Additional Considerations: Focuses users on the standard tools but may reduce confidence in them unnecessarily. Will require future adjustments to the Handbook as the issues are corrected.

F) VERIFICATION CHECKLIST

Add an additional template to the Handbook that helps regulators review and verify CCS forms effectively and consistently. This addition is recommended for the Technical Guidance & Instructions after page TT-39. This addition will reduce use of the Issue Resolution Punchlist by reserving it for intractable issues that cannot be worked out informally.

Rationale: The verification checklist significantly enhances review quality of submitted CCS forms and reduces staff time needed for review. The verification checklist can help jurisdictions understand many of the details upon which their submissions will be judged.

Additional Considerations: Increases the number of forms for users to understand.

G) LOAD REDUCTION ELIGIBILITY CLARIFICATION

A set of findings from stream restoration research and policy discussions leads to recommendations to clarify the load reduction eligibility from stream restoration and other innovative practices that provide load reductions additional to the TMDL implementation plan. These recommendations include:

1) Add the following policy guidance to Chapter 0, page 0-5.
   All pollutant load reductions from urban areas are eligible to be considered for meeting Lake Clarity Credit targets in stormwater permits and memoranda of agreement. This includes any urban stormwater load reductions resulting from improving stream environment zones that result in increased filtration and pollutant capture of stormwater runoff.

2) Add the following statement to the CCS Technical Guidance & Instructions Section C, pages TT-17 & 24.
   All load reductions achieved in addition to those identified in the Lake Tahoe TMDL Implementation Plan and supported by a rigorous load reduction estimate may be considered to contribute to an urban jurisdiction's Lake Clarity Credits target. Load reductions resulting from stream restoration outside of the Upper Truckee River, Blackwood Creek or Ward Creek may be considered. Similarly, pollutant sinks not directly linked to a pollutant source in the TMDL may be considered, such as load reductions from increasing floodplain deposition of sediments. However, non-urban load reductions identified in the Implementation Plan of the Lake Tahoe TMDL may not be considered to contribute to an urban load reduction target, because they are already accounted for in the TMDL Implementation Plan.

   All implementers are encouraged to innovate and develop previously unexpected pollutant control strategies to cost effectively reduce pollutant loading and restore lake clarity. When urban jurisdictions identify effective non-urban load reduction opportunities that were not identified in the TMDL, they should discuss the opportunities with regulators to determine if the opportunities may be eligible to generate credits. For eligible load reduction opportunities the urban jurisdiction and regulator will determine acceptable methods to develop load reduction estimates, document expected conditions and assess conditions over time to determine ongoing performance. Depending on the circumstances, it may not be possible to determine an acceptable estimation method, or equivalency and uncertainty ratios may be applied that will provide assurances that the environmental benefit for non-urban pollutant controls are at least as beneficial to lake clarity as those achieved from urban stormwater reductions.

   When a certain type of pollutant control becomes widely implemented, regulators and implementers will develop standard methods to estimate load reductions, document expected conditions and assess conditions over time. Once accepted, these standard methods will be adopted through the Lake Clarity Crediting Program's Program Improvement Process.

Rationale: This recommendation addresses findings that confusion exists about the regulatory classification of stream zone improvements and their relationship to urban load reductions. It also provides incentive for all Crediting Program participants to discover innovative ways to reduce pollutant loads to Lake Tahoe.

Additional Considerations: Uncertainty surrounding the amount of load reduction will be higher for innovative approaches until standard estimation methods and tools become available. This consideration can be addressed through the use of uncertainty ratios until standard methods are developed.

H) OBSERVATION-PARAMETER CROSSWALK

Provide a crosswalk between condition assessment observations in the BMP RAM and PLRM parameters that model expected conditions. This addition is recommended for Section C of the CCS Technical Guidance & Instructions after page TT-20.

Rationale: This product will substantially clarify the critical linkage between expected conditions modeled in PLRM and actual conditions assessed with the RAMs. Jurisdictions have expressed desires for this additional guidance.

Additional Considerations: Many of the linkages are not direct and technically rigorous at this time. For instance the Constant Head Permeameter measurements of infiltration rate in the BMP RAM do not provide comparable information to the infiltration rate field for BMPs in PLRM. SNPLMA-funded research is currently underway to provide scientific guidance on this issue and is expected to inform future improvements.

I) ROAD RAM INTEGRATION

Update Handbook guidance to reflect Road RAM concepts, for instance the Road Group concept will be converted to the Road Class concept. The Handbook was completed about a year before Road RAM and several concepts have evolved substantially. These changes are recommended for Section C of the CCS Technical Guidance & Instructions on page TT-21 and Appendix C: Credit Award Method, page C-7.

Rationale: Misalignment between the PLRM and Road RAM are a source of substantial confusion among jurisdictions that have learned how to use the Crediting Program. This Handbook update will synchronize terminology and concepts.

Additional Considerations: the design of the PLRM was completed before Road RAM was complete and lacks certain features that would facilitate comparison of actual conditions to expected conditions. For example, there is no single water quality rating for Road Groups and PLRM uses an activity-based system for predicting runoff pollutant concentration. This update to the Handbook will make several changes, but will focus on describing the relationship between PLRM maintenance activity -> pollutant concentration curve and the corresponding Road RAM pollutant concentration curve -> RAM score. Changes to PLRM are necessary in the future and are not possible through the Support Services contract.

J) LOAD MODELING METHODOLOGY

Update Handbook technical guidance regarding when to use the Private Property BMP versus Treatment BMP methodology to calculate load reductions in PLRM. This change is recommended for Section D of the CCS Technical Guidance & Instructions, page TT-27.

Rationale: Jurisdictions are free to use the methodology that best suits their needs, but there may be strategic choices that can maximize credit. This guidance will help all jurisdictions realize these choices and level the playing field used by the Crediting Program.

K) BASIC EDITORIAL ADJUSTMENTS

Make basic usability enhancements and editorial clarifications throughout the Handbook and CCS. Staff and the consultant team are currently

a. Changing order of Inspection Summary and Maintenance Summary

b. Changing units of pollutants to match PLRM – saves conversion effort and errors; can be converted to TMDL (metric) units en mass at a later time if necessary

c. Changing order of CCS pollutant fields to match PLRM output order

d. Aligning Private Property BMP section of CCS to match with PLRM inputs and outputs – reduces effort and comprehension issues with users

e. Making minor text edits – punctuation, word choice and layout that do not substantively change Crediting Program or TMDL concepts

ANTICIPATED FUTURE TOPICS & DECISIONS

Executives should be aware of several topics that are actively being discussed and may require a decision during one of 2-3 executive interactions anticipated during 2012. These topics should be discussed with staff, but are not expected to be discussed in the September 2011 executive decision meeting.

JURISDICTION-WIDE CREDITING

Allow jurisdictions to earn Credits from activities in areas outside of registered catchments. This topic has been brought up by several jurisdictions in regard to their road maintenance activities.

Rationale: A policy allowing jurisdiction-wide crediting would reduce administrative overhead and create a practical alternative to registering every catchment before receiving Credits for pollutant controls that are acknowledged to produce substantial load reductions (e.g. abrasive management and sweeping). This desire can be satisfied through use of a special CCS that includes the entire jurisdiction.

Lake Clarity Credits (Credits) – One credit is equivalent to $1x10^{14}$ particles of <16 micron fine sediment, or roughly 200 pounds. Credits are generated by implementing pollutant controls such as effective operation and maintenance of roads, stormwater treatment and policies. Credits are awarded on an annual basis based on evidence that pollutant controls are operating at or near performance expectations.

Additional Considerations: This complicates program by necessitating a special form and requiring that jurisdictions subtract jurisdiction-wide load reductions from those calculated when new catchments are registered.

CREDITING NON-URBAN SOURCES

Staff and interest groups have raised the topic of giving credit for non-urban source categories

Rationale: Any bonafide load reduction is valuable for enhancing lake clarity. The infrastructure of the Crediting Program does track estimated Load Reductions. The TMDL Management System project is developing template crediting protocols for other source categories in 2012-2013.

Additional Considerations: The Crediting Program is currently focused on urban sources because (1) they are the largest portion of the load, (2) there will be mechanisms in place to enforce Credit requirements and (3) building a focused program will allow major issues to be resolved before complications arise due to additional source categories.

TMDL MANAGEMENT SYSTEM & TOOL INTEGRATION PROJECT

Many enhancements to the Crediting Program are expected through two efforts that have been recently funded. The TMDL Management System project will define the critical processes necessary to sustain the TMDL over time and produce the first set of key products, including

a. **TMDL Performance Report**
b. **Public Reporting Platform**
c. **Synthesis of Findings**
d. **Stakeholder participation process**
e. **Lists of operational improvements and areas for investigation**

The Tool Integration Project will connect and streamline the technology tools that manage information for the TMDL and Crediting Program. The major products that come from these efforts are expected to strategically complete program needs and several will be reviewed by the executives.

II. INTRODUCTION & BACKGROUND

The Lake Clarity Crediting Program (Crediting Program) motivates effective action to improve Lake Tahoe clarity by tracking pollutant load reductions and enabling urban jurisdictions flexibility to most efficiently meet load reduction targets. The Crediting Program is systematically improved through a structured recommendation and decision making process to ensure 1) operational efficiencies reduce administrative costs, and 2) new scientific information enables jurisdictions to maximize the load reduction achieved at least possible cost.

SUPPORT SERVICES PROJECT

The Crediting Program Support Services (Support Services) project enabled improvement of the Crediting Program by supporting implementation and refinement through a beta-testing process. The primary regulating agencies – the Nevada Division of Environmental Protection (NDEP) and Lahontan Regional Water Quality Control Board (Water Board or Lahontan) – worked with local jurisdictions and transportation agencies in a non-regulatory atmosphere in order to implement and test the protocols, tools and methods outlined in the beta version of the Crediting Program Handbook. Processes of the Crediting Program that were tested include: (1) selection and inventory of a test catchment, (2) estimation of potential load reductions under baseline and expected conditions, and (3) verification and registration of load reductions.

The Support Services project was capped with an Executive Decision Meeting where action was taken, followed by production of a revised Crediting Program Handbook that will be used to guide the kickoff of the Crediting Program.

DOCUMENT CONTEXT

This document is an internal product, designed to be used primarily by regulatory agency staff. It is intended to serve as a long-term reference that will inform regulatory agency project managers and developers of the Crediting Program Handbook (Handbook) of (1) actions that took place during the project and (2) feedback received on the Crediting Program and TMDL-related tools.

DOCUMENT STRUCTURE

Throughout this project, the team has developed a series of "Best Practice" or "Additional Guidance" memos based on understanding gained while aiding jurisdictions in completing Crediting Program products. This document is a collection of the findings from those memos including issues addressed, lessons learned, and recommendations surrounding the following topics

- Catchment Selection & Delineation
- Catchment Inventory
- Catchment Credit Schedule
- PLRM Load Estimation Tool
- Catchment Verification & Registration

Many of the recommendations capture changes that were made between version 0.99 and version 1.0 of the Handbook – the primary product of the Crediting Program Support Services project. Recommendations made throughout the document are captured in the Summary section which was presented to TMDL executives as a separate recommendations memo to support decision making.

The appendices include jurisdictions' catchment credit schedules, a tabular summary of recommendations, formal program improvement recommendations from jurisdictions and a summary of assistance provided directly to jurisdictions.

The Recommendations Summary Table, included in Appendix C and used throughout this document, includes specific change recommendations, the document or tool that the change recommendation is referencing, and several rating categories described in the table below.

Summary Rating Table

Criteria	Rating	Narrative Justification
Importance	5	If the change is not implemented, it will be a substantial hindrance to the adoption and eventual success of the Crediting Program.
	3	The change will lead to a substantial increase to participant satisfaction with the Crediting Program.
	1	The change would be nice to have, but is not influential on the overall success of the Crediting Program.
Anticipated Effort	5	Implementing the change will require multiple months of effort.
	3	Implementing the change will require approximately one week of effort.
	1	Implementing the change will require approximately one day of effort.
Recommendation Status	C	**Complete** - The recommendation was completed as part of the Support Services project.
	F	**Funded** – The recommendation is planned within the scope of a currently funded project.
	O	**Outstanding** – The recommendation is still an outstanding need to be resolved.

III. CATCHMENT SELECTION & DELINEATION

Crediting Program Support Services (CPSS) participants selected one test catchment to use as a real-life, hands-on learning scenario for the duration of the project. During the early months of 2010, participants worked with the project team to identify catchments that would give each jurisdiction an opportunity to effectively apply the protocols and processes of the Crediting Program within a catchment in their respective jurisdictions. The project team worked to ensure that a variety of catchments (size, land use, connectivity, pollutant control strategy, etc.) were used so as to provide an assortment of catchments to truly test the guidance and processes defined by the Handbook.

EXISTING GUIDANCE

- Crediting Program Handbook Step 1.1.1 (pg. 1-4)
- CCS Technical Guidance & Instructions (TT 14-17)
- Example Products: Handbook Appendix A, Attachment 3: Catchment Delineation & Outfalls Map

ISSUES ADDRESSED & LESSONS LEARNED

CATCHMENT VARIATION & USER TYPES

Relevance: Crediting Program
Context: Public works jurisdictions vs. transportation jurisdictions

Recommended Action

Crediting Program Handbook Revision: Retain the common name "urban jurisdiction" but explain that this term encompasses two jurisdictions: public works and transportation entities.

Lessons Learned & Best Practices

Traditional definition of "urban jurisdiction" has included county (e.g. Douglas County), city (e.g. City of South Lake Tahoe) and transportation (e.g. NDOT) entities. For purposes of defining catchments for the Crediting Program, however, it is evident that counties and cities will define more traditionally shaped catchments that adhere to hydrologic boundaries whereas transportation jurisdictions commonly define linear catchments. By recognizing this distinction, it helps these two different types of jurisdictions delineate catchments that are of reasonable size and designation while reducing confusion regarding right of way and hydrologic connectivity.

Products

The Project Team developed guidance that expanded the definition of an urban catchment to accommodate catchments that intersect other catchments and/or are not directly connected to a surface water body; primarily, this addressed the unique linear catchments generally used by road jurisdictions.

Considerations & Process for Selecting Test Catchments (1/28/10)

Additional Considerations for Catchment Delineation (4/2/10)

CATCHMENT SIZE

Relevance: PLRM, Crediting Program
Context: Jurisdictions are provided no specific limitations (max/min) for catchment area

Recommended Action

Approve existing guidance: Users should consult the 1) PLRM guidance on catchment size (10-100 acres), 2) the minimum investment of resources required to develop a catchment credit schedule, and 3) the Crediting Program's high degree of flexibility (and the Project Team's resulting emphasis on "grouping" or "lumping" similar topics to increase efficiency). See also "sub-catchments in PLRM" in the guidance developed.

Lessons Learned & Best Practices

Some jurisdictions wish to register large catchments (+100 acres) while it is more practical for others to register smaller catchments (~10 acres). The Crediting Program & PLRM are flexible, but jurisdictions should be encouraged to think about which catchment size is more practical for their jurisdiction.

Products

The Project Team developed guidance that explained different scenarios for catchment size, run-on and cross-jurisdiction ownership.

Related Issues - Catchment Run-On Guidance (5/11/10)

CATCHMENT MEMOS & ASSOCIATED PRODUCTS

Relevance: Crediting Program
Context: Catchment memos contents

Recommended Action

Develop new Appendices: With the information gained during this project, the Handbook should include a full example of all Crediting Program Products, using the best products created by jurisdictions during this project.

Lessons Learned & Best Practices

Products produced by jurisdictions varied in depth, breadth and quality. The most useful maps were those that clearly identified the features required by the Crediting Program layered with key information that provided a general understanding of the natural and built environment. Useful catchment selection memos provided a brief narrative assessment of the general pollutant control strategy while calling out in a clear (bulleted) format the information used to assemble and assess the catchment. When used together,

these two products provide a reader unfamiliar with the catchment or area with a good understanding of the catchment and general pollutant control strategy. The Project Team focused jurisdictions on producing concise memos.

Products

The Project Team developed guidance that gave specific instructions and requirements for developing catchment memos.

Considerations & Process for Selecting Test Catchments (1/28/10)

Additional Considerations for Catchment Delineation (4/2/10)

RUN-ON & COMINGLED WATER

Relevance: Crediting Program, BMP RAM, Road RAM, PLRM

Context: Treating pollutant loads that jurisdictions legally do not have responsibility for; jurisdictions were unclear how they should deal with non-urban run-on

Recommended Actions

Approve existing guidance: Users should consult the Catchment Run-On Guidance developed during this project as a resource for understanding concerns, approached and best practices when run-on is a concern in their catchment.

Crediting Program Handbook Protocol: Jurisdictions who plan to model run-on from another catchment should always coordinate with the primary jurisdiction responsible for the run-on to ensure that the run-on has not been previously accounted for and that claiming any associated load reduction from the run-on is acceptable. (This is particularly important when considering run-on from transportation jurisdictions such as NDOT or Caltrans.)

Crediting Program Handbook Protocol: Run-on from non-urban source categories should not be entered into PLRM or included in any load reduction estimates. Jurisdictions should explain how they plan to address this run-on in their catchment within the catchment implementation plan section of the CCS.

Lessons Learned & Best Practices

Addressing run-on and right of way is important for all jurisdictions especially when concerning transportation jurisdictions and general improvement districts. This consideration is essential when evaluating credit sharing between jurisdictions.

The Project Team, in coordination with regulatory agencies, came to the conclusion that run-on (ie., off-site flow into a catchment) is only important to be modeled if the flows are not bypassed and are subsequently routed to a stormwater treatment control located in the catchment. All other pollutant loading for private parcels is assessed by private parcel BMP and source control certificate percentages.

This guidance also explained that "erosion potential" in PLRM is used to represent undeveloped urban lots and not forested land. In addition, this guidance clearly advised users to use PLRM only as a tool for estimating pollutant loading from urban areas.

Products

The Project Team developed guidance that detailed different scenarios that aid jurisdictions in evaluating if they should model run-on in their catchment or not.

Catchment Run-On Guidance (5/11/10)

RECOMMENDATIONS

Summary Table

#	Change Recommendation	Document/ Tool	Importance	Anticipated Effort	Recommendation Status
1	Refine User Type Guidance & Definition	Handbook	4	2	C
2	Incorporate Catchment Size Guidance	Handbook	4	2	C
3	Incorporate Catchment Delineation Definition & Guidance	Handbook	4	2	C
4	Develop Catchment Memo Guidance & Example	Handbook	2	3	C
5	Incorporate Run-On & Comingled Water Guidance	Handbook	3	3	C
6	Provide Rationale & Guidance Regarding Modeling Non-Urban Loading	Handbook	2	3	C
7	Consider Ways to Allow Jurisdiction-wide Reporting	Handbook	4	2	O

1. **Refine User Type Guidance & Definition** - Develop specific guidance and Crediting Program language that recognizes and addresses the differences between jurisdictions.
2. **Incorporate Catchment Size Guidance** - Develop a set of considerations to include in the Crediting Program Handbook that prompts users to consider investment of time and acceptable methods for increasing efficiency when delineating an urban catchment.
3. **Incorporate Catchment Delineation Definition & Guidance**– Expand the definition and develop guidance for urban catchments in the Crediting Program. Ideally, catchments should generally be delineated in a manner that preserves hydrologic boundaries, however, in certain situations it may be cumbersome, and even unnecessary, to define catchments that preserve hydrologic boundaries for a jurisdictional calculation of pollutant loads when using PLRM. When necessary, a jurisdiction may define a catchment that intersects another jurisdiction's catchment. In this instance, the jurisdiction seeking to intersect another catchment must coordinate with the appropriate jurisdiction(s) and regulatory agency to ensure that no load reduction is double-counted (e.g., overlap in catchment boundaries, run-on/run-off, etc.).
4. **Develop Catchment Memo Guidance & Example Catchment Memo -** Incorporate additional catchment memo requirements identified and detailed in guidance developed through the Support Services Project. Develop an ideal example of a catchment memo for the Crediting Program Handbook Appendix.
5. **Incorporate Run-On & Comingled Water Guidance –** Incorporate and further develop language and specific guidance for the Crediting Program Handbook that explains scenarios and options for modeling load reductions where run-on and comingling of water occurs.
6. **Provide Rationale & Guidance Regarding Modeling Non-Urban Loading** - Develop or provide guidance and/or rationale regarding run-on to an urban catchment from forested lands and other source categories.
7. **Consider Ways to Allow Jurisdiction-wide Reporting** - Develop or provide guidance and/or rationale for jurisdictions to report and get credit for broadly applied pollutant-reducing activities such as road sweeping or ordinances.

IV. CATCHMENT INVENTORY

Jurisdictions were trained in inventory protocols and methodologies to employ when inventorying their selected test catchment. During a full-day training, the Project Team provided training, guidance and examples for the following tools: Treatment BMP RAM, Treatment BMP RAM Database, Road RAM Protocols (draft). After training sessions, jurisdictions went into the field to apply the protocols with other jurisdictions. The Project Team gathered feedback, provided targeted assistance in the field and ensured that jurisdictions were familiar with the tools to the degree that each attendee could inventory their test catchment.

Roads were inventoried during this project for each jurisdiction's test catchment; however the Road RAM was not used directly because it had not yet been drafted. Since catchments were inventoried, the Road RAM has been completed and it is now the recommended approach to inventory roads for the Crediting Program.

EXISTING GUIDANCE

- Crediting Program Handbook
- CCS Technical Guidance
- BMP RAM User Manual
- BMP RAM Technical Documentation
- Road RAM User Manual
- Road RAM Technical Documentation

ISSUES ADDRESSED & LESSONS LEARNED

INCONSISTENT NOMENCLATURE

Relevance: Crediting Program, PLRM, BMP RAM, Road RAM, A&T Tool, Annual Reports

Context: Different names for different items can be confusing and cumbersome for jurisdictions, add to this new terminology and requirements, and jurisdictions have a tendency to become frustrated.

Recommended Action

Approve existing guidance: Users should consult the guidance developed during this project as a resource for understanding concerns, approached and best practices in their catchment.

Lessons Learned & Best Practices

Although aligning nomenclature for BMPs, urban catchments, etc. for all jurisdictions is a significant undertaking, tool developers can limit confusion by providing clear definitions and explicit descriptions for users.

Products

The Project Team developed additional guidance that provided specific and clear requirements for a number of topics that were unclear and refined definitions of terminology unique to the Crediting Program and associated tools.

Considerations & Process for Selecting Test Catchments (1/28/10)
Additional Considerations for Catchment Delineation (4/2/10)
PLRM Sweeper Guidance (5/10/10)
Catchment Run-On Guidance (5/11/10)
BMP RAM Sediment Trap Diameter Conversion Tool (5/27/10)
Catchment Inventory Data Checklist – Crediting Program, RAMs & PLRM (5/28/10)

Road RAM Draft Inventory Guidance (6/11/10)

PRACTICALITY OF TOOLS IN TIMES OF CONSTRAINED RESOURCES

Relevance: Crediting Program, PLRM, BMP RAM, Road RAM, A&T Tool

Context: Users expressed serious concerns regarding the increase in workload required to use these tools especially with limited resources

Recommended Action

Approve existing guidance: Users should consult the guidance developed during this project as a resource for understanding concerns, approached and best practices in their catchment.

Lessons Learned & Best Practices

Tools should be made to be as easy to use as possible. To do this, tool developers should support mass import/export functionality at a minimum. A central tool hosted online would be preferred, however, such that jurisdictions would not have to install special software, enter data multiple times and avoid a number of other costly steps and missteps inherent in the existing tools.

Products

The Project Team developed additional guidance and tools that helped simplify and clarify steps of inventorying a catchment including using PLRM and the RAMs.

PLRM Sweeper Guidance (5/10/10)
BMP RAM Database Update (7/7/10)
Inventory Data Checklist & Time Estimate (5/28/10)
BMP RAM Sediment Trap Diameter Conversion Tool (5/27/10)
Catchment Inventory Data Checklist – Crediting Program, RAMs & PLRM (5/28/10)
Road RAM Draft Inventory Guidance (6/11/10)

RECOMMENDATIONS

Summary Table

#	Change Recommendation	Document/ Tool	Importance	Anticipated Effort	Recommendation Status
8	Integrate RAM Tools in Online Database	All	4	5	F
9	Coordinate & Unify Nomenclature	Handbook	2	5	C
10	Develop BMP RAM Import Capabilities	BMP RAM	3	3	F
11	Add functionality to BMP RAM to calculate observation values based on a target RAM score	BMP RAM	3	4	F
12	Determine need for benchmark and threshold values for Cartridge Filters	BMP RAM	3	3	O

8. **Integrate RAM Tools in Online Database** - Develop one central, web-based and GIS enabled tool that incorporates all existing stormwater tools into an online web application.

9. **Coordinate & Unify Nomenclature -** Encourage all-jurisdiction development and adoption of comprehensive nomenclature for stormwater terms (e.g., BMP types, catchments, etc.) in the Tahoe Basin. Ensure that new terminology and data requirements in stormwater tools are clear and concise (e.g., bullets), and – importantly – consistent. Specifically, consider the creation of an information graphic showing links between names for common BMPs, BMP RAM Types & PLRM Fields.

10. **Develop BMP RAM Import Capabilities**- Develop the BMP RAM database to accept standard format imports and also complete export functionality to increase the ability of users to interact with the database efficiently.
11. **Add Functionality to BMP RAM to Calculate Observation Values Based on a Target RAM Score**- Create a new report in the BMP RAM database that back-calculates observation values equivalent to a user-defined RAM score that can then be modeled in PLRM.
12. **Determine Need for Benchmark and Threshold Values for Cartridge Filters**- Conduct further research into the effectiveness of cartridge filters to inform the importance and practicability of obtaining benchmark and threshold values for cartridge filters.

V. CATCHMENT CREDIT SCHEDULE

Jurisdictions produced Catchment Credit Schedule forms that documented expected load reductions from one test catchment. The project team led an introduction to the forms and necessary supporting materials that were needed. The project team then provided extensive one-on-one attention to each jurisdiction as it progressed through the creation and review process. When the CCS and supporting materials were of adequate quality, regulators used a structured review form to provide regulatory comments. Each jurisdiction also met with its regulator in a "Verification Meeting" to work out remaining issues and create a punch list of changes needed to register the test catchment.

EXISTING GUIDANCE

- CCS Form
- CCS Technical Guidance & Instructions
- Example products: Handbook Appendix A, Attachments 1-8

ISSUES ADDRESSED & LESSONS LEARNED

REFINE BASELINE DATE

Relevance: Crediting Program Handbook

Context: CSLT has suggested a change in the date of projects that are eligible for full credit to those that are completed after May 1, 2004 because they treated very little runoff during the 2004 construction season.

Recommended Action

Clarify Handbook: Adjust baseline definition in Section 1.1.4 and glossary to define the baseline cutoff to be May 1, 2004. Also clarify that the infrastructure must be treating stormwater rather than "in place."

Lessons Learned & Best Practices

- CSLT reviewed rainfall and runoff data and found that very little stormwater flowed through projects built during the construction season of 2004. They conclude that it would be inappropriate to include the effects of this runoff in the baseline loading condition. This would result in a somewhat greater number of projects being eligible for "full" credit for infrastructure built rather than "partial" credit based on improvements in operating conditions.
- A cutoff date of May 1, 2004 is appropriate because it is often unclear if a project is completed exactly by the October 15 grading deadline. The lack of clarity comes from (1) deadline waivers or penalties paid for lateness and (2) need for administrative time to finish billing and close contracts. Typically no construction occurs during the winter (October-April) and this time can function as a grace period for tying up loose ends on projects. Particularly those completed at the end of the baseline period.
- Although May 1 does not align with the water year, the construction cycle does align well with it and no significant change in infrastructure on the ground is anticipated.
- This change in the baseline cutoff helps jurisdictions feel that more of their effort is accepted/appreciated because they can include projects that were on the cusp. During this period of adoption, the baseline date refinement does not make a significant accounting difference in loads but will help regulated entities accept the TMDL.

Products

A Program Improvement Recommendation has been developed by CSLT

CHANGE CCS FORM

Relevance: Crediting Program Handbook

Context: Use of the CCS form revealed several areas of potential improvement that ranged from instructional text to structural changes.

Recommended Action

Adjust CCS Form: The following updates will enhance quality of data collected and ease of entry:

1. Add runoff volume as one of the tracked parameters in the CCS form. This additional information requirement is easy to provide for implementers because this parameter is an output of PLRM. This parameter could be a useful proxy for load reductions that is particularly easy to monitor and verify.
2. Convert CCS to a PDF that can autopopulate summary fields and allow rapid export of data to other tools such as the A&T Tool. This change will save jurisdiction time and increase accuracy of transferred information.
3. Exchange order of Inspection (#8) and Maintenance (#7) subsections for Section C; parts II, III, and IV.
4. Move Section B, I: Catchment Connectivity to an appropriate place in Sec. D <u>and</u> E. This will allow representation of changes in the connectivity of the catchment to a surface water.
    a. Include a text box to summarize connectivity rationale
    b. Include a system to more consistently define connectivity (see related Issue Addressed section)
5. Checkbox guidance throughout Sections B-E refer to the wrong subsection in A. Currently it should be changed from A.17 to A.14, however this should be confirmed once the final numbering is set.
6. The CCS units of load reduction should be given in pounds/year to align with PLRM's output. The order of the pollutants should be made consistent with PLRM reports and internally. Subsection F.4 has nutrients in reverse order from previous sections. PLRM order is: Volume (ac-ft/yr), FSP (lbs/yr), Total Phosphorus (lbs/yr), Total Nitrogen (lbs/yr).
7. Add a version number to the CCS Form. This will assist in tracking changes made over time and could reduce frustration of users when they update their CCS for a catchment that has been registered previously.
8. Adjust Section C, 16 to specs defined in this report. Issue Addressed: Private property BMPs.
9. Remove checkboxes (or extensively clarify instructions) in Section D.2 and E.4. These boxes were intended to call out use of parameters outside of PLRM's recommended ranges. In general jurisdictions did not check yes when they had changed default parameters or used parameters outside of recommended ranges. These checkboxes are particularly difficult to use because some of the default values in PLRM (DCIA @ 50% and Treatment Vault effectiveness) are not set at appropriate levels or otherwise should not have a default.
10. Add Baseline Map to list of supporting materials and file names (A. 14.)

Lessons Learned & Best Practices

- Douglas County's restoration efforts in their test catchment changed the outlet location of their catchment, providing a longer flow path and more vegetation exposure before outflows reach a surface water. This kind of change has potential to significantly reduce pollutant loads and should be incorporated in the CCS.
- Some urban jurisdictions were scared away from customizing PLRMs more sensitive parameters by the checkboxes in section D.2. because this would cause them extra work. As described in a recommended action above, these boxes should be removed because they are somewhat ambiguous anyway.
- Urban jurisdictions often incorporated inspection plan summaries into their Maintenance plan summaries. It is important to make this distinction in the Handbook instructions for filling out this section of the CCS. These sections should also be in reverse order so that jurisdictions consider the inspection aspect first.
- Many errors made on the load reduction sections of the CCS could be attributed to conversions and information transfers when moving information from PLRM or various sections of the CCS. A standard spreadsheet was constructed to check conversions and calculated load reductions. This sheet could be circulated to urban jurisdictions to reduce their effort and increase consistency.

Products

The Project Team developed additional guidance and review tools that helped simplify and clarify steps of inventorying a catchment including using PLRM and the RAMs.

Crediting Program Load Calculation Check Tool (Nov 2010)

Crediting Program Handbook v1.0 (Oct 2011)

CHANGE HANDBOOK CCS INSTRUCTIONS

Relevance: Crediting Program Handbook, Technical Guidance & Instructions section

Context: Use of the CCS form revealed several areas of potential improvement that ranged from instructional text to structural changes.

Recommended Action

Adjust Handbook Technical Guidance & Instructions: The following updates will clarify the information needed and facilitate rapid completion of necessary tasks.

1. Guidance on p. TT-16, para. 3 of Handbook should not recommend a separate CCS for each non-100% connected outfall. This recommendation is currently causing need for more CCS work than necessary because many of these catchments can be represented as modeling catchments in PLRM and then have their connectivity averaged, thereby saving jurisdiction effort. The loss of accuracy due to averaging is expected to be small relative to the variability due to subjective connectivity estimates.
2. Add a section describing known issues to user guidance on each TMDL tool. Examples include: Add a note about BMP RAM Access database error that occurs when saving the db on a network hard drive. This will permanently corrupt the database, necessitating reentry of all information.
3. Provide more description of what should be included in implementation plan summaries for inspection and maintenance. Descriptions should include:
    a. Fully describe details/features that are specific to the catchment
    b. Reference established protocols if they are used and describe how/when they will be triggered
    c. Summarize in a sentence or two the Stormwater (or other) plans of the jurisdiction and reference the specific section that relates to that portion of the CCS.

4. Update guidance to match Road RAM terminology (e.g. change road groups to "road class"). See p. TT-21 (section III), TT-23 text box, for important examples of this consistency check.
5. Add features required to catchment delineation map: runon points, flow paths. These should be added to TT-16 "Instructions" bullet #2.
6. Clarify that supporting BMPs need not be documented in the CCS supporting tables. Changes on p. TT-19 Treatment BMP Implementation Summary section.
7. Add a table that shows correspondence of every BMP Type "Observation" to "Related PLRM Value." Also clarify the instructions for this step. Changes on p. TT-20 table and related text.
8. Enhance narrative explaining how to determine the expected condition score for Roads. This is currently described in the table of TT-22, but needs more detail. Probably more detail than will fit in the table.
9. Align private property BMP information with that needed by PLRM and enhance instructions (see related *Issue Addressed and Lesson Learned*)
10. Sec D: Expected loading Estimate p. TT-28: provide more detail about definition of fine sediment (<16 micron) and provide reference to specifics of conversion factors
11. Sec E: Baseline Loading Estimate p.TT-29: change baseline date (see related Issue Addressed and Lesson Learned); check to make sure that we will use the basinwide average conditions for each catchment.
12. Align choices in Standard Baseline Modeling Parameters table with PLRM (e.g. sweeping strategy).
13. Clarify that loads can be modeled using the most appropriate and advantageous method for the jurisdiction. For instance, jurisdictions may need to choose between modeling treated area at large redevelopment projects as "treatment BMPs" or as "private property BMPs."
14. Language should be added that clarifies when non-urban load reductions can be accounted in the Crediting Program. These guidelines were developed with executives in the Climate project report produced by 2NDNATURE. Situations that may be creditable are stream restorations where streams other than the 3 main streams included in the TMDL PRO report are restored. This section should also explain when urban loads are potentially reduced when floodplains are reconnected to streams.

Products

Crediting Program Handbook v1.0 (Oct 2011)

EDITORIAL & FIGURE CHANGES TO HANDBOOK APPENDICES

Relevance: Crediting Program Handbook, Appendices A, B, C

Context: Use of the Handbook revealed several changes relating to examples, figures and clarity of communication.

Recommended Action

Adjust Handbook Appendices: The following updates will clarify the information presented

Appendix A

1. Create a synthesized "best" CCS example based on information submitted by jurisdictions during the Support Services effort. Ensure that the new example is based on the revised CCS form developed in 2011.

Appendix B

2. Review carefully for minor text edits (see p. B-1)

Appendix C

3. Revise Figure C.1. Pollutant Controls conceptual model such that Stormwater Treatment reduced "Concentration & Volume" rather than EMC and Runoff.
4. Figure C.3. Relationship between baseline: check color coding and consider ways to simplify/distill the crucial points. Caption is inconsistent with others.
5. Figure C.6. Relationship between observation values… check scale of bottom chart; it should be positive values; adjust refrences in text as well.
6. Review text for minor edits
    a. be careful of using the term "scenario" because it can be confusing with a PLRM scenario; "situation" is a possible synonym
    b. Review for use of the term "average" in relation to Road RAM (p. C-8), use "integration" as a synonym

Products

Crediting Program Handbook v1.0 (Oct 2011)

RECOMMENDATIONS

Summary Table

#	Change Recommendation	Document/ Tool	Importance	Anticipated Effort	Recommendation Status
13	Adopt Crediting Program Handbook v1.0	Handbook	4	2	C
14	Adjust Baseline Definition	Handbook	3	1	C
15	Clarify Handbook Methodology for calculating Private Property BMP Values	Handbook	2	1	C

13. **Adopt Crediting Program Handbook v1.0 –** Work with executives of Lahontan and NDEP to review the adjustments proposed above and adopt the revised Handbook v1.0 as the guiding protocols for the Crediting Program.

14. **Adjust Baseline Definition –** Change the date of projects eligible for full credit to those completed after May 1, 2004 and clarify that infrastructure must be treating stormwater rather than simply being "in place."

15. **Clarify Handbook Methodology for Calculating Private Property BMP Values-** Refine existing language in the Handbook and consider simplifying the process to calculate private property BMP values in a catchment.

VI. PLRM LOAD ESTIMATION TOOL

The Pollutant Load Reduction Model (PLRM) was used by participants to estimate test-catchment loads for baseline and expected condition scenarios. Most jurisdictions found the PLRM to have a reasonably user-friendly interface and produce acceptable estimates. However there are some usability enhancements and consistency issues with other TMDL tools that should be addressed in future versions. At the time of this report regulators were working to secure funding to make PLRM upgrades. This section provides recommendations for PLRM enhancement.

EXISTING GUIDANCE

- PLRM Documentation
  - User's Manual
  - Applications Guide
  - Model Development Document
  - GIS Layers
  - PLRM Update History
  - PLRM Input Template
- Crediting Program Handbook v0.99

ISSUES ADDRESSED & LESSONS LEARNED

CLARIFY RELATIONSHIPS BETWEEN BMP RAM AND PLRM PARAMETERS

Relevance: Crediting Program Handbook

Context: CSLT and other jurisdictions have asked questions about the specific relationships between field observations in the BMP RAM and the input parameters for PLRM treatments. Questions have also surfaced regarding the recommended methods to model named BMP types from BMP RAM which are not named in PLRM.

Recommended Action

Use Crosswalk Table: The project team has produced a draft crosswalk table which explains relationships between field observations and input parameters. This table has been modified and formatted for the Crediting Program Handbook.

Lessons Learned & Best Practices

- Several of the field observations, such as the Constant Head Permeameter do not correspond to PLRM inputs such as Ksat, with the same units (in./hr.). Research is ongoing to provide a well-documented conversion factor. A basic rule of thumb will be provided in the Handbook v1.0.
- Several of the BMP types in the BMP RAM are not used in the PLRM. Although these BMPs function based on distinct treatment processes, PLRM developers are not comfortable with methods that currently exist to model load reduction. Users should note however, that existing PLRM treatments can be modified to represent all BMP types from BMP RAM using carefully documented assumptions. These assumptions should be captured in the CCS Memo.

Products

Treatment BMP Relationships section of Crediting Program Handbook v1.0 - pg. TT-26 (Oct 2011)

Draft BMP RAM to PLRM Crosswalk Table – Excel File (August 2011)

TREATMENT VAULT REPRESENTATION IN PLRM

Relevance: PLRM, Crediting Program

Context: Initial use of the PLRM has shown that most users select a Treatment Vault flow rate that does not target removal of pollutants of concern. This inconsistency is causing the PLRM to over-predict performance of Treatment Vaults for load reductions.

Recommended Actions

Adjust PLRM: The current representation of Treatment Vault performance in the PLRM should be adjusted to help PLRM users identify and resolve this issue.

1. In the near-term: a PLRM user must justify that the Treatment Vault and the associated Maximum Treatment Flow rate selected will target removal of pollutants of concern.
2. In the long-term:
    a. Modify the default representation of a Treatment Vault in PLRM to produce small load reductions, which will require a PLRM user to adjust default values to increase load reductions. Where modification to default values will be flagged by the program and require justification.
    b. Develop a new section within the PLRM Applications Guide that comprehensively discusses the issue and provides guidance.
    c. Modify the PLRM to include a tool tip in the Treatment Vault Editor that links to guidance in the PLRM Applications Guide.

Lessons Learned & Best Practices

- PLRM user's consistently input a very high Maximum Treatment Flow for a Treatment Vault. The value for the Maximum Treatment Flow is often taken from a manufacture's recommendation, but this recommendation may not be applicable to Lake Tahoe pollutants of concern (e.g., FSP, and dissolved species of nitrogen and phosphorus). Whereas, the PLRM assumes the Maximum Treatment Flow targets Lake Tahoe pollutants of concern. This inconsistency is causing PLRM to over-predict performance of Treatment Vaults for pollutant load reduction estimates.
- The selection of an appropriate Maximum Treatment Flow that targets pollutants of concern is challenging for PLRM users because manufacturers typically specify treatment flow rates that target trash or gross pollutants. (In many cases this may indicate that the Treatment Vault will not be effective for removal of pollutants of concern at any flow rate).
- A near-term work around for this issue is to adjust the default characteristic effluent concentrations (CECs) for Treatment Vaults upwards until the output for pollutant removal is consistent with maintenance records for vault clean-out, or consistent with anecdotal observations of vault performance.

Products

The Project Team has provided PLRM user's with guidance on this issue during a PLRM training, and through comments transmitted after review of PLRM models.

Advanced PLRM Training Report (5/5/11)

DIRECTLY CONNECTED IMPERVIOUS AREA REPRESENTATION IN PLRM

Relevance: PLRM, Crediting Program

Context: PLRM output is very sensitive to the representation of directly connected impervious area (DCIA). Initial use of the PLRM has shown that many users do not adjust default values for DCIA, which can lead to inaccurate estimates of stormwater runoff and pollutant loading.

Recommended Actions

Use GIS Layer To Estimate DCIA: The PLRM team has made an initial estimate of DCIA for all Tahoe Basin roads and packaged it in a GIS layer. This file should be used to initially estimate inputs to PLRM for crediting program use, however jurisdictions can improve on this estimate with careful field-based estimates if site-specific studies are undertaken.

Adjust PLRM: Do not provide a default value for the DCIA parameter so that PLRM cannot produce an output unless the user consciously provides a value. Add a warning so that users know why PLRM is not able to run the scenario.

Provide Additional Guidance: Guidance and support tools for estimating DCIA should be improved to help PLRM users estimate this sensitive input parameter.

1. Develop expanded guidance for the PLRM Applications Guide illustrating approaches for estimating DCIA.
2. Add a tool tip for drainage condition editor that links to the guidance in the PLRM applications guide.

Lessons Learned & Best Practices

- PLRM v1.1 uses a default value of 50% DCIA for all urban land uses. A default value is provided to ensure the program will run. However, many users accept the default value instead of developing site specific estimates. PLRM output is very sensitive to the representation of DCIA.
- Estimation of DCIA can be challenging and is somewhat subjective, especially in locations such as the Tahoe Basin where most development was constructed without engineered drainage systems.
- A GIS shapefile that provides an initial estimate of DCIA for all Tahoe Basin roads was released in 2011. The GIS shapefile provides a starting point for a PLRM user to estimate DCIA of roads within their project area. The shapefile should be revised when detailed analyses supports modifications to improve accuracy.
- Section 3 of the PLRM Applications Guide (Oct 2010) was updated to better explain the importance of site specific estimates of DCIA. The guidance also includes an example of how to estimate DCIA for Tahoe Basin roads using GIS methods.
- Section 5 of the PLRM Applications Guide (Oct 2010) includes recommendations for presenting supporting information to project reviewers that documents how DCIA estimates were made.

Products

PLRM Applications Guide (Oct 2010)

Road Shoulder Condition GIS Layer (March 2011)

SEDIMENT TRAP REPRESENTATION IN PLRM

Relevance: PLRM, Crediting Program

Context: Many public works and transportation entities have expressed a strong desire to model the performance of sediment traps in PLRM. The current version of PLRM does not have an explicit method for modeling sediment traps.

Recommended Actions

Provide Additional Guidance: Develop guidance to include in the PLRM Applications Guide that demonstrates a suggested method for simulating sediment traps by applying currently available PLRM algorithms. Note sensitive parameters in guidance.

Lessons Learned & Best Practices

- Public works and transportation entities commonly construct sediment traps as part of drainage system improvements for water quality improvement projects. Furthermore, removal of material deposited in sediment traps is a common maintenance activity. Consequently, public works and transportation entities have expressed a strong desire to have a method for estimating the performance of sediment traps in PLRM.
- Analysis of maintenance records from Placer County show that street sweeping provides an order of magnitude more sediment removal and cost effectiveness compared to vactoring sediment traps.[3]
- PLRM v1.1 does not include an explicit method for simulating the performance of sediment traps. This approach was taken because sediment traps are: 1) assumed by the PLRM designers to primarily target coarse sediment removal and will not remove a significant amount of the pollutants of concern modeled by PLRM; and 2) the distributed nature of sediment traps within a drainage catchment is difficult to adequately represent within PLRM.
- Section 3 of the PLRM Applications Guide (Oct 2010) discusses a method for using the Infiltration Facility Editor in PLRM to represent porous concrete. An experienced user of the PLRM could adapt this guidance to model the function of sediment traps. Specific adoptions to porous pavement example would include:
    - Step 1 – Calculate the area of the roads within the PLRM catchment that drain to sediment traps. Enter this area as a percentage of the total road area within the PLRM catchment in the row "Area Draining to Infiltration Facilities" in the Drainage Conditions Editor for the Road Methodology.
    - Step 2 – Calculate the Combined Unit Area Storage of all sediment traps. Where Combined Unit Area Storage equals the combined storage volume of all sediment traps divided by the total impervious area tributary to all sediment traps.
    - Step 3 – Enter the Combined Unit Area Storage value in the Infiltration Facility Editor for the targeted roads. Additionally, enter an estimate of the average saturated hydraulic conductivity for infiltration in the sediment traps that will be occur between maintenance intervals.

Products

None produced to date beyond this summary.

[3] Placer County Stormwater TMDL Strategy Final Technical Report, 2011

CUT SLOPE REPRESENTATION IN PLRM

Relevance: PLRM, Crediting Program

Context: Public works and transportation entities have expressed a strong desire to model pollutant loading generated from cut slopes in PLRM. The current version of PLRM does not have an explicit method for modeling cut slopes.

Recommended Actions

Augment PLRM Using RCAT: Develop and incorporate modeling algorithms into PLRM that allow a user to estimate pollutants loads from cut slope erosion. Modeling algorithms would be adapted from the *Road Cut and Fill Slope Sediment Loading Assessment Tool* (IERS, 2011), which was developed from a significant amount of monitoring data and uses rapid field observations to relate the condition of a road cut slope to measured sediment loading.

Lessons Learned & Best Practices

- Road cut slope stabilization is a component of many water quality improvement projects. Public works and transportation entities desire an accepted method for quantifying pollutant load reductions associated with cut slope stabilization practices to receive credit under the TMDL.
- PLRM v1.1 does not include an explicit method for simulating pollutant loading from cut slopes. Current PLRM guidance recommends that pollutant loading from cut slope erosion should be accounted for outside of a PLRM simulation.
- The following approach is presented for information purposes only, and summarizes how road cut slopes could be represented in PLRM v1.1 using existing algorithms. The approach presented has significant limitations and is not intended for use with TMDL Crediting. An experienced user of the PLRM could use the following steps to model a road cut slope to obtain an order of magnitude estimate of pollutant loading and pollutant load reduction.
    - Step 1 – Define a separate catchment in the PLRM model to represent cut slopes within the project area in the Baseline/Existing Condition. Define the catchment area to be the area of cut slopes in a similar condition. Connect this catchment to other catchments within the PLRM model using a Junction.
    - Step 2 – Define the land use of the catchment to be one of the five available Erosion Potential classes within PLRM to represent the condition of the cut slope. Note that Erosion Potential land use classes represent degrees of disturbance for forested land uses. There is no method available to relate a specific Erosion Potential land use class to a cut slope condition.
    - Step 3 – In the Drainage Conditions Editor, adjust the saturated hydraulic conductivity for the "All Others" land use to represent the expected average infiltration rate of the cut slope.
    - Step 4 – Under the Expected Condition Scenario, where cut slope stabilization practices have been implemented, adjust the Erosion Potential land use class and the saturated hydraulic conductivity within the catchment to represent the improved condition of the cut slope.
    - Step 5 – Compare pollutant loading within the Scenario Reports generated from the catchment in the Baseline/Existing Condition to the Expected Condition to estimate the pollutant load reduction.

Products

RCAT User Manual (Oct 2010)

RCAT Final Report (Oct 2010)

RCAT Spreadsheet Tool (Oct 2010)

PLRM PARAMETER EXPORT FUNCTION

Relevance: PLRM

Context: Use of the PLRM model by less experienced users revealed a few aspects that can be improved with additional guidance or revisions to the software.

Recommended Action

Develop export function: Add functionality to export all values used in the analysis. Organize report to present most sensitive parameters first and highlight those that are outside of recommended ranges.

Lessons Learned & Best Practices

- Several sections of the PLRM Applications Guide are very helpful for urban jurisdictions to understand concepts necessary to use the PLRM. In particular section 5.0 is related to registering an urban catchment and section 3.0 is related to recently available default condition maps for roads, and section 4.0 is related to modeling techniques for specific situations that commonly occur and should be accurately represented within the Crediting Program. Future participants should be directed to this guidance.

Products

PLRM Applications Guide (Oct 2010)

RECOMMENDATIONS

Summary Table

#	Change Recommendation	Document/ Tool	Importance	Anticipated Effort	Recommendation Status
16	Develop Crosswalk of BMP RAM Observations and PLRM Parameters	PLRM & BMP RAM	4	2	C
17	Increase Accuracy of Treatment Vault Performance	PLRM	2	4	F
18	Use GIS Layer to Estimate DCIA	PLRM	4	2	C
19	Remove Default DCIA Value	PLRM	3	4	F
20	Develop Guidance for Simulating Sediment Traps	PLRM	2	3	O
21	Add Export Function to PLRM	PLRM	3	4	F

16. **Develop Crosswalk of BMP RAM Observations and PLRM Parameters –** Include a crosswalk table in the Handbook which explains relationships between field observations and input parameters. This table should also suggest possibilities for representing BMP RAM BMP Types in the limited number of PLRM BMPs.
17. **Increase Accuracy of Treatment Vault Performance –** Adjust representation in PLRM to help users target removal of pollutants of concern. Focus users on fine sediment particles less than 16 micrometers in diameter and associated nutrients.
18. **Use GIS Layer to Estimate DCIA –** Add guidance in the Handbook to estimate the DCIA input parameter in PLRM through use of the DCIA GIS layer that was produced by nhc in 2010. This layer is currently available on the TIIMS.ORG website. Provide additional guidance in Handbook about situations when on-the-ground research provides better information than the GIS layer.
19. **Remove Default DCIA Value –** Force users to consciously provide a DCIA value by otherwise prohibiting the PLRM to run a scenario. The current default value of 50% is allowing the model to run without thoughtful input from users.

20. **Develop Guidance for Simulating Sediment Traps –** Define explicit method for modeling sediment traps and include in the Handbook or PLRM Applications Guide. This recommendation is necessary because jurisdictions feel that large load reductions are possible from these BMPs; however the best demonstrations of these BMPs have shown that very little load reduction is likely.
21. **Add Export Function to PLRM –** Increase efficiency with export function and highlight values that are outside recommended ranges.

VII. CATCHMENT VERIFICATION & REGISTRATION

Each jurisdiction produced a CCS and supporting materials that were reviewed by regulators. After adequate email-based review jurisdictions also met with their regulator in a "Verification Meeting" to work out remaining issues and create a punch list of changes needed to register the test catchment. After all changes were made, jurisdictions used the A&T Tool to register their catchment and declare credits. This section describes lessons learned and makes recommendations for the verification and registration process.

EXISTING GUIDANCE

- Crediting Program Handbook v0.99, Step 1.2 & 1.3
- Handbook Appendix A: Sections A1.2, A1.3, & A1.6
- Draft A&T Tool User Manual

ISSUES ADDRESSED & LESSONS LEARNED

VERIFICATION CHECKLIST

Relevance: Catchment Credit Schedule

Context: Regulators need a structured way to review the CCS so that they can consistently comment on existing content and recall details that may have been omitted. Jurisdictions would have benefitted from a boiled down version of the details that were checked on the CCS and supporting materials.

Recommended Actions

Use Verification Checklist: The verification checklist should be initiated by regulators and used by jurisdictions to capture comments on the evolving versions of the CCS and supporting materials. The Verification Checklist should provide a long term record of all comments and responses through all rounds of the review process.

Lessons Learned & Best Practices

- The verification checklist should be used early in the review process of the CSS to capture comments, questions and responses. Each entry into a "notes" section should begin with the initials of the commenter and the date. Newest entries should be at the top of each "notes" section so that there is a historical record with the most recent information at the top of each section. Older entries should not be erased. Color coding based on commenter identity is helpful in quick review.
- Urban jurisdictions can use the Verification Checklist to understand specific details that will be checked on their CCS and supporting materials. The Verification Checklist however, is not complete enough for jurisdictions to learn how to provide the correct information in the CSS. Urban jurisdictions need to refer to the Crediting Program Handbook, Technical Guidance and Instructions section for instructional details.

Products

The Project Team produced an initial draft of the Verification Checklist and tested it with regulators. The product was then revised based on comments and an updated version of the Handbook includes this form.

Verification Checklist (page TT-45) (Sept 2011)

VERIFICATION MEETING

Relevance: Catchment Credit Schedule

Context: Regulators and jurisdictions needed guidance in the way that a verification meeting should be conducted and how to preserve the outcomes for future reference.

Recommended Actions

Adjust PLRM: The current representation of Treatment Vault performance in the PLRM should be adjusted to help PLRM users identify and resolve this issue.

Lessons Learned & Best Practices

- Verification meetings should be conducted with appreciation for the extensive work that has been invested by the jurisdiction to produce the CCS and regulator to carefully review it. Both the regulator and jurisdiction should find constructive ways to move toward documentation of a catchment that reduces loads and can earn credits. Small details that do not affect load calculations or understanding of the methods to achieve load reductions should not become issues of contention.
- It is expected that one or more rounds of comments will be exchanged via the Verification Checklist before an in-person Verification meeting is scheduled. However, scheduling of a meeting can provide incentive to complete necessary revisions.
- If jurisdictions and regulators are well prepared, it is possible to discuss multiple catchments (and related CCS materials) in a single verification meeting. The intent of the Crediting Program is to hold only one verification meeting annually. If participants are not prepared another verification meeting will become necessary.
- At the meeting, all participants should use the Verification Meeting Capture Template to ensure that a complete punchlist of necessary changes is recorded for later reference. The punchlist needs to be complete and specific enough that all parties will be satisfied when all items are addressed. Without a complete punchlist. The Meeting Capture Template is attached to the end of the Verification Meeting Plan file produced in November 2010. This form should be available to regulators.
- Meeting Process – For each major section of the CCS, jurisdictions should briefly present their catchment and highlighted results. Jurisdictions should also present key assumptions and rationale for their use. It is valuable for regulators to attend verification meetings in each state to build consistency among CCS forms and meeting process.

Products

The Project Team produced verification meeting plans for participant context, a capture template for use in future meetings and summarized each verification meeting in a short report.

Verification Meeting Plan (Nov 2010)

Verification Meeting Capture Template (Dec 2010)

Verification Meeting Notes/Reports for each Jurisdiction (Dec 2010 – March 2011)

ACCOUNTING AND TRACKING TOOL (A&T TOOL)

Relevance: Catchment Credit Schedule, credit declaration, A&T Tool

Context: Crediting Program participants need a tool in which to register their catchments, provide annual condition of pollutant controls and award/recieve credits. The A&T Tool is a MS Access database that provides these functions as well as reports that will be useful in annual reporting for all participants. The primary inputs to the A&T Tool are based on

information in the CCS and annual self-inspections. The outputs are the verified number of credits at jurisdictional through Basin-wide scales. Participants used the A&T Tool during the Spring of 2011.

Recommended Actions

Create Web-based Version: Provide better user control and access to the A&T Tool by rebuilding it using a web-based programming environment. A lack of access to the live A&T Tool was frustrating to participants.

Lessons Learned & Best Practices

- It would be more satisfying for users if they did not have to enter data for the Crediting Program in more than one place. For instance information from the CCS and BMP RAM could be automatically referenced by the A&T Tool if there was an integrated system.
- A long term hosting strategy for the A&T Tool is necessary. Issues with the current hosting on TIIMS.ORG and Log-Me-In single user system were not viable for the needs of any program participants.
- Tool guidance enhancements and tips should include:
  - Only verified catchments should be entered into the tool.
  - The tool automatically calculates credit award potential based on the number of performing pollutant controls in your catchment. Users, however, must declare credit award percentages and should provide rationale for any deviation from the default. The credit calculation equation and detailed explanations are in Appendix C of the Crediting Program Handbook.
- Manual querying of the TRPA BMP database is time consuming because each BMP certificate needs to be checked. Since private property BMPs change slowly, this process should only be required every 3-5 years. An alternative suggestion is to create a less time consuming way to gather the necessary data (e.g. area of BMP parcels).
- Bulk-import functionality for the tool is highly desirable. The current version has some capability for this function but it is limited.

Products

The Project Team produced an exercise to allow participants to work with the A&T Tool and referred to a draft version of user guidance.

A&T Tool Database Registration Meeting Supporting Documents (March 2011)

Draft A&T Tool User Manual (2010)

RECOMMENDATIONS

Summary Table

#	Change Recommendation	Document/ Tool	Importance	Anticipated Effort	Recommendation Status
22	Create Web-based Version of A&T Tool	A&T Tool	4	4	F
23	Reduce Frequency of Private Property BMP Checks	A&T Tool	3	1	F
24	Develop TRPA BMP Database Query	TRPA BMP DB	3	3	O

22. **Create Web-based Version of A&T Tool –** A web-based version of the A&T Tool would allow for additional features and reduce effort necessary to participate in the Crediting Program. Additional features should focus on better user accounts that allows multiple access, enhanced reports and bulk upload of information. Effort reductions could be realized by allowing the A&T Tool to gather information from other TMDL tools for use in the annual award of credits. For instance the A&T Tool could automatically gather information from the BMP RAM condition assessments, CCS load reductions and upload files from the PLRM.

23. **Reduce Frequency of Private Property BMP Checks –** Since the current TRPA BMP database requires users to individually sum the areas of certified properties, this task can be tedious and time consuming. The A&T Tool currently requires this check every year. Since Private Property BMP implementation changes slowly, jurisdictions should only be required to update this data every 3-5 years.

24. **Develop TRPA BMP Database Query –** Develop a spatially based method for querying the TRPA BMP database that is accessible to the public. The TRPA has an early stage, internal GIS tool that has this functionality. Additional assistance or requests for this feature to be made public would be helpful for TRPA staff. This feature would greatly benefit many types of BMP research.

VIII. PROJECT ACTIONS & ACCOMPLISHMENTS SUMMARY

CREDITING PROGRAM SUPPORT SERVICES - PROJECT ACTIONS & ACCOMPLISHMENTS				
Tasks & Deliverables NV	CA	Deliverables & Products	Date Completed	Links/Notes
1.2	**1.2**	**Progress Reports & Invoices**		
1.A	(1)	Progress Report & Invoice Files	Monthly	See Email Records
1	**1.4**	**Online Collaboration Workspaces**		
1.B	(1)	Support Services Participant Forum	Ongoing	Link
1.B	(1)	Support Services Team Workspace	Ongoing	Link
2.1	**2.1**	**Project Kickoff Meeting**		
-	(1)	Project Kickoff Meeting Notes	1/28/10	Download
2.2	**2.2**	**Select Test Catchments**		
-	-	Considerations & Process for Selecting Test Catchments Memo	1/28/2010	Download
-	-	Related Issues - Catchment Run-On Guidance	5/11/2010	Download
-	-	Additional Considerations for Catchment Delineation	4/2/2010	Download
2A	(1)	Brief Test Catchment Memos	Misc.	Download Zip*
2.3	**2.3**	**Catchment Selection Review Meetings**		
-	(1)	Catchment Selection Review Meeting Notes	6/11/2010	Download
-	-	Additional Considerations for Catchment Delineation	4/2/2010	Download
-	-	Test Catchment Run-On Guidance	5/11/2010	Download
2.4	**2.4**	**Catchment Delineation & BMP/Roadway Inventory Development**		
-	-	Catchment Inventory Training	5/12/2010	Download
-	-	Inventory Training Packet	5/12/2010	Download
-	-	Road RAM Draft Inventory Guidance	6/11/2010	Download
-	(1)	Catchment Delineation & Inventory Meeting Notes	5/28/2010	Download
2.5	**2.5**	**Support BMP/Roadway Inventory Development**		
-	(1)	Written Comment on Catchment Delineation Maps	Misc.	Download Zip*
-	-	BMP RAM Database Update	7/7/2010	Download
-	-	Inventory Data Checklist & Time Estimate	5/28/2010	Download
-	-	BMP Sediment Trap Diameter Conversion Tool	5/27/2010	Download
-	(2)	Written Comment on Jurisdiction Inventories	Misc.	Download Zip
2B	(3)	Recommendations Memo - Catchment Selection & Inventory Section	12/23/11	Download
3.1	**3.1**	**Implementation Plan & Load Estimate Group Meeting**		
-	(1)	Implementation Plan & Load Estimate Group Meeting Notes	7/2/2010	Download
-	-	CCS-PLRM Training Presentation	6/23/2010	Download
-	-	CCS-PLRM Training Plan	6/21/2010	Download
-	-	PLRM Activity Instructions v1	6/23/2010	Download
-	-	CPSS Inventory Tables – Activity Template	6/23/2010	Download
-	-	CPSS Inventory Table Instructions	6/23/2010	Download
3.2	**3.2**	**Catchment Implementation Plan Summary and Expected Condition Determination**		
-	(1)	Written Comments on Implementation Plan Summaries	Misc.	Download Zip*
3.3	**3.3**	**Support Baseline and Current Load Estimation**		

CREDITING PROGRAM SUPPORT SERVICES - PROJECT ACTIONS & ACCOMPLISHMENTS				
Tasks & Deliverables NV	CA	Deliverables & Products	Date Completed	Links/Notes
-	(1)	Written Comment on Load Estimates	Misc.	Download Zip*
-	-	PLRM Sweeper Guidance	5/10/2010	Download
-	-	PLRM Application Guide	October 2010	Download
-	-	Road Shoulder Condition GIS Layer	March 2011	Download
3.4	**3.4**	**Catchment Credit Schedule Meeting Notes**		
-	(1)	Catchment Credit Schedule Meeting Notes	7/2/2010	Download
-	-	CCS-PLRM Training Presentation	6/23/2010	Download
-	-	CCS-PLRM Training Plan	6/21/2010	Download
-	-	PLRM Activity Instructions v1	6/23/2010	Download
-	-	CPSS Inventory Tables – Activity Template	6/23/2010	Download
-	-	CPSS Inventory Table Instructions	6/23/2010	Download
3.5	**3.5**	**Catchment Credit Schedule Support**		
-	(1)	Written Comment on Catchment Credit Schedules	Misc.	Download Zip*
3A	(2)	Recommendations Memo - Load and Credit Schedule Section	12/23/11	Download
-	-	CCS PLRM Lessons Learned Presentation	8/18/2010	Download
-	-	CCS PLRM Lessons Learned Meeting Agenda	8/18/2010	Download
4.1	**4.1**	**Facilitate Verification Meetings**		
-	(1)	Jurisdiction-Regulator Meeting Notes	Misc.	Download Zip*
-	-	Verification Meeting Plan	2/15/11	Download
4.2	**4.2**	**Catchment Credit Schedule Registration Meeting**		
-	(1)	Accounting and Tracking Database Registration Meeting Notes	3/1/2011	Download
-	-	Accounting and Tracking Database Registration Meeting Supporting Documents	3/1/2011	Download
4.3	**4.3**	**Support Accounting and Tracking Database Use**		
-	(1)	Written Comment on Catchment Credit Schedule Registration, Condition Assessment Results and Credit Declarations	Misc.	Download Zip*
4A	-	Credit Registration and Declaration Memo	9/1/2011	Download
4B	(2)	Recommendations Memo - Coordination and Accounting and Tracking Database Section	12/23/11	Download
-	-	Accounting and Tracking Tool User Guidance v1.0	5/6/2011	Download
5.1	**5.1**	**Review Potential Program Adjustment Recommendations**		
5A	(1)	Recommendations Summary Table	12/23/11	Download
-	-	Catchment Connectivity Categorization Presentation	-	Download
-	-	Program Improvement Recommendation by CSLT	11/9/2010	Download
-	-	Draft BMP RAM to PLRM Crosswalk Table	August 2011	Download
5.2	**5.2**	**Change Recommendation and Project Wrap-Up Meeting**		
-	(1)	Recommendations and Wrap-Up Meeting Notes	5/3/2011	Download
-	-	Recommendations and Wrap-Up Meeting Plan	4/27/2011	Download
5.3	**5.3**	**Change Recommendation Support**		
-	(1)	Edits and Comments on Change Recommendations	9/1/2011	Download
5.4	**5.4**	**Facilitate Change Recommendation Decision Meeting and Decision Record**		
-	(1)	Upper-Management Decision Meeting Notes	9/13/2011	Download

CREDITING PROGRAM SUPPORT SERVICES - PROJECT ACTIONS & ACCOMPLISHMENTS				
Tasks & Deliverables NV	CA	Deliverables & Products	Date Completed	Links/Notes
5B	-	Change Recommendation Decision Record	9/13/2011	Download
-	-	Crediting Program Recommendation Briefing	9/1/2011	Download
-	-	Upper-Management Decision Meeting Plan	9/8/2011	Download
-	-	Executive Decision Meeting Handout	9/8/2011	Download
5.5	**5.5**	**Adjust LCCP Handbook**		
5C	(1)	Revised Lake Clarity Crediting Program Handbook	10/25/2010	Download
-	-	Temporary Best of CCS	5/2/2010	Download
5.6	**5.6**	**Develop Brief Project Report**		
5D	(1)	Draft and Final Project Report	12/23/11	Download
6.1	**-**	**Public Presentation**		
6A	-	ASIWPCA Presentation	7/19/2010	Download
7	**-**	**Enhanced Urban Jurisdiction Service**		
7A	-	Jurisdiction Assistance Report and Request Log (monthly updates)	Misc.	Download
-	-	Jurisdiction Products and Comments	Misc.	Download Zip*
-	-	Crediting Program Load Calculation Tool v1	5/4/2011	Download
-	-	Additional Support Funding Process v1 Memo	2/10/2010	Download
-	-	Support Services Augmentation Opportunity v1.0	January 2010	Download

*Please note that this file is a very large download: 258 Megabytes.

IX. APPENDICES

APPENDIX A: FINAL JURISDICTION PRODUCTS

The jurisdictions' most recent Catchment Credit Schedules are provided in this section. Follow this link to view all supporting documents.

CCS forms provided next page.

CCS — CATCHMENT CREDIT SCHEDULE

SECTION A: CORRESPONDENCE & CATCHMENT CREDIT SCHEDULE SUMMARY

The Correspondence & Catchment Credit Schedule Summary section is completed incrementally throughout the process of establishing a Catchment Credit Schedule (CCS), as defined in Chapter 1 of the Lake Clarity Crediting Handbook (Handbook). Subsequent sections of this template prompt users to complete the corresponding summary items here in Section A.

I. GENERAL CATCHMENT INFORMATION SUMMARY

1. CATCHMENT STATUS

Check the appropriate status and add date of previous approval if applicable

- ☒ NEW CATCHMENT
- ☐ REVISION
- ☐ EXTENSION

Date of previous approval

2. CATCHMENT ID

Provide the unique catchment ID & common name

Catchment ID: CSLTG12

Common Catchment Name: Al Tahoe

3. PRIMARY JURISDICTION

Identify the primary urban jurisdiction and primary point of contact within the urban jurisdiction

- ☐ CALTRANS
- ☒ CSLT
- ☐ DOUGLAS
- ☐ EL DORADO
- ☐ NDOT
- ☐ PLACER
- ☐ WASHOE

Primary Contact: Robert Erlich

Phone Number: (530) 542-6038

E-mail Address: rerlich@cityofslt.us

4. REGULATORY AGENCY

Identify the responsible regulatory agency and primary point of contact within the agency

- ☒ LRWQCB
- ☐ NDEP

Primary Contact: Robert Larsen

Phone Number: (530) 542-5439

E-mail Address: RLarsen@waterboards.ca.gov

II. CATCHMENT CREDIT SCHEDULE SUMMARY

5. BASIC CATCHMENT POLLUTANT CONTROL STRATEGY NARRATIVE

In the space provided, describe the basic strategies employed to reduce pollutant loading within the catchment

Basic Narrative

Source control methods such as revegetation and shoulder stabilization will be implemented to prevent or reduce sediment and nutrients from entering storm water runoff. Emphasis will be placed on utilization and maintenance of natural drainage pathways for flow reduction, and seperation of clean and polluted flows. Porous pavement designed to infiltrate stormwater and snowmelt will reduce the volume of runoff significantly. The addition of infiltrating drain inlets and sediment traps, as well as existing conveyence features, will effectively route stormwater to a Pretreatment Vault and two Cartridge Filter (Stormwater) Vaults which will decrease the amount of untreated storm water runoff reaching the lake.

6. EFFECTIVE LOAD REDUCTION ESTIMATE

Note the load reduction estimate amounts from Section F

Fine sediment particles (#)	Fine sediment mass (kg)	Total nitrogen (kg)	Total phosphorous (kg)
1.94796E+17	1770.87	33.02	10.30

7. CREDIT POTENTIAL AMOUNT

Note the credit amount

19.5 CREDITS

8. ESTABLISHMENT DATE

Note the catchment establishment date from Section F for final CCS only

Establishment Date: 10/15/10

9. FINAL YEAR

Note the final year of the CCS from Section F for final CCS only

Final Year: 2020

III. COORDINATION CHECKLIST

10. SUBMITTED FOR VERIFICATION REVIEW

Note the date submitted and urban jurisdiction staff person (Step 1.3)

Date Submitted	Name of Staff Person

11. STATEMENT OF COMPLETENESS & APPROPRIATENESS

Representative from urban jurisdiction must certify the completeness of the CCS (Step 1.3)

I certify that the information contained in this Catchment Credit Schedule and the analyses related to this Catchment Credit Schedule are complete and appropriate.

Printed Name	Date

Signature

12. VERIFIED BY REGULATOR

Regulator must certify the verification step is complete (Step 1.4)

I certify that the Verification Step is complete.

Printed Name	Date

Signature

13. REGISTERED AND SUBMITTED FOR APPROVAL

Note the date that the catchment was registered in the Accounting and Tracking Database (Step 1.5)

Date

14. SUPPORTING MATERIALS CHECKLIST AND FILENAMES

Confirm each file is included in the digital submission and provide the filename and save date

Checklist	Filename	Save Date
☒ CCS FORM	CSLTG12_08112010.doc	9/30/10
☒ CCS MEMO (IF NECCESARY)	CSLTG12 Memo.docx	9/30/10
☒ CATCHMENT DELINEATION MAP FOR CATCHMENT 1	CSLTG12_Catchment Delineation Map_Portrait.mxd	8/9/10
☒ OVERALL CATCHMENT DELINEATION MAP	Urban Planning Catchments.mxd	9/30/10
☒ TREATMENT BMP INVENTORY MAP	CSLTG12_BMP Inventory Map.mxd	8/10/10
☒ TREATMENT BMP INVENTORY TABLE	CSLTG12_BMP Inventory.xlsx	8/16/10
☒ ROADS INVENTORY MAP	CSLTG12_Road Inventory Map.mxd	8/17/10
☒ ROADS INVENTORY TABLE	CSLTG12_Road Inventory.xlsx	8/16/10
☐ ROADS MAINTENANCE MAP(S) (NOT REQUIRED)		
☐ BASELINE TREATMENT BMP INVENTORY TABLE	Map: CSLTG12_Baseline Inventory Map.mxd	8/18/10
☐ CATCHMENT REGISTRATION REPORT (FINAL ONLY)		
☒ PLRM PROJECT FILE (DIGITAL FILE ONLY)	Project1	9/29/10
☒ AS-BUILT DRAWINGS AND EQUIPMENT SPECIFICATIONS (DIGITAL FILES ONLY)	AT_PROJ1_STG2_03-12-2010	7/21/10

SECTION B: CATCHMENT DELINEATION

Credits and load reductions are tracked for specific urban catchments. The same urban catchment area must be used in both baseline and expected loading estimates. In order to prevent double counting, no land area may be included in two urban catchments.

I. CATCHMENT CONNECTIVITY

1. CATCHMENT ID	Confirm the catchment ID and name	2. CATCHMENT DELINEATION MAP	Confirm the catchment delineation map is complete
☒ CATCHMENT ID IS PROPERLY LISTED IN A.1		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	
3. OVERALL URBAN JURISDICTION CATCHMENT MAP	Confirm the overall catchment delineation map is complete	**4. CATCHMENT HISTORY**	Note any previous catchments that included a portion of this catchment
☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		Previous Catchment Name	Establishment Date
5. CATCHMENT AREA	Provide the total catchment area	**6. CATCHMENT CONNECTIVITY**	Provide the percent connectivity that will be used to modify the load reduction estimate
Total Area (acres)		Percent Connectivity	
79		☒ 100% ☐ OTHER ____%	
		☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO CATCHMENT CONNECTIVITY SECTION	

SECTION C: IMPLEMENTATION PLAN SUMMARY

The Implementation Plan Summary defines the expected conditions for treatment BMPs, roads, private property BMPs, and other pollutant control strategies based on the urban jurisdiction's planned operations, maintenance and program implementation activities in the urban catchment. The Implementation Plan Summary may pull information from multiple sources and ideally relies upon one or more of the broader implementation plans used by the urban jurisdictions.

I. DEFINE LOAD REDUCTION STRATEGY

1. TREATMENT BMPS	Check the most appropriate description	2. ROAD OPERATIONS	Check the most appropriate description
☒ PRIMARY		☐ PRIMARY	
☐ SECONDARY		☒ SECONDARY	
☐ TERTIARY		☐ TERTIARY	
☐ NONE		☐ NONE	
3. PRIVATE PARCEL BMPS	Check the most appropriate description	**4. OTHER POLLUTANT CONTROL STRATEGY**	Check the most appropriate description
☐ PRIMARY		☐ PRIMARY	
☐ SECONDARY		☐ SECONDARY	
☒ TERTIARY		☐ TERTIARY	
☐ NONE		☐ NONE	

II. TREATMENT BMP IMPLEMENTATION SUMMARY

5. TREATMENT BMP INVENTORY TABLE	Confirm the table is complete	6. TREATMENT BMP INVENTORY MAP	Confirm the map is complete
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	

7. TREATMENT BMP MAINTENANCE PLAN SUMMARY — In the space provided, summarize planned treatment BMP maintenance actions for the overall catchment (reference implementation planning documents if applicable)

The City Stormwater Inspector inspects Drain inlets and Sediment Traps within CSLTG12 on an annual basis between spring and fall. Street Maintenance Division maintains Drain Inlets and Sediment Traps within CSLTG12 annually based on inspection prioritization. Other BMP's such as Treatment Vaults and Cartridge Filters have a maintenance program that provides for regular inspection and assessment. Typically, maintenance for Pretreatment Vaults and Cartridge Filters (or other BMP's in a confined space) is performed by the manufacturer, in this case Contech. Porous Pavement will be swept using regenerative air (dustless) sweepers at least 2 times per year, or as needed. Typical maintenance for Sediment Traps and Drain Inlets is performed using a vactor truck. For more information, see the City's annual MEP update or the NPDES Annual Report (Section II.C Traction Abrasive Deicing Material).

8. TREATMENT BMP INSPECTION PLAN SUMMARY — In the space provided, summarize planned treatment BMP inspection actions for the overall catchment (reference implementation planning documents if applicable)

The City Stormwater Inspector inspects all treatment BMP's within CSLTG12 on an annual basis from late spring through fall to determine maintenance priorities. For more information, see the City's annual MEP Update or the NPDES Annual Report (Section II.C Traction Abrasive Deicing Material).

9. ADDITIONAL TREATMENT BMP IMPLEMENTATION INFORMATION — Indicate whether additional information is provided in the CCS memo to adequately describe the treatment BMPs within the catchment

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO TREATEMENT BMP IMPLEMENTATION SUMMARY SECTION

III. ROADS OPERATION IMPLEMENTATION SUMMARY

10. ROAD INVENTORY TABLE	Confirm the table is complete	11. ROADS INVENTORY MAP	Confirm the map is complete
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	

12. ROADS MAINTENANCE PLAN SUMMARY	In the space provided, summarize planned road maintenance actions for the overall catchment (reference implementation planning documents if applicable)

See the CSLT NPDES Annual Report (Section II.C Traction Abrasive Deicing Material) for a description of the Sanding and sweeping practices in the City of South Lake Tahoe. Typical abrasive application occurs during the winter months in the steepest areas of the City (Heavenly Valley, Gardner Mountain, etc). The City Uses a Regenerative Air Sweeper and sweeps CSLTG12 streets approximately two times per year. The City plans to Maintain all roads within CSLTG12 to obtain a RAM score of 3.

13. ROADS MAINTENANCE MAP(S)	Confirm road maintenance maps
☐ ROAD MAINTENANCE MAPS ARE PROPERLY IN A.17 (NOT REQUIRED)	

14. ROADS INSPECTION PLAN SUMMARY	In the space provided, summarize planned road inspection actions for the overall catchment (reference implementation planning documents if applicable)

The City plans to inspect and maintain all roads within the CSLT Jurisdiction according to the Road RAM, maintaining a RAM score of 3. The City Stormwater Inspector currently inspects curbs and gutters, and road shoulders within CSLTG12 on an annual basis. Inspections typically begin after the spring snowmelt and continue through the summer. For more information on the road inspection plan, see the City's Annual MEP Update or NPDES Annual Report (Section II.C Traction Abrasive Deicing Material).

15. ADDITIONAL ROAD IMPLEMENTATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the roads within the catchment
☒ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO ROADS IMPLEMENTATION SUMMARY SECTION	

IV. PRIVATE PROPERTY BMP IMPLEMENTAION SUMMARY

16. PRIVATE PROPERTY BMP INVENTORY

In the space provided, note the total number of developed single-family residential (SFR) parcels and the number of SFR parcels with BMP and source control certificates. Also, note the total area of multi-family residential (MFR) and commercial properties (CICU) and the area with BMP and source control certificates. Provide the percentage area with BMP and source control certificates that should be used as the expected value.

Total Area of SFR (acres)	Total # of SFR	Total # of SFR w/ BMP Cert.	Total % of SFR w/BMP Cert.	Total # of SFR w/ SC Cert.	Total % of SFR w/ SC Cert.
41.33	260	44	17%	0	0%

Total area of MFR (acres)	Area of MFR with BMP Certificates (acres)	Total Area of CICU (acres)	Area of CICU with BMP Certificates (acres)
10.13	1.03	4.02	0.41

Expected percentage of area with BMP certificates	Expected percentage of area with source control certificates
17%	0%

17. URBAN JURISDICTION PRIVATE PROPERTY BMP PROGRAM SUMMARY

In the space provided, describe any planned variations from the general private property BMP program for this urban catchment (reference implementation planning documents if applicable)

The City adheres to the current Private Property BMP Program guidelines. Although the City encourages residents to implement BMP's, there is no current regulation. The City is in the process of creating a web-based GIS system that will aloow GIS tracking of current BMP status with a semi-annual update from the TRPA database. The City currently utilizes the TRPA BMP database to gather information about BMP's within CSLTG12. That information is queried in GIS to provide an up to date BMP inventory within CSLTG12.

18. PRIVATE PROPTERY BMP INSPECTION PLAN SUMMARY

In the space provided, identify the data sources supporting these private property BMP calculations (reference implementation planning documents if applicable)

The City tracks private property BMP's in CSLTG12 using the TRPA database and querying the data with our GIS records. The City is currently working with TRPA to develop a BMP spreadsheet to track private property BMP's within the City, which will be updated on a semi-annual basis.

19. ADDITIONAL PRIVATE PROPERTY BMP INFORMATION

Indicate whether additional information is provided in the CCS memo to adequately describe the private property BMP implementation efforts in the catchment

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO PRIVATE PROPERTY BMP IMPLEMENTATION SUMMARY SECTION

V. OTHER POLLUTANT CONTROL STRATEGIES IMPLEMENTATION SUMMARY

20. OTHER POLLUTANT CONTROL PROGRAM SUMMARY

If other pollutant control strategies are implemented in the urban catchment, indicate that they are described in the CCS memo

☒ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO OTHER POLLUTANT CONTROL STRATEGIES SECTION

SECTION D: EXPECTED LOADING ESTIMATE

The expected loading estimate reflects annual average loading assuming treatment BMPs, roads, private property BMPs and other pollutant controls are maintained and operated to achieve the expected conditions defined in the Implementation Plan Summary.

I. EXPECTED LOADING ESTIMATE

1. LOAD ESTIMATION METHOD	Select the method used to estimate the expected and baseline loading for the catchment
☒ POLLUTANT LOAD REDUCTION MODEL (PLRM) V1.0 ☐ OTHER (DESCRIPTION IS INCLUDED IN CCS MEMO)	Name and version (If you selected Other)
2. EXPECTED LOADING PARAMETERS, ASSUMPTIONS & DATASETS	Check yes if any parameter values, assumptions or datasets used deviate from default values or recommendations
☐ YES ☒ NO (only defaults used)	☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO LOAD ESTIMATION APPROACH AND ASSUMPTIONS SECTION

If Yes, please explain

Notes: PLRM expected conditions from model run "Option 3".

3. EXPECTED LOADING PROJECT FILE	Confirm that the expected loading estimate scenario is included	4. EXPECTED LOAD	Provide the expected loads for fine sediment, nitrogen and phosphorus
☒ THE EXPECTED LOADING ESTIMATE SCENARIO IS INCLUDED IN THE LOAD ESTIMATION PROJECT FILE AND IS LISTED IN A.17		Fine sediment mass (kg) 175.36	Fine sediment particles (#) 1.92895E+16
		Total nitrogen (kg) 20.73	Total phosphorus (kg) 2.04

SECTION E: BASELINE LOADING ESTIMATE

The urban catchment baseline loading estimate sets the reference point for determining load reductions.

I. BASELINE LOADING ESTIMATE

1. BASELINE INVENTORY TABLE	Confirm baseline inventory table	2. BASELINE INFRASTRUCTURE MAP	Confirm baseline infrastructure map
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	
3. CHANGES SINCE 2004		Summarize any changes to treatment BMPs since 2004	

The Al tahoe ECP is scheduled for completetion in 2010. Improvements include destruction and replacement of DI's as infiltrating sediment traps and drain inlets. Storm drain pipes have been replaced with infiltration trenches (infiltration features)

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO BASELINE CONDITIONS SECTION	
4. BASELINE LOADING PARAMETERS, ASSUMPTIONS & DATASETS	Indicate if any parameter values, assumptions or datasets used deviate from default values or recommendations
☐ YES ☒ NO	☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO BASELINE CONDITIONS SECTION

If Yes, please explain

5. BASELINE LOAD ESTIMATE		Provide the baseline loads for fine sediment, nitrogen and phosphorus	
Fine sediment mass (kg) **1946.23**	Fine sediment particles (#) **2.14085E+17**	Total nitrogen (kg) **53.75**	Total phosphorus (kg) **12.34**

SECTION F: CATCHMENT CREDIT SCHEDULE AMOUNT & DURATION

The final determination of the appropriate CCS credit potential amount and duration is made by the regulator in consultation with the urban jurisdiction. The urban jurisdiction proposes the CCS credit potential amount based on the load reduction estimate, and the duration based on the primary and secondary pollutant control strategies.

I. LOAD REDUCTION ESTIMATE & CATCHMENT CREDIT SCHEDULE AMOUNT

1. LOAD REDUCTION ESTIMATE		Note the load reduction estimate amounts	
Fine sediment mass (kg)	Total phosphorus (kg)	Total nitrogen (kg)	
1770.87	10.30	33.02	

2. FINE SEDIMENT PARTICLE NUMBER CONVERSION	Using Equation 0.3, convert the fine sediment mass to number of fine sediment particles	3. CATCHMENT CONNECTIVITY	From item B.5
Fine sediment particles (#)		Percent Connectivity	
1.94796E+17		100 %	

4. EFFECTIVE LOAD REDUCTION ESTIMATE		Multiply the vaues in items F.1 and F.2 by F.3	
Fine sediment mass (kg)	Fine sediment particles (#)	Total phosphorous (kg)	Total nitrogen (kg)
1770.87	1.94796E+17	10.30	33.02

5. CREDIT AMOUNT CALCULATION	Using equation 0.2 calculate the credit amount

19.5 CREDITS

II. CREDIT SCHEDULE DURATION

6. CREDIT SCHEDULE DURATION	Indicate the catchment credit schedule duration	7. DURATION RATIONALE	Briefly explain the rationale for the selected duration
☐ 5 YEARS ☒ 10 YEARS ☐ 15 YEARS ☐ OTHER (SPECIFY) ____YEARS		Explanation The City expects the reductions from the current ECP to provide effective treatement for at least the next ten years.	

III. ESTABLISHMENT SUMMARY

8. ESTABLISHMENT DATE	Note the date that the CCS is submitted to the regulator	9. ESTABLISHMENT YEAR CREDIT POTENTIAL	Note the appropriate establishment year percentage and amount
Date		Percentage	Credit Amount
		100%	19.5

10. FINAL YEAR OF CREDIT SCHEDULE	Note the appropriate final year of the credit schedule
Final Year	
2020	

11. ADDITIONAL EXPECTED CCS AMOUNT AND DURATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the private property BMP implementation efforts in the catchment
☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO CCS AMOUNT AND DURATION SECTION	

CCS — CATCHMENT CREDIT SCHEDULE

SECTION A: CORRESPONDENCE & CATCHMENT CREDIT SCHEDULE SUMMARY

The Correspondence & Catchment Credit Schedule Summary section is completed incrementally throughout the process of establishing a Catchment Credit Schedule (CCS), as defined in Chapter 1 of the Lake Clarity Crediting Handbook (Handbook). Subsequent sections of this template prompt users to complete the corresponding summary items here in Section A.

I. GENERAL CATCHMENT INFORMATION SUMMARY

1. CATCHMENT STATUS

Check the appropriate status and add date of previous approval if applicable

- ☒ NEW CATCHMENT
- ☐ REVISION
- ☐ EXTENSION

Date of previous approval:

2. CATCHMENT ID

Provide the unique catchment ID & common name

Catchment ID: 50(7.5-8.5)

Common Catchment Name: US 50 Milepost 7.5 to 8.5

3. PRIMARY JURISDICTION

Identify the primary urban jurisdiction and primary point of contact within the urban jurisdiction

- ☐ CALTRANS
- ☐ CSLT
- ☐ DOUGLAS
- ☐ EL DORADO
- ☒ NDOT
- ☐ PLACER
- ☐ WASHOE

Primary Contact: Tyler Thew

Phone Number: (775) 888-7574

E-mail Address: tthew@dot.state.nv.us

4. REGULATORY AGENCY

Identify the responsible regulatory agency and primary point of contact within the agency

- ☐ LRWQCB
- ☒ NDEP

Primary Contact: Jason Kuchnicki

Phone Number: (775) 687-9450

E-mail Address: jkuch@ndep.nv.gov

II. CATCHMENT CREDIT SCHEDULE SUMMARY

5. BASIC CATCHMENT POLLUTANT CONTROL STRATEGY NARRATIVE

In the space provided, describe the basic strategies employed to reduce pollutant loading within the catchment

Basic Narrative

Reduction of sediment and nutrients conveyed from this catchment to Lake Tahoe will be accomplished by the following strategies:

1) Source control: reduced use of traction abrasives, increased frequency and efficiency of road sweeping, shoulder stabilization and slope stabilization. The PLRM does not have a method for estimating load reductions generated by slope stabilization. In the future this catchment may be revised to include FSP reductions associated with the slope stabilization improvements.

2) Treatment: Infiltration facilities have been constructed to reduce both the volume of stormwater reaching Lake Tahoe and the FSP concentration leaving the facilities. Many sediment traps have also been constructed to provide pre-treatment for the infiltration facilities; however, they are not included in the BMP RAM or PLRM for this catchment.

6. EFFECTIVE LOAD REDUCTION ESTIMATE

Note the load reduction estimate amounts from Section F

Fine sediment particles (#)	Fine sediment mass (kg)	Total nitrogen (kg)	Total phosphorous (kg)
2.4E+17	2146	7	4

7. CREDIT POTENTIAL AMOUNT

Note the credit amount

24 CREDITS

8. ESTABLISHMENT DATE

Note the catchment establishment date from Section F for final CCS only

Establishment Date:

9. FINAL YEAR

Note the final year of the CCS from Section F for final CCS only

Final Year:

III. COORDINATION CHECKLIST

10. SUBMITTED FOR VERIFICATION REVIEW	Note the date submitted and urban jurisdiction staff person (Step 1.3)
Date Submitted March 3, 2011	Name of Staff Person Jason Kuchnicki

11. STATEMENT OF COMPLETENESS & APPROPRIATENESS	Representative from urban jurisdiction must certify the completeness of the CCS (Step 1.3)

I certify that the information contained in this Catchment Credit Schedule and the analyses related to this Catchment Credit Schedule are complete and appropriate.

Printed Name	Date
Tyler J. Thew	

Signature

12. VERIFIED BY REGULATOR	Regulator must certify the verification step is complete (Step 1.4)

I certify that the Verification Step is complete.

Printed Name	Date

Signature

13. REGISTERED AND SUBMITTED FOR APPROVAL	Note the date that the catchment was registered in the Accounting and Tracking Database (Step 1.5)

Date

14. SUPPORTING MATERIALS CHECKLIST AND FILENAMES	Confirm each file is included in the digital submission and provide the filename and save date	
Checklist	Filename	Save Date
☒ CCS FORM	US_50_Test_Catchment_Credit_Schedule.Doc	
☐ CCS MEMO (IF NECCESARY)		
☒ CATCHMENT DELINEATION MAP FOR CATCHMENT 1	US50-TMDL-Catchments_MAP.pdf	
☒ OVERALL CATCHMENT DELINEATION MAP	US50-TMDL-Catchments_MAP.pdf	
☒ TREATMENT BMP INVENTORY MAP	US50-TMDL-Catchments_BMP_Inventory.pdf	
☒ TREATMENT BMP INVENTORY TABLE		
☐ ROADS INVENTORY MAP		
☐ ROADS INVENTORY TABLE		
☐ ROADS MAINTENANCE MAP(S) (NOT REQUIRED)		
☒ BASELINE TREATMENT BMP INVENTORY TABLE	US50_BMPRAM_Output.pdf	
☐ CATCHMENT REGISTRATION REPORT (FINAL ONLY)		
☒ PLRM PROJECT FILE (DIGITAL FILE ONLY)	PLRM/Projects/Project1/ Scenario 1 & Scecnario 6	
☒ AS-BUILT DRAWINGS AND EQUIPMENT SPECIFICATIONS (DIGITAL FILES ONLY)	Contract 3293_Partial.pdf	

SECTION B: CATCHMENT DELINEATION

Credits and load reductions are tracked for specific urban catchments. The same urban catchment area must be used in both baseline and expected loading estimates. In order to prevent double counting, no land area may be included in two urban catchments.

I. CATCHMENT CONNECTIVITY

1. CATCHMENT ID	Confirm the catchment ID and name	2. CATCHMENT DELINEATION MAP	Confirm the catchment delineation map is complete
☒ CATCHMENT ID IS PROPERLY LISTED IN A.1		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	
3. OVERALL URBAN JURISDICTION CATCHMENT MAP	Confirm the overall catchment delineation map is complete	**4. CATCHMENT HISTORY**	Note any previous catchments that included a portion of this catchment
☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		Previous Catchment Name	Establishment Date
5. CATCHMENT AREA	Provide the total catchment area	**6. CATCHMENT CONNECTIVITY**	Provide the percent connectivity that will be used to modify the load reduction estimate
Total Area (acres) 22		Percent Connectivity ☐ 100% ☒ OTHER 75%	
		☒ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO CATCHMENT CONNECTIVITY SECTION	

SECTION C: IMPLEMENTATION PLAN SUMMARY

The Implementation Plan Summary defines the expected conditions for treatment BMPs, roads, private property BMPs, and other pollutant control strategies based on the urban jurisdiction's planned operations, maintenance and program implementation activities in the urban catchment. The Implementation Plan Summary may pull information from multiple sources and ideally relies upon one or more of the broader implementation plans used by the urban jurisdictions.

I. DEFINE LOAD REDUCTION STRATEGY

1. TREATMENT BMPS	Check the most appropriate description	2. ROAD OPERATIONS	Check the most appropriate description
☐ PRIMARY ☐ SECONDARY ☒ TERTIARY ☐ NONE		☒ PRIMARY ☐ SECONDARY ☐ TERTIARY ☐ NONE	
3. PRIVATE PARCEL BMPS	Check the most appropriate description	**4. OTHER POLLUTANT CONTROL STRATEGY**	Check the most appropriate description
☐ PRIMARY ☐ SECONDARY ☐ TERTIARY ☒ NONE		☐ PRIMARY ☒ SECONDARY ☐ TERTIARY ☐ NONE	

II. TREATMENT BMP IMPLEMENTATION SUMMARY

5. TREATMENT BMP INVENTORY TABLE	Confirm the table is complete	6. TREATMENT BMP INVENTORY MAP	Confirm the map is complete
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	

7. TREATMENT BMP MAINTENANCE PLAN SUMMARY

In the space provided, summarize planned treatment BMP maintenance actions for the overall catchment (reference implementation planning documents if applicable)

NDOT maintenance crews assigned to this section of road perform frequent visual inspections of the drain inlets, sediment traps, and treatment facilities while driving along US 50 and perform maintenance as needed. At a minimum all drain inlets, sediment traps, treatment vaults, and infiltration facilities are physically inspected and cleaned once a year. NDOT has contracted out the cleaning of these facilities. Typically the contracted maintenance/cleaning program starts in late spring and runs through early fall.

8. TREATMENT BMP INSPECTION PLAN SUMMARY

In the space provided, summarize planned treatment BMP inspection actions for the overall catchment (reference implementation planning documents if applicable)

NDOT maintenance crews assigned to this section of road perform frequent visual inspections of the drain inlets, sediment traps, and treatment facilities while driving along US 50 and perform maintenance as needed. At a minimum all drain inlets, sediment traps, treatment vaults, and infiltration facilities are physically inspected and cleaned once a year. NDOT is currently planning on implementing the BMP RAM and will maintain treatment BMP's with a RAM score less than 3.

9. ADDITIONAL TREATMENT BMP IMPLEMENTATION INFORMATION

Indicate whether additional information is provided in the CCS memo to adequately describe the treatment BMPs within the catchment

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO TREATEMENT BMP IMPLEMENTATION SUMMARY SECTION

III. ROADS OPERATION IMPLEMENTATION SUMMARY

10. ROAD INVENTORY TABLE	Confirm the table is complete	11. ROADS INVENTORY MAP	Confirm the map is complete
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	

12. ROADS MAINTENANCE PLAN SUMMARY	In the space provided, summarize planned road maintenance actions for the overall catchment (reference implementation planning documents if applicable)

NDOT has implemented the Road Weather Information System (RWIS) to develop an effective winter maintenance strategy that allows for better control over when, where and in what quantity sand and salt mixtures will be applied to the roadway. The system has sensors imbedded into the pavement that send information about road temperatures and conditions to computer systems for analysis. They also collect information about air temperatures, wind speed and the actual detection of rain, snow and ice on the road. Engineers and maintenance workers use that information to determine the best response to current and anticipated road conditions.

Each sensor, along with surface pavement forecasts, can determine when the road is going to freeze. This information allows crews to efficiently determine strategies before the storm and reduce unnecessary application of sand and salt. There are ten RWIS stations in the Lake Tahoe Basin and 5 are located along US 50.

NDOT has equipped some of its sand application trucks with Epoke spreaders. These devices allow for improved control of the sand application rate and where the sand is applied resulting in a reduction in the amount of sand used. NDOT uses mechanical broom sweepers with a vacuum assist system. Road sweeping occurs as soon as possible after every application of sand. During the late spring through early Fall roads are swept at least twice.

13. ROADS MAINTENANCE MAP(S)	Confirm road maintenance maps
☐ ROAD MAINTENANCE MAPS ARE PROPERLY IN A.17 (NOT REQUIRED)	

14. ROADS INSPECTION PLAN SUMMARY	In the space provided, summarize planned road inspection actions for the overall catchment (reference implementation planning documents if applicable)

NDOT has a maintenance crew assigned to US 50 and they are continuously performing maintenance and inspection of the road. Due to the continuous nature of the maintenance and inspection of US 50 NDOT practices exceed the inspection plan suggested by the Road RAM and therefore NDOT is not planning on implementing the Road RAM.

15. ADDITIONAL ROAD IMPLEMENTATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the roads within the catchment
☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO ROADS IMPLEMENTATION SUMMARY SECTION	

IV. PRIVATE PROPERTY BMP IMPLEMENTAION SUMMARY

16. PRIVATE PROPERTY BMP INVENTORY		In the space provided, note the total number of developed single-family residential (SFR) parcels and the number of SFR parcels with BMP and source control certificates. Also, note the total area of multi-family residential (MFR) and commercial properties (CICU) and the area with BMP and source control certificates. Provide the percentage area with BMP and source control certificates that should be used as the expected value.			
Total Area of SFR (acres)	Total # of SFR	Total # of SFR w/ BMP Cert.	Total % of SFR w/BMP Cert.	Total # of SFR w/ SC Cert.	Total % of SFR w/ SC Cert.
			%		%
Total area of MFR (acres)	Area of MFR with BMP Certificates (acres)	Total Area of CICU (acres)		Area of CICU with BMP Certificates (acres)	
Expected percentage of area with BMP certificates		**Expected percentage of area with source control certificates**			
%		%			

17. URBAN JURISDICTION PRIVATE PROPERTY BMP PROGRAM SUMMARY	In the space provided, describe any planned variations from the general private property BMP program for this urban catchment (reference implementation planning documents if applicable)

18. PRIVATE PROPTERY BMP INSPECTION PLAN SUMMARY	In the space provided, identify the data sources supporting these private property BMP calculations (reference implementation planning documents if applicable)

19. ADDITIONAL PRIVATE PROPERTY BMP INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the private property BMP implementation efforts in the catchment

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO PRIVATE PROPERTY BMP IMPLEMENTATION SUMMARY SECTION

V. OTHER POLLUTANT CONTROL STRATEGIES IMPLEMENTATION SUMMARY

20. OTHER POLLUTANT CONTROL PROGRAM SUMMARY	If other pollutant control strategies are implemented in the urban catchment, indicate that they are described in the CCS memo

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO OTHER POLLUTANT CONTROL STRATEGIES SECTION

SECTION D: EXPECTED LOADING ESTIMATE

The expected loading estimate reflects annual average loading assuming treatment BMPs, roads, private property BMPs and other pollutant controls are maintained and operated to achieve the expected conditions defined in the Implementation Plan Summary.

I. EXPECTED LOADING ESTIMATE

1. LOAD ESTIMATION METHOD	Select the method used to estimate the expected and baseline loading for the catchment
☒ POLLUTANT LOAD REDUCTION MODEL (PLRM) V1.0 ☐ OTHER (DESCRIPTION IS INCLUDED IN CCS MEMO)	Name and version (If you selected Other)
2. EXPECTED LOADING PARAMETERS, ASSUMPTIONS & DATASETS	Check yes if any parameter values, assumptions or datasets used deviate from default values or recommendations
☐ YES ☒ NO (only defaults used)	☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO LOAD ESTIMATION APPROACH AND ASSUMPTIONS SECTION

If Yes, please explain

The PLRM does not account for the implementation of source controls on steep slopes. NDOT has stabilized steep erosive slopes in this catchment through revegetation and riprap installation. The erosion reduction for slope stabilization improvements is not included in the calculations for this catchment. NDOT anticipates a future revision to this catchment to include the source control improvements.

3. EXPECTED LOADING PROJECT FILE	Confirm that the expected loading estimate scenario is included	4. EXPECTED LOAD	Provide the expected loads for fine sediment, nitrogen and phosphorus
☒ THE EXPECTED LOADING ESTIMATE SCENARIO IS INCLUDED IN THE LOAD ESTIMATION PROJECT FILE AND IS LISTED IN A.17		Fine sediment mass (kg) 2596	Fine sediment particles (#) 2.9E+17
		Total nitrogen (kg) 28	Total phosphorus (kg) 8

SECTION E: BASELINE LOADING ESTIMATE

The urban catchment baseline loading estimate sets the reference point for determining load reductions.

I. BASELINE LOADING ESTIMATE

1. BASELINE INVENTORY TABLE	Confirm baseline inventory table	2. BASELINE INFRASTRUCTURE MAP	Confirm baseline infrastructure map
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	
3. CHANGES SINCE 2004		Summarize any changes to treatment BMPs since 2004	

Improved sand and salt application methods resulting in a reduction of sand and salt applied, Increased sweeping frequency, installed infiltration facilties, stabilized shoulders and slopes.

☒ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO BASELINE CONDITIONS SECTION	
4. BASELINE LOADING PARAMETERS, ASSUMPTIONS & DATASETS	Indicate if any parameter values, assumptions or datasets used deviate from default values or recommendations
☐ YES ☒ NO	☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO BASELINE CONDITIONS SECTION

If Yes, please explain

5. BASELINE LOAD ESTIMATE		Provide the baseline loads for fine sediment, nitrogen and phosphorus	
Fine sediment mass (kg) **5458**	Fine sediment particles (#) **6.0E+17**	Total nitrogen (kg) **38**	Total phosphorus (kg) **13**

SECTION F: CATCHMENT CREDIT SCHEDULE AMOUNT & DURATION

The final determination of the appropriate CCS credit potential amount and duration is made by the regulator in consultation with the urban jurisdiction. The urban jurisdiction proposes the CCS credit potential amount based on the load reduction estimate, and the duration based on the primary and secondary pollutant control strategies.

I. LOAD REDUCTION ESTIMATE & CATCHMENT CREDIT SCHEDULE AMOUNT

1. LOAD REDUCTION ESTIMATE		Note the load reduction estimate amounts	
Fine sediment mass (kg)	Total phosphorus (kg)	Total nitrogen (kg)	
2862	5	10	

2. FINE SEDIMENT PARTICLE NUMBER CONVERSION	Using Equation 0.3, convert the fine sediment mass to number of fine sediment particles	3. CATCHMENT CONNECTIVITY	From item B.5
Fine sediment particles (#)		Percent Connectivity	
3.1E+17		75 %	

4. EFFECTIVE LOAD REDUCTION ESTIMATE		Multiply the vaues in items F.1 and F.2 by F.3	
Fine sediment mass (kg)	Fine sediment particles (#)	Total phosphorous (kg)	Total nitrogen (kg)
2146	2.4E+17	4	7

5. CREDIT AMOUNT CALCULATION	Using equation 0.2 calculate the credit amount

24 CREDITS

II. CREDIT SCHEDULE DURATION

6. CREDIT SCHEDULE DURATION	Indicate the catchment credit schedule duration	7. DURATION RATIONALE	Briefly explain the rationale for the selected duration
☐ 5 YEARS ☒ 10 YEARS ☐ 15 YEARS ☐ OTHER (SPECIFY) ____ YEARS		Explanation NDOT typically schedules pavement improvements every 8-10 yr.	

III. ESTABLISHMENT SUMMARY

8. ESTABLISHMENT DATE	Note the date that the CCS is submitted to the regulator	9. ESTABLISHMENT YEAR CREDIT POTENTIAL	Note the appropriate establishment year percentage and amount
Date		Percentage %	Credit Amount

10. FINAL YEAR OF CREDIT SCHEDULE	Note the appropriate final year of the credit schedule
Final Year	

11. ADDITIONAL EXPECTED CCS AMOUNT AND DURATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the private property BMP implementation efforts in the catchment
☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO CCS AMOUNT AND DURATION SECTION	

CCS — CATCHMENT CREDIT SCHEDULE

SECTION A: CORRESPONDENCE & CATCHMENT CREDIT SCHEDULE SUMMARY

The Correspondence & Catchment Credit Schedule Summary section is completed incrementally throughout the process of establishing a Catchment Credit Schedule (CCS), as defined in Chapter 1 of the Lake Clarity Crediting Handbook (Handbook). Subsequent sections of this template prompt users to complete the corresponding summary items here in Section A.

I. GENERAL CATCHMENT INFORMATION SUMMARY

1. CATCHMENT STATUS

Check the appropriate status and add date of previous approval if applicable

- ☒ NEW CATCHMENT
- ☐ REVISION
- ☐ EXTENSION

Date of previous approval

2. CATCHMENT ID

Provide the unique catchment ID & common name

Catchment ID: EDC05

Common Catchment Name: Nottaway Catchment

3. PRIMARY JURISDICTION

Identify the primary urban jurisdiction and primary point of contact within the urban jurisdiction

- ☐ CALTRANS
- ☐ CSLT
- ☐ DOUGLAS
- ☒ EL DORADO
- ☐ NDOT
- ☐ PLACER
- ☐ WASHOE

Primary Contact: Brendan Ferry

Phone Number: (530) 573-7905

E-mail Address: brendan.ferry@edcgov.us

4. REGULATORY AGENCY

Identify the responsible regulatory agency and primary point of contact within the agency

- ☒ LRWQCB
- ☐ NDEP

Primary Contact: Robert Larsen

Phone Number: (530) 542-5439

E-mail Address: RLarsen@waterboards.ca.gov

II. CATCHMENT CREDIT SCHEDULE SUMMARY

5. BASIC CATCHMENT POLLUTANT CONTROL STRATEGY NARRATIVE

In the space provided, describe the basic strategies employed to reduce pollutant loading within the catchment

Basic Narrative

El Dorado County will implement the following pollutant control strategies to achieve significant load reductions:

Operations & Maintenance: Bi-annual sweeping targeted in the spring and fall; Targeted road sand application.

Key BMP Implementation: Wet Basin; Sand Filter.

Essential BMP Implementation: Curb & Gutter; Sediment Traps; Treatment Vault; Revegetation.

Private BMPs: Continue to support the efforts of TRCD and TRPA and provide incentives to homeowners for regional treament where feasible.

6. EFFECTIVE LOAD REDUCTION ESTIMATE

Note the load reduction estimate amounts from Section F

Fine sediment particles (#)	Fine sediment mass (kg)	Total nitrogen (kg)	Total phosphorous (kg)
1.7 x 10^17	1515.7	17.3	6.5

7. CREDIT POTENTIAL AMOUNT

Note the credit amount

17 CREDITS

8. ESTABLISHMENT DATE

Note the catchment establishment date from Section F for final CCS only

Establishment Date: 2/1/11

9. FINAL YEAR

Note the final year of the CCS from Section F for final CCS only

Final Year: 2/1/16

III. COORDINATION CHECKLIST

10. SUBMITTED FOR VERIFICATION REVIEW	Note the date submitted and urban jurisdiction staff person (Step 1.3)
Date Submitted 1/28/11	Name of Staff Person Brendan Ferry

11. STATEMENT OF COMPLETENESS & APPROPRIATENESS	Representative from urban jurisdiction must certify the completeness of the CCS (Step 1.3)

I certify that the information contained in this Catchment Credit Schedule and the analyses related to this Catchment Credit Schedule are complete and appropriate.

Printed Name	Date
Brendan Ferry	1/28/11

Signature

12. VERIFIED BY REGULATOR	Regulator must certify the verification step is complete (Step 1.4)

I certify that the Verification Step is complete.

Printed Name	Date

Signature

13. REGISTERED AND SUBMITTED FOR APPROVAL	Note the date that the catchment was registered in the Accounting and Tracking Database (Step 1.5)

Date

14. SUPPORTING MATERIALS CHECKLIST AND FILENAMES	Confirm each file is included in the digital submission and provide the filename and save date	
Checklist	Filename	Save Date
☒ CCS FORM	S:\PROJECTS\95959 PLR\LCCP\El Dorado\Active Catchments\CATCH_005\Documents	1/27/11
☐ CCS MEMO (IF NECCESARY)		
☒ CATCHMENT DELINEATION MAP FOR CATCHMENT 1	S:\PROJECTS\95959 PLR\LCCP\El Dorado\Active Catchments\CATCH_005\Maps & Data\PDF Maps	3/24/10
☒ OVERALL CATCHMENT DELINEATION MAP	S:\PROJECTS\95959 PLR\LCCP\El Dorado\Active Catchments\CATCH_005\Maps & Data\PDF Maps	3/24/10
☒ TREATMENT BMP INVENTORY MAP	S:\PROJECTS\95959 PLR\LCCP\El Dorado\Active Catchments\CATCH_005\Maps & Data\PDF Maps	1/28/11
☒ TREATMENT BMP INVENTORY TABLE	S:\PROJECTS\95959 PLR\LCCP\El Dorado\Active Catchments\CATCH_005\Maps & Data\Tables	1/28/11
☒ ROADS INVENTORY MAP	S:\PROJECTS\95959 PLR\LCCP\El Dorado\Active Catchments\CATCH_005\Maps & Data\PDF Maps	8/19/10
☐ ROADS INVENTORY TABLE	In Progress	
☐ ROADS MAINTENANCE MAP(S) (NOT REQUIRED)		
☒ BASELINE TREATMENT BMP INVENTORY TABLE	S:\PROJECTS\95959 PLR\LCCP\El Dorado\Active Catchments\CATCH_005\Maps & Data\Tables	1/28/11
☒ CATCHMENT REGISTRATION REPORT (FINAL ONLY)	S:\PROJECTS\95959 PLR\LCCP\El Dorado\Active Catchments\CATCH_005\Documents	1/28/11
☒ PLRM PROJECT FILE (DIGITAL FILE ONLY)	S:\PROJECTS\95959 PLR\LCCP\El Dorado\Active Catchments\CATCH_005\Maps & Data\Model Data	1/26/11
☒ AS-BUILT DRAWINGS AND EQUIPMENT SPECIFICATIONS (DIGITAL FILES ONLY)	Available upon request	12/10/06

SECTION B: CATCHMENT DELINEATION

Credits and load reductions are tracked for specific urban catchments. The same urban catchment area must be used in both baseline and expected loading estimates. In order to prevent double counting, no land area may be included in two urban catchments.

I. CATCHMENT CONNECTIVITY

1. CATCHMENT ID	Confirm the catchment ID and name	2. CATCHMENT DELINEATION MAP	Confirm the catchment delineation map is complete
☒ CATCHMENT ID IS PROPERLY LISTED IN A.1		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	
3. OVERALL URBAN JURISDICTION CATCHMENT MAP	Confirm the overall catchment delineation map is complete	**4. CATCHMENT HISTORY**	Note any previous catchments that included a portion of this catchment
☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		Previous Catchment Name	Establishment Date
		None	None
5. CATCHMENT AREA	Provide the total catchment area	**6. CATCHMENT CONNECTIVITY**	Provide the percent connectivity that will be used to modify the load reduction estimate
Total Area (acres)		Percent Connectivity	
35.19 Acres		☒ 100% ☐ OTHER ___%	
		☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO CATCHMENT CONNECTIVITY SECTION	

SECTION C: IMPLEMENTATION PLAN SUMMARY

The Implementation Plan Summary defines the expected conditions for treatment BMPs, roads, private property BMPs, and other pollutant control strategies based on the urban jurisdiction's planned operations, maintenance and program implementation activities in the urban catchment. The Implementation Plan Summary may pull information from multiple sources and ideally relies upon one or more of the broader implementation plans used by the urban jurisdictions.

I. DEFINE LOAD REDUCTION STRATEGY

1. TREATMENT BMPS	Check the most appropriate description	2. ROAD OPERATIONS	Check the most appropriate description
☒ PRIMARY ☐ SECONDARY ☐ TERTIARY ☐ NONE		☐ PRIMARY ☒ SECONDARY ☐ TERTIARY ☐ NONE	
3. PRIVATE PARCEL BMPS	Check the most appropriate description	**4. OTHER POLLUTANT CONTROL STRATEGY**	Check the most appropriate description
☐ PRIMARY ☐ SECONDARY ☒ TERTIARY ☐ NONE		☐ PRIMARY ☐ SECONDARY ☐ TERTIARY ☐ NONE	

II. TREATMENT BMP IMPLEMENTATION SUMMARY

5. TREATMENT BMP INVENTORY TABLE	Confirm the table is complete	6. TREATMENT BMP INVENTORY MAP	Confirm the map is complete
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	

7. TREATMENT BMP MAINTENANCE PLAN SUMMARY — In the space provided, summarize planned treatment BMP maintenance actions for the overall catchment (reference implementation planning documents if applicable)

All roadways will be swept bi-annually, at a minimum, focusing on areas where traction abrasives are applied. Sediment traps and the treatment vault will be cleaned with a vactor truck once their trapping sump capacities are greater than 50% full. The wet basin will be maintained as needed, once failures or clogging is noted during field inspections. The sand filter will be monitored annually to ensure it is performing as designed. It will be maintained on an approximate five year cycle by replacing the filter media. All key and essential BMPs will be maintained to ensure they are performing as designed.

8. TREATMENT BMP INSPECTION PLAN SUMMARY — In the space provided, summarize planned treatment BMP inspection actions for the overall catchment (reference implementation planning documents if applicable)

All BMPs will be inspected once annually and after major storm events, at a minimum. BMP data shall be entered into the County's BMP database for tracking and reporting purposes to ensure that adequate field conditions exist indicating that the BMPs are functioning as designed. If failures, or sub-standard conditions are noted during the annual inspections, maintenance will be scheduled to ensure that BMPs continue to remain in a funcitonal condition. County inspection and tracking protocols will be followed for each BMP type. These include the following:

For sediment traps and drop inlets: Visual inspection, field measurement, field data sheet recording, BMP database entry and reporting. If the BMP is at greater than 50% capacity, maintenance will be scheduled.

For basins: Visual inspection, field data sheet recording (including infiltration test, vegetation monitoring, photographic documentation, sediment deposition monitoring, inlet/outlet inspections, etc.), BMP database entry and reporting. If the BMP fails inspection due to non-functionality of one or more items noted, maintenance will be scheduled.

For rock-lined or grass-lined swales: Visual inspection, field data sheet recording, photographic documentation, BMP database entry and reporting. If the BMP fails inspection due to non-functionality, maintenance will be scheduled.

For treatment vaults: Visual inspection, field measurement, field data sheet recording, photographic documentation, BMP database entry and reporting. If the BMP is at greater than 50% capacity, maintenance will be scheduled.

For sand filters: Visual inspection, field measurement, infiltration test, field data sheet recording, photographic documentation, BMP database entry and reporting. If the BMP fails field measurements, maintenance will be scheduled.

For revegetation: Visual inspection and photographic documentation. If vegetation is not present, as designed, appropriate maintenance will be scheduled.

9. ADDITIONAL TREATMENT BMP IMPLEMENTATION INFORMATION — Indicate whether additional information is provided in the CCS memo to adequately describe the treatment BMPs within the catchment

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO TREATEMENT BMP IMPLEMENTATION SUMMARY SECTION

III. ROADS OPERATION IMPLEMENTATION SUMMARY

10. ROAD INVENTORY TABLE	Confirm the table is complete	11. ROADS INVENTORY MAP	Confirm the map is complete
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	

12. ROADS MAINTENANCE PLAN SUMMARY	In the space provided, summarize planned road maintenance actions for the overall catchment (reference implementation planning documents if applicable)

All roadways within the catchment will be swept bi-annually, at a minimum, focusing on areas where traction abrasives are applied. Sweeping will also be timed prior to large storm events and/or prior to the spring runoff. Failing pavement areas will be scheduled for maintenance as is deemed necessary and/or as resources become available.

13. ROADS MAINTENANCE MAP(S)	Confirm road maintenance maps
☐ ROAD MAINTENANCE MAPS ARE PROPERLY IN A.17 (NOT REQUIRED)	

14. ROADS INSPECTION PLAN SUMMARY	In the space provided, summarize planned road inspection actions for the overall catchment (reference implementation planning documents if applicable)

Roads will be visually inspected once annually and after major storm events, at a minimum. Inspection data shall be entered into the County's database for tracking and reporting purposes to ensure that adequate field conditions exist indicating that the road conditions are functioning as stated in our PLRM for the Project area. If inadequate conditions are noted during the annual inspections, maintenance will be scheduled accordingly to maintain the roadway surfaces at a level that was used in the PLRM modeling to ensure that load reduction and crediting is accurate.

15. ADDITIONAL ROAD IMPLEMENTATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the roads within the catchment
☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO ROADS IMPLEMENTATION SUMMARY SECTION	

IV. PRIVATE PROPERTY BMP IMPLEMENTAION SUMMARY

16. PRIVATE PROPERTY BMP INVENTORY		In the space provided, note the total number of developed single-family residential (SFR) parcels and the number of SFR parcels with BMP and source control certificates. Also, note the total area of multi-family residential (MFR) and commercial properties (CICU) and the area with BMP and source control certificates. Provide the percentage area with BMP and source control certificates that should be used as the expected value.			
Total Area of SFR (acres)	Total # of SFR	Total # of SFR w/ BMP Cert.	Total % of SFR w/BMP Cert.	Total # of SFR w/ SC Cert.	Total % of SFR w/ SC Cert.
SFI = 3.38, SFP = 13.38	108	11	10%	2	2%
Total area of MFR (acres)	Area of MFR with BMP Certificates (acres)	Total Area of CICU (acres)		Area of CICU with BMP Certificates (acres)	
0	0	0		0	
Expected percentage of area with BMP certificates		**Expected percentage of area with source control certificates**			
20%		8%			

17. URBAN JURISDICTION PRIVATE PROPERTY BMP PROGRAM SUMMARY	In the space provided, describe any planned variations from the general private property BMP program for this urban catchment (reference implementation planning documents if applicable)

El Dorado County will continue to support TRPA and TRCD in their BMP implementation efforts and will continue water quality outreach efforts as part of its NPDES Permit, its EIP Project implementation and its Storm Water Management Program.

18. PRIVATE PROPTERY BMP INSPECTION PLAN SUMMARY	In the space provided, identify the data sources supporting these private property BMP calculations (reference implementation planning documents if applicable)

El Dorado County will check in with TRCD annually to update its files with the current number of BMP certificates issued.

19. ADDITIONAL PRIVATE PROPERTY BMP INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the private property BMP implementation efforts in the catchment

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO PRIVATE PROPERTY BMP IMPLEMENTATION SUMMARY SECTION

V. OTHER POLLUTANT CONTROL STRATEGIES IMPLEMENTATION SUMMARY

20. OTHER POLLUTANT CONTROL PROGRAM SUMMARY	If other pollutant control strategies are implemented in the urban catchment, indicate that they are described in the CCS memo

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO OTHER POLLUTANT CONTROL STRATEGIES SECTION

SECTION D: EXPECTED LOADING ESTIMATE

The expected loading estimate reflects annual average loading assuming treatment BMPs, roads, private property BMPs and other pollutant controls are maintained and operated to achieve the expected conditions defined in the Implementation Plan Summary.

I. EXPECTED LOADING ESTIMATE

1. LOAD ESTIMATION METHOD	Select the method used to estimate the expected and baseline loading for the catchment
☒ POLLUTANT LOAD REDUCTION MODEL (PLRM) V1.0 ☐ OTHER (DESCRIPTION IS INCLUDED IN CCS MEMO)	Name and version (If you selected Other)
2. EXPECTED LOADING PARAMETERS, ASSUMPTIONS & DATASETS	Check yes if any parameter values, assumptions or datasets used deviate from default values or recommendations
☐ YES ☒ NO (only defaults used)	☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO LOAD ESTIMATION APPROACH AND ASSUMPTIONS SECTION

If Yes, please explain

3. EXPECTED LOADING PROJECT FILE	Confirm that the expected loading estimate scenario is included	4. EXPECTED LOAD	Provide the expected loads for fine sediment, nitrogen and phosphorus
☒ THE EXPECTED LOADING ESTIMATE SCENARIO IS INCLUDED IN THE LOAD ESTIMATION PROJECT FILE AND IS LISTED IN A.17		Fine sediment mass (kg) 662.8	Fine sediment particles (#) 7.3X10^16
		Total nitrogen (kg) 26.1	Total phosphorus (kg) 4.5

SECTION E: BASELINE LOADING ESTIMATE

The urban catchment baseline loading estimate sets the reference point for determining load reductions.

I. BASELINE LOADING ESTIMATE

1. BASELINE INVENTORY TABLE	Confirm baseline inventory table	2. BASELINE INFRASTRUCTURE MAP	Confirm baseline infrastructure map
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	
3. CHANGES SINCE 2004		Summarize any changes to treatment BMPs since 2004	

The County installed curb and gutter, sediment traps, drop inlets, a wet basin, a treatment vault and a sand filter in the project area in 2005. The County has also increased sweeping frequency, modified road abbrasive applications and coorindated with TRCD on private property BMP outreach.

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO BASELINE CONDITIONS SECTION

4. BASELINE LOADING PARAMETERS, ASSUMPTIONS & DATASETS	Indicate if any parameter values, assumptions or datasets used deviate from default values or recommendations
☐ YES ☒ NO	☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO BASELINE CONDITIONS SECTION

If Yes, please explain

5. BASELINE LOAD ESTIMATE		Provide the baseline loads for fine sediment, nitrogen and phosphorus	
Fine sediment mass (kg)	Fine sediment particles (#)	Total nitrogen (kg)	Total phosphorus (kg)
2178.5	**2.4 x 10^18**	**43.4**	**11.0**

SECTION F: CATCHMENT CREDIT SCHEDULE AMOUNT & DURATION

The final determination of the appropriate CCS credit potential amount and duration is made by the regulator in consultation with the urban jurisdiction. The urban jurisdiction proposes the CCS credit potential amount based on the load reduction estimate, and the duration based on the primary and secondary pollutant control strategies.

I. LOAD REDUCTION ESTIMATE & CATCHMENT CREDIT SCHEDULE AMOUNT

1. LOAD REDUCTION ESTIMATE		Note the load reduction estimate amounts	
Fine sediment mass (kg)	Total phosphorus (kg)	Total nitrogen (kg)	
1515.7	6.5	17.3	

2. FINE SEDIMENT PARTICLE NUMBER CONVERSION	Using Equation 0.3, convert the fine sediment mass to number of fine sediment particles	3. CATCHMENT CONNECTIVITY	From item B.5
Fine sediment particles (#)		Percent Connectivity	
1.7 x 10^17		100 %	

4. EFFECTIVE LOAD REDUCTION ESTIMATE		Multiply the vaues in items F.1 and F.2 by F.3	
Fine sediment mass (kg)	Fine sediment particles (#)	Total phosphorous (kg)	Total nitrogen (kg)
Same as above			

5. CREDIT AMOUNT CALCULATION	Using equation 0.2 calculate the credit amount

17 CREDITS

II. CREDIT SCHEDULE DURATION

6. CREDIT SCHEDULE DURATION	Indicate the catchment credit schedule duration	7. DURATION RATIONALE	Briefly explain the rationale for the selected duration
☒ 5 YEARS ☐ 10 YEARS ☐ 15 YEARS ☐ OTHER (SPECIFY) -YEARS		Explanation Since this is a new concept, we want to revisit this at the end of the permit term.	

III. ESTABLISHMENT SUMMARY

8. ESTABLISHMENT DATE	Note the date that the CCS is submitted to the regulator	9. ESTABLISHMENT YEAR CREDIT POTENTIAL	Note the appropriate establishment year percentage and amount
Date		Percentage	Credit Amount
2/1/11		100%	17

10. FINAL YEAR OF CREDIT SCHEDULE	Note the appropriate final year of the credit schedule
Final Year	
2/1/16	

11. ADDITIONAL EXPECTED CCS AMOUNT AND DURATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the private property BMP implementation efforts in the catchment
☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO CCS AMOUNT AND DURATION SECTION	

CCS — CATCHMENT CREDIT SCHEDULE

SECTION A: CORRESPONDENCE & CATCHMENT CREDIT SCHEDULE SUMMARY

The Correspondence & Catchment Credit Schedule Summary section is completed incrementally throughout the process of establishing a Catchment Credit Schedule (CCS), as defined in Chapter 1 of the Lake Clarity Crediting Handbook (Handbook). Subsequent sections of this template prompt users to complete the corresponding summary items here in Section A.

I. GENERAL CATCHMENT INFORMATION SUMMARY

1. CATCHMENT STATUS

Check the appropriate status and add date of previous approval if applicable

- ☒ NEW CATCHMENT
- ☐ REVISION
- ☐ EXTENSION

Date of previous approval

2. CATCHMENT ID

Provide the unique catchment ID & common name

Catchment ID: DP1 (PLRM Subcatchments DP3 and DP4)

Common Catchment Name: Dollar Point

3. PRIMARY JURISDICTION

Identify the primary urban jurisdiction and primary point of contact within the urban jurisdiction

- ☐ CALTRANS
- ☐ CSLT
- ☐ DOUGLAS
- ☐ EL DORADO
- ☐ NDOT
- ☒ PLACER
- ☐ WASHOE

Primary Contact: Peter Kraatz

Phone Number: (530) 581-6230

E-mail Address: pkraatz@placer.ca.gov

4. REGULATORY AGENCY

Identify the responsible regulatory agency and primary point of contact within the agency

- ☒ LRWQCB
- ☐ NDEP

Primary Contact: Robert Larsen

Phone Number: (530) 542-5439

E-mail Address: RLarsen@waterboards.ca.gov

II. CATCHMENT CREDIT SCHEDULE SUMMARY

5. BASIC CATCHMENT POLLUTANT CONTROL STRATEGY NARRATIVE

In the space provided, describe the basic strategies employed to reduce pollutant loading within the catchment

Basic Narrative

The predominant PSC for Catchment DP1 consists of the Dollar Point Erosion Control Project constructed by Placer County in 2008, identified as TRPA EIP Project No. 10063. Based on the County's delineation of urban planning catchments (UPCs), the project includes portions of UPC #s 20 and 22 and is situated in PLRM Met Grid Number 342 along the north shore of Lake Tahoe within land uses occupied predominantly by secondary roads, SFRs and MFRs. Erosion control improvements consist of hydrologic source controls (HSCs) including energy dissapation structures, infiltration galleries, numerous sediment traps, rock lined swales, vegetated swales, and rock lined transitions. No SWTs were built or are anticipated for the catchment. Private BMP promotion is not a significant PCS, however, road maintenance will increase (i.e., sweeping frequency and technology) from baseline conditions and related inspections by County staff will occur to validate road and HSC conditions and provide appropriate maintenance responses.

6. EFFECTIVE LOAD REDUCTION ESTIMATE

Note the load reduction estimate amounts from Section F

Fine sediment particles (#)	Fine sediment mass (kg)	Total nitrogen (kg)	Total phosphorous (kg)
16.2 x 10^16	**1470 kg**	**28 kg**	**6 kg**

7. CREDIT POTENTIAL AMOUNT

Note the credit amount

16.2 CREDITS

8. ESTABLISHMENT DATE

Note the catchment establishment date from Section F for final CCS only

Establishment Date: 1/25/11

9. FINAL YEAR

Note the final year of the CCS from Section F for final CCS only

Final Year: 1/25/21

III. COORDINATION CHECKLIST

10. SUBMITTED FOR VERIFICATION REVIEW	Note the date submitted and urban jurisdiction staff person (Step 1.3)
Date Submitted 01/19/2011	Name of Staff Person Robert Larsen

11. STATEMENT OF COMPLETENESS & APPROPRIATENESS	Representative from urban jurisdiction must certify the completeness of the CCS (Step 1.3)

I certify that the information contained in this Catchment Credit Schedule and the analyses related to this Catchment Credit Schedule are complete and appropriate.

Printed Name	Date
Peter Kraatz	2/18/11

Signature

12. VERIFIED BY REGULATOR	Regulator must certify the verification step is complete (Step 1.4)

I certify that the Verification Step is complete.

Printed Name	Date
Robert Larsen	

Signature

13. REGISTERED AND SUBMITTED FOR APPROVAL	Note the date that the catchment was registered in the Accounting and Tracking Database (Step 1.5)
Date 1/25/11	

14. SUPPORTING MATERIALS CHECKLIST AND FILENAMES	Confirm each file is included in the digital submission and provide the filename and save date	
Checklist	Filename	Save Date
☒ CCS FORM	PC_DLP_ CCS 01-25-11	1/25/11
☒ CCS MEMO (IF NECCESARY)	PC Supporting Information and Memo 1.25.11.doc	1/25/11
☒ CATCHMENT DELINEATION MAP FOR CATCHMENT 1	PC_DLP_01 Catchment Delineation Map (Catch1)	1/25/11
☒ OVERALL CATCHMENT DELINEATION MAP	PC_DLP_01 Catchment Delineation Map (OvrAll)	1/25/11
☒ TREATMENT BMP INVENTORY MAP	PC_DLP_01…	1/25/11
☒ TREATMENT BMP INVENTORY TABLE	PC20 Treatment BMP Inventory.pdf	1/25/11
☒ ROADS INVENTORY MAP	PC_DLP_01 Roads Map	1/25/11
☒ ROADS INVENTORY TABLE	PC_DLP_01 Roads Table	1/25/11
☐ ROADS MAINTENANCE MAP(S) (NOT REQUIRED)	n/a	
☐ BASELINE TREATMENT BMP INVENTORY TABLE	There are no baseline treatment BMPs.	
☐ CATCHMENT REGISTRATION REPORT (FINAL ONLY)	n/a	
☒ PLRM PROJECT FILE (DIGITAL FILE ONLY)	PC20 PLRM Projects.zip	1/25/11
☒ AS-BUILT DRAWINGS AND EQUIPMENT SPECIFICATIONS (DIGITAL FILES ONLY)	PC20 DLP Erosion Cntrl Record Drawings (1of4).pdf PC20 DLP Erosion Cntrl Record Drawings (2of4).pdf PC20 DLP Erosion Cntrl Record Drawings (3of4).pdf PC20 DLP Erosion Cntrl Record Drawings (4of4).pdf	1/25/11

SECTION B: CATCHMENT DELINEATION

Credits and load reductions are tracked for specific urban catchments. The same urban catchment area must be used in both baseline and expected loading estimates. In order to prevent double counting, no land area may be included in two urban catchments.

I. CATCHMENT CONNECTIVITY

1. CATCHMENT ID	Confirm the catchment ID and name	2. CATCHMENT DELINEATION MAP	Confirm the catchment delineation map is complete
☒ CATCHMENT ID IS PROPERLY LISTED IN A.1		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	
3. OVERALL URBAN JURISDICTION CATCHMENT MAP	Confirm the overall catchment delineation map is complete	**4. CATCHMENT HISTORY**	Note any previous catchments that included a portion of this catchment
☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		Previous Catchment Name n/a	Establishment Date
5. CATCHMENT AREA	Provide the total catchment area	**6. CATCHMENT CONNECTIVITY**	Provide the percent connectivity that will be used to modify the load reduction estimate
Total Area (acres) 216 acres		Percent Connectivity ☒ 100% ☐ OTHER 50%	
		☒ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO CATCHMENT CONNECTIVITY SECTION	

SECTION C: IMPLEMENTATION PLAN SUMMARY

The Implementation Plan Summary defines the expected conditions for treatment BMPs, roads, private property BMPs, and other pollutant control strategies based on the urban jurisdiction's planned operations, maintenance and program implementation activities in the urban catchment. The Implementation Plan Summary may pull information from multiple sources and ideally relies upon one or more of the broader implementation plans used by the urban jurisdictions.

I. DEFINE LOAD REDUCTION STRATEGY

1. TREATMENT BMPS	Check the most appropriate description	2. ROAD OPERATIONS	Check the most appropriate description
☐ PRIMARY ☐ SECONDARY ☐ TERTIARY ☒ NONE		☐ PRIMARY ☐ SECONDARY ☒ TERTIARY ☐ NONE	
3. PRIVATE PARCEL BMPS	Check the most appropriate description	**4. OTHER POLLUTANT CONTROL STRATEGY**	Check the most appropriate description
☐ PRIMARY ☐ SECONDARY ☐ TERTIARY ☒ NONE		☐ PRIMARY ☐ SECONDARY ☐ TERTIARY ☒ NONE	

II. TREATMENT BMP IMPLEMENTATION SUMMARY

5. TREATMENT BMP INVENTORY TABLE	Confirm the table is complete	6. TREATMENT BMP INVENTORY MAP	Confirm the map is complete
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	

7. TREATMENT BMP MAINTENANCE PLAN SUMMARY — In the space provided, summarize planned treatment BMP maintenance actions for the overall catchment (reference implementation planning documents if applicable)

The primary PSC for DP01 outside of road operations are hydrologic source control (HSC) facilities consisting of energy dissipation structures, infiltration galleries, numerous sediment traps, rock lined swales, vegetated swales, and rock lined transitions. Both the lack of ROW and runoff emanating primarily from secondary roads, SFRs, and MFRs were reasons that treatment type BMPs (SWT facilities) were not deployed in DP01 such as basins or vaults.

Maintenance will be performed at near or better-than-expected conditions according to BMP RAM protocols to maintain adequate RAM Score as the HSC facilities are predominantly in the road shoulders. Inspection for maintenance of HSC facilites will occur twice a year, once in the spring and once in the fall, and maintained at a frequency equivalent to removing sediment once facilities are over half full. Typical maintenace will include sediment removal by use of vactor trucks. Maintenance activities will be conducted by Placer County roads maintenance staff who have been trained regarding proper maintenance. Vactoring of sediment traps at least annually and infiltration feature would be required and tracked.

8. TREATMENT BMP INSPECTION PLAN SUMMARY — In the space provided, summarize planned treatment BMP inspection actions for the overall catchment (reference implementation planning documents if applicable)

Treatment BMPs have not been deployed in DP01 as HSC facilities represent the primary PSC. HSC facility inspections will be conducted consistant with BMP RAM protocols to assess the condition of the HSC facilities as they are located predominantly along road shoulders. Trained Placer County employees will utilize Road RAM Field Observation Datasheets while documenting each HSC facility during the inspection process, as will a field journal to record additonal pertinent observations.

Inspections at a minimum of twice per year (spring and fall) will occur to assess the structural integrity of each outfall, vegetation cover, rock lined swales, litter accumulation, and capacity of in/out flow conveyance features.

Knowledgeable staff will determine number and type of Field Observation Datasheets to bring into field via utilization of the BMP Inventory Table. The BMP Inventory Map will also be used to quickly locate each HSC facility, informing as to location and correct type of facility. Applicable Field Observation Datasheet will be used for each HSC facility, detailing type of measurements and observations collected for each HSC facility.

Inspections will include: type and percent vegetation cover, depth of sediment accumulation measured via staff gauge, and conveyance obstructions per the BMP RAM User Manual.

The applicable BMP RAM Field Observation Datasheet will be used to document the inspection process and record observations collected at all sediment traps, infiltration features, and all conveyances to ensure proper function and adequate condition. Data obtained will be entered into the BMP RAM database, receiving a BMP RAM score used to inform as to the level and priority of maintenance activities to be planned in this catchment.

9. ADDITIONAL TREATMENT BMP IMPLEMENTATION INFORMATION — Indicate whether additional information is provided in the CCS memo to adequately describe the treatment BMPs within the catchment

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO TREATEMENT BMP IMPLEMENTATION SUMMARY SECTION

III. ROADS OPERATION IMPLEMENTATION SUMMARY

10. ROAD INVENTORY TABLE	Confirm the table is complete	11. ROADS INVENTORY MAP	Confirm the map is complete
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	

12. ROADS MAINTENANCE PLAN SUMMARY	In the space provided, summarize planned road maintenance actions for the overall catchment (reference implementation planning documents if applicable)

The road maintenance plan emphasizes how often traction abrasives are swept. Currently, roads in DP01 are swept twice per year in the spring/summer consistent with baseline conditions modeled in PLRM. Future or expected conditions for road sweeping as modeled in PLRM will increase on medium and high risk roads to four times per year (twice in winter and twice in summer) using a tandem operation where a vacuum sweeper follows a traditional broom sweeper. The tandem operation will be contingent upon a vacuum sweeper purchased in the summer of 2011.

Other road maintenance will include vactoring

Placer County will continue to maintain our roadways consistent with our 2004 practices to maintain baseline conditions in terms of frequency (twice per year - once in spring and once in fall). The add

13. ROADS MAINTENANCE MAP(S)	Confirm road maintenance maps
☐ ROAD MAINTENANCE MAPS ARE PROPERLY IN A.17 (NOT REQUIRED)	

14. ROADS INSPECTION PLAN SUMMARY	In the space provided, summarize planned road inspection actions for the overall catchment (reference implementation planning documents if applicable)

Placer County will continue to inspect our roadways consistent with our 2004 practices to maintain baseline conditions in terms of frequency (twice per year - once in spring and once in fall). The inspection program will be updated though to align with the Road RAM protocols and more specifically, measurements will be taken on all roads to assess the areas of priority sweeping (tandem operation) which at this point as modeled, would be all medium and high risk roads. Actual inspection will verify this modeled assumption.

15. ADDITIONAL ROAD IMPLEMENTATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the roads within the catchment
☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO ROADS IMPLEMENTATION SUMMARY SECTION	

IV. PRIVATE PROPERTY BMP IMPLEMENTAION SUMMARY

16. PRIVATE PROPERTY BMP INVENTORY

In the space provided, note the total number of developed single-family residential (SFR) parcels and the number of SFR parcels with BMP and source control certificates. Also, note the total area of multi-family residential (MFR) and commercial properties (CICU) and the area with BMP and source control certificates. Provide the percentage area with BMP and source control certificates that should be used as the expected value.

Total Area of SFR (acres)	Total # of SFR	Total # of SFR w/ BMP Cert.	Total % of SFR w/BMP Cert.	Total # of SFR w/ SC Cert.	Total % of SFR w/ SC Cert.
137.4	578	58	10.4%	0	0%

Total area of MFR (acres)	Area of MFR with BMP Certificates (acres)	Total Area of CICU (acres)	Area of CICU with BMP Certificates (acres)
23.3	0	4.2	0

Expected percentage of area with BMP certificates	Expected percentage of area with source control certificates
8.7%	0%

17. URBAN JURISDICTION PRIVATE PROPERTY BMP PROGRAM SUMMARY

In the space provided, describe any planned variations from the general private property BMP program for this urban catchment (reference implementation planning documents if applicable)

Under current conditions in DP01 and as modeled in PLRM under baseline conditions, 7% by area of SFRs have BMP certificates and under expected conditions, an increase in 3.4% by area of SFRs is expected to a total of 10.4%.

Uncertainty exists in the area of MFR and CICU as well as the respective areas certified under current and expected conditions. Additional verification needs to be performed by County staff to provide a better implementation plan for MFRs and CICU.

The BMP Implemenation Plan could be more aggressive if the County had more certainty on future incentives and enforcement actions. Placer County will be an active participant in this area as it is paramount that private BMP implementation is paramount to reaching FSP reduction targets and improving lake clarity. As such, we will revisit this CCS should a program be implemented during the credit schedule duration timeframe.

To facilitate the expected SFR area increase in BMP certificates, Placer County will continue to enforce private property BMP compliance through the process of when building permits are issued. In additon, we will continue to work on promotion and education efforts throught the Tahoe Resource Conservation District (i.e., free site evaluations)

18. PRIVATE PROPTERY BMP INSPECTION PLAN SUMMARY

In the space provided, identify the data sources supporting these private property BMP calculations (reference implementation planning documents if applicable)

The November 2004 Existing Conditions Assessment Memorandum for the Lake Forest Erosion Control Project was used as a basis for assessing baseline BMP compliance. Tracking future implementation will be performed by completing an annual inventory of buiding permits implemented in DP01 and verifying with the TRPA website (http://www.tiims.org/bmptoolkit/searchBMP.asp).

Related to BMP inspection, when BMPs are installed as part of a building permit issuance, BMP installation is inspected to ensure they are installed in accordance with approved plans. Resources for inspecting previously installed BMPs are not contemplated at this time.

19. ADDITIONAL PRIVATE PROPERTY BMP INFORMATION

Indicate whether additional information is provided in the CCS memo to adequately describe the private property BMP implementation efforts in the catchment

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO PRIVATE PROPERTY BMP IMPLEMENTATION SUMMARY SECTION

V. OTHER POLLUTANT CONTROL STRATEGIES IMPLEMENTATION SUMMARY

20. OTHER POLLUTANT CONTROL PROGRAM SUMMARY

If other pollutant control strategies are implemented in the urban catchment, indicate that they are described in the CCS memo

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO OTHER POLLUTANT CONTROL STRATEGIES SECTION

SECTION D: EXPECTED LOADING ESTIMATE

The expected loading estimate reflects annual average loading assuming treatment BMPs, roads, private property BMPs and other pollutant controls are maintained and operated to achieve the expected conditions defined in the Implementation Plan Summary.

I. EXPECTED LOADING ESTIMATE

1. LOAD ESTIMATION METHOD	Select the method used to estimate the expected and baseline loading for the catchment
☒ POLLUTANT LOAD REDUCTION MODEL (PLRM) V1.0 ☐ OTHER (DESCRIPTION IS INCLUDED IN CCS MEMO)	Name and version (If you selected Other)
2. EXPECTED LOADING PARAMETERS, ASSUMPTIONS & DATASETS	Check yes if any parameter values, assumptions or datasets used deviate from default values or recommendations
☐ YES ☒ NO (only defaults used)	☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO LOAD ESTIMATION APPROACH AND ASSUMPTIONS SECTION

If Yes, please explain

3. EXPECTED LOADING PROJECT FILE	Confirm that the expected loading estimate scenario is included	4. EXPECTED LOAD	Provide the expected loads for fine sediment, nitrogen and phosphorus
☒ THE EXPECTED LOADING ESTIMATE SCENARIO IS INCLUDED IN THE LOAD ESTIMATION PROJECT FILE AND IS LISTED IN A.17		Fine sediment mass (kg) 4,956	Fine sediment particles (#) 54.5 * 10^16
		Total nitrogen (kg) 182	Total phosphorus (kg) 39

SECTION E: BASELINE LOADING ESTIMATE

The urban catchment baseline loading estimate sets the reference point for determining load reductions.

I. BASELINE LOADING ESTIMATE

1. BASELINE INVENTORY TABLE	Confirm baseline inventory table	2. BASELINE INFRASTRUCTURE MAP	Confirm baseline infrastructure map
☐ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☐ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	

3. CHANGES SINCE 2004	Summarize any changes to treatment BMPs since 2004

In November 2004, the Existing Conditions Assessment Memorandum was finalized for the Lake Forest area of Placer County which includes the Dollar Point subdivision. This report formed the basis for planning, designing and building stormwater BMPs in DP01 which include the series of HSC facilities previously discussed and referred to in attached figures. The HSC implementation reduces road runoff volumes through disconnection of impervious surfaces and conveying flow to rock and vegetated swales, and sediment traps for infiltration and capturing sediment. In addition, with this CCS, road maintenance efforts will be enhanced through increased frequency and technology of sweepers deployed on medium and high risk roads.

☒ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO BASELINE CONDITIONS SECTION

4. BASELINE LOADING PARAMETERS, ASSUMPTIONS & DATASETS	Indicate if any parameter values, assumptions or datasets used deviate from default values or recommendations
☒ YES ☐ NO	☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO BASELINE CONDITIONS SECTION

If Yes, please explain

PLRM files, assumptions, and values have been created with assistance from consultants (NHC and 2nd Nature) and verified by County staff, both using the 11/2004 ECAM and Dollar Point Erosion Control Project as-built plans.

5. BASELINE LOAD ESTIMATE		Provide the baseline loads for fine sediment, nitrogen and phosphorus	
Fine sediment mass (kg)	Fine sediment particles (#)	Total nitrogen (kg)	Total phosphorus (kg)
6,430 kg	**70.7 * 10^16**	**211**	**45**

SECTION F: CATCHMENT CREDIT SCHEDULE AMOUNT & DURATION

The final determination of the appropriate CCS credit potential amount and duration is made by the regulator in consultation with the urban jurisdiction. The urban jurisdiction proposes the CCS credit potential amount based on the load reduction estimate, and the duration based on the primary and secondary pollutant control strategies.

I. LOAD REDUCTION ESTIMATE & CATCHMENT CREDIT SCHEDULE AMOUNT

1. LOAD REDUCTION ESTIMATE		Note the load reduction estimate amounts	
Fine sediment mass (kg)	Total phosphorus (kg)	Total nitrogen (kg)	
1,474 kg	**6**	**29**	

2. FINE SEDIMENT PARTICLE NUMBER CONVERSION	Using Equation 0.3, convert the fine sediment mass to number of fine sediment particles	3. CATCHMENT CONNECTIVITY	From item B.5
Fine sediment particles (#)		Percent Connectivity	
16.2 x 10^16 FSP		**100** %	

4. EFFECTIVE LOAD REDUCTION ESTIMATE		Multiply the vaues in items F.1 and F.2 by F.3	
Fine sediment mass (kg)	Fine sediment particles (#)	Total phosphorous (kg)	Total nitrogen (kg)
1,470 kg	**16.2 x 10^16 FSP**	**6**	**28**

5. CREDIT AMOUNT CALCULATION	Using equation 0.2 calculate the credit amount

16.2 CREDITS

II. CREDIT SCHEDULE DURATION

6. CREDIT SCHEDULE DURATION	Indicate the catchment credit schedule duration	7. DURATION RATIONALE	Briefly explain the rationale for the selected duration
☒ 5 YEARS ☐ 10 YEARS ☐ 15 YEARS ☐ OTHER (SPECIFY) ——YEARS		Explanation The HSC facilities deployed in DP01 are expected to function as designed for at least 20 years if adequatelty maintained. However, a shorter duraton of 5 years is being submitted based on potential changes in both private BMP implementation enforcement and road maintenance frequency and technology. Within 5 years, there may be enforcment and/or incentive programs deployed that could significantlt increase expected private BMP implementation, and road inspections may dictate changes to our road sweeping frequency and/or technology deployed. There may also be improvement in sand abrasive type and application techniques during the next five years that could result in a revision to this CCS.	

III. ESTABLISHMENT SUMMARY

8. ESTABLISHMENT DATE	Note the date that the CCS is submitted to the regulator	9. ESTABLISHMENT YEAR CREDIT POTENTIAL	Note the appropriate establishment year percentage and amount
Date		Percentage	Credit Amount
3/31/11		84%	13.6X10^16

10. FINAL YEAR OF CREDIT SCHEDULE	Note the appropriate final year of the credit schedule
Final Year	
3/31/21	

11. ADDITIONAL EXPECTED CCS AMOUNT AND DURATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the private property BMP implementation efforts in the catchment
☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO CCS AMOUNT AND DURATION SECTION	

CCS — CATCHMENT CREDIT SCHEDULE

SECTION A: CORRESPONDENCE & CATCHMENT CREDIT SCHEDULE SUMMARY

The Correspondence & Catchment Credit Schedule Summary section is completed incrementally throughout the process of establishing a Catchment Credit Schedule (CCS), as defined in Chapter 1 of the Lake Clarity Crediting Handbook (Handbook). Subsequent sections of this template prompt users to complete the corresponding summary items here in Section A.

I. GENERAL CATCHMENT INFORMATION SUMMARY

1. CATCHMENT STATUS

Check the appropriate status and add date of previous approval if applicable

- [x] NEW CATCHMENT
- [ ] REVISION
- [ ] EXTENSION

Date of previous approval:

2. CATCHMENT ID

Provide the unique catchment ID & common name

Catchment ID: WC-IC1

Common Catchment Name: Washoe County, Incline Creek #1

3. PRIMARY JURISDICTION

Identify the primary urban jurisdiction and primary point of contact within the urban jurisdiction

- [ ] CALTRANS
- [ ] CSLT
- [ ] DOUGLAS
- [ ] EL DORADO
- [ ] NDOT
- [ ] PLACER
- [x] WASHOE

Primary Contact: Kris Klein

Phone Number: 775-328-2046

E-mail Address: kklein@washoecounty.us

4. REGULATORY AGENCY

Identify the responsible regulatory agency and primary point of contact within the agency

- [ ] LRWQCB
- [x] NDEP

Primary Contact: Jason Kuchnicki

Phone Number: 775-687-9450

E-mail Address: jkuchnic@ndep.nv.gov

II. CATCHMENT CREDIT SCHEDULE SUMMARY

5. BASIC CATCHMENT POLLUTANT CONTROL STRATEGY NARRATIVE

In the space provided, describe the basic strategies employed to reduce pollutant loading within the catchment

Basic Narrative

Washoe County relies on mobile source control as the primary (essential) means to reduce fine sediment load.

The Fairway/Mill Creek EIP project was constructed after May 2004 and primarily installed conveyance enhancements, but also a Vortechnics vault and some enhanced infiltration features. The Vortechnics vault is considered an essential BMP.

This catchment is dominated by commercial land use (48%) with the Sierra Nevada College and Hyatt hotel parcels taking the majority of the commercial area. Washoe County disputes the default road risk because of the high traffic load on Country Club and Incline Way servicing the commercial properties. The baseline model was run with both the original and the perferred road risk resulting in a 2.5% increase FSP load. The perferred road risk was used for all PLRM model runs reported in this document.

6. EFFECTIVE LOAD REDUCTION ESTIMATE

Note the load reduction estimate amounts from Section F

Fine sediment particles (#)	Fine sediment mass (kg)	Total nitrogen (kg)	Total phosphorous (kg)
4.1x10E17	3704	37	16

7. CREDIT POTENTIAL AMOUNT

Note the credit amount

41 CREDITS

8. ESTABLISHMENT DATE

Note the catchment establishment date from Section F for final CCS only

Establishment Date:

9. FINAL YEAR

Note the final year of the CCS from Section F for final CCS only

Final Year:

III. COORDINATION CHECKLIST

10. SUBMITTED FOR VERIFICATION REVIEW

Note the date submitted and urban jurisdiction staff person (Step 1.3)

Date Submitted	Name of Staff Person

11. STATEMENT OF COMPLETENESS & APPROPRIATENESS

Representative from urban jurisdiction must certify the completeness of the CCS (Step 1.3)

I certify that the information contained in this Catchment Credit Schedule and the analyses related to this Catchment Credit Schedule are complete and appropriate.

Printed Name	Date

Signature

12. VERIFIED BY REGULATOR

Regulator must certify the verification step is complete (Step 1.4)

I certify that the Verification Step is complete.

Printed Name	Date

Signature

13. REGISTERED AND SUBMITTED FOR APPROVAL

Note the date that the catchment was registered in the Accounting and Tracking Database (Step 1.5)

Date

14. SUPPORTING MATERIALS CHECKLIST AND FILENAMES

Confirm each file is included in the digital submission and provide the filename and save date

Checklist	Filename	Save Date
☐ CCS FORM	WC-IC1_CCS	10 Jan 2011
☐ CCS MEMO (IF NECCESARY)	WC_IC1 MemoFinal.docx	
☐ CATCHMENT DELINEATION MAP FOR CATCHMENT 1		
☐ OVERALL CATCHMENT DELINEATION MAP		
☐ TREATMENT BMP INVENTORY MAP	WCI_WC_IC1_assets.pdf	
☐ TREATMENT BMP INVENTORY TABLE	TiiMS database	
☐ ROADS INVENTORY MAP		
☐ ROADS INVENTORY TABLE	Road Risk for IV.xlsx	
☐ ROADS MAINTENANCE MAP(S) (NOT REQUIRED)		
☐ BASELINE TREATMENT BMP INVENTORY TABLE	none	
☐ CATCHMENT REGISTRATION REPORT (FINAL ONLY)		
☐ PLRM PROJECT FILE (DIGITAL FILE ONLY)	WC_IC1_PLRM.zip	
☐ AS-BUILT DRAWINGS AND EQUIPMENT SPECIFICATIONS (DIGITAL FILES ONLY)		

SECTION B: CATCHMENT DELINEATION

Credits and load reductions are tracked for specific urban catchments. The same urban catchment area must be used in both baseline and expected loading estimates. In order to prevent double counting, no land area may be included in two urban catchments.

I. CATCHMENT CONNECTIVITY

1. CATCHMENT ID	Confirm the catchment ID and name	2. CATCHMENT DELINEATION MAP	Confirm the catchment delineation map is complete
☒ CATCHMENT ID IS PROPERLY LISTED IN A.1		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	
3. OVERALL URBAN JURISDICTION CATCHMENT MAP	Confirm the overall catchment delineation map is complete	**4. CATCHMENT HISTORY**	Note any previous catchments that included a portion of this catchment
☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		Previous Catchment Name	Establishment Date
5. CATCHMENT AREA	Provide the total catchment area	**6. CATCHMENT CONNECTIVITY**	Provide the percent connectivity that will be used to modify the load reduction estimate
Total Area (acres) 135 acres		Percent Connectivity ☒ 100% ☐ OTHER ___%	
		☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO CATCHMENT CONNECTIVITY SECTION	

SECTION C: IMPLEMENTATION PLAN SUMMARY

The Implementation Plan Summary defines the expected conditions for treatment BMPs, roads, private property BMPs, and other pollutant control strategies based on the urban jurisdiction's planned operations, maintenance and program implementation activities in the urban catchment. The Implementation Plan Summary may pull information from multiple sources and ideally relies upon one or more of the broader implementation plans used by the urban jurisdictions.

I. DEFINE LOAD REDUCTION STRATEGY

1. TREATMENT BMPS	Check the most appropriate description	2. ROAD OPERATIONS	Check the most appropriate description
☒ PRIMARY ☐ SECONDARY ☐ TERTIARY ☐ NONE		☒ PRIMARY ☐ SECONDARY ☐ TERTIARY ☐ NONE	
3. PRIVATE PARCEL BMPS	Check the most appropriate description	**4. OTHER POLLUTANT CONTROL STRATEGY**	Check the most appropriate description
☐ PRIMARY ☒ SECONDARY ☐ TERTIARY ☐ NONE		☐ PRIMARY ☐ SECONDARY ☐ TERTIARY ☒ NONE	

II. TREATMENT BMP IMPLEMENTATION SUMMARY

5. TREATMENT BMP INVENTORY TABLE	Confirm the table is complete	6. TREATMENT BMP INVENTORY MAP	Confirm the map is complete
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	

7. TREATMENT BMP MAINTENANCE PLAN SUMMARY	In the space provided, summarize planned treatment BMP maintenance actions for the overall catchment (reference implementation planning documents if applicable)

The maintenance practice in Washoe County is inspect twice annually and after major storms and to perform maintenance if based on historical experience.

8. TREATMENT BMP INSPECTION PLAN SUMMARY	In the space provided, summarize planned treatment BMP inspection actions for the overall catchment (reference implementation planning documents if applicable)

inspect twice annually and after major storms.

9. ADDITIONAL TREATMENT BMP IMPLEMENTATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the treatment BMPs within the catchment
☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO TREATEMENT BMP IMPLEMENTATION SUMMARY SECTION	

III. ROADS OPERATION IMPLEMENTATION SUMMARY

10. ROAD INVENTORY TABLE	Confirm the table is complete	11. ROADS INVENTORY MAP	Confirm the map is complete
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	

12. ROADS MAINTENANCE PLAN SUMMARY	In the space provided, summarize planned road maintenance actions for the overall catchment (reference implementation planning documents if applicable)

During the winter, roads are swept as soon as they are dry with a dustless sweeper.

During the summer, roads are swept every six weeks.

Traction control material is applied with a computer control application system and is only at intersections and known problem areas.

Brine is used when appropriate.

13. ROADS MAINTENANCE MAP(S)	Confirm road maintenance maps
☐ ROAD MAINTENANCE MAPS ARE PROPERLY IN A.17 (NOT REQUIRED)	

14. ROADS INSPECTION PLAN SUMMARY	In the space provided, summarize planned road inspection actions for the overall catchment (reference implementation planning documents if applicable)

Inspections are not generally required because streets are swept as soon as possible in the winter.

Road RAM will be used as appropriate when sufficient manpower is available.

15. ADDITIONAL ROAD IMPLEMENTATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the roads within the catchment
☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO ROADS IMPLEMENTATION SUMMARY SECTION	

IV. PRIVATE PROPERTY BMP IMPLEMENTAION SUMMARY

16. PRIVATE PROPERTY BMP INVENTORY

In the space provided, note the total number of developed single-family residential (SFR) parcels and the number of SFR parcels with BMP and source control certificates. Also, note the total area of multi-family residential (MFR) and commercial properties (CICU) and the area with BMP and source control certificates. Provide the percentage area with BMP and source control certificates that should be used as the expected value.

Total Area of SFR (acres)	Total # of SFR	Total # of SFR w/ BMP Cert.	Total % of SFR w/BMP Cert.	Total # of SFR w/ SC Cert.	Total % of SFR w/ SC Cert.
23	46	27	41%	0	0%

Total area of MFR (acres)	Area of MFR with BMP Certificates (acres)	Total Area of CICU (acres)	Area of CICU with BMP Certificates (acres)
30	0	65	2.4

Expected percentage of area with BMP certificates	Expected percentage of area with source control certificates
10%	0%

17. URBAN JURISDICTION PRIVATE PROPERTY BMP PROGRAM SUMMARY

In the space provided, describe any planned variations from the general private property BMP program for this urban catchment (reference implementation planning documents if applicable)

Incline Village is a leader in certificates for single family residential parcels. But clearly much has to be accomplished for multi family and commercial properties.

The impervious area for CICU is much lower (30%) than the 70% defaul in the model. The other impervious percentages for SFR and MFR are similar to the defaul values.

18. PRIVATE PROPTERY BMP INSPECTION PLAN SUMMARY

In the space provided, identify the data sources supporting these private property BMP calculations (reference implementation planning documents if applicable)

none

19. ADDITIONAL PRIVATE PROPERTY BMP INFORMATION

Indicate whether additional information is provided in the CCS memo to adequately describe the private property BMP implementation efforts in the catchment

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO PRIVATE PROPERTY BMP IMPLEMENTATION SUMMARY SECTION

V. OTHER POLLUTANT CONTROL STRATEGIES IMPLEMENTATION SUMMARY

20. OTHER POLLUTANT CONTROL PROGRAM SUMMARY

If other pollutant control strategies are implemented in the urban catchment, indicate that they are described in the CCS memo

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO OTHER POLLUTANT CONTROL STRATEGIES SECTION

SECTION D: EXPECTED LOADING ESTIMATE

The expected loading estimate reflects annual average loading assuming treatment BMPs, roads, private property BMPs and other pollutant controls are maintained and operated to achieve the expected conditions defined in the Implementation Plan Summary.

I. EXPECTED LOADING ESTIMATE

1. LOAD ESTIMATION METHOD	Select the method used to estimate the expected and baseline loading for the catchment
☒ POLLUTANT LOAD REDUCTION MODEL (PLRM) V1.0 ☐ OTHER (DESCRIPTION IS INCLUDED IN CCS MEMO)	Name and version (If you selected Other) PLRM 1.1
2. EXPECTED LOADING PARAMETERS, ASSUMPTIONS & DATASETS	Check yes if any parameter values, assumptions or datasets used deviate from default values or recommendations
☒ YES ☐ NO (only defaults used)	☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO LOAD ESTIMATION APPROACH AND ASSUMPTIONS SECTION

If Yes, please explain

1. We modeled an exceptional performance of the water quality treatment vault that is not representative of known performance parameters, but until told otherwise, we're sticking with the default CECs.

2. Washoe County has worked with NHC to change the default road risk for this catchment and all of Washoe County in the Tahoe Basin (see the attached spreadsheet). The pollutant load reduction was modeled using the updated road risk for the baseline and the 2010 conditions.

3. Out of range values were used for the Veg 3 landuse. This landuse is a sports field with a french drain system under the entire field which drains the field and adjacent parking lot to a wet basin. As a result, rain storage was increased to 0.5 inches and DCIA was decreased to zero.

3. EXPECTED LOADING PROJECT FILE	Confirm that the expected loading estimate scenario is included	4. EXPECTED LOAD	Provide the expected loads for fine sediment, nitrogen and phosphorus
☒ THE EXPECTED LOADING ESTIMATE SCENARIO IS INCLUDED IN THE LOAD ESTIMATION PROJECT FILE AND IS LISTED IN A.17		Fine sediment mass (kg) 1524	Fine sediment particles (#) 1.7x10E17
		Total nitrogen (kg) 45	Total phosphorus (kg) 5.8

SECTION E: BASELINE LOADING ESTIMATE

The urban catchment baseline loading estimate sets the reference point for determining load reductions.

I. BASELINE LOADING ESTIMATE

1. BASELINE INVENTORY TABLE	Confirm baseline inventory table	2. BASELINE INFRASTRUCTURE MAP	Confirm baseline infrastructure map
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	
3. CHANGES SINCE 2004		Summarize any changes to treatment BMPs since 2004	

Incline Village Tourist/Fairway WQIP Phase II was a $1.8M project completed in July 2006

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO BASELINE CONDITIONS SECTION

4. BASELINE LOADING PARAMETERS, ASSUMPTIONS & DATASETS	Indicate if any parameter values, assumptions or datasets used deviate from default values or recommendations
☒ YES ☐ NO	☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO BASELINE CONDITIONS SECTION

If Yes, please explain

1. Washoe County has worked with NHC to change the default road risk for this catchment and all of Washoe County in the Tahoe Basin (see the attached spreadsheet). The pollutant load reduction was modeled using the updated road risk for the baseline and the 2010 conditions.

2. Out of range values were used for the Veg 3 landuse. This landuse is a sports field with a french drain system under the entire field which drains the field and adjacent parking lot to a wet basin. As a result, rain storage was increased to 0.5 inches and DCIA was decreased to zero.

5. BASELINE LOAD ESTIMATE		Provide the baseline loads for fine sediment, nitrogen and phosphorus	
Fine sediment mass (kg) **5227**	Fine sediment particles (#) **5.8x10E17**	Total nitrogen (kg) **82**	Total phosphorus (kg) **22**

SECTION F: CATCHMENT CREDIT SCHEDULE AMOUNT & DURATION

The final determination of the appropriate CCS credit potential amount and duration is made by the regulator in consultation with the urban jurisdiction. The urban jurisdiction proposes the CCS credit potential amount based on the load reduction estimate, and the duration based on the primary and secondary pollutant control strategies.

I. LOAD REDUCTION ESTIMATE & CATCHMENT CREDIT SCHEDULE AMOUNT

1. LOAD REDUCTION ESTIMATE		Note the load reduction estimate amounts	
Fine sediment mass (kg)	Total phosphorus (kg)	Total nitrogen (kg)	
3704	16	37	

2. FINE SEDIMENT PARTICLE NUMBER CONVERSION	Using Equation 0.3, convert the fine sediment mass to number of fine sediment particles	3. CATCHMENT CONNECTIVITY	From item B.5
Fine sediment particles (#)		Percent Connectivity	
4.1x10E17		100 %	

4. EFFECTIVE LOAD REDUCTION ESTIMATE		Multiply the vaues in items F.1 and F.2 by F.3	
Fine sediment mass (kg)	Fine sediment particles (#)	Total phosphorous (kg)	Total nitrogen (kg)
3704	4.1x10E17	16	37

5. CREDIT AMOUNT CALCULATION	Using equation 0.2 calculate the credit amount

41 CREDITS

II. CREDIT SCHEDULE DURATION

6. CREDIT SCHEDULE DURATION	Indicate the catchment credit schedule duration	7. DURATION RATIONALE	Briefly explain the rationale for the selected duration
☒ 5 YEARS ☐ 10 YEARS ☐ 15 YEARS ☐ OTHER (SPECIFY) ____YEARS		Explanation sweeper technology and default database values will likely change in 5 years and the modeled results should be revisited.	

III. ESTABLISHMENT SUMMARY

8. ESTABLISHMENT DATE	Note the date that the CCS is submitted to the regulator	9. ESTABLISHMENT YEAR CREDIT POTENTIAL	Note the appropriate establishment year percentage and amount
Date		Percentage %	Credit Amount

10. FINAL YEAR OF CREDIT SCHEDULE	Note the appropriate final year of the credit schedule
Final Year	

11. ADDITIONAL EXPECTED CCS AMOUNT AND DURATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the private property BMP implementation efforts in the catchment
☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO CCS AMOUNT AND DURATION SECTION	

Pollutant Load Reduction Model (PLRM)
Caltrans Test Catchment Analysis
Lake Tahoe

DATE: April 22, 2010

This memo contains a description of the Pollutant Load Reduction Model (PLRM) test catchment chosen by Caltrans and the selection process that was implemented. Caltrans selected a portion of State Highway Route 28 in Placer County at Kings Beach as the test catchment. The catchment includes 0.8 miles of roadway and includes eight sub-catchment areas that drain to separate sand vault and biofiltration swale facilities and have separate outfalls. The drainage plans (provided as an attachment) shows the sub-catchments and best management practices (BMPs) that were constructed as part of the project.

Criteria Used

Caltrans selected this portion of State Highway Route 28 because the area is typical of other Caltrans highway facilities in the region. It includes numerous small sub-catchment areas that drain to different BMPs. The sub-catchments range in size from 0.04 acres to 1.0 acres. In addition, detailed plans exist that clearly show the drainage for the area and the BMPs that were constructed and what areas these BMPs treat.

Map and Description

The selected test catchment area project location grids (Grid Nos. 600 and 601) and the drainage area map are attached to this memorandum. The catchment lies on the north-west side of Lake Tahoe and includes the portion of Route 28 east of Chipmunk Street to the California-Nevada border. The highway improvement project has eight distinct tributary drainage areas treated by seven sand vaults (treatment vaults) and two biofiltration swales.

The assumptions used in the development of this test catchment model simulation include:

- Default values for drainage design.
- PLRM manual suggestions for road shoulder conditions.
- Default values for sweeping effectiveness.

Default values for characteristic runoff concentrations for primary roads; however, these may differ from Caltrans discharge concentrations.
Run-on flows from offsite (upstream of Caltrans roadway) were not considered.

Additional Rationale

The project selected is typical of Caltrans roadway projects incorporating treatment BMPs within the Tahoe Basin. The project selected has been completed, and treatment BMPs are operational. Test catchment focused on the Caltrans roadway prism (edge of right-of-way to edge of right-of-way only).

Catchments Considered
The selected project catchment considered for testing is along 0.8 miles of SR 28. For a linear roadway project with multiple outfalls, the project drainage boundaries can be considered eight distinct catchment areas with separate treatment BMPs and separate outfalls.

Available Information
The information for the catchment includes:
- Project as-builts for the roadway improvement with drainage features, outfalls, and BMP locations;
- Drainage areas for the sub-catchments;
- Topographic data, and
- Types and descriptions for Caltrans BMPs in the region.

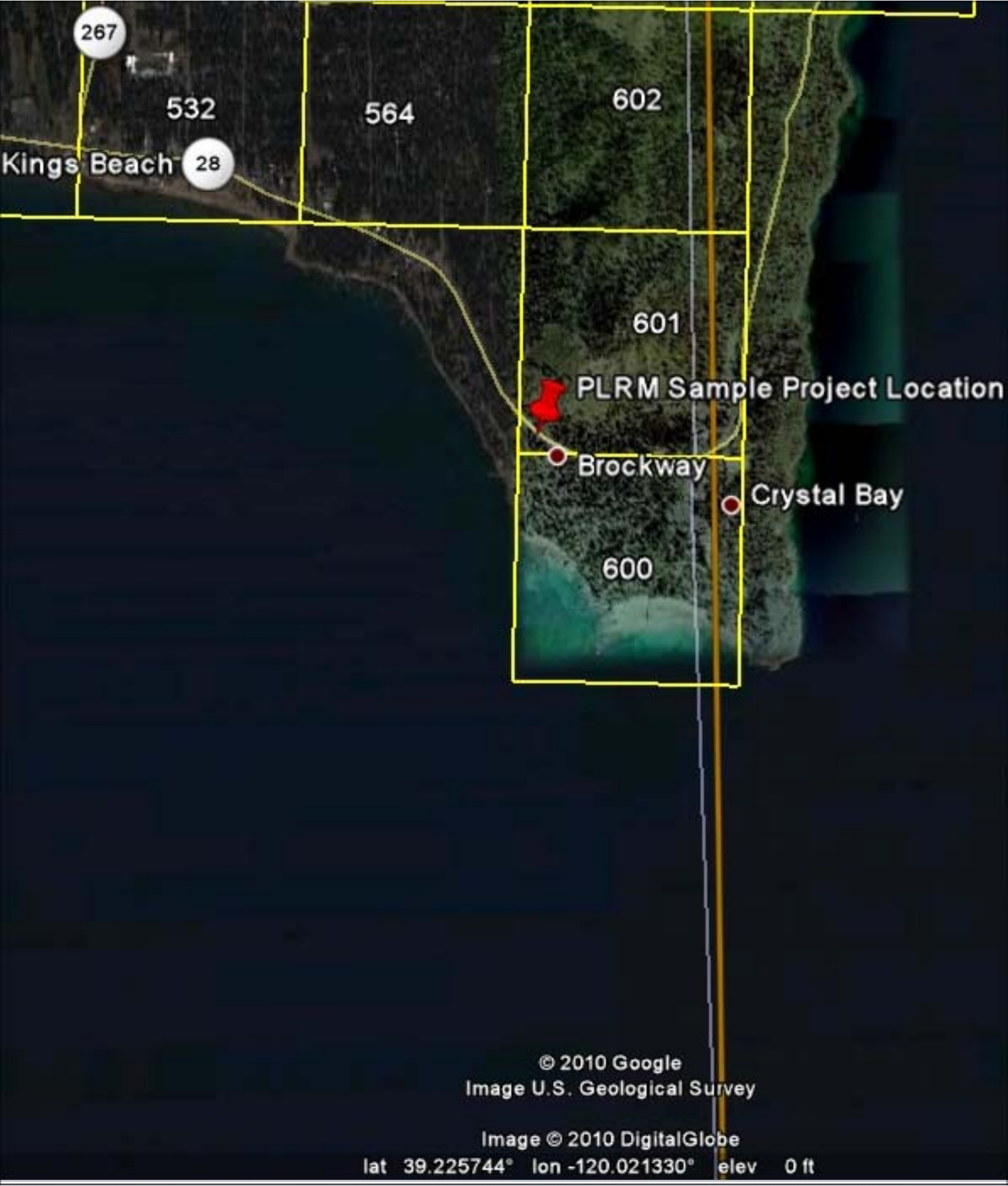
Lessons Learned
During development of the PLRM simulation for this catchment area, Caltrans developed a list of concerns with regard to how the model represents Caltrans highway facilities.

1. The model development process takes approximately one hour per outfall for small drainage areas (includes collection of data, as-builts review, drainage area delineation, data input to PLRM, and model run). A combined model for multiple outfalls was attempted; however, because model processing took several hours, separate models for each outfall/catchment area were created instead.
2. PLRM currently does not allow for revisions to Caltrans-specific characterization data (some of the default values do not apply to Caltrans).
3. PLRM Will need to allow for additional BMP types (Caltrans has nine approved BMP devices), including:
    - Dry Basin (yes, applicable to Caltrans)
    - Wet Basin (yes, applicable to Caltrans)
    - Infiltration Basin (yes, applicable top Caltrans)
    - Filter Bed (assumed same as a media filter or multi-chambered treatment train [MCTT])
    - Cartridge Filter (not applicable to Caltrans)
    - Treatment Vault (assumed same as Caltrans traction sand trap)

    Comment: need to allow for biofiltration strips/swales (vegetated treatment)
4. Caltrans has multiple outfalls for roadway projects, which will be tedious for the 68 miles of Caltrans highway facilities in the watershed (the 0.8 miles of roadway used in this test catchment included eight distinct outfalls with multiple BMPs)
5. The model only allows acreage to be inserted for down to a 0.1 level of precision. For values with acreage levels of 0.01 or more, steps 2 and 4 of the model are showing erroneous values.
6. The model does not handle catchments less than 0.1 acres in size, and Caltrans has many drainage areas that are smaller than 0.1 acres.
7. BMP performance default values need adjustment; Caltrans will need the flexibility to use Caltrans-specific BMP testing data, especially for BMPs in the Caltrans approved list that are not included in the PLRM default BMP types.
8. The model is simple to use. However, with numerous outfalls associated with a linear roadway prism along 68 miles, its use for establishing baseline and load reduction

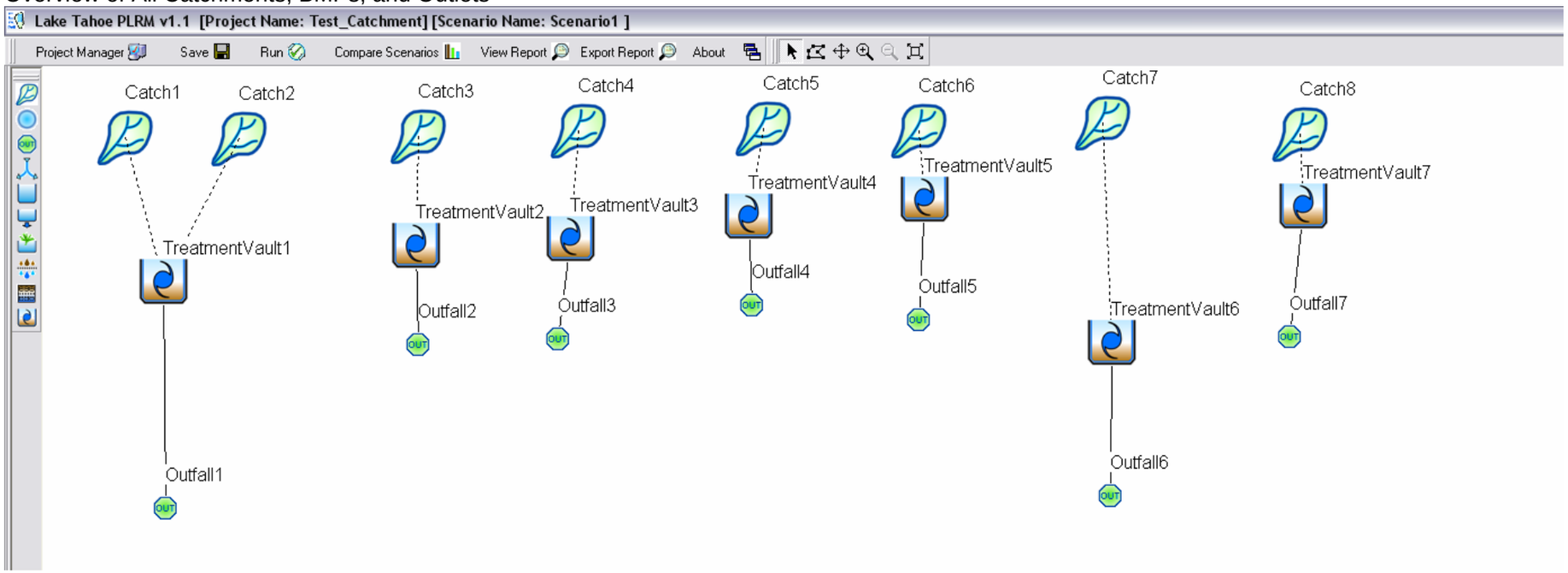
estimation would require development of several hundred models (likely one for each outfall or catchment area with treatment BMPs for pollutant reduction credits).

9. Run-on flows to the Caltrans right-of-way is likely, especially in areas along national forest land (non-urban upland areas), and modeling for Caltrans baseline and pollutant reduction will need to be further evaluated.
10. PLRM provides a baseline estimate and pollutant reduction estimate only for each catchment area. An overall assessment of Caltrans loads would likely need to be estimated as a cumulative (total) of all catchments or by other methods.

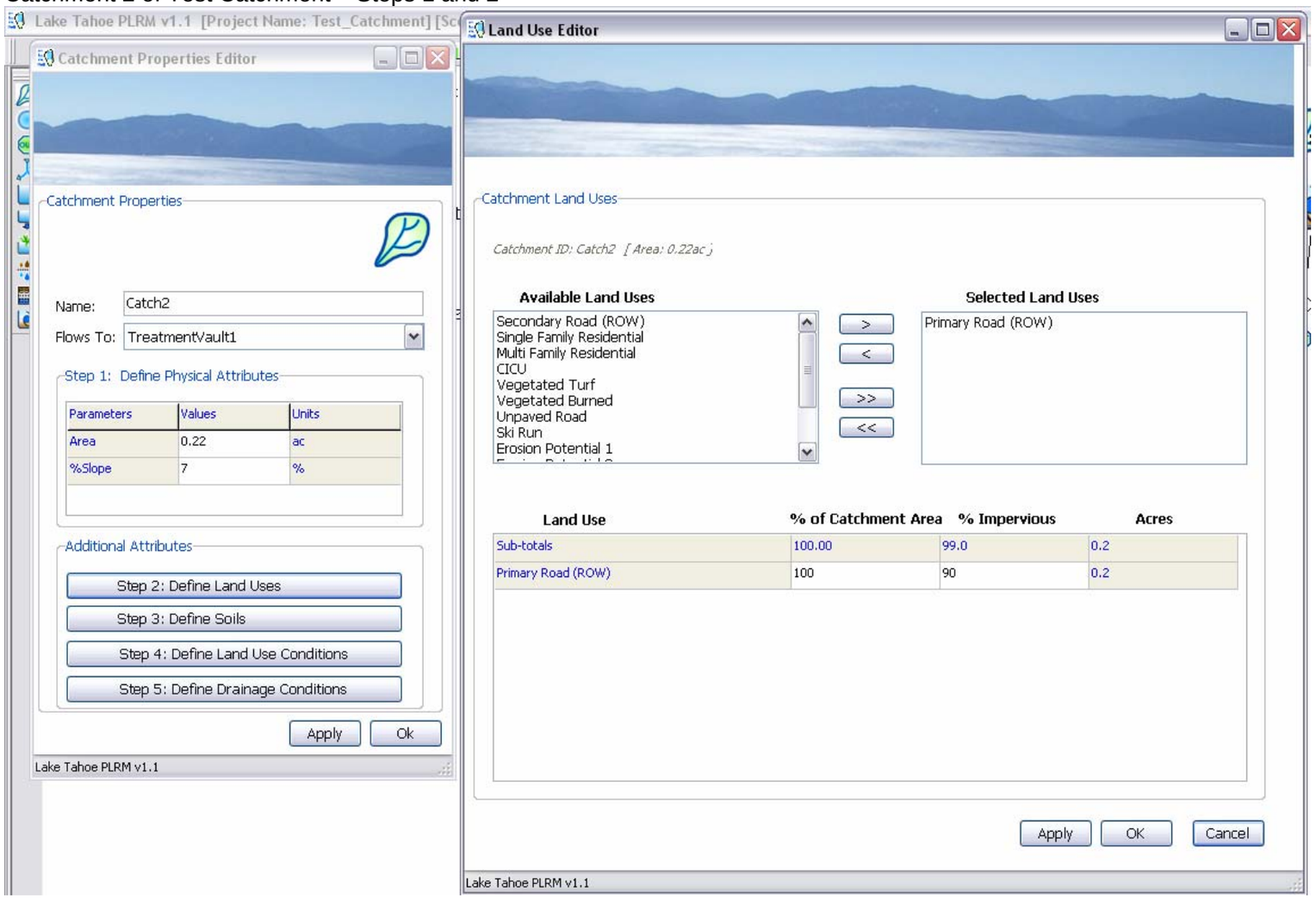

267
532
564
602
Kings Beach
28
601
PLRM Sample Project Location
Brockway
Crystal Bay
600
© 2010 Google
Image U.S. Geological Survey
Image © 2010 DigitalGlobe
lat 39.225744° lon -120.021330° elev 0 ft

Test Catchment for the PLRM Model

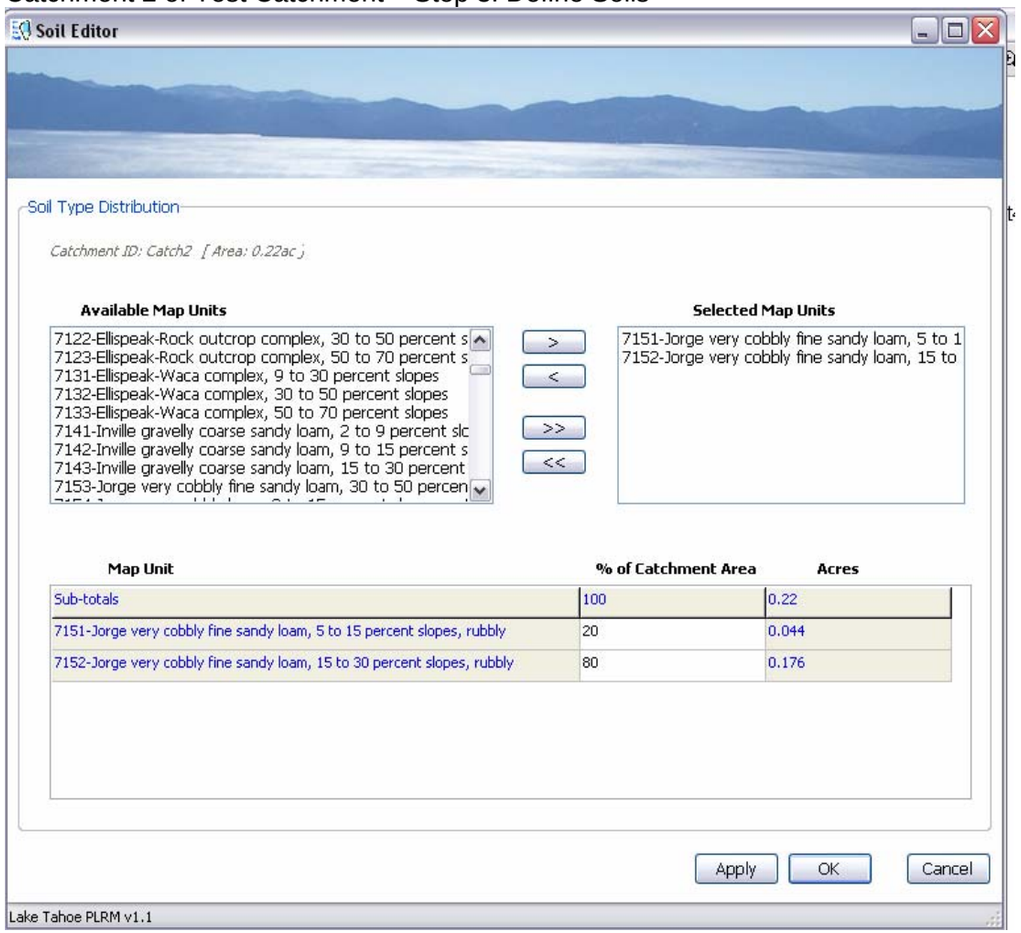
Overview of All Catchments, BMPs, and Outlets



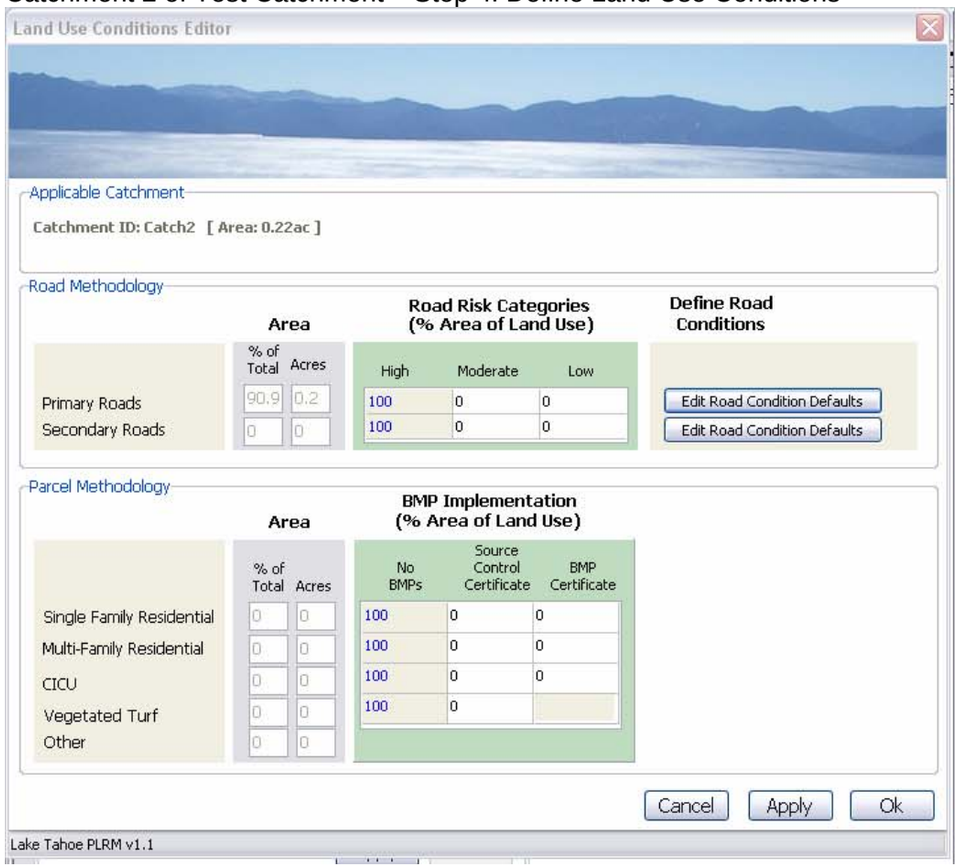
Catchment 2 of Test Catchment – Steps 1 and 2



Catchment 2 of Test Catchment – Step 3: Define Soils



Catchment 2 of Test Catchment – Step 4: Define Land Use Conditions



Land Use Conditions Editor

Applicable Catchment

Catchment ID: Catch2 [Area: 0.22ac]

Road Methodology

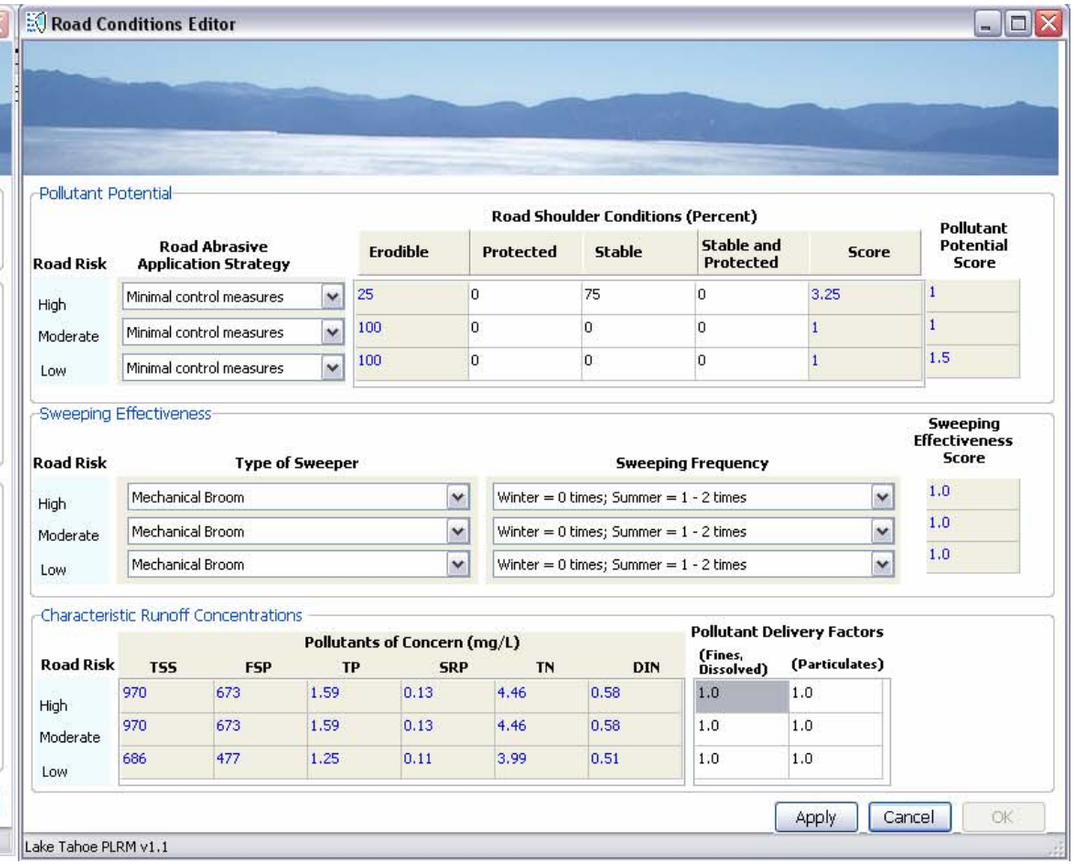
	Area		Road Risk Categories (% Area of Land Use)			Define Road Conditions
	% of Total	Acres	High	Moderate	Low	
Primary Roads	90.9	0.2	100	0	0	Edit Road Condition Defaults
Secondary Roads	0	0	100	0	0	Edit Road Condition Defaults

Parcel Methodology

	Area		BMP Implementation (% Area of Land Use)		
	% of Total	Acres	No BMPs	Source Control Certificate	BMP Certificate
Single Family Residential	0	0	100	0	0
Multi-Family Residential	0	0	100	0	0
CICU	0	0	100	0	0
Vegetated Turf	0	0	100	0	
Other	0	0			

Cancel Apply Ok

Lake Tahoe PLRM v1.1



Road Conditions Editor

Pollutant Potential

Road Risk	Road Abrasive Application Strategy	Road Shoulder Conditions (Percent) Erodible	Protected	Stable	Stable and Protected	Score	Pollutant Potential Score
High	Minimal control measures	25	0	75	0	3.25	1
Moderate	Minimal control measures	100	0	0	0	1	1
Low	Minimal control measures	100	0	0	0	1	1.5

Sweeping Effectiveness

Road Risk	Type of Sweeper	Sweeping Frequency	Sweeping Effectiveness Score
High	Mechanical Broom	Winter = 0 times; Summer = 1 - 2 times	1.0
Moderate	Mechanical Broom	Winter = 0 times; Summer = 1 - 2 times	1.0
Low	Mechanical Broom	Winter = 0 times; Summer = 1 - 2 times	1.0

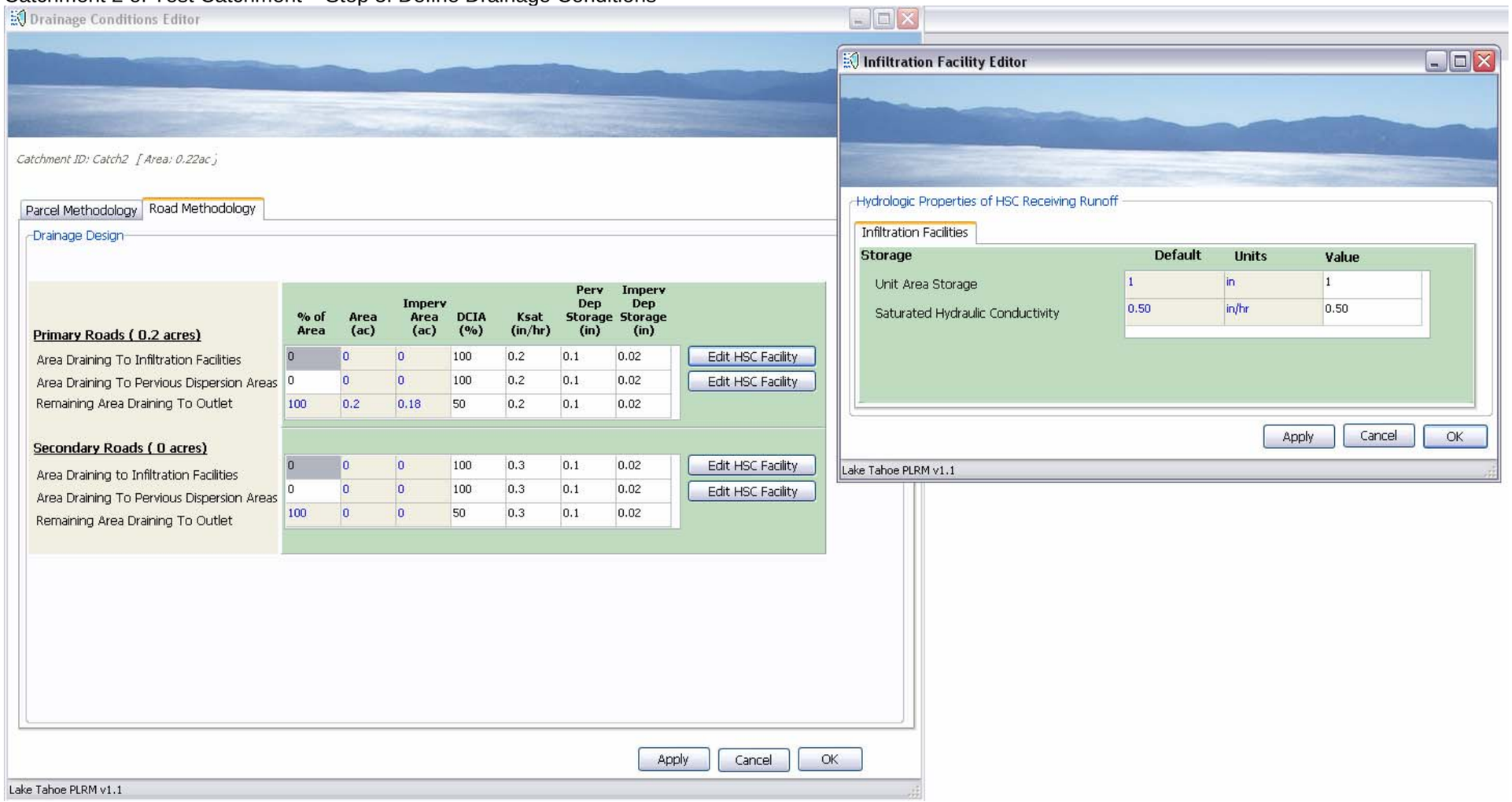
Characteristic Runoff Concentrations

Road Risk	Pollutants of Concern (mg/L) TSS	FSP	TP	SRP	TN	DIN	Pollutant Delivery Factors (Fines, Dissolved)	(Particulates)
High	970	673	1.59	0.13	4.46	0.58	1.0	1.0
Moderate	970	673	1.59	0.13	4.46	0.58	1.0	1.0
Low	686	477	1.25	0.11	3.99	0.51	1.0	1.0

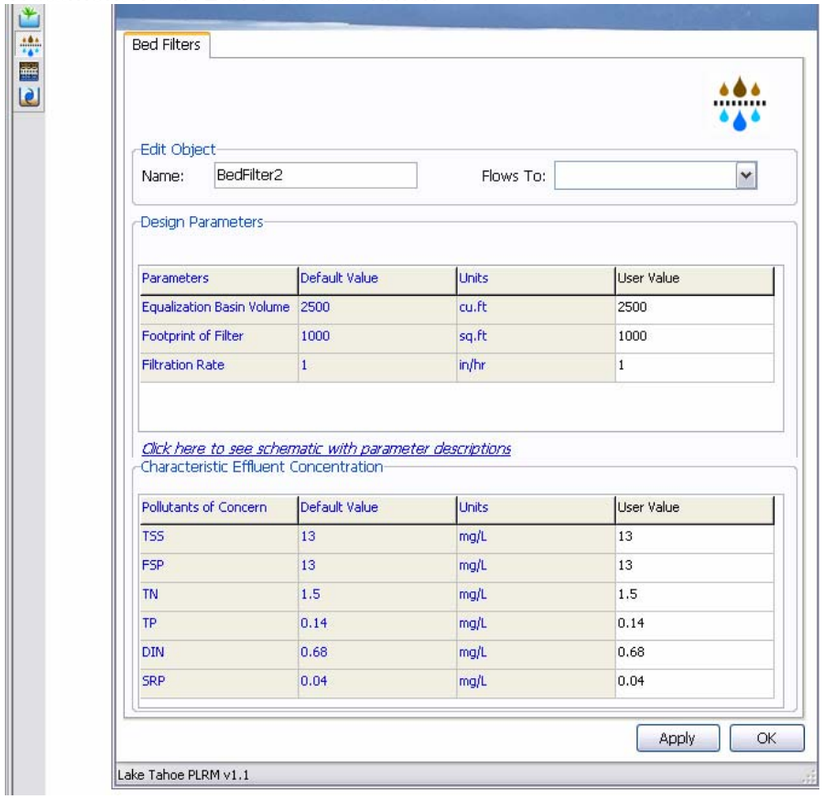
Apply Cancel OK

Lake Tahoe PLRM v1.1

Catchment 2 of Test Catchment – Step 5: Define Drainage Conditions



Treatment Vault 1 of Test Catchment



Bed Filters

Edit Object

Name: BedFilter2

Flows To:

Design Parameters

Parameters	Default Value	Units	User Value
Equalization Basin Volume	2500	cu.ft	2500
Footprint of Filter	1000	sq.ft	1000
Filtration Rate	1	in/hr	1

Click here to see schematic with parameter descriptions

Characteristic Effluent Concentration

Pollutants of Concern	Default Value	Units	User Value
TSS	13	mg/L	13
FSP	13	mg/L	13
TN	1.5	mg/L	1.5
TP	0.14	mg/L	0.14
DIN	0.68	mg/L	0.68
SRP	0.04	mg/L	0.04

Apply OK

Lake Tahoe PLRM v1.1

CCS — CATCHMENT CREDIT SCHEDULE

SECTION A: CORRESPONDENCE & CATCHMENT CREDIT SCHEDULE SUMMARY

The Correspondence & Catchment Credit Schedule Summary section is completed incrementally throughout the process of establishing a Catchment Credit Schedule (CCS), as defined in Chapter 1 of the Lake Clarity Crediting Handbook (Handbook). Subsequent sections of this template prompt users to complete the corresponding summary items here in Section A.

I. GENERAL CATCHMENT INFORMATION SUMMARY

1. CATCHMENT STATUS

Check the appropriate status and add date of previous approval if applicable

- ☒ NEW CATCHMENT
- ☐ REVISION
- ☐ EXTENSION

Date of previous approval:

2. CATCHMENT ID

Provide the unique catchment ID & common name

Catchment ID: DC_KUC_01

Common Catchment Name: Lower Kahle Urban Catchment

3. PRIMARY JURISDICTION

Identify the primary urban jurisdiction and primary point of contact within the urban jurisdiction

- ☐ CALTRANS
- ☐ CSLT
- ☒ DOUGLAS
- ☐ EL DORADO
- ☐ NDOT
- ☐ PLACER
- ☐ WASHOE

Primary Contact: Mahmood Azad, County Engineer

Phone Number: (775) 782-9063

E-mail Address: MAzad@co.douglas.nv.us

4. REGULATORY AGENCY

Identify the responsible regulatory agency and primary point of contact within the agency

- ☐ LRWQCB
- ☒ NDEP

Primary Contact: Jason Kuchnicki

Phone Number: (775) 687-9444

E-mail Address: jkuchnic@ndep.nv.gov

II. CATCHMENT CREDIT SCHEDULE SUMMARY

5. BASIC CATCHMENT POLLUTANT CONTROL STRATEGY NARRATIVE

In the space provided, describe the basic strategies employed to reduce pollutant loading within the catchment

Basic Narrative

A number of treatment BMPs have been installed in the catchment, including numerous sediment traps and drop inlets for sediment removal, vortex separator treatment vaults, sand/oil separators, and a large wet basin. Runoff from all roads and parcels flows directly to the drop inlets, which flow first to the vortechnic unit and a sand/oil separator, and then into the large wet basin for flow volume reduction and decreased effluent concentration. An additional control strategy has been to install immovable barriers along the north side of Kahle Drive to prevent off-road parking of vehicles on the adjacent Forest Service land. This will decrease the amount of sediment that is introduced from these vehicles due to the off-site parking onto Kahle Drive.

6. EFFECTIVE LOAD REDUCTION ESTIMATE

Note the load reduction estimate amounts from Section F

Fine sediment particles (#)	Fine sediment mass (kg)	Total nitrogen (kg)	Total phosphorous (kg)
10 * 10^16	933	16.15	14.55

7. CREDIT POTENTIAL AMOUNT

Note the credit amount

10 CREDITS

8. ESTABLISHMENT DATE

Note the catchment establishment date from Section F for final CCS only

Establishment Date: 1/31/11

9. FINAL YEAR

Note the final year of the CCS from Section F for final CCS only

Final Year: 2015

III. COORDINATION CHECKLIST

10. SUBMITTED FOR VERIFICATION REVIEW	Note the date submitted and urban jurisdiction staff person (Step 1.3)
Date Submitted December 7, 2010	Name of Staff Person Jason Kuchnicki

11. STATEMENT OF COMPLETENESS & APPROPRIATENESS	Representative from urban jurisdiction must certify the completeness of the CCS (Step 1.3)

I certify that the information contained in this Catchment Credit Schedule and the analyses related to this Catchment Credit Schedule are complete and appropriate.

Printed Name	Date
Mahmood Azad	12/7/10

Signature

12. VERIFIED BY REGULATOR	Regulator must certify the verification step is complete (Step 1.4)

I certify that the Verification Step is complete.

Printed Name	Date
Jason Kuchnicki	

Signature

13. REGISTERED AND SUBMITTED FOR APPROVAL	Note the date that the catchment was registered in the Accounting and Tracking Database (Step 1.5)
Date 2/17/11	

14. SUPPORTING MATERIALS CHECKLIST AND FILENAMES	Confirm each file is included in the digital submission and provide the filename and save date	
Checklist	Filename	Save Date
☒ CCS FORM	CCS FORM	2/16/11
☒ CCS MEMO (IF NECCESARY)	CCS MEMO	2/16/11
☒ CATCHMENT DELINEATION MAP FOR CATCHMENT 1	CATCHMENT DELINEATION MAP	2/16/11
☐ OVERALL CATCHMENT DELINEATION MAP		
☒ TREATMENT BMP INVENTORY MAP	TREATMENT BMP INVENTORY MAP	2/16/11
☒ TREATMENT BMP INVENTORY TABLE	TREATMENT BMP INVENTORY TABLE	2/16/11
☒ ROADS INVENTORY MAP	ROADS INVENTORY MAP	2/16/11
☒ ROADS INVENTORY TABLE	ROADS INVENTORY TABLE	2/16/11
☐ ROADS MAINTENANCE MAP(S) (NOT REQUIRED)		
☒ BASELINE TREATMENT BMP INVENTORY TABLE	BASELINE TREATMENT BMP INVENTORY TABLE	2/16/11
☐ CATCHMENT REGISTRATION REPORT (FINAL ONLY)		
☒ PLRM PROJECT FILE (DIGITAL FILE ONLY)	Project 1 (Baseline Conditions) Project 2 (Expected Conditions)	1/17/11
☒ AS-BUILT DRAWINGS AND EQUIPMENT SPECIFICATIONS (DIGITAL FILES ONLY)	DC_KUC_01 Wet Basin WB_01 Design Drawings	2/16/11

SECTION B: CATCHMENT DELINEATION

Credits and load reductions are tracked for specific urban catchments. The same urban catchment area must be used in both baseline and expected loading estimates. In order to prevent double counting, no land area may be included in two urban catchments.

I. CATCHMENT CONNECTIVITY

1. CATCHMENT ID	Confirm the catchment ID and name	2. CATCHMENT DELINEATION MAP	Confirm the catchment delineation map is complete
☒ CATCHMENT ID IS PROPERLY LISTED IN A.1		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	
3. OVERALL URBAN JURISDICTION CATCHMENT MAP	Confirm the overall catchment delineation map is complete	**4. CATCHMENT HISTORY**	Note any previous catchments that included a portion of this catchment
☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		Previous Catchment Name	Establishment Date
5. CATCHMENT AREA	Provide the total catchment area	**6. CATCHMENT CONNECTIVITY**	Provide the percent connectivity that will be used to modify the load reduction estimate
Total Area (acres) 73.31 acres (Figure 1)		Percent Connectivity ☐ 100% ☒ OTHER 75%	
		☒ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO CATCHMENT CONNECTIVITY SECTION	

SECTION C: IMPLEMENTATION PLAN SUMMARY

The Implementation Plan Summary defines the expected conditions for treatment BMPs, roads, private property BMPs, and other pollutant control strategies based on the urban jurisdiction's planned operations, maintenance and program implementation activities in the urban catchment. The Implementation Plan Summary may pull information from multiple sources and ideally relies upon one or more of the broader implementation plans used by the urban jurisdictions.

I. DEFINE LOAD REDUCTION STRATEGY

1. TREATMENT BMPS	Check the most appropriate description	2. ROAD OPERATIONS	Check the most appropriate description
☒ PRIMARY ☐ SECONDARY ☐ TERTIARY ☐ NONE		☐ PRIMARY ☐ SECONDARY ☐ TERTIARY ☒ NONE	
3. PRIVATE PARCEL BMPS	Check the most appropriate description	**4. OTHER POLLUTANT CONTROL STRATEGY**	Check the most appropriate description
☐ PRIMARY ☒ SECONDARY ☐ TERTIARY ☐ NONE		☐ PRIMARY ☐ SECONDARY ☒ TERTIARY ☐ NONE	

II. TREATMENT BMP IMPLEMENTATION SUMMARY

5. TREATMENT BMP INVENTORY TABLE	Confirm the table is complete	6. TREATMENT BMP INVENTORY MAP	Confirm the map is complete
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	

7. TREATMENT BMP MAINTENANCE PLAN SUMMARY — In the space provided, summarize planned treatment BMP maintenance actions for the overall catchment (reference implementation planning documents if applicable)

The most important BMPs in the KUC catchment include a wet basin and two Vortechnics treatment vaults. These will be maintained at near or better-than-expected conditions according to BMP RAM protocols. Maintenance activities will be conducted by and coordinated between Douglas County roads maintenance staff and Oliver Park General Improvement District (GID) personnel, who have been trained on the BMP RAM protocols and other maintenance procedures.

The essential feature of this catchment is the wet basin which was designed to require little maintenance, with sediment removal not normally constituting a major activity on an annual basis. Unless dictated otherwise by BMP RAM field observations, every 5-7 years sediment should be removed from the basin forebay and the forebay shall be regraded. Approximately every 15-20 years, accumulated sediment should be removed from the wet basin itself.

The key features in this catchment are two Vortechnics treatment vaults, which will require a minimum of annual removal of accumulated material with an eductor truck, and cleaning of the inlet, all chambers, and the outlet, unless BMP RAM field observations dictate otherwise.

References:

* See attached Table 1 - Treatment BMP Inventory Table, and Figure 2 - Treatment BMP Map.
* See Attachment 2, CASQA Fact Sheet TC-20, Wet Ponds, and Attachment 3, CASQA Fact Sheet MP-51, Vortex Separator for more information.

8. TREATMENT BMP INSPECTION PLAN SUMMARY — In the space provided, summarize planned treatment BMP inspection actions for the overall catchment (reference implementation planning documents if applicable)

Inspection of the Key and Essential Treatment BMPs will be conducted by following the BMP RAM protocols for condition assessment. Inspections will be conducted by and coordinated between Douglas County maintenance staff and Oliver Park GID personnel who will be trained in the use of the protocols and condition assessments for the applicable BMPs. The BMP RAM Field Observation Datasheets for each BMP will be used to document the inspection process and record observations.

The essential treatment BMP, the Wet Basin (WB_01) will require semiannual/annual inspections for burrows, sediment accumulation, structural integrity of the outfall, vegetation cover, and litter accumulation. Inspection staff will use the applicable BMP RAM Field Observation Datasheet detailing the location and type of measurement collected for the wet basin. Primary inspection points according to the datasheet are type and percent of vegetation cover, and depth of sediment accumulation as measured at the installed staff gauge. Inspections will be completed in the late spring and early fall, in order to ensure maximum capacities prior to the winter and prior to the summer.

The key treatment BMPs are the vortechnic treatment vaults, which should be inspected after storm events to check for accumulated sediment and debris. These units are considered "key" due to their intent of achiveing a significant load reduction from their function; the vault located upstream of the wet basin removes a significant portion of sediment that would otherwise enter the wet basin and cause sediment accumulation in the wet basin that would decrease it's capacity. The applicable BMP RAM Field Observation Datasheet will be used to document the inspection process and record observations collected at the treatment vaults. An additional inspection will be made of the associated conveyance features to verify that they are in properly functioning condition, i.e., that the sediment depth accumulated is within specified depths, and that they are properly conveying water to the treatment vaults.

Data obtained in this inspection will be entered from the datasheets into the BMP RAM database. The subsequently received BMP RAM scores obtained will provide the county with the level and priority of maintenance activities to be planned in this catchment.

Wet basin inspection particulars:

1-2 times/year (early spring, late fall): Inspect for burrows, structural integrity of outfall, percent vegetation cover, litter accumulation.

1-2 times/year (early spring, late fall): Conduct measurement of depth of sediment accumulation at staff gauge installed in north end of basin.

Vortechnics units inspection particulars:

Inspect after storm events yielding > 1 inch of precipitation over 24-hour period. Prepare to vaccuum contents out.

Inspect prior to storm season (October) to ensure little to no accumulation of sediment inside vault.

References

1. BMP RAM User's Manual

Field Observation Datasheet - Treatment Vault

Field Observation Protocol - Material Accumulation (pps. 55-57)

Field Observation Protocol - Treatment Vault Capacity (pps. 61-62)

2. CASQA Fact Sheets

Fact Sheet TC-20 - Wet Ponds

Fact Sheet MP-51 - Vortex Separator

3. Douglas-Tahoe Stormwater Assests Operation and Maintenance Handbook

Inspection and Maintenance Guidance Sheet - Drainage Inlet and Sediment Traps (pps. 35-40)

Inspection and Maintenance Guidance Sheet - Treatment Basins (pps. 49-55)

Inspection and Maintenance Guidance Sheet - Stormwater Treatment Vault and Cartridge Filter (pps. 57- 63).

9. ADDITIONAL TREATMENT BMP IMPLEMENTATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the treatment BMPs within the catchment
☒ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO TREATEMENT BMP IMPLEMENTATION SUMMARY SECTION	

Attached hereto are the design drawings for the Wet Basin.

III. ROADS OPERATION IMPLEMENTATION SUMMARY

10. ROAD INVENTORY TABLE	Confirm the table is complete	11. ROADS INVENTORY MAP	Confirm the map is complete
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	

12. ROADS MAINTENANCE PLAN SUMMARY	In the space provided, summarize planned road maintenance actions for the overall catchment (reference implementation planning documents if applicable)

See attached Roads Inventory Table and Roads Inventory Map.

Planned Abrasive Strategy: The road abrasive application strategies represent long-term efforts to minimize total mass of road abrasives applied while maintaining safe driving conditions. In the Lower Kahle Urban Catchment, minimum and advanced control measures will be used. Minimum control measures include the application of a miniumum amount of abrasive to high and moderate risk roads in the catchment, as seen on the attached Roads Inventory Map. Equipment operators shall apply the minimum amount of abrasive (sand) to these roads. Frequency of abrasive application shall be in accordance with major storms. On low risk roads, no abrasives will be used (representative of advanced control measures), as these are extremely low slope (<1%), with minimal traffic in this predominantly residential catchment.

- Minimum control measures - apply minimum sand to high and moderate risk roads
- Advanced control measures – no abrasive application to low risk roads

Because of the extremely low slope, minimal traffic in this area and no vacuum truck sweeper available, there will be no planned sweeping of this catchment. Because of the density of sediment traps, the treatment vaults and the wet basin's efficacy of removing sediment from the catchment, this is not a detriment to water quality. PLRM modeling runs show little effect between scenarios of using a sweeper and not using a sweeper.

Other Source Control Practices: The source control practice used on Kahle Drive includes implementation of parking barriers on the north side of Kahle Drive, to prevent traffic from driving over the curb and onto the embankments on the north side of the road and parking off the road on the dirt area. This will preclude additional inputs of sediment entering Kahle Drive year-round, especially in the summer with increased visitors to the adjacent Forest Service land. This is represented in the PLRM model by changing road shoulder conditions along this segment of the road from erodible to stable and protected.

13. ROADS MAINTENANCE MAP(S)	Confirm road maintenance maps
☐ ROAD MAINTENANCE MAPS ARE PROPERLY IN A.17 (NOT REQUIRED)	

14. ROADS INSPECTION PLAN SUMMARY	In the space provided, summarize planned road inspection actions for the overall catchment (reference implementation planning documents if applicable)

It is expected that the roads in the catchment should be maintained and returned to expected conditions within 1-2 weeks after a storm. Calibration inspections should be completed at least once in the winter before and after application of abrasives. A reasonable inspection should follow the entrance of Kahle Drive, a left turn on Laura Drive, right on Irwin/Edward to Michelle Drive, then a right back onto Kahle Drive. This route will give inspectors an overview of the conditions on high, moderate and low risk roads within the catchment.

During winter inspections, there should be little to no abrasives on the side streets (low risk, low slope roads in the housing areas), with some expected abrasives remaining on Kahle Drive, depending on the time since the last storm. During a summer inspection, there should be no cars parked off the road north off Kahle Drive. This is a verification of expected conditions in the catchment. There should be little to no sand on the road during the summer months.

An application of the Road Rapid Assessment Methodology (ROAD RAM) is currently underway for Douglas County roads. Upon its implementation, protocols will be established based on this methodology to maintain an inventory and condition of the roads in this catchment. Because of the publication date of the ROAD RAM very close to the date of this CCS submittal, there was not enough time to prepare an inventory for this catchment. When the catchment is registered again in 2015 this will be completed.

15. ADDITIONAL ROAD IMPLEMENTATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the roads within the catchment
☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO ROADS IMPLEMENTATION SUMMARY SECTION	

IV. PRIVATE PROPERTY BMP IMPLEMENTAION SUMMARY

16. PRIVATE PROPERTY BMP INVENTORY		In the space provided, note the total number of developed single-family residential (SFR) parcels and the number of SFR parcels with BMP and source control certificates. Also, note the total area of multi-family residential (MFR) and commercial properties (CICU) and the area with BMP and source control certificates. Provide the percentage area with BMP and source control certificates that should be used as the expected value.			
Total Area of SFR (acres)	Total # of SFR	Total # of SFR w/ BMP Cert.	Total % of SFR w/BMP Cert.	Total # of SFR w/ SC Cert.	Total % of SFR w/ SC Cert.
46.2 acres	8	0	0%	8	1.3%
Total area of MFR (acres)	Area of MFR with BMP Certificates (acres)	Total Area of CICU (acres)		Area of CICU with BMP Certificates (acres)	
7.1 acres	0	7.5 acres		0	
Expected percentage of area with BMP certificates		**Expected percentage of area with source control certificates**			
0%		1.3%			

17. URBAN JURISDICTION PRIVATE PROPERTY BMP PROGRAM SUMMARY	In the space provided, describe any planned variations from the general private property BMP program for this urban catchment (reference implementation planning documents if applicable)

18. PRIVATE PROPTERY BMP INSPECTION PLAN SUMMARY	In the space provided, identify the data sources supporting these private property BMP calculations (reference implementation planning documents if applicable)

A list of private parcel BMPs was obtained from the TRPA website (http://www.tiims.org/bmptoolkit/searchBMP.asp). There are eight Source Control Certificates awarded to private parcels in this catchment. The acreage of each parcel is listed on the certificate. These acreages have been summed to account to be 0.85 acres of private parcels with Source Control Certificates.

The residences with Source Control Certificates are shown on Figure 4.1, Private Party BMP Map.

19. ADDITIONAL PRIVATE PROPERTY BMP INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the private property BMP implementation efforts in the catchment

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO PRIVATE PROPERTY BMP IMPLEMENTATION SUMMARY SECTION

V. OTHER POLLUTANT CONTROL STRATEGIES IMPLEMENTATION SUMMARY

20. OTHER POLLUTANT CONTROL PROGRAM SUMMARY	If other pollutant control strategies are implemented in the urban catchment, indicate that they are described in the CCS memo

☒ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO OTHER POLLUTANT CONTROL STRATEGIES SECTION

Installation of immovable parking barriers blocking access to the unpaved road shoulder adjacent to the north side of Kahle Drive is expected to result in fewer cars parked off pavement and reduced soils disturbance within the catchment. Observations will be equated to an estimated level of road shoulder protection in the expected loading estimate.

In PLRM, this change in road shoulder protection has been effectuated by decreasing the percentage of erodible road shoulders and increasing the percentage of stable and protected road shoulders representative of Kahle Drive.

This CCS and accompanying memo define the inspection approach and frequency as a driving survey of Kahle Drive at least three times per year during non-snow conditions. The table in the memo provides a description of how visual surveys of parking behaviour and road shoulder disturbance will be used to define conditions.

SECTION D: EXPECTED LOADING ESTIMATE

The expected loading estimate reflects annual average loading assuming treatment BMPs, roads, private property BMPs and other pollutant controls are maintained and operated to achieve the expected conditions defined in the Implementation Plan Summary.

I. EXPECTED LOADING ESTIMATE

1. LOAD ESTIMATION METHOD	Select the method used to estimate the expected and baseline loading for the catchment
☒ POLLUTANT LOAD REDUCTION MODEL (PLRM) V1.0 ☐ OTHER (DESCRIPTION IS INCLUDED IN CCS MEMO)	Name and version (If you selected Other)
2. EXPECTED LOADING PARAMETERS, ASSUMPTIONS & DATASETS	Check yes if any parameter values, assumptions or datasets used deviate from default values or recommendations
☐ YES ☒ NO (only defaults used)	☒ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO LOAD ESTIMATION APPROACH AND ASSUMPTIONS SECTION

If Yes, please explain

Default PLRM model values have been used for all parameters. Areal extent of land uses have been determined from Douglas County Assessor's Office parcel information, and the Lake Tahoe GIS Land Use layer. Soils data has been obtained from the NRCS Web Soil Survey. Road area, shoulder, and road risk have been calculated from parcel information, visual observations, and the Lake Tahoe Road Risk GIS layer. The area and volume of the wet basin have been determined from the design drawings, while the treatment vault capacities have been determined from local research.

3. EXPECTED LOADING PROJECT FILE	Confirm that the expected loading estimate scenario is included	4. EXPECTED LOAD	Provide the expected loads for fine sediment, nitrogen and phosphorus
☒ THE EXPECTED LOADING ESTIMATE SCENARIO IS INCLUDED IN THE LOAD ESTIMATION PROJECT FILE AND IS LISTED IN A.17		Fine sediment mass (kg) 542 kg	Fine sediment particles (#) 5.9* 10^16
		Total nitrogen (kg) 94.78 kg	Total phosphorus (kg) 18.52 kg

SECTION E: BASELINE LOADING ESTIMATE

The urban catchment baseline loading estimate sets the reference point for determining load reductions.

I. BASELINE LOADING ESTIMATE

1. BASELINE INVENTORY TABLE	Confirm baseline inventory table	2. BASELINE INFRASTRUCTURE MAP	Confirm baseline infrastructure map
☒ TABLE FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17		☒ MAP FOLLOWS TECHNICAL GUIDANCE AND IS LISTED IN A.17	
3. CHANGES SINCE 2004		Summarize any changes to treatment BMPs since 2004	

Since 2004, additional BMPs have been implemented in the Lower Kahle Urban Catchment. These include a large wet basin, and an additional vortex separator upstream of the wet basin to minimize the amount of sediment loading to the wet basin, lengthening its useful life. Numerous sediment traps and drop inlets have also been installed, all of which also decrease the sediment loading to the vortex separators and wet basin. Sand/oil separators have also been installed. A number of homes have also recevied Source Control Certificates for their "private party BMPs".

☒ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO BASELINE CONDITIONS SECTION	
4. BASELINE LOADING PARAMETERS, ASSUMPTIONS & DATASETS	Indicate if any parameter values, assumptions or datasets used deviate from default values or recommendations
☒ YES ☐ NO	☒ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO BASELINE CONDITIONS SECTION

If Yes, please explain

Default PLRM model values have been used for all parameters. Areal extent of land uses have been determined from Douglas County Assessor's Office parcel information, and the Lake Tahoe GIS Land Use layer. Soils data has been obtained from the NRCS Web Soil Survey. Road area, shoulder, and road risk have been calculated from parcel information, visual observations, and the Lake Tahoe Road Risk GIS layer. The existing treatment vault capacity has been determined from manufacturer's data.

5. BASELINE LOAD ESTIMATE		Provide the baseline loads for fine sediment, nitrogen and phosphorus	
Fine sediment mass (kg) **1786 kg**	Fine sediment particles (#) **1.97* 10^17**	Total nitrogen (kg) **116.32 kg**	Total phosphorus (kg) **37.92 kg**

SECTION F: CATCHMENT CREDIT SCHEDULE AMOUNT & DURATION

The final determination of the appropriate CCS credit potential amount and duration is made by the regulator in consultation with the urban jurisdiction. The urban jurisdiction proposes the CCS credit potential amount based on the load reduction estimate, and the duration based on the primary and secondary pollutant control strategies.

I. LOAD REDUCTION ESTIMATE & CATCHMENT CREDIT SCHEDULE AMOUNT

1. LOAD REDUCTION ESTIMATE		Note the load reduction estimate amounts	
Fine sediment mass (kg)	Total phosphorus (kg)	Total nitrogen (kg)	
1244 kg	**19.4 kg**	**21.54 kg**	

2. FINE SEDIMENT PARTICLE NUMBER CONVERSION	Using Equation 0.3, convert the fine sediment mass to number of fine sediment particles	3. CATCHMENT CONNECTIVITY	From item B.5
Fine sediment particles (#)		Percent Connectivity	
1.36 * 10^17		**75 %**	

4. EFFECTIVE LOAD REDUCTION ESTIMATE		Multiply the vaues in items F.1 and F.2 by F.3	
Fine sediment mass (kg)	Fine sediment particles (#)	Total phosphorous (kg)	Total nitrogen (kg)
933 kg	**10 * 10^16**	**14.55 kg**	**16.15 kg**

5. CREDIT AMOUNT CALCULATION	Using equation 0.2 calculate the credit amount

10 CREDITS

II. CREDIT SCHEDULE DURATION

6. CREDIT SCHEDULE DURATION	Indicate the catchment credit schedule duration	7. DURATION RATIONALE	Briefly explain the rationale for the selected duration
☒ 5 YEARS ☐ 10 YEARS ☐ 15 YEARS ☐ OTHER (SPECIFY) ____YEARS		Explanation The essential treatment BMP in this catchment is a wet basin, which has long-term results. Therefore, this catchment should receive a long-duration credit schedule (15 years). However, due to the planned redevelopment of the lower 15 acres of the catchment that is estimated to be planned to further decrease sediment loads, this catchment credit schedule should be revised in 5 years upon expected completion of this project, "Tahoe Beach Club."	

III. ESTABLISHMENT SUMMARY

8. ESTABLISHMENT DATE	Note the date that the CCS is submitted to the regulator	9. ESTABLISHMENT YEAR CREDIT POTENTIAL	Note the appropriate establishment year percentage and amount
Date		Percentage	Credit Amount
1/31/11		84%	8.4

10. FINAL YEAR OF CREDIT SCHEDULE	Note the appropriate final year of the credit schedule
Final Year	
1/1/15	

11. ADDITIONAL EXPECTED CCS AMOUNT AND DURATION INFORMATION	Indicate whether additional information is provided in the CCS memo to adequately describe the private property BMP implementation efforts in the catchment

☐ ADDITIONAL INFORMATION IS PROVIDED IN THE CCS MEMO CCS AMOUNT AND DURATION SECTION

APPENDIX B: JURISDICTION PROGRAM IMPROVEMENT RECOMMENDATION FORMS

PIR forms provided next page.

PIR PROGRAM IMPROVEMENT RECOMMENDATION

SECTION A: GENERAL INFORMATION

Recommendations submitted with this form will be considered for inclusion in the **Program Adjustment Recommendations**. For each program change recommendation, fill in a separate Change Recommendation section.

I. CHANGE IDENTIFICATION

1. TITLE USED TO IDENTIFY CHANGE	2. YEAR OF PROPOSED CHANGE DECISION
Title: Baseline Year Water Treatment	Year: 2010

3. POINT OF CONTACT — Provide the contact information for the appropriate representative

Name	E-mail	Phone
Robert Erlich	rerlich@cityofslt.us	(530) 542-6038

4. CHANGE PROPOSED AND ACTIVELY SUPPORTED BY

Urban Jurisdictions

- ☐ CALTRANS
- ☒ CSLT
- ☐ DOUGLAS
- ☐ EL DORADO
- ☐ NDOT
- ☐ PLACER
- ☐ WASHOE

Funding Partners & Scientists

- ☐ CTC
- ☐ NDSL
- ☐ RSWMP INVESTIGATORS
- ☐ OTHER: _____

Regulatory Agencies

- ☒ LRWQCB
- ☒ NDEP
- ☐ TRPA
- ☐ U.S. EPA

Stakeholders (name of group or individual)

- ☐ OTHER:_____
- ☐ OTHER:_____
- ☐ OTHER:_____
- ☐ OTHER:_____

II. RECOMMENDATION

5. PROPOSED CHANGE — Indicate all of the following related to the proposed change.

- ☐ LOAD REDUCTION ESTIMATION METHODS
- ☒ PROGRAM OPERATIONS & CREDITING PROGRAM HANDBOOK
- ☐ CONDITION ASSESSMENT METHODS
- ☒ OTHER: 2004 Baseline Water Treatment

6. NEEDS ADDRESSED BY RECOMMENDATION — Briefly describe the need for change and the issues that the change would address. If applicable, refer to items on the Identified Operational Improvements list.

Projects constructed in 2004 did not provide substantial treatment to stormwater in the catchment during the 2003/4 Water Year, and should not be part of the baseline. At the Lake Tahoe Airport only 0.07inches of precipitation was recorded from July through September 2004. Most projects constructed during 2004 would not be functioning before July. So, nearly all of the WY 2003/4 runoff occurred before the project could influence its load. It would be an error to assume that projects constructed in 2004 had significant impacts on baseline loads.

7. RECOMMENDED ACTION — Describe the specific changes that are required to implement the change. Include section references to documents and specific language, if appropriate.

Rephrase definitions of baseline: "All infrastructure present within the a catchment as of October 2004 is part of the baseline, except for new infrastructure where construction started and was completed during the 2004 construction season. These 2004 projects, which would not have had substantial impacts on baseline loading estimates within the catchment during the 2002-2004 baseline period, are not considered part of the baseline."

8. POTENTIAL COMPLICATIONS/IMPACTS OF ACTION — Describe any ramifications or related changes that would be required to completely implement the change.

A few projects which were started and completed in 2004 would be eligible for credits, and would no longer be part of the baseline. Minimal impacts on baseline load calculations are expected.

9. ADDITIONAL MATERIALS — If additional space is needed, specify in a separate memo or attachment, and complete the fields below.

Filename	Date

APPENDIX C: RECOMMENDATIONS SUMMARY TABLE

Summary Rating Table

Criteria	Rating	Narrative Justification
Importance	5	If the change is not implemented, it will be a substantial hindrance to the adoption and eventual success of the Crediting Program.
	3	The change will lead to a substantial increase to participant satisfaction with the Crediting Program.
	1	The change would be nice to have, but is not influential on the overall success of the Crediting Program.
Anticipated Effort	5	Implementing the change will require multiple months of effort.
	3	Implementing the change will require approximately one week of effort.
	1	Implementing the change will require approximately one day of effort.
Recommendation Status	C	**Complete** - The recommendation was completed as part of the Support Services project.
	F	**Funded** – The recommendation is planned within the scope of a currently funded project.
	O	**Outstanding** – The recommendation is still an outstanding need to be resolved.

Recommendation Summary Table

#	Change Recommendation	Document/ Tool	Importance	Anticipated Effort	Recommendation Status
1	Refine User Type Guidance & Definition	Handbook	4	2	C
2	Incorporate Catchment Size Guidance	Handbook	4	2	C
3	Incorporate Catchment Delineation Definition & Guidance	Handbook	4	2	C
4	Develop Catchment Memo Guidance & Example	Handbook	2	3	C
5	Incorporate Run-On & Comingled Water Guidance	Handbook	3	3	C
6	Provide Rationale & Guidance Regarding Modeling Non-Urban Loading	Handbook	2	3	C
7	Consider Ways to Allow Jurisdiction-wide Reporting	Handbook	4	2	O
8	Integrate RAM Tools in Online Database	All	4	5	F
9	Coordinate & Unify Nomenclature	Handbook	2	5	C
10	Develop BMP RAM Import Capabilities	BMP RAM	3	3	F
11	Add functionality to BMP RAM to calculate observation values based on a target RAM score	BMP RAM	3	4	F
12	Determine need for benchmark and threshold values for Cartridge Filters	BMP RAM	3	3	O
13	Adopt Crediting Program Handbook v1.0	Handbook	4	2	C
14	Adjust Baseline Definition	Handbook	3	1	C
15	Clarify Handbook Methodology for calculating Private Property BMP Values	Handbook	2	1	C
16	Develop Crosswalk of BMP RAM Observations and PLRM Parameters	PLRM & BMP RAM	4	2	C
17	Increase Accuracy of Treatment Vault Performance	PLRM	2	4	F
18	Use GIS Layer to Estimate DCIA	PLRM	4	2	C
19	Remove Default DCIA Value	PLRM	3	4	F
20	Develop Guidance for Simulating Sediment Traps	PLRM	2	3	O
21	Add Export Function to PLRM	PLRM	3	4	F
22	Create Web-based Version of A&T Tool	A&T Tool	4	4	F
23	Reduce Frequency of Private Property BMP Checks	A&T Tool	3	1	F
24	Develop TRPA BMP Database Query	TRPA BMP DB	3	3	O

APPENDIX D: DIRECT JURISDICTION ASSISTANCE SUMMARY

Jurisdiction Assistance Report

CONTRACT INITIATION THROUGH SEPTEMBER 30, 2011

This report summarizes services and costs associated with direct assistance to jurisdictions participating in the Crediting Program Support Services project. State regulatory sponsors have budgeted $4000 in direct assistance to each jurisdiction, however some jurisdictions have chosen to augment their budget with their own funds. This report is intended to keep jurisdictions aware of the services received and appraised of their remaining funds.

The direct jurisdiction budget allocations have been divided among several tasks to help jurisdictions understand the stages of the project in which assistance should be needed. Tasks include:

- **Task 1:** Project admin and coordination – Not relevant to direct jurisdiction assistance
- **Task 2:** Selection and inventory of test catchments – A primary focus of direct jurisdiction assistance
- **Task 3:** Support load estimation and CCS development – A primary focus of direct jurisdiction assistance
- **Task 4:** Verification of CCS and A&T Tool Submittal – A secondary focus of direct jurisdiction assistance
- **Task 5:** Identify LCCP adjustments – A secondary focus of direct jurisdiction assistance

JURISDICTION SUPPORT PROVIDED

CALTRANS

- Called CalTrans to initiate & advise on test catchment selection
- Reviewed test catchment memo
    - Consulted with Brent Wolfe on PLRM functionality and details
- Provided guidance regarding PLRM modeling catchment size and complexity
- Prepared for, participated in and followed up on NEAT meeting
- Attempts to schedule feedback session on early products
- Provided guidance and initial review of draft CCS and PLRM estimates
- Reviewed comments provided by Caltrans subcontractor regarding PLRM, BMP RAM and Crediting Program protocols and processes
- Reviewed draft catchment credit schedule products and provided detailed written comments

CITY OF SOUTH LAKE TAHOE

- Visited office to initiate test catchment selection process and answer initial questions
- Reviewed two rounds of draft products for catchment selection and delineation
- Answered questions and produced square sed trap conversion tool for entering info into BMP RAM (this time was spread among other jurisdictions)
- Walked test catchment to answer questions and provide insight regarding catchment inventory efforts including BMP types
- Consultations by Brent Wolfe (nhc)
    - PLRM Modeling capability
    - 8th & Glorine project BMP types
- Provided troubleshooting assistance with BMP RAM database
- Answered questions regarding BMP RAM inputs and required fields
- Reviewed draft catchment credit schedule products and provided detailed written comments

- Answered questions regarding
    - BMP RAM for sediment traps
    - Forebay representation in PLRM
- Reviewed rationale for changing Crediting Program Baseline date from October 2004 to May 2004
    - Consulted with regulatory staff to gain initial proof of concept
- Reviewed draft final catchment credit schedule products
- Reviewed formal Program Improvement Recommendation for changing Crediting Program Baseline date
- Provided BMP RAM database troubleshooting
- Developed BMP RAM v1.2 with bulk upload capabilities
- Assisted with A&T Tool login and troubleshooting
- Synthesized Baseline Water Year PIR and assembled supporting documentation
- Advised regarding implementation of Crediting Program in context of city-wide TMDL adoption
- Developed temporary "best practices" CCS for reference use until updated Handbook release
- NHC assist with baseline and connectivity discussions and review

DOUGLAS COUNTY

- Scheduled calls and office visit to initiate catchment selection and discuss possible test catchment options
- Assessed runoff/runon conditions and test catchment suitability through two driving reviews of Kahle catchment
- Reviewed two rounds of maps for Kahle catchment, requests for memo
- Posted guidance regarding run-on issues in test catchment
- Discussed via phone conversations: level of effort & timing for catchment inventories
- Discussed via phone conversations: staffing and outsourcing plan for Douglas County participation
- Initial review of draft CCS, PLRM and catchment inventory products and provided initial feedback
- Assisted Douglas consultant with BMP RAM troubleshooting and questions
- Initiated in-depth review of draft CCS, PLRM and catchment inventory products
- Provided final review of draft CCS, PLRM and catchment inventory products prior to verification meeting
- Discussed and researched General Improvement District challenges in the Crediting Program
- Provided guidance regarding development of PIR for General Improvement District challenges in the Crediting Program
- Provided BMP RAM database troubleshooting
- Attended Douglas County Commissioners meeting to provide guidance and external feedback
- Developed BMP RAM v1.2 with bulk upload capabilities
- Advised on GID engagement and communications strategy
- Attended, provided in-meeting assistance and summarized GID engagement meeting for consideration in Crediting Program Handbook protocols/processes
- Initiated review and development of Connectivity Guidance
- Developed temporary "best practices" CCS for reference use until updated Handbook release

NDOT

- Established contact with key personnel at NDOT & introduced Support Services project
- Initiated calls and coordination on approach & need for test catchment selection
- Reviewed and commented on draft test catchment delineation products

- Assisted with BMP RAM troubleshooting through remote and in-person assistance
- Provided initial guidance on credit sharing opportunities and coordination with Washoe County
- Researched & provided initial guidance regarding cut/fill slope representation in Crediting Program
- Maintained contact to schedule delivery of draft products, final delivery: week of Nov. 22
- Assisted with PLRM & BMP RAM database troubleshooting
- Researched modeling slope stabilization load reductions and associated Crediting Program implications
- Maintained regular contact to schedule delivery of draft products, final delivery: mid-December 2010
- Reviewed draft BMP RAM database and provided troubleshooting support
- Developed BMP RAM v1.2 with bulk upload capabilities
- Reviewed and provided written and verbal comments on draft products
- Engaged nhc for PLRM Modeling review
- Scheduled and planned verification meeting
- Reviewed and provided comments on draft final CCS
- Reviewed and provided comments on PLRM modeling
- Planned, facilitated and summarized CCS verification meeting
- Initiated development of updated run-on guidance per NDOT recommendations
- Initiated development of guidance for transportation jurisdiction modeling in PLRM (road cuts, etc.)
- Developed temporary "best practices" CCS for reference use until updated Handbook release

EL DORADO COUNTY

- Visited office to define needs of test catchment and El Dorado approach to selection
- Reviewed 2 rounds of test catchment delineation products
- Answered questions regarding test catchment inventory efforts
- Considered details of guiding selection of % Connectivity in catchment credit schedule
- Meeting to discuss Crediting Program product development, use of stormwater tools and respond to issue of crediting of physical sediment removed from BMPs
- Initial cursory review of draft CCS, PLRM and catchment inventory products
- Reviewed draft catchment credit schedule products and provided detailed written comments
- nhc review and analysis of El Dorado County PLRM hydrology validation and comparison alternative method for baseline estimates
- Maintained regular contact to schedule delivery of draft products
- Reviewed and provided written and verbal comments on draft products
- Scheduled, planned, facilitated and summarized verification meeting

PLACER COUNTY

- Visited offices to initiate test catchment discussion
- Reviewed test catchment maps and memo
- Answered questions regarding test catchment inventory efforts
    - Discussed BMP RAM veg. type differentiation on two calls
- Produced estimate of time and personnel needed to do inventory of test catchment (much of this time was split to other jurisdictions)
- Maintained contact to schedule delivery of draft products; target submission date is Nov 19, 2010
- Worked with Placer intern, 2NDNATURE and other jurisdictions to fund an enhancement to BMP RAM database so that it can accept bulk information uploads

- Developed BMP RAM v1.2 with bulk upload capabilities
- Assisted Placer County staff in rapid understanding and development of Crediting Program Products to bring Placer County up to date with Support Services Project
- Reviewed draft products in advance of verification meeting to be held Feb 6 (tentatively)
- Facilitated and summarized verification meeting
- Reviewed and commented on draft final CCS products
- Consulted with staff regarding implementation of Crediting Program and Road RAM

WASHOE COUNTY

- Visited office to introduce and initiate test catchment selection & introduce test catchment selection
- Provided information and guidance regarding test catchment inventory
- Conveyed concerns to NDEP regarding jurisdictional primacy issues with GIDs
- Coordinated with NDOT re: test catchment mapping & credit sharing
- Reviewed 2 rounds of test catchment selection map and memo products
- Answered service augmentation process questions
- Visited test catchment to provide technical assistance with inventory of conditions and BMPs
- Responded to road shoulder condition assessment issues
- Researched drop inlet/sediment can FSP removal estimates for crediting and PLRM efforts
- Answered questions regarding BMP RAM inventory and provided clarification for road shoulder condition definition
- Maintained contact to schedule delivery of draft products
- Coordinated with NTCD to manage and schedule delivery of draft Washoe County products
    - Delivery: Week of Nov. 22
    - Verification meeting: Nov 29 or 30
- Provided phone and e-mail troubleshooting and training for Crediting Program Protocols, PLRM and BMP RAM
- Developed BMP RAM v1.2 with bulk upload capabilities
- Reviewed and commented on NTCD connectivity assessment methodology
- Provided extensive phone and e-mail troubleshooting and training for Crediting Program Protocols, PLRM and BMP RAM
- Reviewed draft products including PLRM and draft Catchment Credit Schedule
- Planned, facilitated and summarized CCS verification meeting
- Initiated development of updated run-on guidance per Washoe recommendations
- Provided guidance regarding implementation of BMP RAM and Road RAM at jurisdiction scale

Attachment F

Lake Tahoe Stormwater Tools Improvement Nomination

ROUND 12 CAPITAL PROJECT NOMINATION FORM
LAKE TAHOE FEDERAL SHARE EIP CAPITAL PROJECTS
APPENDIX K

Project Name:	Lake Tahoe Stormwater Tools Improvement	**EIP Number:** (***Required***)	628, 10110, 10111
Federal Agency Sponsor: (***Required***)	US Environmental Protection Agency	**Contact:**	Jack Landy
Threshold:	Water Quality	**Phone Number:**	775-589-5248
Threshold Standard:	WQ-1, WQ-2, WQ-3, WQ-4, WQ-5	**Email:**	Landy.Jacques@epamail.epa.gov
FUNDING REQUESTED IN THIS ROUND:	**$** 480,000		

Federal Share EIP Consideration

Select "yes" or "no" for each question. If you have a "yes" response, briefly describe. ***Projects must meet one or more of these 5 items.***

1. **Does the project involve federal land? If yes, is the federal land involved important to successful implementation of the project?** — ***Yes*** ☐ ***No*** ☒

2. **Is this project identified in the EIP? If yes, please ensure the EIP number is identified in the above project information box. If no, provide a description of the project's contribution to the EIP program.** — ***Yes*** ☒ ***No*** ☐

EIP # 628 Urban runoff model
EIP # 10110 Direct loading from urbanized and non-urbanized area
EIP # 10111 Loading rates from stormwater runoff

3. **Does the project involve the conservation of a federal or regional threatened, rare, endangered, or special interest species? If yes, identify.** — ***Yes*** ☐ ***No*** ☒

4. **Does the project involve an identified federal interest such as the detection and eradication of non-native invasive species (aquatic or terrestrial)? If yes, identify.** — ***Yes*** ☒ ***No*** ☐

This project will ultimately help to restore and maintain the waters of Lake Tahoe. Tahoe is designated an Outstanding National Resource Water (ONRW) due its ecological status as one of the few large, deepwater, ultraoligotrophic lakes in the world with unique transparency, color and clarity. Not only is restoration of Lake Tahoe clarity mandated under federal anti-degradation policy, but is necessary to maintain its value for human enjoyment and recreation, as a supply of municipal and domestic drinkng water and as an substantial economic asset.

To that end, the federal government has enacted legislation and appropriated hundreds of millions of dollars in the Environmental Improvement Program. However, transparency and accountability for expenditures of these funds has been lacking and is sorely needed. The stormwater tools to be enahanced and refined through this project will not only act to target actions on those which are most cost-effective and in areas with the greatest acheivable benefits, but will enable transparent and consistent reporting of accomplishments. Furthermore, the tools will enable implementing jurisdictions to demonstrate accountability for acceptance of these grant monies and thereby ensure protection of the public investment which have gone towards these efforts.

5. **Does the project develop knowledge and/or information to develop future capital projects in the EIP? (such projects that fulfill this function would include technical assistance, data management, and/or resource inventories)** ***Yes*** ☒ ***No*** ☐

Yes, this project will enahnce and refine beta-version stormwater tools that Lake Tahoe urban jurisdictions will use to target stormwater pollutant load reduction actions and strategies. The load reduction estimation model will be used at a jurisdictional scale to identify areas where the greatest load reductions may be acheived. The model has recently been applied in a jurisdiction for the purposes of informing the development of a stormwater management plan. The investigation has identified the locations where water quality improvements should be prioritized. Moreover, the anaylsis has provided invaluable information on the cost-effectiveness of actions which will likely fundamentally change the priority actions and strategies that will jurisdictions will implement. Consequently, these results also have significant policy implications as well.

It will also be used to develop and evaluate different alternatives at the project scale, enabling for the most cost-effective alternative to be identified. Estimated load reduction results will be reported to a public reporting platform. Rapid assessment methodologies will be used not only to verify that stormwater treatment facilities and roadways are are being maintained in a condition that is appropriate to protect downstream water quality, but will also provide valuable information to jurisdictions regarding maintenance priorities of structural best management practices as well operations and maintanence practices.

Check all Capital Focus Area(s) that apply (as defined in the Federal Vision):

☒ 1. **Watershed and Habitat Improvement**

☐ 2. **Forest Health**

☒ 3. **Air Quality and Transportation**

☐ 4. **Recreation and Scenic**

Check all that apply (must meet a minimum of one category):

☐ 1. **Continued emphasis on forest ecosystem health/fuels reduction projects considering the LTBMU Stewardship Fireshed Assessment and Lake Tahoe Basin Multi-Jurisdictional Fuels Reduction and Wildfire Prevention Strategy.**

☐ 2. **Continued implementation and/or completion of projects approved in Rounds 5 through 11 which implement the EIP. Project proposal should clearly describe the phase/product being produced along with the consequence of not completing the project phase proposed for Round 12.**

List Previously Approved Rounds and funding(provide project titles):

☒ *3.* **Project is consistent with and contributes toward TMDL pollutant reductions within the four source categories (atmospheric, urban & groundwater, forested uplands, and stream channel).** ***NOTE: If "yes", then please respond to questions in the Accomplishments section of the nomination proposal.***

☐ 4. **Control of aquatic invasive species and prevention and/or detection of new aquatic invasive species.**

Project Nomination Proposal Outline

Project Summary (a brief summary which clearly describes the proposed project –maximum 200 words)

- Summarize ONLY the Round 12 project (also summarize scaling of funding to be described in more detail in the "Project Description" section below)**.**

A suite of tools have been developed to identify the most effective opportunities to reduce fine sediment particles (FSP), phosphorus and nitrogen pollutant loads that enter Lake Tahoe via urban stormwater. The Pollutant Load Reduction Model (PLRM), Best Management Practice Rapid Assessment Methodology (BMP RAM), Road Rapid Assessment Methodology (Road RAM), and the TMDL Accounting and Tracking Tool (ATT), each play critical roles that enable municipalities and departments of transportation (collectively referred to as jurisdictions) to prioritize capital investments, staff time and maintenance equipment deployment to most effectively reduce stormwater pollutant loading. This project seeks to leverage the aproximate $2 million investment to date to develop these beta-version tools by taking them to fully functional initial versions. Enhnacements and refinements in the tools to accomplished will be based on user-feedback provided by the jurisdictions, who have already or will soon undergo training and testing of the tools. Refining and enhancing the tools will facilitate acceptance of the tools by the jurisdictions. Moreover, because these tools represent an important component for reporting accomplishments, there completion is essential in overcoming the historical lack of transparency and accountability for expenditures of public dollars on water quality improvements.

Project Description

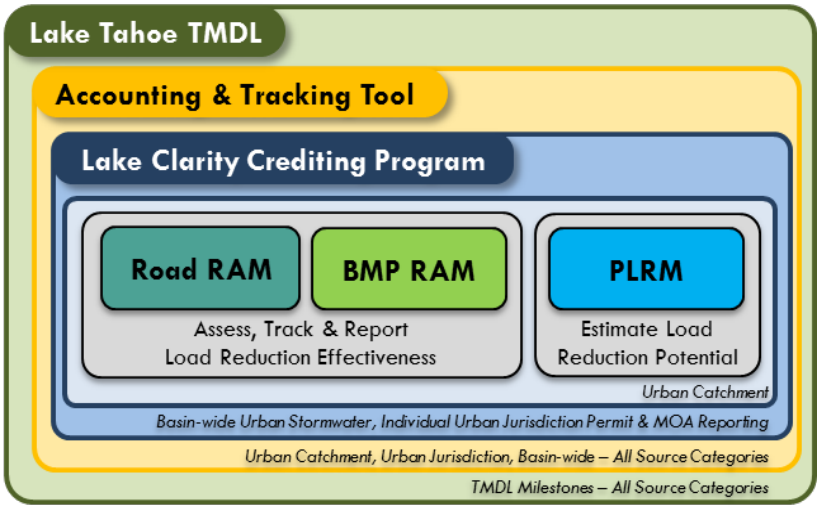
Introduction

- Provide project background which explains the situation and state the problem and how it will be addressed.

Note: *Focus needs to be the project in Round 12 not a history of an ongoing project or program.*

The Lake Clarity Crediting Program (Crediting Program) is the program under which the urban stormwater source category of the Lake Tahoe Total Maximum Daily Load (TMDL) will be implemented. The Crediting Program seeks to motivate effective actions to improve lake clarity by establishing an accounting framework that connects on-the-ground actions to load reduction goals defined in the Lake Tahoe TMDL report. The Crediting Program provides flexibility for jurisdictions to prioritize pollutant control activities that address the most effective and efficient load reduction opportunities; increases transparency and accountability by comparing load reductions achieved by jurisdictions and basin-wide to accepted targets; and defines the procedures for jurisdictions to use the stormwater tools in an integrated fashion to 1) identify and document expected load reductions, and 2) report ongoing effectiveness of operations.

The Crediting Program uses a suite of user friendly tools developed to identify the most effective opportunities to reduce loading of fine sediment particles, phosphorus and nitrogen from entering Lake Tahoe. The Pollutant Load Reduction Model (PLRM), Best Management Practice Maintenance Rapid Assessment Methodology (BMP RAM), Road Rapid Assessment Methodology (Road RAM), and the TMDL Accounting and Tracking Tool (ATT), each play critical roles that enable municipalities and departments of transportation (collectively referred to as jurisdictions) to prioritize capital investments, staff time and maintenance equipment deployment to most effectively reduce pollutant loading from urban stormwater. Please note a one page attachment has been included with this application describing these tools in more detail.



Each of the 7 urban stormwater jurisdictions are participating in the Crediting Program Support Services Project through which they are beta-testing and training of the initial versions of the stormwater tools on a non-regulatory basis. The process is expected to result in recommendations for technical improvements to the stormwater tools that will make each of the tools more efficient, functional and better able to support targeted efforts to reduce pollutant loadings. Round 12 SNPLMA Capital funding is being requested to carry out these recommendations. The outcome will be second versions of the PLRM, BMP and Road RAMs and ATT with improved operability, functionality and which end-user will be more willing to accept. This funding will leverage the approximate $2 Million that has already been invested in these tools:

Stormwater Tool	**Amount**	**Funding Source**
PLRM prototype (named PLRE-STS)	$335,000	USACE Sacramento District Lahontan RWQCB (through SNPLMA)
PLRM (current beta-version)	$820,000	TOTAL
	$506,500	USACE Sacramento District
	$313,500	NDEP (through SNPLMA)
BMP RAM	$156,000	USACE Sacramento District
Road RAM	$263,400	TOTAL
	$153,400	CTC
	$110,000	NDEP
Accounting and Tracking Tool	$140,000	USACE Sacramento District
Integrated Tahoe Stormwater Tool	$142,000	TOTAL
	$60,000	Lahontan (earmarked)
	$69,000	NDSL (request pending)
	$13,000	NDEP (earmarked)
Trainings/Workshops	~$100,000	CTC, USACE, TRPA/NDEP
ALL TOOLS	**~$1,950,000**	

Demonstration of accountability through accomplishments reporting is a high priority in order to maintain the capital funding stream for water quality improvements. The ATT currently includes functionality to report load reductions at a variety of scales and for all source categories. However, the information stored in the ATT is not publically available. The soon to be initiated TMDL Management System project will produce a web-based Activity Tracking and Public Reporting platform. This platform will enable TMDL implementers to track planned and completed activities aimed at achieving load reductions and report visual and summary text displays to the public and stakeholders regarding the status of TMDL related science (monitoring and research) activities as well as progress toward achieving TMDL load reductions. While this will be beneficial, the platform is more rigid in that it will necessitate manual updates and lacks functionality that a more robust web-based map viewer system could provide. Such a map-based visual reporting platform would not only improve the transparency and accountability for capital funds received to implement water quality improvements but deliver expanded functionality for stormwater managers, enabling them to increase their productivity and efficacy.

- Describe what Round 12 is specifically funding; list the number of years the requested funding will cover; briefly describe how this project links into previous projects/rounds (identify and describe other round projects and funding received). Show scaling of project (reduced funding request and associated reduction in accomplishments).

NOTE: *Focus should be on finishing current/phased projects. If project is new in Round 12, clearly identify if the project is for planning or implementation and how it will be completed with Round 12 funds. Identify if other funds will be needed to complete the project. Please identify total non-SNPLMA funds that are being contributed/dedicated to the proposed Round 12 project and the source of those funds.*

WORK TO BE PERFORMED

Task 1. PLRM Technical Improvement Tasks

The beta version of the PLRM was released in the Fall of 2009. Upon its release, jurisdictions and regulators participated in a three-part series of independent trainings for the tool. The scope of the US Army Corps of Engineers contract included an effort for the model developers to solicit and prioritize recommended improvements based on feedback from the trainees. The outcome of the process included a number of desirable improvements and updates to PLRM that would greatly improve the functionality and applicability of the tool. Please note that while the subtask list below represents the priority improvements as identified during the testing and feedback received from the training sessions, the order of prioritization has been slightly modified based on: 1) additional feedback from PLRM users during the testing period for the Catchment Registration process; 2) partial completion of some of the proposed improvements through other funding sources; and 3) common errors observed among PLRM users during the first 1.5 years of model use.

Task 1A. Integrate Road RAM Into PLRM

Research collected in support of the Road RAM has shown that the current structure of the PLRM Road Shoulder Conditions form and supporting algorithms could be improved to better integrate with the Road RAM and to support future validations of the algorithms through research and monitoring. Contractors will modify PLRM road methodology to better align with Road RAM tool concepts, outputs and approach. Subtasks include: 1. Incorporate Road RAM research and approach into PLRM algorithms 2. Re-organize Road Shoulder Conditions Form in PLRM to align with Road RAM concepts.

Task 1B. Pollutant Generation Output By Urban Land Use

Pollutant generation by urban land use is not currently reported with PLRM output. This limits the ability for a user to assess the significance of pollutant sources in their project area. Improving PLRM output reporting functions will assist planning efforts, including better estimates of jurisdictional baseline loading and the formulation of strategies to achieve TMDL allocations. Subtasks include: 1. Develop code to identify pollutant loading generated by urban land use 2. Revise output reports in PLRM to include this information.

Task 1C. Update Characteristic Effluent Concentrations (CECs)
Some of the CECs used to represent performance of storm water treatment facilities in PLRM were developed from data sources outside of the Tahoe Basin. Additionally, the estimates of fine sediment particle (FSP) CECs currently in PLRM are supported by minimal data. This task would refine the CEC defaults in PLRM for FSP, total suspended sediment (TSS), total phosphorous (TP) and dissolved phosphorous (DP) based on results from Tahoe specific stormwater research conducted after release of the PLRM version 1.

Task 1D. Refine Stormwater Treatment Vault Option
Initial use of treatment vault option in PLRM has raised concerns that performance may be over-predicted for this storm water treatment facility, especially for FSP removal. This task would refine the representation of the Treatment Vault option in PLRM to require justification of CECs for a User-Defined SWT (which can be a treatment vault) to reduce the chances that treatment performance is over-predicted. Subtask include: 1. Modify graphical user interface (GUI) and require CECs to be confirmed by user. 2. Flag CECs regardless of values in Recommended Range Report as a warning (requires justification to use).

Task 1E. Incorporate Climate Change Analysis Option
The current meteorological dataset used in the PLRM is based on an 18-year historic dataset. Scientific evidence suggests that climate change may affect hydrology and storm water runoff in the Tahoe Basin. The climate change analysis conducted for the TMDL indicates that Lake Tahoe may experience a 10% decrease in precipitation and a 2°C increase in temperature. A new algorithm will be developed under this task to generate a meteorological dataset that can be used in PLRM to estimate how potential climate change effects may influence pollutant loading.

Task 1F. Increase Program Stability and Improve User Experience
The PLRM programming code needs additional development to reduce access violations caused when both the PLRM and SWMM5 (the parent model upon which PLRM is based) try to access the same Windows program. The errors result in PLRM program crashes. Additionally, this task will correct program deficiencies identified during testing with participants from the SWQIC, and prioritized for correction by the SWQIC participants. This task will increase overall PLRM stability, resulting in a better user experience.

Task 1G. Develop Infiltration and Cut Slope Algorithms and Guidance.
The current PLRM algorithms do not provide adequate default values to represent infiltration for urban land uses (in particular for compacted road shoulders). Additionally, there is no direct method to represent cut slope erosion in the PLRM. This task will incorporate currently ongoing and recently completed research to improve algorithms and guidance to better estimate both infiltration on pervious road shoulders and pollutant loads from cut slopes.

Task 1H. Model Testing and Update Documentation
This task is necessary to test the revised version of the model after completion of Task 1A through 1G and to update the technical documentation and user documentation. In the process of testing PLRM v2, source code no longer in use will be eliminated, guidance within code on general architecture, linkages, and function will be created as well as a mapping document of code to allow future transfer of the tool to another code manager.

Task 2. RAM Tools Improvement Tasks
The beta first versions of the BMP RAM and RRAM were released in the Fall of 2009 and 2010, respectively. BMP RAM testing and training has been provided to jurisdictions through the current Crediting Program Support Services project and a detailed Road RAM training is planned for April 21, 2011. User feedback on the utility of the tools and priority recommendations for improvements will be documented through the Support Services effort. A prioritization process will be carried out in order to dedicate available funding to those tasks of the highest importance. The following subtasks will greatly improve utility of the RAMs and thereby facilitate jurisdictional acceptance of them:

Task 2A. BMP RAM Technical Improvements

Priority improvements based on developer testing and feedback from the Crediting Program Support Services project will be incorporated into the BMP RAM protocol. One known deficiency is that PLRM input parameters do not currently align with the observations defined in BMP RAM. However, BMP RAM is the method used to confirm that expected conditions for BMP performance are being maintained over time. Translators must be created and incorporated into BMP RAM and PLRM protocols and user guidance to align PLRM input parameters for treatment BMP performance with measured values as quantified using the BMP RAM. Tahoe specific research is being conducted to inform the development of these performance metric translations for infiltration rate, treatment BMP capacity and other metrics. This will require definition of testable hypotheses, engineering estimates, and analyses of recently obtained field datasets. These and other technical improvements will be incorporated into BMP RAMv2 and documented in BMP RAM Technical Guidance document. The BMP RAM User Manual will also be updated.

Task 2B. Road RAM Technical Improvements

Priority improvements based on developer testing and feedback from the Crediting Program Support Services project will be incorporated into the RRAM protocol, including functional improvements to the database data analysis/reporting/display. Improvements will result in a database that is capable for integration with the ATT. This task will also feature updating of the RRAM Technical Guidance and User Manual documents.

Task 3. Update the Tahoe Integrated Stormwater Tool

NDEP and the Lahontan Water Board have earmarked $70K and submitted funding requests to the US Army Corps of Engineers and Nevada Division of State Lands to overcome what is deemed the greatest impediment to the acceptance and use of the existing stormwater tools - the confusion and administrative burden resulting from the current stormwater tools operating independently. The Integrated Tahoe Stormwater Tool project will produce a single online user interface that allows jurisdictions to upload PLRM outputs and enter all information necessary for registering catchments in the Crediting Program, prioritize maintenance activities, report road and treatment BMP conditions, declare credits, and generate outputs necessary to complete certain requirements of annual stormwater reports.

Update of the PLRM and RAMS based on user feedback will necessitate a corresponding update of the Tahoe Integrated Stormwater Tool (description provided in the Introductory section of this application). Subtasks include: 1. Updating common fields between each tool identify where field definitions require additional alignment to be defined in the same units and terms. 2. Updating the data relationship wireframe structure for the Integrated Tahoe Stormwater Tool that will seamlessly integrate the required data, functions and infrastructure of the BMP RAM, Road RAM and ATT to minimize data entry and complexity for the users, while increasing functionality and reporting ease; 3. Updating the file type and field specifications that enable PLRM outputs to be uploaded to the Integrated Tahoe Stormwater Tool; 4. Update standardized data outputs that will allow information in the Integrated Tahoe Stormwater Tool to be exported and available for upload to jurisdiction asset management systems and the EIP database.

Task 4. Urban Stormwater Management and Reporting Platform Development

This task will leverage investments to develop the Tahoe Integrated Stormwater Tool and the Activity Tracking and Public Reporting Platform (funded through separate efforts) by building off of them and linking them to a web-based map viewer with expanded functionalities relevant to stormwater managers. Priority tasks to be completed for this project will be identified by the Stormwater Quality Improvement Committee (SWQIC) who will also oversee development and completion of this task. The following subtasks may be accomplished based on the amount of funding available for this effort and final input with respect to workplan and priorities. It is important to recognize that this task is intended to build off – not duplicate- existing stormwater management systems that jurisdictions may currently operate. Furthermore, if possible, this tool will be developed in conjunction with the Tahoe Integrated Information Management System.

Task 4A. Web-based Map Viewer Development

A web-based map viewer could be developed that displays a variety of information relevant to urban stormwater management, including reporting of accomplishments. The map viewer would serve as one stop

shop where urban stormwater managers, funders, regulators and stakeholders can observe up-to-date information such as what and where load reduction activities/BMPs have been or are planned to be implemented; Crediting Program catchment credit schedules; and jurisdictional and basin-wide progress toward achieving TMDL load reductions. The enhanced visual reporting platform would improve the transparency and accountability for capital funds received to implement water quality improvements. The tool could feature zoom capability, such that different information is displayed at scales ranging from the basin to the catchment level. While input would be solicited through the SWQIC to finalize what information shall be displayed, examples of information that could be extracted or displayed by clicking on specific map features include but are not limited to the following:

1. Jurisdictional stormwater load reduction plans
2. Jurisdictional or basin-wide progress toward accomplishing TMDL load reductions (ie., ATT linkage)
3. Crediting Program catchment credit schedules
4. BMP RAMs and RRAM inspection results
5. Structural and private parcel BMPs
6. Roadway operations and maintenance practices

Task 4B. PLRM Input Functionalities Development

This task would seek to furnish specific functionalities to the web-based map viewer that would increase urban stormwater manager's productivity and efficiency. Currently, parameters that must be input into the PLRM in order to run the model include the distribution of soils, land uses, parcel level BMP implementations, and directly connected impervious area in the catchment (ie.,project) area. Generating this information has the potential to occupy a significant amount of personnel time, which would be minimized through the inclusion of an "intersection" function that automatically tabulates and summarizes PLRM input parameters once a catchment boundary is imported into the map viewer. Reducing the time required for managers to accomplish PLRM runs would allow them to focus more time on scenario development, thereby improving their ability to target actions where the greatest load reductions will be realized and in the most cost-effective manner of doing so.

CONNECTION TO TIIMS & LONG TERM MAINTENANCE OF TOOLS

The TMDL agencies agree that the ideal place to host the stormwater tools are on TIIMS. The vision is to host these tools there and in fact some of the stormwater tools are currently hosted on TIIMS. We furthermore believe that building the map viewer on TIIMS could offer a significant cost savings. This stated, a task in the upcoming Lake Tahoe TMDL Management System project is to assist the TMDL agencies in the development of a strategic plan on the long-term administration, operations and maintenance and funding for TMDL-related tools either existing or which will be developed through this project. Associated with this task is carrying out a feasibility evaluation of potential options including but not limited to integration with TIIMS, simply hosting on TIIMS; and various options with respect to agency administration of the tools. This would need to be closely coordinated with the EIP Working Group and final recommendation endorsed by the Basin partners - Tahoe Interagency Executives Steering Committee (TIE SC) to ensure that systems are developed and linked to meet long term objectives for reporting EIP accomplishments, etc..

- Describe the "readiness" of this project to move forward (urgency, capacity, capability, environmental documentation, interagency agreements, etc).

The project is anticipated to be ready to move forward at the time when funding is assumed to become available and funding agreements are in place (January 2011). Tasks 1, 2 and 3 are the highest priorities and are considered urgent. Task 4 is also a high priority but is not considered urgent. USEPA and NDEP possess the capacity to administer the grant and will see the project through to successful completion. NDEP has administered a previous SNPLMA funded project that was successfully completed and serves as the administrator of two current SNPLMA projects.

- Describe partnerships for this project. (if applicable, project should identify and describe committed/secured partner funding and/or other partner contributions and how it is integrated into the project).

The project involves the collaboration and coordination of the following entities:

USEPA – project sponsor, grant administration, and project advisory committee agency member;

NDEP – grant administration, subcontract manager, and potential in-kind federal match as project advisory committee agency member (~$15,000K);

Lahontan Water Board - in-kind match as project advisory committee agency member ($12,000);

TRPA – potential in-kind match as project advisory committee agency member (~$8,000)

SWQIC – this project will be coordinated with the Stormwater Quality Improvement Committee; the Committee will be asked to provide one or two local jurisdiction representatives to participate on the project advisory committee (approximately $8,000 in in-kind match); in addition, if Task 4 is funded, all SWQIC agencies will be asked to provide input in the production of a final workplan for the map-based tool; finally, regular updates will be provided to the SWQIC regarding the progress and outcomes of the project.

TSC – the Tahoe Science Consortium will be invited to provide one representative to participate on the project advisory committee. However, funding will not be provided for the representative's participation; therefore TSC participation could result in additional in-kind match contribution.

Note: *The form requests information about project goals, objectives, accomplishments, and questions the program is designed to answer across several different sections. These issues are closely linked and your individual responses should provide a cohesive description.*

Goal – Purpose and Need (“larger” statement of future expected outcome – usually not measurable)

The pending Lake Tahoe Restoration Act commits a minimum of $40M to stormwater management, TMDL implementation and erosion control. Furthermore, LTRA requires reporting accomplishments (ie., performance measures) which with respect to TMDL are pounds of TMDL pollutants (fine sediment particles, phosphorous, nitrogen) reduced. Therefore, this project directly addresses LTRA by improving the tools to report accomplishments with respect to TMDL implementation and particularly the urban stormwater source category. The specific goals of this project are to:

- Increase the acceptance of the Tahoe stormwater tools and reduce the cost and complexity of their use to support the Crediting Program.
- Improve the ability for jurisdictions and funders to target investments and communicate priorities for stormwater pollutant controls to document effective load reductions.
- Simplify and streamline reporting of results of stormwater management to support LTRA and annual stormwater reporting requirements, which will increase transparency and accountability for the use of EIP funds.

Objectives (specific measurable statements of action – Round 12 only - which when completed will move towards achieving the goal)

Note: *Objectives will form the basis for the milestones/deliverables to be identified in Appendix B-8*

- Describe how fulfilling objectives will contribute to the achievement of one or more environmental thresholds (air quality, water quality, soil conservation, vegetation, fisheries, wildlife, scenic, noise, recreation). Provide measures if applicable. For example: acres treated, miles of stream restored for each objective.

The associated objectives to achieve the stated goals include:

- Enhancement and refinement of the beta-tested versions of PLRM, BMP RAM~~s~~, RRAM and subsequent update of the Tahoe Integrated Stormwater Tool by addressing known operational improvement needs;
- Creation of an easily accessible, centralized, web-based map-viewer application that enables jurisdictions, funders, regulators, stakeholders and decision-makers to observe spatial and tabular data of the progress made toward achieving TMDL load reductions at a variety of scales, including where and what types of project and other load reduction actions have been implemented on the ground.
- Providing specific functionalities to the web-based map viewer that will facilitate urban stormwater managers to target their actions on those source areas which are most cost-effective and capable of achieving the greatest load reductions.

Fulfilling the project objectives will result in the cost-efficient restoration of clarity within Lake Tahoe.

- Describe the estimated environmental risks from unintended consequences of the proposed project (if applicable)**.**

There are no known environmental risks from unintended consequences of the proposed project.

Accomplishments

- Describe the anticipated project accomplishments (i.e. products or identifiable environmental benefits being produced or implemented under this project), and how the project results/accomplishments will be communicated and made available to the public.

Note: *Differentiate between direct and/or primary project effects and secondary and/or overall watershed effects.*

Anticipated benefits are both environmental and economic as this project will aid in the cost-efficient restoration of clarity within Lake Tahoe. Project accomplishments include the following products and deliverables:

- Technical improvement to PLRM - include enhanced functionality, stability and greater user experience
- Technical improvements to the BMP RAM – Updated field protocol, user manual and technical document based on jurisdiction input
- Technical improvements to the Road RAM - Updated field protocol, user manual and technical document based on jurisdiction input
- Updated Tahoe Integrated Stormwater Tool – based on corresponding updates to the PLRM and RAMs
- Urban Stormwater Management and Reporting Platform – a publicly accessible web-based map to increase transparency and accountability of public dollars spent for water quality improvements and with increased functionality to improve the efficacy of urban jurisdictional stormwater management.

Once the project is complete, the Lahontan Water Board, NDEP and TRPA will post the deliverables on their respective websites and send out a notice of availability to the public and stakeholder distribution lists the agencies maintain.

- If you checked "yes" for the project being consistent with and contributing to TMDL pollutant reductions, please consider and integrate the following in the project description:

a) Describe whether, and how, the project demonstrates advanced, alternative, or innovative practices.

Because this project is a water quality implementation planning project, advanced, alternative or innovative practices are not demonstrated through actual on-the-ground implementation. However, the stormwater tools to be updated and improved with this request each support the implementation of advanced, alternative or innovative practices called for in the TMDL implementation plan. For example, the PLRM enables users to calculate catchment scale pollutant loading for the implementation of various advanced roadway operations and management practices, such as the use of high technology vacuum sweepers, reduction of or alternatives to abrasive material applications, as well as the use of advanced treatment structural BMPs. The RAMs evaluate the functional condition of the BMPs and roadways to verify that the actions implemented are actually performing to an appropriate level for the protection of water quality.

b) If project includes project level monitoring, describe ability of proposed monitoring strategy to contribute to the state of TMDL knowledge. Also describe if purpose of the capital project is to conduct data collection and/or analysis related to Lake Tahoe clarity.

Monitoring is not a component of this project. However, monitoring data and results from current projects, some of which are SNPLMA-funded, will be used in the update of the tools. Additionally, the RAM tools in particular provide standardized, cost effective and scientifically defensible means to monitor and evaluate the water quality effectiveness of both road management practices and Treatment BMPs at specific locations overtime throughout the Tahoe Basin. Thus, funding for this project will not only result in greater instantaneous data integration across the Tahoe basin, but will vastly improve how effectiveness data is used to inform load reduction activities.

c) Describe treatment approach for reducing pollutants and/or measures to address connectivity between pollutant sources and Lake Tahoe or its tributaries. Identify target pollutants, and, to the degree feasible, provide quantitative estimates of project effectiveness at reducing pollutant loads (and/or a commitment to provide post-project estimates).

Because this project is a water quality implementation planning project, quantitative estimates of project effectiveness or load reductions resulting from the project are not applicable. The project improves the beta-version of decision-making support and rapid assessment tools developed for the purpose of estimating and tracking load reductions accomplished by local and state highway jurisdictions.

d) If appropriate, describe whether, and how, the project can be combined or coordinated with other TMDL implementation projects.

Not applicable.

Monitoring

- Describe the project monitoring that will be implemented as part of this project including:

  - List the questions the monitoring program is designed to answer.

Not applicable.

  - Describe any coordination with, or input from, the science community on monitoring and adaptive management that has occurred on the development of this nomination and what changes (if any) to the project were made as a result of this input.

It is intended that members of the science community will be retained to carry out the tasks and invited to participate on the Project Advisory Committee. Additionally, results from other SPLMA-funded research will be used to enhance and update the existing stormwater tools to the extent possible.

  - Describe the methods and strategies (i.e. monitoring, research, or both) that will be used to verify whether the project goals and objectives have been met? (*Note: A detailed monitoring plan and/or research plan is not required, however, enough detail must be provided to allow someone that is unfamiliar with the project to understand and evaluate the proposed methods and strategies.*)

EPA will be the grant administrator while NDEP will be the manager of the project. Both agencies will provide all technical and administrative services needed for contract completion, including monitoring, supervision and review of all work performed as well as budget coordination and scheduling to assure that the project work is completed within budget, on schedule, and in accordance with approved procedures, applicable laws, and regulations. Progress reports describing the activities undertaken and the accomplishments toward achieving project goals, tasks and targets shall be submitted on a quarterly basis. Accomplishment of project goals and objectives will be fulfilled with the submittal of all indicated deliverables.

  - Describe whether the monitoring or research associated with this project fits into or is part of a larger monitoring or research program.

Monitoring and research is not proposed for this project. However, monitoring data and research results will be used in the update of the tools.

  - Describe how information from the monitoring and/or research will be used to improve the continued performance of the proposed project or future similar projects.

While monitoring and research is not proposed for this project, the tools updated and produced through this project are intended to improve the performance of water quality implementation projects into the future. The RAM tools in particular provide standardized, cost effective and scientifically defensible means to monitor and evaluate the water quality effectiveness of both road management practices and Treatment BMPs at specific locations overtime throughout the Tahoe Basin. Thus, funding for this project will not only result in greater instantaneous data integration across the Tahoe basin, but will vastly improve how effectiveness data is used to inform load reduction activities.

Attachments:

1. Supplementary Information Regarding Lake Clarity Crediting Program Associated Stormwater Tools
2. Douglas County Letter of Support
3. Washoe County Letter of Support
4. City of South Lake Comment Letter/Letter of Support

Appendix B-8

LAKE TAHOE RESTORATION PROJECTS
ESTIMATED NECESSARY EXPENSES & KEY MILESTONE DATES

Project Name:	Lake Tahoe Stormwater Tools Improvement	Agency:	United Stated Environmental Protection Agency
Prepared by:	USEPA, NDEP, Lahontan Water Board	Phone:	(775) 589-5248
SNPLMA Project #:		EIP #:	628,10110, 10111

Identify estimated costs of eligible reimbursement expenses:

1. **Planning, Environmental Assessment and Research Costs** (specialist surveys, reports, monitoring, data collection, analysis, NEPA, etc.)	$		%
2. **FWS Consultation – Endangered Species Act**	$		%
3. **Direct Labor (Payroll) to Perform the Project**	$	20000	4 %
4. **Project Equipment** (tools, software, specialized equipment, etc.)	$		%
5. **Travel** (including per diem where official travel status required to carry out project, such as serve as COR, experts to review reports, etc.)	$		%
6. **Official Vehicle Use** (pro rata cost for use of Official Vehicles when required to carry out project)	$		%
7. **Cost of Contracts, Grants and/or Agreements to Perform the Project**	$	400000	85 %
8. **Other Direct and Contracted Labor:** Agency payroll for the Contracting Officer to do project procurement, COR, Project Inspector, Sec. 106 Consultation if required, NEPA Lead, Project Manager, Project Supervisor, and subject experts to review contracted surveys, designs/drawings, plans, reports, etc.; Also covered is the cost to contract for a Project Manager and/or Project Supervisor if contracted separately from other project contract(s)	$	60000	11% %
9. **Other Necessary Expenses** (see Appendix B-11): Indirect costs associated with implementing a project, such as support services, budget tracking etc.	$		%
TOTAL:	$	480000	100 %

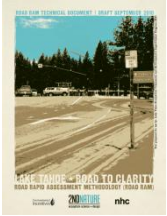
Estimated Key Milestone Dates:

Milestones/Deliverables:	Date:
Detailed workplan/agreement with NDEP in place	7/31/2012
NDEP subcontracts in place	12/30/2012
Second versions of BMP and Road RAM	12/30/2013
Second version of PLRM	3/31/2014
Urban Stormwater Management and Reporting Platform	6/30/2014
Final Completion Date: 6/30/2014	

COMMENTS:

SUPPLEMENTARY INFORMATION REGARDING LAKE CLARITY CREDITING PROGRAM ASSOCATED STORMWATER TOOLS

ROAD RAPID ASSESSMENT METHODOLOGY



SHORT NAME	FUNDER	FORMAT	COMPLETED
Road RAM	**NDEP & CTC**	**Online Database**	**12/10**

Download v1.0 User Guidance, Technical Document & Online Database here
http://www.tahoeroadram.com/

v1: Cost-effective, repeatable and simple set of field observations that define the relative pollutant load generation from urban roads in different conditions.

v2 (proposed): Incorporate priority improvements based on developer testing and feedback from jurisdiction users during the 2010 beta-testing of the Road RAM.

BEST MANAGEMENT PRACTICE MAINTENANCE RAPID ASSESSMENT METHODOLOGY

SHORT NAME	FUNDER	FORMAT	COMPLETED
BMP RAM	**US ACE**	**Access Database**	**9/09**

Download version 1.0 User Guidance, Technical Document & Database here
http://tinyurl.com/bmpramuser, http://tinyurl.com/bmpramtech, http://tinyurl.com/bmpramdbv1

v1: Simple, repeatable set of field observations that assist in determining the relative condition of urban stormwater treatment BMPs to inform the relative urgency for maintenance of water quality Treatment BMPs and to inform the estimation of load reduction achieved in a given year.

v2 (proposed): Incorporate priority improvements based on developer testing and feedback from jurisdiction users during the 2010 beta-testing of the BMP RAM.

POLLUTANT LOAD REDUCTION MODEL

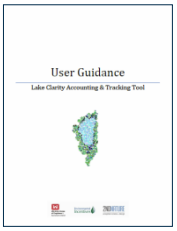
SHORT NAME	FUNDER	FORMAT	COMPLETED
Accounting & Tracking Tool	**USACE**	**PC Application**	**12/09**

Download version 1.0 PLRM Application, User's Manual & Applications Guide here
http://tinyurl.com/plrmexe, http://tinyurl.com/plrmuserman, http://tinyurl.com/plrmapplguide

v1: An advanced continuous-simulation model, PLRM was specifically designed to evaluate and compare pollutant load reduction alternatives for stormwater quality improvement projects in the Tahoe Basin.

v2 (proposed): Incorporate priority improvements based on developer testing and feedback from jurisdiction users during the 2010 beta-testing of the PLRM.

TMDL ACCOUNTING & TRACKING TOOL



SHORT NAME	FUNDER	FORMAT	COMPLETED
PLRM	**USACE & CA Water Board**	**Access Database**	**9/09**

Download v1.0 User Guidance & MS Access Database here
http://tinyurl.com/atuserguide, http://tinyurl.com/atdbzip

v1: A Microsoft Access® database to track and report load reductions from TMDL implementation activities in all source categories.

v2: Functions will be assumed by the Integrated Tahoe Stormwater Tool, a single online user interface allowing jurisdictions to upload PLRM outputs and enter all information necessary for registering catchments in the Crediting Program, prioritize maintenance activities, report road and treatment BMP conditions, declare credits, and generate outputs necessary to complete certain requirements of annual stormwater reports. NDEP and Lahontan have earmarked $70K to develop the Integrated Tahoe Stormwater Tool and additional funding is being requested through US Army Corps of Engineers and Nevada Division of State Lands. **Rd 12 Capital funding is being requested to link the Tahoe Integrated Stormwater Tool to a web-based map viewer and increase the utility as a stormwater management and reporting platform.**

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COMMUNITY DEVELOPMENT
1594 Esmeralda Avenue, Minden, Nevada 89423

Mahmood Azad, P.E.
COUNTY ENGINEER

775-782-9063
FAX: 775-782-6297
website: www.douglascountynv.gov

Planning Division
Engineering Division
Building Division
Regional Transportation
Code Enforcement

23rd December, 2010

Mr. Jeff Marsolais
Acting Forest Supervisor
Lake Tahoe Basin Management Unit
United States Forest Service
35 College Drive
South Lake Tahoe, CA 96150

Dear Mr. Marsolais,

Douglas County, NV is in full support of the proposal entitled *Lake Tahoe Stormwater Tools Improvement* that was submitted for consideration of Round 12 Southern Nevada Public Lands Management Act Capital funding by the Nevada Division of Environmental Protection in partnership with the Lahontan Water Board. As a part of the Lake Clarity Crediting Program Support Services project that our agency is actively participating in, we have tested and received training on the Pollutant Load Reduction Model (PLRM) Best Management Practices Maintenance Rapid Assessment Methodology (BMP RAM) and Road Rapid Assessment Methodology (Road RAM) and have deemed them as very useful.

The testing and training our agency has accomplished on the initial versions of the stormwater tools has indicated that these are valuable tools which facilitate municipalities and departments of transportation to prioritize capital investments, staff time and the deployment of maintenance equipment to most effectively reduce pollutant loading from urban stormwater. The proposed project will carry out recommendations for improvements to the stormwater tools to make them more efficient.

In conclusion, we strongly support the proposed work and request you to award funding for the project. If you have any questions please call me at (775) 782-9063.

Sincerely,

Mahmood Azad

Mahmood Azad, PE
County Engineer

MAILING ADDRESS: P.O. Box 218, Minden, Nevada 89423

WASHOE COUNTY

Department of Public Works

"Dedicated to Excellence in Public Service"

Dan St. John, P.E., Public Works Director

1001 East 9th Street PO Box 11130 Reno, Nevada 89520 Telephone: (775) 328-2040 Fax: (775) 328-3699

January 21, 2011

Mr. Jeff Marsolais
Acting Forest Supervisor
Lake Tahoe Basin Management Unit
United States Forest Service
35 College Drive
South Lake Tahoe, CA 96150

Re: Letter of Support for *Lake Tahoe Stormwater Tools Improvement Grant Proposal,* Round 12 SNPLMA Capital

Dear Mr. Marsolais,

I would like to express our agency's support of the proposal entitled *Lake Tahoe Stormwater Tools Improvement* that was submitted for consideration of Round 12 Southern Nevada Public Lands Management Act Capital funding by the Nevada Division of Environmental Protection in partnership with the Lahontan Water Board. As a part of the Lake Clarity Crediting Program Support Services project that our agency is actively participating in, we have tested and received training on the Pollutant Load Reduction Model (PLRM) Best Management Practices Maintenance Rapid Assessment Methodology (BMP RAM) and Road Rapid Assessment Methodology (Road RAM) and have been asked to provide feedback that will be used to improve them in the future.

The testing and training our agency has accomplished on the initial versions of the stormwater tools has indicated that these are valuable tools which will facilitate the County to prioritize capital investments, staff time and the deployment of maintenance equipment to most effectively reduce pollutant loading from urban stormwater. However, we also believe the current versions of these tools are better characterized as beta versions. The proposed project will carry out technical improvements to the stormwater tools that will make them more efficient, functional and better able to support targeted efforts to reduce pollutant loadings.

In addition, the proposed Urban Stormwater Management and Reporting Platform would be a beneficial product for the County. The web-based map viewer will not only improve the transparency and accountability for capital funds received to implement water quality improvements, thus helping to maintain the funding stream for these projects, but will also improve urban jurisdictions abilities to observe and track our load reduction activities, including the maintenance of assets. Moreover, with enhanced functionality features to be provided will better enable stormwater managers to target cost-effective actions in areas where the greatest load reductions can be achieved.

In conclusion, we strongly support the proposed work and implore you to award funding for the project.

Sincerely,

Dan St. John, P.E.
Public Works Director

cc: Dave Childs, Kimble Corbridge, Kris Klein, Jason Kuchnicki

City of South Lake Tahoe

"making a positive difference now"

March 7, 2011

Mr. Jeff Marsolais
Acting Forest Supervisor
Lake Tahoe Basin Management Unit
United States Forest Service
35 College Drive
South Lake Tahoe, CA 96150
jmarsolais@fs.fed.us

Dear Mr. Marsolais:

I would like to express our agency's support of the proposal entitled *Lake Tahoe Stormwater Tools Improvement* that was submitted for consideration of Round 12 Southern Nevada Public Lands Management Act Capital funding by the Nevada Division of Environmental Protection in partnership with the Lahontan Water Board. As a part of the Lake Clarity Crediting Program Support Services project that our agency is actively participating in and funding, we have tested and received training on the Pollutant Load Reduction Model (PLRM) and Best Management Practices Maintenance Rapid Assessment Methodology (BMP RAM), and have been asked to provide feedback that will be used to improve them in the future.

Our work with the initial versions of the stormwater tools has indicated that these are valuable tools which facilitate municipalities and departments of transportation to prioritize capital investments, staff time and the deployment of maintenance equipment to most effectively reduce pollutant loading from urban stormwater. However, we also believe the current versions of these tools are better characterized as beta versions, and that we've learned how they could be improved during this beta-testing period. The proposed project will carry out regulatory agency and jurisdictions' recommendations for technical improvements to the stormwater tools that will make them more efficient, functional and better able to support targeted efforts to reduce pollutant loadings.

At this point, we support funding for Tasks 1-3. Technical improvements to improve PLRM and RAMs, and provide better integration with other TMDL tools are important to us. The City and favors adding a section to Task 1 to refine PLRM sediment trap options. Just as Task 1D helps address a concern that vault performance may be over-predicted, the City and other jurisdictions are concerned that the performance of thousands of sediment traps in retaining fine sediment is under-predicted. After we've reviewed and have received training in the Road RAM, we hope to have an opportunity for input on tasks related to improving the Road RAM.

At this time our support for Task 4 is conditional. Given the timeframe (contracts with consultants in place by the end of July 2012), the first part of Task 4 should be to review existing GIS platforms already in use by the jurisdictions. Rather than constructing a new GIS platform, it may be more

efficient to use one of the existing jurisdictions' GIS platforms, or maybe set up a system to import data from the jurisidictions' GIS platforms. For a product with a delivery date in mid 2014, most or all of the jurisdictions may already have developed web-based map viewers that already perform many of these functions. The jurisdictions are likely to maintain and update their own GIS systems, because they would be using them for asset management, tracking inspections, and scheduling maintenance practices. It is not clear what agencies would be the long-term hosts, and responsible for maintenance, operation, and updates for the Urban Stormwater Management and Reporting Platform. We can support a modified Task 4A which would help jurisdictions with tasks such as updating information on structural and private parcel BMPs. For Task 4B, the deliverable could be modified to provide GIS coverages or geo-databases to jurisdictions which could be used with their existing GIS platforms, rather than to specify that the product is being developed only for the web viewer specified in Task 4A.

In conclusion, we strongly support the proposed work as identified above, and ask you to award funding for the project.

Sincerely,

Robert Erlich

Robert Erlich
Stormwater Coordinator
Public Works Department
City of South Lake Tahoe

rerlich@cityofslt.us
530-542-6038