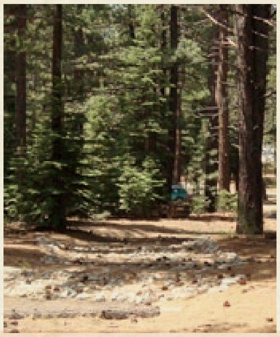
BEST MANAGEMENT PRACTICES MAINTENANCE RAPID ASSESSMENT METHODOLOGY

BMP RAM TECHNICAL DOCUMENT

TOOL PREPARED FOR USE BY:
THE LAKE TAHOE STORMWATER COMMUNITY AND
ENVIRONMENTAL IMPROVEMENT PROGRAM (EIP)

FINAL – SEPTEMBER 2009



Best Maintenance Practices Maintenance Rapid Assessment Methodology

BMP RAM Technical Document
Final September 2009

The BMP RAM development is part of a multi-stakeholder collaborative effort to minimize the deleterious effects of urban stormwater on the ecosystem and economy of the Lake Tahoe Basin. This product would not be possible without the generous participation of several Basin regulatory and project implementing entities. This specific product is authorized pursuant to Section 234 of the Water Resources Development Act of 1996 (PL 104-303) which provides for coordinated interagency efforts in the pursuit of water quality and watershed planning.

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Executive Summary

The Best Management Practices Maintenance Rapid Assessment Methodology (BMP RAM) is a simple and repeatable field observation and data management tool that can assist Lake Tahoe natural resource managers in determining the relative **condition** of urban stormwater **Treatment BMPs**. The primary purpose of the BMP RAM is to inform the user of the relative urgency of water quality maintenance for Treatment BMPs. The BMP RAM evaluations, therefore, do not specifically address or consider the quality of the design of a particular Treatment BMP relative to other Treatment BMPs. Rather the BMP RAM provides a practical, consistent and reliable tool to track the condition of a particular Treatment BMP, relative to its observed condition at time of installation or immediately following complete maintenance.

Key Concepts

The BMP RAM is based on a progression of four concepts that represent the best scientific understanding of current stormwater treatment infrastructure in the Lake Tahoe Basin (Figure ES.1).

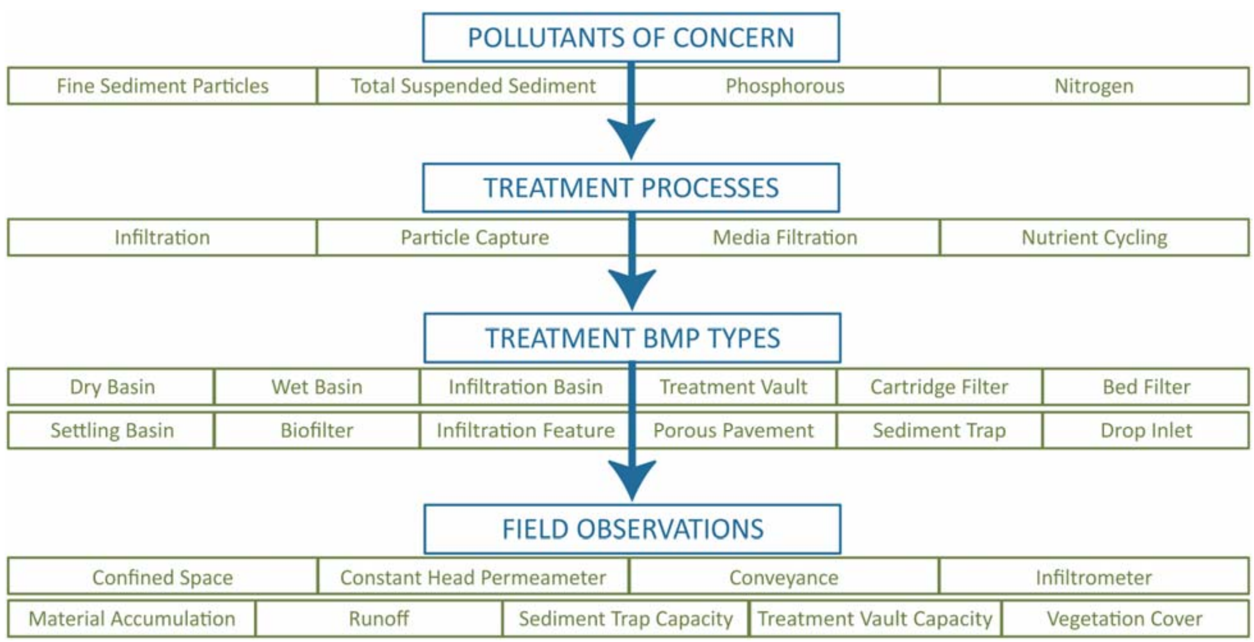


Figure ES.1 Key concepts upon which the BMP RAM is based.

Fine sediment particles have been identified as the priority **pollutants of concern** in the Lake Tahoe Basin, though a variety of sediment and nutrient species are known to impair Lake Tahoe water clarity. These pollutant species are targeted by 4 distinct **treatment processes** to improve water quality of stormwater runoff: infiltration, particle settling, media filtration and nutrient cycling. The combination of treatment processes relied upon to reduce pollutant loads and other characteristics are used to define 12 unique Treatment BMP Types. Each Treatment BMP Type has one or more rapid field observations that can be conducted to evaluate the functional condition of the respective treatment processes. The results of the field observation are integrated and expressed as a **BMP RAM Score** from 0 (worst) to 5 (best) that represents the relative condition of each specific Treatment BMP. BMP RAM Scores can be used to track the condition of Treatment BMPs throughout Lake Tahoe over time due to the consistent management of all data in the BMP RAM Database (**database**) version 1. The results across different Treatment BMPs will inform future improvements in design and maintenance strategies of specific Treatment BMP types.

BMP RAM Implementation

The BMP RAM consists of a series of six STEPs that have been designed for ease and practicality from the user's perspective (Table ES.1). BMP RAM STEPs 1 and 2 are the identification, mapping and inventorying of Treatment BMPs within the urban catchment of interest. BMP RAM STEPs 1 and 2 are completed one time prior to making observations at the Treatment BMPs. The final product of BMP RAM STEPs 1 and 2 is a comprehensive mapped inventory of all Treatment BMPs within the area of interest. BMP RAM STEP 3 establishes critical values that are necessary for future relative condition assessment. This step is done at first for each Treatment BMP and then is updated only when deemed necessary by the user. BMP RAM STEPs 4-6 define the sequence of data collection and analysis STEPs required to assess the operational condition of Treatment BMPs with respect to water quality impacts. BMP RAM STEPs 4-6 are repeated as often as condition scores are needed.

Table ES.1 Summary of BMP Maintenance BMP RAM STEPs implemented by the user.

BMP RAM STEP #	BMP RAM STEP Name
1	Define URBAN CATCHMENT of interest
2	Create INVENTORY
3	Set BENCHMARK and THRESHOLD Values
4	Conduct FIELD OBSERVATIONS
5	Obtain BMP RAM SCORE
6	Analyze Results

BMP RAM STEP 1 – Define URBAN CATCHMENT of Interest

The spatial area of interest is ideally an urban planning catchment (UPC) that is consistently defined by the local jurisdiction for other Lake Tahoe stormwater management efforts, such as the Pollutant Load Reduction Strategy, the Pollutant Load Reduction Model (PLRM), the TMDL Tracking Tool, the Lake Clarity Crediting Program, and others. However, the area of interest to complete the BMP RAM can include any catchment, an entire jurisdiction, an EIP project area, or any other urban area as defined by the user.

BMP RAM STEP 2 – Create INVENTORY

The user creates an inventory of the Treatment BMPs within the catchment defined in STEP 1. The user will utilize as-built drawings and design reports to map, determine Treatment BMP Type and characterize each Treatment BMP. Each Treatment BMP Type has a set of required characteristic information (i.e., footprint, number of inlets, water quality treatment volume, etc.) that must be determined and entered into the database. Each Treatment BMP is given a unique ID code. The product of BMP RAM STEP 2 is a comprehensive map with key characteristics of all relevant Treatment BMPs within the urban catchment.

BMP RAM STEP 3 – Set BENCHMARK and THRESHOLD Values

In RAM STEP 3, the user establishes benchmark and threshold values for each Treatment BMP's associated field observations. Benchmark and threshold values define a linear spectrum of Treatment BMP condition, ranging from the best achievable to the condition when maintenance is required to maintain an acceptable water quality benefit.

In most instances, the benchmark values for each specific Treatment BMP are observed by the user when the specific Treatment BMP is at its achievable, highest, best relative condition such as shortly following construction or immediately following complete maintenance actions. Benchmark values are not design concepts or modeled values. A Treatment BMP at benchmark condition will have a RAM Score of 5, representing the best achievable condition for that Treatment BMP.

Threshold values for each field observation define the condition in which the Treatment BMP is no longer providing the intended minimum water quality benefit. When the threshold is reached the BMP RAM Score will be less than, or equal, to 2 and maintenance is required to restore the function of the respective treatment processes. Thresholds are either set by the user or default values in the database.

BMP RAM STEP 4 – Conduct FIELD OBSERVATIONS

For each Treatment BMP type, the user performs a set of simple field observations according to the appropriate BMP RAM field observation protocols. The observations are proxies, either independently or in combination, for the current condition of the Treatment BMP to perform its treatment process. The results of the individual observations are integrated by the database and compared to the benchmark and threshold conditions to determine the current condition at the time of observations. The user also confirms that each of the inlets and outlets of a Treatment BMP appear to convey stormwater runoff to/from the BMP as intended. All observations are recorded on field datasheets and later transferred into the database.

BMP RAM STEP 5 – Obtain BMP RAM SCORE

The database calculates a BMP RAM Score using field observation results, benchmark values and threshold values. For each of the relevant processes operating in any given Treatment BMP Type, observations and are integrated within the database to calculate BMP RAM Score from 0-5 for each

Treatment BMP evaluated. Table ES.2 summarizes the condition and relative urgency of maintenance for the range of BMP RAM Scores.

<table>
<tr><th colspan="4">Table ES.2 BMP RAM Scores relative to Treatment BMP condition and relative maintenance urgency.</th></tr>
<tr><th>BMP RAM Score</th><th>Condition</th><th>Maintenance Urgency</th><th>Description</th></tr>
<tr><td>0-1.0</td><td>Failure</td><td rowspan="3">Required</td><td>Little to no downgradient water quality benefit and downgradient water quality may be adversely affected due to failure of Treatment BMP function. Maintenance required immediately.</td></tr>
<tr><td>>1.0-
< 2.0</td><td>Below acceptable</td><td>Treatment BMP load reduction potential is below acceptable condition. Maintenance is required prior to next runoff event.</td></tr>
<tr><td>2.0</td><td>Threshold</td><td>Threshold condition set by user that corresponds to condition where maintenance is required.</td></tr>
<tr><td>> 2.0-
< 3.0</td><td rowspan="2">Acceptable</td><td>Moderate</td><td>Acceptable downgradient water quality benefit, but Treatment BMP condition is closer to threshold than benchmark. Maintenance should be performed if time and resources permit.</td></tr>
<tr><td>> 3.0-
< 5.0</td><td>Low</td><td>Acceptable downgradient water quality benefits. No immediate maintenance needed.</td></tr>
<tr><td>5.0</td><td>Benchmark</td><td>None</td><td>Maximum achievable downgradient water quality benefit for the specific Treatment BMP. No maintenance actions needed.</td></tr>
</table>

BMP RAM STEP 6 – Data Analysis

The BMP RAM consistency of data generation and data management will significantly increase the future spatial and temporal Treatment BMP datasets throughout the Lake Tahoe Basin. The individual Treatment BMP Scores, color coded catchment maps and database information can be used to identify areas of high maintenance needs, develop appropriate maintenance schedules, and assist jurisdictions to more easily meet stormwater permit requirements. The data analysis is best communicated through the mapping of BMP RAM results. Time series of catchment BMP RAM Scores, displayed in a standardized color gradation progressing from red to green to visually indicate low to high Treatment BMP condition, simply communicates a large amount of spatial BMP RAM results. Scientists and empirical modelers can begin to integrate Treatment BMP conditions with high resolution water quality performance evaluations to improve our quantitative understanding of condition and water quality treatment capabilities. The integration of Treatment BMP condition with high resolution water quality evaluations can inform future Treatment BMP design improvements to maximize load reductions for the Lake Tahoe pollutants of concern.

Document Use and Audience

BMP RAM documentation consists of three main components that are primarily targeted to urban jurisdictions' stormwater managers and Operations & Maintenance (O&M) personnel. The BMP RAM version 1 components are distributed as separate electronic files:

- BMP RAM Technical Document.pdf
- BMP RAM User Manual v1.pdf
- BMP RAM Database v1.accdb

The BMP RAM Technical Document provides the background and scientific underpinnings of the BMP RAM and will be necessary for stormwater managers who need to understand how the tool works and the rationale supporting tool development choices. It is possible to successfully collect data and work with the database without reviewing the BMP RAM Technical Document, but the user would be less familiar with the rationale behind certain terms, procedures and components of the tool. The technical document is primarily targeted to the stormwater managers of urban jurisdictions.

The BMP RAM User Manual details the specific process and protocols necessary for field and office personnel to create a Treatment BMP inventory, conduct field observations and interact with the database. The User Manual is primarily targeted to O&M personnel who are expected to implement the BMP RAM observations over time (STEPs 4-6). STEPs 1-3 will require collaboration between O&M personnel, engineering departments and GIS specialists to complete the one-time stormwater asset inventory (STEP 2) and set the benchmark/threshold values for each Treatment BMP (STEP 3). The O&M personnel should always have a field-ready hard copy of the BMP RAM Users Manual when implementing the BMP RAM observations in the field (STEP 4). Stormwater managers should also be familiar with the BMP RAM User Manual, particularly the office-based procedures for mapping Treatment BMPs and managing the database.

The BMP RAM Database manages all necessary data and information generated by the BMP RAM implementation to calculate BMP RAM Scores over time. This file is intended to be managed by personnel experienced with databases and does not need to be well understood by field crews. Each jurisdiction will maintain its own BMP RAM database file.

Chapter 1: Overview and Goals

Introduction

The Best Management Practices Maintenance Rapid Assessment Methodology (BMP RAM) has been developed to provide a tool to Lake Tahoe urban land managers to rapidly evaluate the relative condition and determine the urgency of maintenance for Treatment BMPs typically implemented in the Lake Tahoe Basin. Treatment BMPs are implemented in urban catchments to treat urban stormwater by reducing pollutant loads. The BMP RAM is a complete tool for land managers to inventory, evaluate and track the relative condition of Treatment BMPs over time.

Treatment BMPs that provide water quality improvement will tend to accumulate the pollutants that have been removed from the stormwater routed through the Treatment BMP. The capability of a Treatment BMP to perform its desired treatment function and provide maximum water quality benefits will typically decrease over time unless maintenance actions are performed to restore the process function. At some point, accumulation of pollutants can drastically decrease the functional efficiency of passive treatment processes and poorly maintained Treatment BMPs have been observed to even become *sources* of the pollutants of concern (2NDNATURE, 2006A). The BMP RAM provides a complete and consistent field evaluation and data management tool for jurisdictions to determine the urgency of maintenance, track condition over time and maintain the intended water quality benefits of Treatment BMPs.

The BMP RAM solely addresses Treatment BMPs and is not the complete urban RAM tool. The BMP RAM does not encompass source control BMPs (such as retaining walls) nor conveyance features. Urban road BMPs such as curb and gutter, road shoulder protection, and road maintenance strategies will be evaluated under the Road RAM, expected to be released in spring 2010.

Justification

Rapid Assessment Methodologies (RAMs) are standardized, defensible and low-cost tools to rapidly evaluate the condition of an area, process, or feature. The underlying philosophy behind any RAM is that the relative condition of the feature, area or system can be evaluated using a select number of key observations. In general, environmental RAM approaches focus on the visible, physical and/or biological structure of the attributes being assessed and use proxies to infer the physical, chemical or biological process function. RAMs allow a much more cost-effective application of existing scientific knowledge of system function by implementing simple, repeatable, targeted observations over a much larger spatial area than can be evaluated using more advanced monitoring and evaluation techniques. The rapid observations do not replace the potential need to conduct more rigorous evaluations and monitoring that provide data to validate the assumptive linkages between the proxies and the processes of interest.

The development team conducted a literature review to document the strengths, weaknesses and approach utilized by a number of existing and well-accepted RAMs. The BMP RAM is based on a growing body of scientific literature and practical experience to apply rapid assessment concepts to a variety of aquatic systems. RAMs have been developed for wetland habitats (e.g., Miller, 1997; Mack, 2001; Collins, 2008) to evaluate the relative condition of various wetland components such as landscape, hydrology, physical structure, and biotic structure. RAMs for stream assessment (e.g., Rosgen, 1996; Roth, 1996; Starr, 2001; Montgomery, 2002) generally focus on fluvial morphology, water quality, channel stability, erosion risk, biological indicators, physical in-stream habitat, and riparian habitat. Vegetation and habitat RAMs (e.g., Barbour, 1995; CNPS, 2004) are often used to quickly assess and map the extent of all vegetation types and biological condition in relatively large, ecologically defined regions.

The development team also conducted a number of interviews with Lake Tahoe jurisdictions and resource managers to document the existing techniques employed locally to inventory, evaluate and track stormwater Treatment BMPs. The information gained from these background research efforts were used to direct the BMP RAM tool documented herein.

Goal and Objectives

The BMP RAM has been developed to address current challenges in Treatment BMP management in the Lake Tahoe Basin. These include: (1) the lack of comprehensive inventories of existing Treatment BMPs within urban catchments; (2) a lack of documentation committing to the targeted pollutants for treatment by a specific Treatment BMP; (3) lack of documentation and/or consideration of the primary processes relied upon to improve downgradient water quality; (4) the high cost and long duration of high resolution water quality assessment methods to determine Treatment BMP performance; (5) the lack of standardized maintenance strategies and schedules; and (6) the lack of a logical and informative data management system to inform adaptive management actions.

Goal

- Develop a precise, cost-effective, and simple tool that can repeatedly assess the relative condition of Treatment BMPs in relation to their ability to provide water quality benefit, and rapidly determine maintenance urgency over time.

Objectives

- **Standardize Inventory Protocols -** Standardize a process and protocols to create a spatial inventory of Treatment BMPs within an urban planning catchment or a user-defined urban area.
- **Explain Treatment Processes –** Explain and categorize the physical, chemical, or biological means employed by a Treatment BMP to remove/retain the pollutants of concern and/or reduce stormwater volumes that ultimately reach Lake Tahoe
- **Standardize Treatment BMP Types** – Define a standardized Treatment BMP nomenclature to remove inconsistencies in the Treatment BMP Types. Define Treatment BMPs by the unique set of associated processes relied upon for water quality improvements.
- **Define Simple Field Observations -** Define simple and repeatable field observations at Treatment BMPs that will be consistently indicative of the physical, chemical and/or biological

processes relied upon for retention, removal, and/or treatment of the pollutants of concern. These observations should not be affected by seasonal and annual hydrologic conditions.

- **Score Relative Condition -** Define relative condition such that each numeric RAM Score on a 0-5 scale is directly indicative of relative maintenance urgency of the subject Treatment BMP with respect to improving down-slope water quality.
- **Create Standardized Data Management Structure –** Create simple to use relational database to manage data, generate BMP RAM results and facilitate the power of consistent data management across users and over time.
- **Easily Adoptable -** Create simple procedures and database tools to increase the likelihood for adoption and implementation by local jurisdictions as a means to assess Treatment BMP condition and prioritize operations and maintenance expenditures over time.

CHAPTER 2: KEY TERMS

The following key terms are used throughout the BMP RAM documentation. A complete glossary is included as Chapter 12.

Treatment BMP: Structural BMPs that accept, attenuate, and treat urban stormwater. Treatment BMPs are implemented to reduce pollutant loads in stormwater by either removing pollutants and/or by reducing surface water volumes. The BMP RAM defines Treatment BMP Types by the processes relied upon for water quality improvements, and design characteristics. Users of the BMP RAM must define the Treatment BMP type by these processes, rather than rely on previous naming conventions.

Treatment Process*:* Physical, chemical, or biological means employed by a Treatment BMP to remove/retain the pollutants of concern and/or reduce stormwater volumes that ultimately reach Lake Tahoe. Treatment BMPs in Lake Tahoe rely on 4 primary, passive processes to reduce the load of pollutants in stormwater:

- infiltration
- particle settling
- media filtration
- nutrient cycling

Conveyance: The physical process that transports stormwater downgradient in a manner that mitigates localized flooding. All Treatment BMPs must be able to convey stormwater through the structure, but conveyance alone provides no water quality benefit. Clear evidence of operating inflow and outflow must be present for Treatment BMPs to function as designed.

BMP RAM: The BMP RAM is a simple and repeatable field observation and data management tool to assist Lake Tahoe natural resource managers in determining the relative condition (and relative maintenance urgency) of an urban stormwater Treatment BMP. The tool consists of six distinct BMP RAM STEPs implemented by the user and information stored in a custom database.

Treatment BMP Condition: The condition is defined as a continuum of the water quality performance capability of a Treatment BMP. A Treatment BMP is considered at benchmark following installation and/or after adequate maintenance. As pollutant loading and treatment occurs during subsequent storm events, the condition of a Treatment BMP gradually declines. At some point, the operational performance of the specific Treatment BMP falls below the pre-determined acceptable condition (i.e., threshold) and maintenance is required.

Benchmark: The desired and achievable Treatment BMP condition. The benchmark equate to a RAM Score of 5. In most instances, benchmark condition may be observed shortly following construction or immediately following complete maintenance actions. The exceptions are desired benchmark characteristics that may take some time after construction and/or maintenance to achieve (e.g., benchmark vegetation cover).

Threshold: The Treatment BMP condition that the user has determined to be no longer acceptable from a water quality treatment perspective. The threshold equates to a RAM Score of 2. Typically, threshold values for each of the field observations are determined by the user relative to benchmark values, though strongly recommended default values are provided for each Treatment BMP by the BMP RAM Developers. The integration of field observations are calculated by the database to determine the Treatment BMP RAM Score (i.e. condition) at the time of observations.

BMP RAM Score: The BMP RAM Score is a 0-5 value that represents the Treatment BMP condition at the time of observations. The BMP RAM Score is a weighted integration of field observation results based on Treatment BMP type. A BMP RAM Score of 5 is the achievable benchmark. A BMP RAM score of 2 is a trigger for maintenance or other action to improve condition.

BMP RAM Database (database): Version 1 of the database is a customized Microsoft Access 2007 file that stores and manages all catchment information necessary to implement, track and maintain BMP RAM inventory and results over time. The BMP RAM user generates data and/or information and enters it into the database. Future versions will be created using a web-based platform to allow simple integration, maintenance, and spatial display of BMP RAM data from multiple users throughout Lake Tahoe.

CHAPTER 3: USERS AND APPLICATIONS

The BMP RAM is intended to be implemented by urban jurisdictions, providing a standardized tool to improve the management of Treatment BMPs to maintain pollutant load reductions. The main users at the jurisdictions are stormwater managers and operations & maintenance (O&M) personnel responsible for ensuring that Treatment BMPs are maintained within their jurisdiction. Additional uses of the BMP RAM results include at least annual evaluations of Treatment BMP condition, evaluation of maintenance schedules over time, and providing information for the adaptive management of urban catchments for TMDL water quality improvement goals. This chapter further defines users, describes how they can apply the BMP RAM results and highlights the most important parts of the BMP RAM documentation for primary users.

Primary Users and Applications

The primary user of the BMP RAM is the urban jurisdiction that has specific load reduction requirements through NPDES permits in California, or other implementation requirements in Nevada. Urban jurisdictions are a subset of implementers that includes four counties, the City of South Lake Tahoe, NDOT, and Caltrans. Urban jurisdictions can use the BMP RAM results to prioritize maintenance effort, validate that infrastructure has been maintained appropriately over time and support declarations of Lake Clarity Credits within the Lake Tahoe TMDL.

Implementation of the BMP RAM will primarily be the responsibility of office-based stormwater managers and field-based O&M personnel, both filling different roles. Stormwater managers need to fully understand the concepts and outcomes of each the BMP RAM STEPs and carefully review the BMP RAM Technical Document. O&M personnel should have a basic understanding of the BMP RAM's underlying principles and a strong, operational knowledge of the procedures for carrying out the field work. O&M personnel should focus their time on understanding the BMP RAM User Manual which includes a brief summary of information in the Technical Document. The BMP RAM User Manual is designed to be carried in the field by O&M personnel, while the BMP RAM Technical Document can remain in the office.

Stormwater managers will likely be primarily responsible for completing BMP RAM STEPs 1, 2 and 3, which are performed at the onset of implementing the BMP RAM in a specific catchment and require delineating the area (STEP 1), mapping and classifying each Treatment BMP (STEP 2) and setting benchmark and threshold values (STEP 3) by which future Treatment BMP condition will be determined. In most instances STEPs 1-3 will only be completed once, though minor adjustments may be made at a later date. GIS assistance will be required during STEP 2. The O&M personnel may assist with the installation of the basic instrumentation needed for the BMP RAM or collect any field observation data required during the completion of STEP 3.

Once BMP RAM STEPs 1-3 are completed, the O&M personnel are expected to be responsible for the annual field observations at each Treatment BMP (STEP 4) and completion of field datasheets. Field observation results must be entered into the database to complete STEP 4, and each jurisdiction needs to determine the most appropriate user to complete the data entry. STEPs 5 and 6 (Obtain BMP RAM Scores and Analyze Data) will be completed by either the stormwater managers and/or the O&M personnel.

Additional Users and Applications

The BMP RAM data and results have a number of additional applications. Project funders can use the results to inform funding priorities, set expectations for ongoing operations, and identify when contractual maintenance requirements have been fulfilled. Regulators and water quality program managers can assess the operational effectiveness of implementer maintenance actions and justify award of TMDL Lake Clarity Credits. Scientific researchers can correlate RAM Scores with high-intensity water quality monitoring results. This will enable researchers to better understand and interpret monitoring results, make more accurate pollutant removal projections, and improve empirical modeling assumptions.

CHAPTER 4: POLLUTANTS OF CONCERN

The continued decline in Lake Tahoe water clarity is attributable to both the increased loading in fine sediment particles (<16 µm in diameter) (FSP) and algae production. In suspension, FSP have settling rates on the order of years, and numerical modeling suggests that they may be responsible for nearly two-thirds of the current loss in water clarity (Swift et al., 2006). Increased availability of nitrogen (N) and phosphorous (P) delivered to Lake Tahoe have increased the primary production rates in the Lake, and are also considered key pollutants that cause clarity impairment of Lake Tahoe (USDA 2000). The BMP RAM focuses on the physical, chemical and/or biological processes relied upon to reduce sediment and nutrient loads in urban stormwater.

Sediment

Research for the Lake Tahoe TMDL (LRWQCB and NDEP, 2007) has indicated that 72% of the total annual contribution of fine sediment particles to the Lake is generated from urban stormwater runoff. The Lake Tahoe TMDL provides key strategies to reduce the loading of these pollutants of concern to the Lake, with reduction and control in urban areas as the primary source of focus.

Sediment in Lake Tahoe is characterized by two distinct analytic species, total suspended solids (TSS) and fine sediment particles (FSP; <16 µm). TSS is the mass of sediment contained in a known volume of water, and stormwater samples analyzed for TSS can be used to quantify the suspended sediment loads transported in runoff. Most existing studies examining sediment loads to Lake Tahoe report sediment concentrations as TSS, however the future water quality studies, modeling estimates and tools will include and prioritize FSP as the primary pollutant of concern. FSP refers to the mass fraction of the TSS concentration that consists of particles 16 µm or smaller, expressed as a % TSS by mass and allowing a concentration of FSP to be simply calculated. The Lake Tahoe TMDL program is tracking FSP by number of particles < 16 µm. Although expensive and time consuming, a sediment sample can be sieved and the sediment <16 µm can be analyzed to determine the number of individual particles within the sample. The cost and complexity of the particle analysis for all water samples within the Lake Tahoe Basin make the estimate by number of FSP impractical for all water samples collected. Thus, empirical relationships have been developed and are continuing to be refined by local academic institutions to convert the mass of FSP to # of particles. At the time of this report, the current particle converter indicates 1kg of FSP = 1.12×10^{14} particles <16 µm (TERC 2009).

Nutrients

The primary nutrient species contributing to the decline in Lake Tahoe clarity include nitrogen (N) and phosphorus (P). Results from long-term algal growth bioassay experiments (Goldman et al., 1993) and atmospheric nitrogen studies (Jassby et al., 1994; 1995; 2001) show a clear shift from co-limitation by both nitrogen and phosphorous in the middle of the 20th century, to persistent phosphorous limitation in the phytoplankton community in Lake Tahoe. Thus phosphorous is the primary nutrient of concern. Both N and P exist in solid and dissolved forms. Dissolved nutrient species (<0.45 µm) are biologically available and thus are of utmost concern to resource managers tasked with reversing the decline in Lake water clarity. The dissolved nutrient species are dissolved inorganic nitrogen (DIN) and soluble reactive phosphorous (SRP), respectively. Total nitrogen (TN) and total phosphorous (TP) are determined by the analysis of non-filtered samples, thus the concentrations and loads include all nitrogen or phosphorous adhered to particles and/or incorporated within organic biomass. For a more extensive discussion on the relationship and details of the key nutrient species of concern in Lake Tahoe see 2NDNATURE 2006A.

CHAPTER 5: STORMWATER TREATMENT PROCESSES

There are four primary processes relied upon by typical Treatment BMPs to reduce, retain and/or remove sediment and nutrients species from urban stormwater. The processes are <u>extremely</u> valuable for consistently defining Treatment BMP types. The processes are:

- Infiltration
- Particle capture
- Media filtration
- Nutrient cycling

The BMP RAM Treatment BMP Types (Chapter 6) are defined, in part, by the combination and prioritization of these processes relied upon to improve water quality downgradient. In general, these primary treatment processes are interdependent with multiple processes acting in unison to provide water quality benefits at any given Treatment BMP. The degree to which any single process dominates stormwater treatment depends largely on the designed function of the Treatment BMP. Each Treatment BMP Type has a unique set of characteristics and treatment processes that a BMP RAM user can evaluate in the field. The primary assumptions inherent in the selection of field observations to evaluate each of the four treatment processes are provided below. Each of the four treatment processes are defined below in the context of process function.

Infiltration

Infiltration is the primary passive process relied upon in Lake Tahoe to treat urban stormwater. Stormwater volumes and associated pollutant loads are reduced by infiltration through the soil column, and pervious soils provide the opportunity for rapid infiltration. It is assumed that the ability to infiltrate stormwater is primarily controlled by the infiltration capacity of the soil which is dominated by soil type, porosity, saturated hydraulic conductivity, degree of saturation, and hydraulic head. Infiltration capacity of a particular Treatment BMP can be significantly influenced by location and the relative depth to shallow groundwater. Many Treatment BMPs in urban Lake Tahoe areas are in close proximity to the Lake and possess a very shallow unsaturated zone due to high shallow groundwater tables, particularly in the spring (2NDNATURE 2006B).

Particle Capture

Particle capture involves sequestering sediment through flow attenuation. Decreasing lateral flow velocity limits the particle transport capacity of stormwater, allowing particle settling and retention within the Treatment BMP. Key characteristics that increase a Treatment BMP's ability to capture particles are longer flow path lengths, longer hydraulic residence times (HRT), and potentially the type and amount of vegetation within the flow path. It is assumed that vegetation acts to attenuate flow velocities and provides a substrate for entrained FSP to aggregate and/or adhere, however more detailed quantitative evaluations of the effectiveness of vegetation to retain FSP are still needed. Increasing the contact time between particles also increases fine particle aggregation (fine particles have a slight electric charge), thereby increasing settling velocities and magnitude of capture. Outlet risers that restrict outflow to the surface of the water column increase the particle capture effectiveness of a Treatment BMP. Particulate nutrients are those adhered to sediment or organic matter and are also captured.

Media Filtration

Media filtration reduces the concentrations of pollutants in stormwater through the use of engineered flow-through systems. These systems can be designed to (1) physically trap, separate, and/or sieve particulate matter, and/or (2) use active media to adsorb and remove dissolved constituents as stormwater is transported downgradient. The type of media installed in any particular Treatment BMP should be carefully selected based on the targeted pollutants of concern. The effectiveness of media filtration to retain any particular pollutant of interest is controlled by the geochemical characteristics of both the media and the pollutant. For example, phosphorous has a high affinity for aluminum hydroxide (AlOH) or iron hydroxide (FeOH) species (Stumm and Morgan 1996) and local Lake Tahoe research has noted the ability to reduce phosphorous in stormwater using activated alumina (CalTrans 2007 and Bachand and Heyvaert 2005). However, a media with activated alumina would have little benefit if nitrate (NO_3^-) was the target pollutant due to its geochemical characteristics. Nitrate removal by media filtration in Lake Tahoe would require media containing organic matter and an oxygen source to stimulate denitrification and the release of inert nitrogen (N_2) gas (LRWQCB 2008).

Nutrient Cycling

Nutrient cycling involves the reduction in concentration of biologically available nutrients due to uptake by growing vegetation. This process is most pronounced in Treatment BMPs that are seasonally or frequently inundated with stormwater containing a relatively high concentration of phosphorous and nitrogen. Photosynthesis is the process of vegetation incorporating available nutrients in stormwater to create organic matter. During the fall and winter, respiration of organic matter completes the nutrient cycle and releases inorganic nutrients back into the system. Reducing conditions in Treatment BMPs with more frequent inundation patterns and dense riparian or wetland vegetation communities can significantly increase nutrient cycling rates. The net removal of biologically nitrogen can be very effective in Treatment BMPs with high nutrient cycling due to denitrification. Effective phosphorous species removal may require annual fall harvesting of vegetation to prevent decomposition and the re-release of biologically available nutrients. Infiltration can be effective at reducing FSP and particulate nutrient loads due to trapping of these pollutants in the unsaturated soil column. The absorptive capacity of SRP (soluble reactive phosphorous) likely results in effective capture of this reactive dissolved pollutant. However, the conservative dissolved inorganic nitrogen species, particularly nitrate (NO_X), is poorly treated by soil/water interactions.

Conveyance

Conveyance of stormwater does not provide any downstream water quality improvement, but is a vital characteristic of a functional Treatment BMP. If a Treatment BMP is not receiving or discharging stormwater as designed, the associated water quality benefits are not possible. The BMP RAM includes simple conveyance evaluations to validate that each Treatment BMP is conveying water in and out of the structure adequately. It is assumed that a non-functional inlet or outlet will directly impair the operational condition of a Treatment BMP.

CHAPTER 6: TREATMENT BMP TYPES

Each Treatment BMP employs one or more primary treatment processes to improve water quality and these processes provide an opportunity to consistently define Treatment BMP Types. The Treatment BMP Types preserve traditional names to the extent possible, while minimizing the number of Treatment BMP Types. In some instances, two different Treatment BMP Types rely upon the same treatment processes for water quality improvement; however their respective physical characteristics are distinctly different, requiring very different BMP RAM observations in the field to rapidly assess Treatment BMP condition.

The BMP RAM development team has coordinated and aligned the BMP RAM Treatment BMP Types with the Pollutant Load Reduction Model (PRLM) and BMP Database developers to ensure consistency for relevant Lake Tahoe TMDL tools going forward. Tahoe Basin resource managers will benefit if the these Treatment BMP Types become the standard of reference because stormwater tools will be able to work together, quantitative analyses will be more comparable and semantic discussions surrounding BMPs will be easier. If other efforts do choose to define Treatment BMP types differently, they should take time to produce a translator that allows users to see how their Treatment BMP types correspond to the ones defined in this well-considered standard. Table 6.1 lists the BMP Types, other common names, narrative description and the primary treatment process(es) relied upon to improve water quality.

TABLE 6.1 BMP RAM Treatment BMP Types.

Treatment BMP Type	Other Names	Description	Processes relied upon for water quality treatment IN ORDER OF PRIORITY α
Dry Basin	Extended Detention Basin, 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* β

TABLE 6.1 BMP RAM Treatment BMP Types.

Treatment BMP Type	Other Names	Description	Processes relied upon for water quality treatment IN ORDER OF PRIORITY α
Wet Basin	Wet Pond, Retention Pond, Wetland Swale, Wet Extended - Retention Pond, Stormwater Wetlands, Constructed Wetlands	• 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*
Infiltration Basin	Large-Scale Infiltration Feature	• Constructed basin with little to no treatment storage, meaning stormwater that continues downgradient has the same pollutant concentrations as introduced to the infiltration basin. • Highly permeable substrate designed to rapidly infiltrate significant volumes of stormwater into unsaturated zone. Pollutant load reductions realized due to significant volume reductions. • Vegetation distribution should be minimal, but preferably absent. • Stormwater is typically routed to the BMP and any excess stormwater is expected to be conveyed downgradient as bypass. • Typically a larger sized Treatment BMP type constructed in Lake Tahoe.	Infiltration *Conveyance*

TABLE 6.1 BMP RAM Treatment BMP Types.			
Treatment BMP Type	**Other Names**	**Description**	**Processes relied upon for water quality treatment IN ORDER OF PRIORITY α**
Treatment Vault	Flow Separation Vault, Hydrodynamic Separators	• Flow-through confined space structure that separates sediment, debris and other particulate pollutants from the water volumes via various settling techniques. • Water quality improvements of stormwater continuing downgradient expected as a result of particle capture. No volume loss occurs due to impervious base, thus pollutant load reductions realized by concentration reductions due to particle capture. • Typically manufactured and proprietary structures. • 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.	Particle Capture *Conveyance*
Cartridge Filter	Proprietary 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*
Bed Filter	Surface Sand Filter, Underground Sand Filter, Perimeter Sand Filter, Organic Media Filter	• Typically a settling/pretreatment basin followed by a filter bed (e.g., sand filter, activated alumina) with several feet of volume retention above the bed. Filtration is controlled by the rate of infiltration through the filter bed. • The capture of particles and pollutants is achieved via filtration of stormwater through an activated alumina, sand or other media type. • Hydraulically similar to infiltration basins except the runoff is filtered through the bed, collected into an under drain, and discharged to an outlet rather than being infiltrated to the local unsaturated zone. Little to no volume loss occurs. • Stormwater is routed to the structure or they may be strategically placed in an existing runoff path. • Typically a moderate sized Treatment BMP type constructed in Lake Tahoe.	Media Filtration *Conveyance*

TABLE 6.1 BMP RAM Treatment BMP Types.

Treatment BMP Type	Other Names	Description	Processes relied upon for water quality treatment IN ORDER OF PRIORITY α
Settling Basin	Concrete Forebay	• Structures typically placed at the inlet of other treatment BMPs to pre-treat inflowing stormwater and retain coarse sediment loads prior to stormwater entering subsequent Treatment BMP. • Load reductions are realized by concentration reductions. Minimal to moderate volume loss occurs. • Typically small to moderate sized Treatment BMP type constructed in Lake Tahoe.	Particle Capture *Conveyance*
Biofilter	Grass Swale, Grass Filter Strips, Vegetated Buffer Strips, Bioslopes	• A pervious substrate with dense vegetation coverage (>80%) to provide a concentration reduction by fixing nutrients via biological processes. Some infiltration may occur during inundation. • Typically constructed as pervious stormwater conveyance feature. • Small to moderate sized Treatment BMP type constructed in Lake Tahoe.	Nutrient Cycling Infiltration *Conveyance*
Infiltration Feature	Dry Well, Infiltration Trench, Roof Drip-Line, Rock-Lined Channel	• Land surface modified to sustain maximum infiltration rates, typically consisting of vertical excavation of native soils and filling with coarse drain rock or other highly permeable material. • Stormwater is typically not routed to infiltration features, but rather implemented to reduce volumes generated from adjacent impervious surfaces. • Small sized Treatment BMP type constructed in Lake Tahoe.	Infiltration *Conveyance*
Porous Pavement	Porous Asphalt, Pervious Concrete, Porous Aggregate, Porous Asphalt, Grinding Shoulders, Modular Block	• Porous pavement consist of a durable, pervious surface overlaying a crushed stone base that stores rainwater before it infiltrates into the underlying soil. • Porous pavement can include an underlying reservoir to increase infiltration rates. • Local stormwater is typically not routed to a porous pavement surface, but rather constructed to minimize the volume of stormwater generated and routed downgradient from a previously impervious surface. • Footprint of Treatment BMP type can vary greatly, typically used for parking lots or other impervious surfaces.	Infiltration *Conveyance*
Sediment Trap	Vertical CMP, Catch Basin	• Typically constructed on site using low cost vertical corrugated metal (CMP) and trash rack placed in stormwater flow path to capture sediment, debris, coarse particles and associated pollutants in a deep (>5 ft) sump. • Minimal to no volume loss occurs due to vertical accumulation of road side particulates and relatively small footprint. • Typically located on road shoulder stormwater flow paths. • Small sized Treatment BMP type constructed in Lake Tahoe.	Particle Capture *Conveyance*

TABLE 6.1 BMP RAM Treatment BMP Types.			
Treatment BMP Type	**Other Names**	**Description**	**Processes relied upon for water quality treatment IN ORDER OF PRIORITY α**
Conveyance BMP			
Drop Inlet	DI, Storm Drain, Culvert,	• Stormwater feature placed strictly to collect and convey stormwater. • A drop inlet that includes a sump to capture sediment is termed a **Sediment Trap**. • Typically connected to a culvert and provides no water quality benefit downgradient.	*Conveyance*

α The processes for each Treatment BMP Type are listed in the assumed order of relative contribution (highest to lowest) to the overall annual stormwater pollutant load reduction provided by the specific Treatment BMP Type.

β Conveyance of stormwater in and out is considered a crucial process of a functional Treatment BMP.

CHAPTER 7: RATIONALE FOR BMP RAM OBSERVATIONS

The BMP RAM observations are proxies to evaluate the condition of the four primary stormwater treatment processes: infiltration, particle capture, media filtration, and nutrient cycling. Conveyance is rapidly evaluated at each Treatment BMP to ensure stormwater is being routed in and/or out of the Treatment BMP. The number and type of observations made at any given Treatment BMP depends on the type. Table 7.1 summarizes the BMP RAM STEP 4 field observations by both Treatment BMP Type and the respective treatment process the observation(s) evaluate(s). The observations were determined based on the primary processes relied upon by the Treatment BMP Type in addition to typical BMP sizing, substrate conditions, vegetation characteristics, and other considerations. The BMP RAM Users Manual contains the detailed protocols to direct the user how to make each of the field observations presented in Table 7.1 below. Conveyance observations are important to note, but they are shown in grey because they are not the same as treatment processes.

Table 7.1. BMP RAM STEP 4 field observations by both Treatment BMP Type and the respective treatment process the observation(s) evaluate(s).

		Treatment Process				
		Infiltration	Particle Capture	Media Filtration	Nutrient Cycling	Conveyance
TREATMENT BMP TYPE	Dry Basin	**CHP Veg. Cover**	**Material Accumulation**			**Conveyance**
	Wet Basin		**Material Accumulation**		**Veg. Cover**	
	Infiltration Basin	**CHP Veg. Cover**				
	Treatment Vault		**Treatment Vault Capacity**			
	Cartridge Filter			**Confined Space**		
	Bed Filter	**Veg. Cover**		**CHP**		
	Settling Basin		**Material Accumulation**			
	Biofilter	**Runoff**			**Veg. Cover**	
	Infiltration Feature	**Runoff Veg. Cover**				
	Porous Pavement	**Infiltrometer**				
	Sediment Trap		**Sediment Trap Capacity**			
Conveyance	Drop Inlet	**Conveyance**				

Infiltration Observations

Infiltration of stormwater runoff is one of the primary methods of reducing pollutant loads to Lake Tahoe by decreasing runoff volumes. During infiltration, all pollutants suspended in the water, both dissolved and particulate, are transported into the unsaturated zone. Conservative dissolved compounds, such as nitrate (NO_3^-), chloride (Cl^-) or MTBE (methyl tert-butyl ether) will continue with the infiltrating water to the shallow groundwater table. Non-conservative pollutants, such as heavy hydrocarbons or ionically-charged phosphate (HPO_4^{2-} or SRP), will preferentially bind to soil particles in the unsaturated zone reducing the concentrations of these pollutants as the stormwater water infiltrates through the subsurface. Infiltration, therefore, is a more effective water quality treatment approach for non-conservative pollutants.

Particulate matter contained within infiltrating waters will be captured and trapped within the pore spaces of the surface soils. Overtime, the accumulation of sediment and fine particles in an infiltration Treatment BMP reduces the permeability and hydraulic conductivity of the surface soil layer, directly reducing the infiltration rate. Therefore, one can expect the relative infiltration rate of a specific Treatment BMP to decline as stormwater and associated pollutants are infiltrated through the unsaturated soil layer. The BMP RAM uses several different types of observations to evaluate the relative condition of infiltration at different Treatment BMP Types.

The NRCS has developed a constant head permeameter (CHP) to measure the saturated hydraulic conductivity (Ksat) of soils for use in the Lake Tahoe Basin. The CHP is a well accepted simple instrument to measure the infiltration rate in inches per hour (in/hr) of a surface soil substrate. CHP measurements require the PVC nose of the instrument to be inserted vertically 4 inches into the surface where infiltration of stormwater occurs. For appropriate Treatment BMP Types that rely upon infiltration for stormwater treatment, the BMP RAM user employs a CHP to obtain representative Ksat. The CHP is used to measure the infiltration capability of dry basins, bed filters, and infiltration basins.

Porous pavement cannot be penetrated by a CHP, but is designed to infiltrate some fraction of stormwater generated on and/or introduced to the surface. The infiltration capability of porous pavement is also expected to decline over time as particles and debris slowly accumulate. The BMP RAM user employs a simple 6 inch-diameter infiltrometer to directly measure the infiltration rate (in/hr) of porous pavement over time.

CHP and infiltrometer measurements are not possible at infiltration features, due to their smaller surface areas and substrate. The gravel or cobble surfaces are impenetrable by the CHP. Instead, the main objective of the observer at an infiltration feature is to determine if an infiltration feature appears capable of infiltrating stormwater, or if the BMP has been clogged with fine grained material and debris. The observer conducts a runoff observation, designed to qualitatively evaluate the degree to which a surface is capable of rapidly infiltrating stormwater. Vegetation cover is also visually observed as a potential indication of reduced infiltration capacity of a Treatment BMP, as the presence any significant amount of vegetation indicates the presence of fine grained material possessing a lower infiltration capability than course substrate.

Particle Capture Observations

Two kinds of observations, material accumulation and treatment capacity, have been developed to rapidly evaluate the particle capture process. It is assumed that the ability of a Treatment BMP to retain and sequester sediment is primarily controlled by the hydraulic residence time (HRT), flow path length and lateral flow velocity. Particle capture capability can be increased by increasing storage capacity, lengthening the stormwater flow path from the inlet to outlet, and/or reducing the lateral flow velocity. The presence of vegetation in a Treatment BMP is assumed to increase the tortuousness of the flow path and reduce lateral velocities. Thus within a specific Treatment BMP over time, particle capture capability can be tracked by the relative amount of storage capacity remaining or the amount of material accumulated.

Material accumulation observations are designed to quantitatively track the relative loss of the Treatment BMP storage capacity, as a result of material accumulation in exposed and typically larger Treatment BMP structures. Material accumulation requires the installation of one or more permanent staff plates in at least one representative location near the outlet of the Treatment BMP during STEP 2 of the BMP RAM. The lowest visible value on the staff plate is observed during the BMP RAM field observations.

Treatment vault capacity observations are also designed to quantitatively track the relative loss of capacity within the vault chamber(s), while recognizing the inability of a BMP RAM observer to enter the confined space of a vault. The user must determine the access points (manholes) and the configuration of the storage chambers of each specific vault during the inventory process (STEP 2). Treatment vault capacity consists of repeated manual vertical measurements from the base of the vault (or the top of the accumulated material within the vault) to the manhole invert using a stadia rod. Similarly, sediment trap capacity is determined by one vertical measurement from the base of the trap (or top of the accumulated material) to the invert of the outlet.

Media Filtration Observations

Media filtration reduces the concentrations of pollutants in stormwater through the use of engineered flow-through systems. These systems can be designed to (1) physically trap, separate, and/or sieve particulate matter, and/or (2) use active media to adsorb and remove dissolved constituents as stormwater is transported downgradient. Similar to a Brita water filter, the treatment capability of a media filtration system is dependent upon the pollutant loading rate relative to adsorptive capacity of the media. When the media becomes saturated, flow rates through the system and effluent water quality will measurably decline. Due to the physical complexity of these engineered systems, and the frequent presence of media filtration systems within confined spaces, the options are limited to design reliable and rapid observations to track performance decline and determine maintenance urgency. BMP RAM users will be instructed to follow the confined space observation for any Treatment BMPs that meet these criteria. The confined space observations include qualitative visual observations to simply infer if there is evidence to suggest the confined Treatment BMP may not be operating properly. The BMP RAM results of confined space observations will merely indicate that additional observations, requiring access and testing of the Treatment BMP is warranted and the manufacturer may need to be contacted.

Infiltration measurements using a CHP are required to evaluate media filtration Treatment BMPs (such as bed filters) that may not be located within a confined space, in order to rapidly track the vertical flow-through rate of water.

Nutrient Cycling Observations

Nutrient cycling involves the reduction in concentration of biologically available nutrients due to uptake by growing vegetation. Nutrient cycling is most pronounced in wet basins that are seasonally or frequently inundated with stormwater containing a relatively high concentration of phosphorous and nitrogen. Effective wet basins typically contain 40-75% cover of fast growing wetland plants such as cattails and/or rush species. However, in other Treatment BMP Types the type and density of vegetation is an indication of poor infiltration capability of the underlying soils. The vegetation cover observation is also used to rapidly evaluate of the condition of Treatment BMPs that are intended to infiltrate stormwater. The vegetation cover observation protocols are the same, but the database analyzes the user inputs differently depending upon the Treatment BMP Type.

The BMP RAM characterizes vegetation type into 4 general categories: wetland species, riparian species, grass species, and terrestrial trees. Each of these categories requires a decreasing amount of water to survive within a Treatment BMP. The RAM observer conducts rapid observations of the % cover of each vegetation type within the potentially inundated area of the Treatment BMP being evaluated.

Conveyance Observations

Conveyance of stormwater does not provide any water quality improvement downgradient, but is a vital characteristic of a functional Treatment BMP. If a Treatment BMP is not receiving or discharging stormwater as designed, the associated water quality benefits are not possible. The BMP RAM includes simple observations of each inlet and outlet to verify that a Treatment BMP is conveying water adequately. It is assumed that a non-functional inlet or outlet will directly impair the operational condition of a Treatment BMP. While the BMP RAM is focused upon Treatment BMPs, a BMP RAM user can evaluate the condition of a drop inlet by implementing the conveyance observation. If a drop inlet has been designed with the capacity to store debris or other material, it should be classified as a sediment trap and the corresponding sediment observation used.

CHAPTER 8: BMP RAM SCORING

The BMP RAM field observation data obtained by the user are input into the database (STEP 4) and the database compares each observation result to the benchmark and threshold values. The observation Scores are then empirically aggregated by the database based on the processes relied upon by the specific Treatment BMP. The results are expressed as a Treatment BMP RAM Score on a simple 0-5 scale to indicate the Treatment BMP condition.

Table 8.1 defines how the range of BMP RAM Scores relates to the condition of a Treatment BMP. Treatment BMP RAM Scores reflect the relative ability of the treatment processes to provide downgradient water quality improvements, with distinct scoring ranges corresponding to specific maintenance urgency.

Table 8.1 BMP RAM Scores relative to Treatment BMP condition and relative maintenance urgency.

BMP RAM Score	Condition	Maintenance Urgency	Description
0-1.0	Failure	**Required**	Little to no downgradient water quality benefit and downgradient water quality may be adversely affected due to failure of Treatment BMP function. Maintenance required immediately.
>1.0- < 2.0	Below acceptable		Treatment BMP load reduction potential is below acceptable condition. Maintenance is required prior to next runoff event.
2.0	Threshold		Threshold condition set by user that corresponds to condition where maintenance is required.
> 2.0- < 3.0	Acceptable	**Moderate**	Acceptable downgradient water quality benefit, but Treatment BMP condition is closer to threshold than benchmark. Maintenance may need to be prioritized if time and resources permit.
> 3.0- < 5.0		**Low**	Acceptable downgradient water quality benefits. No immediate maintenance required.
5.0	Benchmark	**None**	Maximum achievable downgradient water quality benefit for the specific Treatment BMP. No maintenance actions are required.

Scoring Process

The primary conceptual framework of the BMP RAM is that cost-effective and rapid observations serve as proxies for the relative condition of one or more treatment processes. It is a fundamental hypothesis of the BMP RAM that a reduction in the condition of the primary treatment process(es), as measured by observation proxies, corresponds to a simultaneous reduction in pollutant load reduction potential of a specific Treatment BMP. The quantification of the pollutant load reduction magnitudes is not the objective of this tool.

The benchmark and threshold can be considered the bookend values that define the condition range of each specific Treatment BMP. The benchmark is defined as the initial condition at time of construction, the condition immediately following complete maintenance actions, or the desired achievable condition for the specific Treatment BMP. The threshold is the lowest acceptable value, below which the user has determined the condition of a specific Treatment BMP should not decline. The benchmark and threshold values are not universally determined by the Treatment BMP Type, but are specific to each Treatment BMP as established in RAM STEP 3.

Benchmark values are either determined from the default data on the specific Treatment BMP or entered manually by the user. Similarly, the threshold values are determined by either a % decline from the benchmark, or an absolute threshold value as determined by the observation and Treatment BMP Type. The database contains recommended default threshold values for each Treatment BMP Type. The BMP RAM User Manual clearly guides the user through the steps necessary to define the appropriate benchmark and threshold values for each Treatment BMP inventoried in STEP 2.

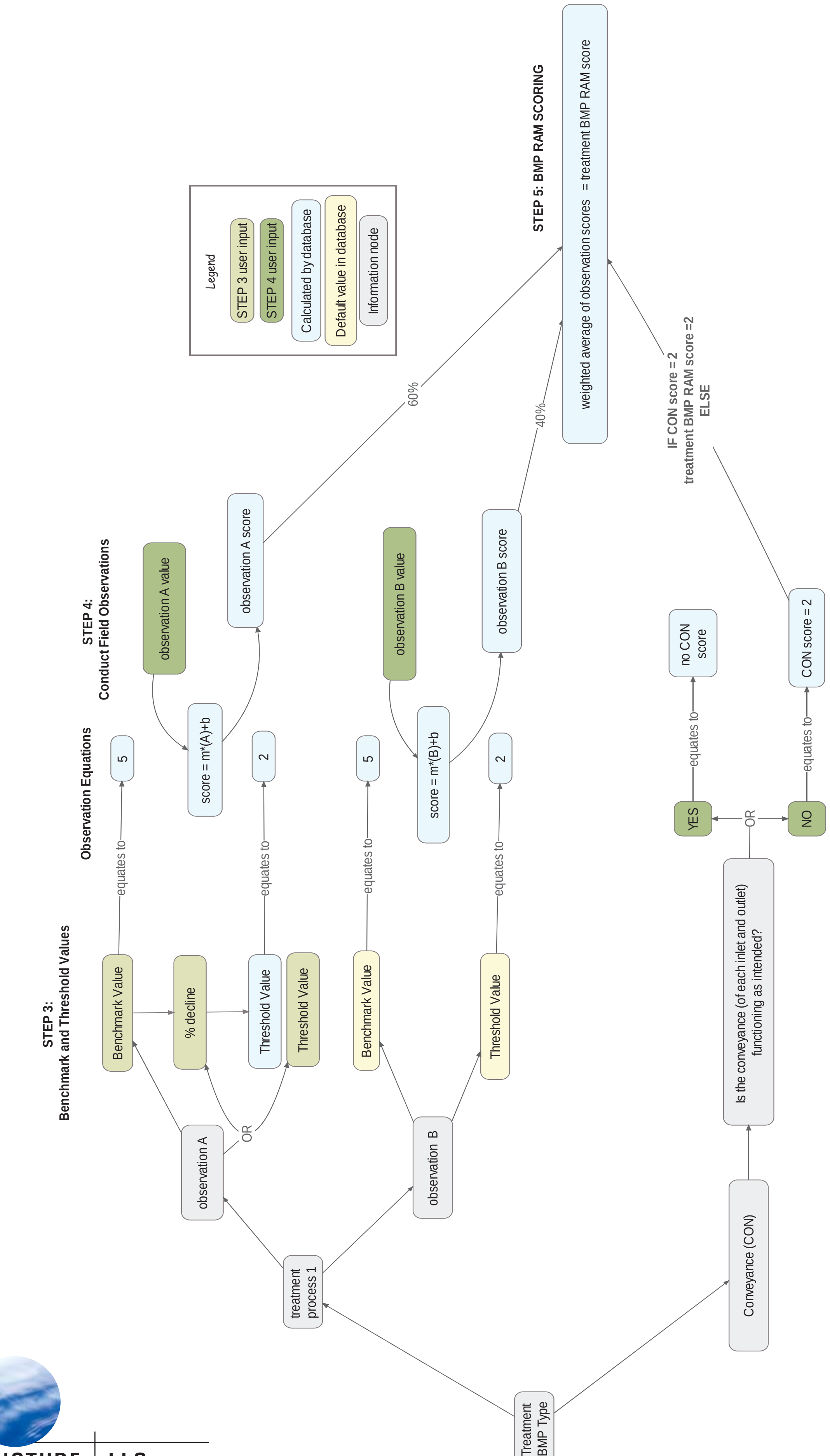
STEP 3: Set Benchmark and Threshold Values

The user must define the benchmark and threshold values for each BMP RAM Observation. Figure 8.1 summarizes the scoring process for a generic Treatment BMP. This schematic shows a Treatment BMP that uses one treatment process that requires two distinct BMP RAM observations, observation A and observation B.

STEP 3 for Observation A indicates that the benchmark value requires user input. User input to set required benchmarks may require field observations when the Treatment BMP is at benchmark condition to determine the appropriate value(s). For example, material accumulation benchmarks for a dry basin require user input into the database. The threshold value for observation A is determined by the % decline of the benchmark value. For material accumulation the user determines the % decline water volume capacity of the dry basin and the database calculates the specific threshold value based on the % decline defined by the user. In some instances, the actual threshold value is determined directly by the user, rather than setting the threshold relative to benchmark conditions. Table 5 in the BMP RAM User Manual provides recommended % decline or threshold values for each observation and Treatment BMP type.

STEP 3 for Observation B indicates that the benchmark value is a default and no user input is required. An example of a default benchmark is the total percent cover of wetland and riparian vegetation species in a dry basin, which is set internally at a value of 0% by the database. The threshold value for observation B is an absolute value rather than an estimated acceptable % decline of the benchmark value. The recommended default threshold value for the maximum wetland and riparian vegetation cover in a dry basin is 20%.

Ultimately, future versions of the BMP RAM will have greater confidence in the specific threshold target values for specific Treatment BMP types as we improve our understanding of the linkage between Treatment BMP observation results, condition and quantitative water quality benefits (i.e., characteristic effluent concentration (CEC's) and pollutant load reductions). However, to date there are very few water quality design standards for Treatment BMPs in the Tahoe Basin and the acceptable ranges of values for each BMP RAM observation by Treatment BMP type are not available yet. The performance of a Treatment BMP is typically a function of multiple design aspects and localized



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BMP RAM SCORING PROCESS AND CALCULATIONS

FIGURE 8.1

conditions making the assignment of default threshold values subjective in this initial version. Dependent upon the specific design of a Treatment BMP, the treatment processes deemed to be the most sensitive on the overall load reduction capability in Table 5 may not adequately represent a user's Treatment BMP. However, the implementation and accumulation of BMP RAM observation data of a wide range of Treatment BMPs will greatly improve understanding.

Rapid conveyance observations are conducted at each inlet and outlet for each Treatment BMP. Conveyance scoring is included in Figure 8.1 to illustrate the conveyance results are binary (yes/no) eliminating the need for benchmark or threshold inputs by the user during STEP 3. If conveyance is observed to be operating properly, it does not have an influence on the BMP RAM Score. However, if any inlet or outlet is observed to be not operating the BMP RAM Score is defaulted to a 2, regardless of other observation results.

Observation Equations

The database uses the benchmark (5) and threshold (2) values to calculate the observation equations. These equations can be determined two ways.

- In most instances the equations are the defined linear trend for each observation where the benchmark value = 5 and the threshold value =2.
- In the case of user-defined min and max threshold values (e.g., vegetation distribution in a wet basin), two equations are generated based on the trend between (1) the benchmark value and the min threshold value and (2) the benchmark value and the max threshold value.

For binary observations (yes/no), one value equates to a 5 and the other, a 2. The most common is conveyance, but confined space and runoff observations are also binary.

STEP 4: Field Observations

Field observations result in values generated by the user during STEP 4 of the BMP RAM. These values are input into the database for each Treatment BMP evaluated. The database empirically integrates the field observation values with the benchmark and threshold values for each Treatment BMP to generate the BMP RAM Score. The database translates each observation value into a value between 0 and 5 using the respective observation equation.

STEP 5: RAM Scoring

The observation scores are integrated as a weighted-average based on the relative prioritization of processes into a Treatment BMP RAM Score (Table 8.2). The relative weighting of each observation is unique for each Treatment BMP Type. The relative weightings for each Treatment BMP observation are fixed within the database to maintain consistency across Treatment BMP Types and users. The consistency of these weightings by Treatment BMP Type will increase comparability and power of future BMP RAM data analysis by Treatment BMP Type to improve our understanding of the linkage between Treatment BMP observation results, condition and quantitative water quality benefits (i.e., characteristic effluent concentration (CEC's) and pollutant load reductions).

The observation weightings in Table 8.2 represent the best professional judgment of the BMP RAM developers. The weights are based on the relative contribution of the processes to overall annual load reductions expected from each Treatment BMP Type. The confidence, repeatability and rigor of each observation to serve as a proxy for the respective process were also considered. It is acknowledged that individual Treatment BMP designs will vary, but the relative weightings presented in Table 8.2 are likely the most common prioritizations expected for each Treatment BMP Type.

TABLE 8.2. Relative weighting of each observation result into the Treatment BMP RAM Score for each Treatment BMP type.

Treatment BMP Type	Processes relied upon for water quality treatment IN ORDER OF PRIORITY α	Observation(s)	Observation weighting to determine Treatment BMP RAM Score
Dry Basin	Infiltration	CHP	50%
		Veg Cover	15%
	Particle Capture	Material Accumulation	35%
Wet Basin	Particle Capture	Material Accumulation	60%
	Nutrient Cycling	Veg Cover	40%
Infiltration Basin	Infiltration	CHP	80%
		Veg Cover	20%
Treatment Vault	Particle Capture	Treatment Vault Capacity	100%
Cartridge Filter	Media Filtration	Confined Space	100%
Bed Filter	Media Filtration	CHP	100%
Settling Basin	Particle Capture	Material Accumulation	100%
Biofilter	Nutrient Cycling	Veg Cover	60%
	Infiltration	Runoff	40%
Infiltration Feature	Infiltration	Runoff	75%
		Veg Cover	25%

TABLE 8.2. Relative weighting of each observation result into the Treatment BMP RAM Score for each Treatment BMP type.

Treatment BMP Type	Processes relied upon for water quality treatment IN ORDER OF PRIORITY α	Observation(s)	Observation weighting to determine Treatment BMP RAM Score
Porous Pavement	Infiltration	Infiltrometer	100%
Sediment Trap	Particle Capture	Sediment Trap Capacity	100%
Conveyance			*IF conveyance at any inlet or outlet not functioning THEN 100%; ELSE 0%*

α The processes for each Treatment BMP Type are listed in the assumed order of relative contribution (highest to lowest) to the overall annual stormwater pollutant load reduction provided by the specific Treatment BMP Type.

CHAPTER 9: BMP RAM DATABASE

The BMP RAM Database (database) is a custom relational database that stores catchment data, calculates Treatment BMP Scores and manages all of the BMP RAM information over time. Version 1 of the database contains a number of user-friendly features to minimize user error and confusion; however a basic familiarity with Microsoft Access 2007 is necessary.

Database Structure

The user interacts with a series of data entry menus and forms to populate data fields with the required information. This data is stored within underlying database tables and the database uses queries to perform calculations and generate reports that the user can print to summarize BMP RAM data. Figure 9.1 illustrates the relational structure of the underlying database tables. These relationships are used by the database to perform queries and calculations to generate the BMP RAM Scores. The typical database user will only interact with the data entry forms (data entry) and reports (data output). Figure 9.2 provides screenshot examples of a data entry menu and a form. Data reports are provided in Appendix A of the User Manual as part of the Coon Catchment example.

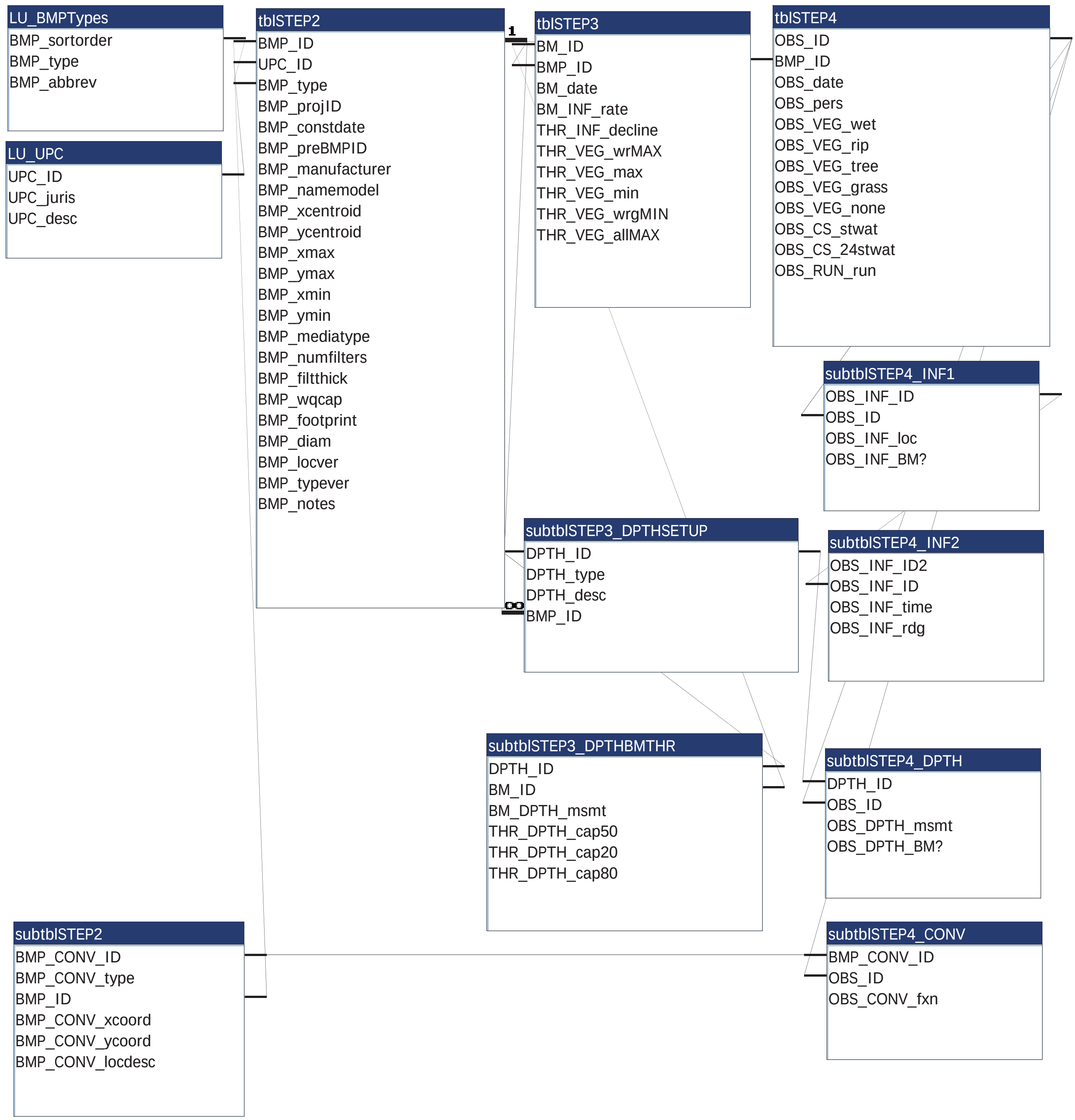
Database Quick Guide

Opening the database

- The BMP RAM database was created in Microsoft Access 2007 (BMPRAM.accdb); however it is fully functional in Microsoft Access 2003 (*.mdb). The database may have limited functionality in Access versions older than 2003.
- Upon opening the database MS Access will warn the user that some content has been disabled. **Click** “Enable Content” to run fully functional database.

Data Entry

- Data entry forms are presented either as menus or forms (Figure 9.2).
    - Menus provide the user with a list of options. The user clicks on the command button next to the desired option. On some menus the user must first make a selection at the top of the menu before clicking a button.
    - Data entry forms are either presented as single forms or as tables.
        - Single Forms present one record on the screen at a time. The user adds a new record by navigating to a blank form.
        - Tables present multiple records in rows. The user adds a new record by entering data in the bottom, empty row.
- In a data entry form, the user navigates between data fields using tab (next field) and shift-tab (previous field).



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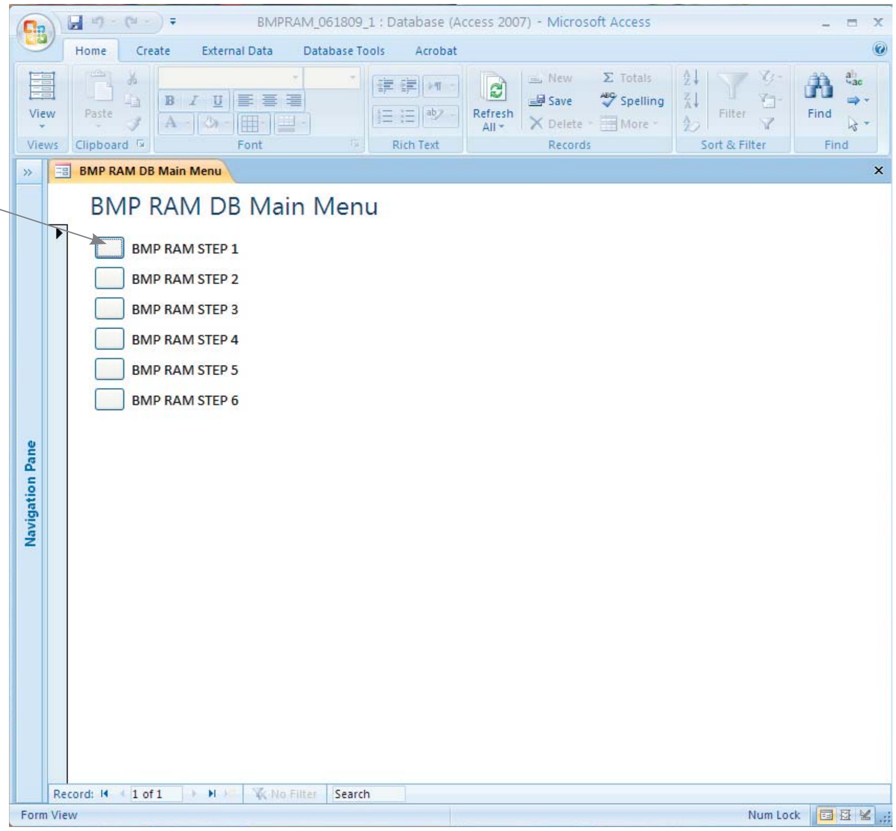
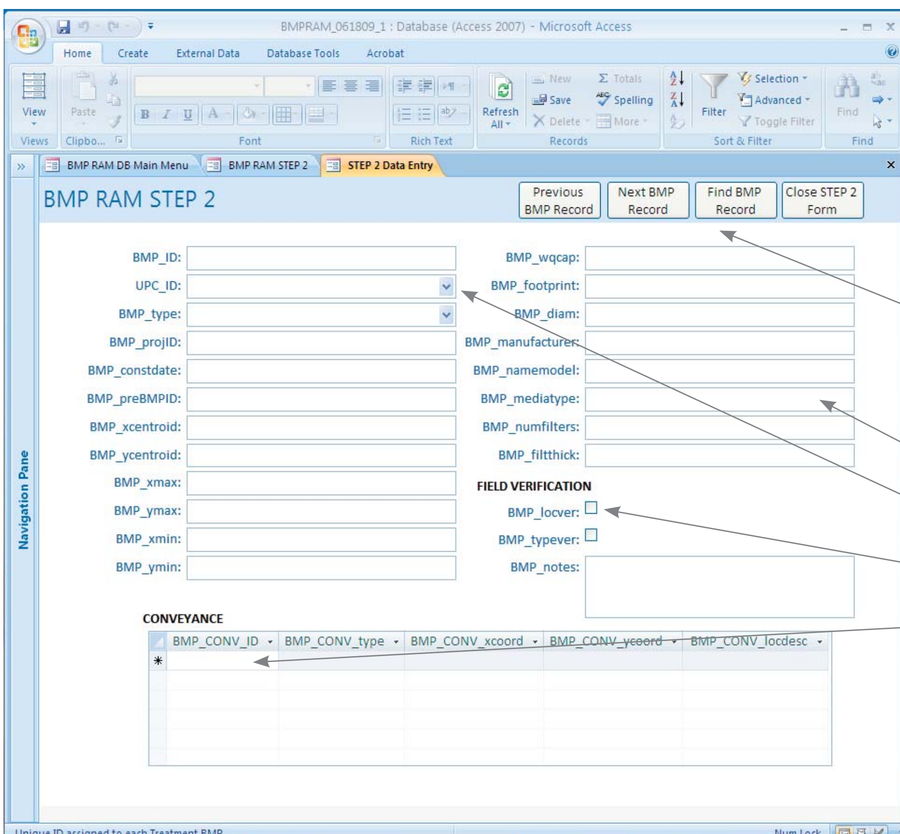
BMP RAM DB STRUCTURE

FIGURE 9.1

Data Entry Menu

- User clicks on command buttons to navigate through database.





Data Entry Form

Single Form

- User navigates between Treatment BMP records using command buttons on top of the form (Previous, Next, Find).
- User populates data fields by
  - (1) typing entries in blank fields,
  - (2) selecting from a drop down list, or
  - (3) checking boxes.

Table

- User adds data to tables by going to the bottom empty row.

Text tips in the status bar provide more information on the data field.

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BMP RAM DB DATA ENTRY FORM EXAMPLES

FIGURE 9.2

- Text tips in the status bar on the lower left (Figure 9.2) provide more description on the data field.
- As shown in Figure 9.2, the user enters data by:
  - Clicking command buttons.
  - Entering text directly into data fields.
  - Selecting from a drop down list.
  - Clicking a checkbox icon.
- Command buttons initiate specific actions such as opening forms and menus, closing forms, finding records, deleting records, navigating through records.
- Text entry allows user to enter information directly. Some fields such as dates have format restrictions. The database provides warning if data has been entered in an incorrect format and will not allow improper entries.
- Drop down lists restrict the user to specific entries stored in the database. This standardizes data entry and minimizes user entry error (e.g., misspellings). The user can either click on the arrow and select from the provided list, or begin typing directly in the text field.
- Checkboxes are used for binary (yes/no) entries. A checked box indicates a “yes” answer.

<u>Common Database Errors</u>

General Access Errors

- “The value you entered isn’t valid for this field”: The data field requires a specific format (date, time, number) and will not allow invalid entries. Correct data entry to be in the necessary format.
- “The text you entered isn’t an item in the list”: Data entry in drop down lists is restricted to the list. Select an entry from the list.
- “You must enter a value in the ‘ ’ field”: Some data fields are required for every record. A record cannot be saved with a blank entry in these fields. Enter data, or click the close button (X) on the upper right of the FORM (not the database) and click ok to not save the record at this time.
- “You can’t go to the specified record”: This is either the very first or very last record. Click ok and then Stop All Macros.

BMP RAM Database Specific Errors

- A form, report or drop down list is blank:
  - The user has not selected from the UPC drop down list on the menu prior to clicking a command button. Return to the menu and select a UPC from the drop down list.
- A BMP ID does not show up in a drop down list:
  - Only those BMPs that have been properly field verified for location and type are shown in drop down lists. If a BMP fails to show up in a list, return to STEP 2 – Review Existing Inventory Data and ensure those two checkboxes are checked.
- The STEP 3 REPORT does not show all benchmark and/or threshold values for a BMP ID.
  - The benchmark observation data entered in STEP 4 and the benchmark and threshold values entered in STEP 3 must share the same date. Change the STEP 3 data entry form so it matches the date of observations.

CHAPTER 10: BMP RAM PROGRAMMATIC INTEGRATION

The BMP RAM informs ongoing maintenance and future planning to ensure that the investment of limited maintenance funds leads to effective treatment of stormwater, contract compliance and regulatory compliance. The BMP RAM results also provide critical context to improve the usefulness of scientific findings from intensive stormwater monitoring efforts.

Ongoing Maintenance & Planning

The BMP RAM will create a dataset of typical operating conditions for common BMPs. This will help project designers understand the likely operational conditions of Treatment BMPs, which they can use to develop relationships between field observations and modeling parameters. With these relationships project designers can better relate loading estimates to expected conditions and consider the realities of maintaining Treatment BMPs.

Over time, BMP RAM results will show which Treatment BMPs require frequent maintenance in order to maintain acceptable treatment function. Armed with a clear understanding of maintenance priority, stormwater managers and maintenance staff can strategically determine the most effective use of available funds. This will inform both future project design and maintenance program budgeting. The ability to plan maintenance expenses and make well-informed decisions about the use of limited maintenance dollars is particularly important during budget cutbacks.

Contract Compliance

Environmental Improvement Program (EIP) funding agreements and contracts between municipalities and the California Tahoe Conservancy or Nevada Division of State Lands contain maintenance requirements. However, over the past decade, funders have not been able to define maintenance requirements. The BMP RAM enables funders and implementers to define maintenance requirements based on standard observations of Treatment BMP condition.

Regulatory Compliance

BMP RAM results will help communicate Treatment BMP conditions and benefits from maintenance activities in annual stormwater reports for stormwater NPDES permits, Memoranda of Agreement (MOA), and the Tahoe Regional Planning Agency's (TRPA) reporting requirements.[1] The TMDL Accounting and Tracking Tool is being designed to use BMP RAM results for comparing actual to expected conditions; BMP RAM results can thus support the determination of Lake Clarity Credits

[1] As of July of 2009 the TRPA is expected to either replace or modify Maintenance Efficiency Plan reporting requirements to match the annual stormwater report requirements from the Lahontan Regional Water Quality Control Board and the Nevada Division of Environmental Protection.

(credits) awarded each year.[2] Credit targets in NPDES permits and MOA will be the basis for determining regulatory compliance. Further, TRPA is expected to use achievement of credit targets as a performance criterion in the annual release of development commodities, such as residential building allocations and commercial floor area.

TMDL, Threshold and EIP Reporting

Annual load reduction estimates will be supported by BMP RAM results to ensure continued performance of Treatment BMPs at expected levels. Load reduction estimates will be tracked in the TMDL Accounting and Tracking Tool along with awarded credits. Load reduction estimates will be used to report basin-wide progress towards meeting Lake Tahoe TMDL load reduction milestones and TRPA Water Quality Thresholds. They are also expected to be used as EIP performance measures to report benefits to water quality that result from the investment of federal, state and local funds.

Stormwater Monitoring

Past stormwater monitoring and research related to the Lake Tahoe TMDL focused on determining load reductions and effluent concentrations from different Treatment BMP Types. However, the treatment processes associated with monitored BMPs and the conditions present during sampling events were not defined. The BMP RAM definitions of Treatment BMP Types and condition assessments during sampling events are expected to be employed by the Regional Stormwater Monitoring Program (RSWMP). The Lake Tahoe BMP Database, currently under development to manage RSWMP data, includes data input fields to document BMP RAM results of specific Treatment BMPs evaluated using high-resolution water quality monitoring techniques. This will improve the understanding what factors drive effluent concentrations, as well as volume and pollutant load reductions. Future versions of PLRM may incorporate this improved understanding of treatment processes to better predict load reductions, which will directly inform future project design and maintenance planning.

Focus on Results

The BMP RAM enables flexibility and consistency. By focusing on condition, rather than on rote adherence to a schedule of maintenance actions in static maintenance plans, stormwater managers and maintenance personnel can determine when and how to maintain the function of treatment BMPs in the most cost-effective manner possible. This encourages practical innovation and respects the professional judgment of stormwater managers while ensuring that the most important Treatment BMPs achieve the goal of reducing pollutant loading to Lake Tahoe.

[2] See the Lake Clarity Crediting Program Handbook for a complete discussion of Lake Clarity Credits and the Lake Clarity Crediting Program.

CHAPTER 11: INITIAL VERSION LIMITATIONS AND NEXT STEPS

The BMP RAM version 1.0 has been developed to meet the goals, objectives and functions of the tool defined by the scope of this effort. The effort was conducted with limited resources and this initial version of the tool is ready for user testing and feedback (Fall 2009). All of the components of the initial BMP RAM version have been implemented, tested and refined on a test urban catchment in Kings Beach, Placer County, California (COON catchment). Results of the test catchment are included as Appendix A of the BMP RAM User Manual to provide a tangible example for future BMP RAM users. It is anticipated that future resources will be secured to incorporate feedback into BMP RAM version 2.0, as well as consider some of the known limitations and potential improvements listed below.

1. The BMP RAM was designed with the primary intent of providing a simple and consistent tool for local jurisdictions to determine the relative maintenance urgency of Treatment BMPs. However, the developers also wanted to create a tool to provide information for jurisdictions and program managers to consistently evaluate and track the condition of Treatment BMPs installed throughout Lake Tahoe in the context of the TMDL and Lake Clarity Crediting Program. Future versions of the BMP RAM should continue to explore opportunities to better integrate the tool with other Lake Tahoe TMDL needs. The future integration priorities are from a programmatic and a data management/operational perspective.

2. The BMP RAM has been designed to be as practical as possible while achieving the basic goal of determining relative maintenance urgency for each Treatment BMP Type typically employed in the Lake Tahoe Basin to improve stormwater quality. The completion of STEPS 1, 2 and 3 of the BMP RAM do require a significant one-time effort in order to identify, map and inventory each existing Treatment BMP. A jurisdiction's strategy to gradually implement the BMP RAM may include the completion of STEPs 1-3 for only a few priority urban catchments each year. Assuming the user is familiar with the BMP RAM protocols and information requirements, the time required to complete the BMP RAM through STEP 3 will depend upon the size of catchment, the completeness of existing maps and information, and the number of Treatment BMPs that exist within the catchment. A first-order time estimate is that the BMP RAM completion through STEP 3 will require an average of 1 hour per Treatment BMP within the catchment or about 0.5 hours per urban acre.

   Once STEP 3 of the BMP RAM has been completed, the evaluation of Treatment BMP condition on an annual or more frequent interval (STEPs 4 and 5) is completed using repeatable and representative rapid field protocols. Funding opportunities to assist local jurisdictions with completing STEPs 1, 2 and 3 of the BMP RAM are currently being explored.

3. The database is an essential component of the tool to facilitate standardized data storage, consistent analysis and simplified presentation of results. The BMP RAM database version 1.0 has defined the main functions, field relationships, queries and user interaction platform.

However, there are great opportunities to improve the BMP RAM database functionality. Future database versions should focus on usability enhancements, such as prompting user inputs by Treatment BMP Type, and bringing the database online. Stand-alone databases require manual efforts to merge the data from two independent files. A web-based system would prevent divergence of data issues, make it more convenient for users to enter data, and simplify future comparative analyses of BMP RAM data and results. A future integrated web-based TMDL data management system would enhance the compatibility and integration with other stormwater tools and associated data.

The ultimate vision of the BMP RAM tool is a fully functional online tool that seamlessly integrates data entry from a multitude of users and presents real-time, interactive spatial summaries of BMP RAM Scores. The current tool combines a stand-alone Access 2007 database with individual ArcGIS shapefiles. Single-user data entry must be manually exchanged between the database and the mapping tools to present a PDF display of results. Future intermediary steps could allow users to upload their individual BMP RAM Scores to a shared online document (such as a Google spreadsheet). A Google Maps KML file created from this online spreadsheet would allow an interactive display of RAM Scores in Google Maps, viewed from a website. Ultimately all data would be input, managed and analyzed in an online database, built using MySQL or some equivalent, stored on a widely accessible website. The database would be displayed using widely available online map tools (e.g., Google Maps) and facilitate up-to-date tracking of Treatment BMP condition and effective adaptive management of Basin-wide maintenance activities.

4. The current BMP RAM provides a 0-5 score for each Treatment BMP within a catchment. The Lake Clarity Crediting Program and the TMDL implementation have a need for spatial and temporal integration of independent Treatment BMP Scores, independent Urban Road RAM Scores and potential other RAM tools to determine catchment condition for a period of interest. Future versions of Lake Tahoe Urban RAM tools should provide procedures to conduct quantitative integrations of RAM results on an urban catchment scale to determine appropriate credit awards based on actual conditions observed by BMP RAM.

5. One primary hypothesis of the BMP RAM is that Treatment BMP condition correlates to relative pollutant load reductions, such that, as the BMP RAM Score declines so does the potential load reduction capability of the specific Treatment BMP for any given storm event. This quantitative link is not well developed at this time due to lack of data and testing. Future high-resolution monitoring of Treatment BMPs should continue to refine the quantitative link between BMP RAM condition for Treatment BMPs to better define the range of estimated annual load reductions and/or characteristic effluent concentrations (CECs) given the acceptable range of Treatment BMP condition.

6. BMP RAM version 1 contains a collection of recommended default threshold values for each Treatment BMP observation as required (BMP RAM User Manual Table 5). The development

team estimated the appropriate threshold values based on professional judgment and the general assumption that the acceptable range of pollutant load reduction capability of any specific Treatment BMP should not decline from the benchmark condition by more than 20%. There currently lacks a clear empirical understanding between treatment process, BMP RAM observations and the range of acceptable average annual load reductions for different Treatment BMP Types. Future research will continue to improve our quantitative understanding of BMP RAM observations and modeled and actual load reduction estimates for specific Treatment BMPs.

7. Infiltration is key process that can have a significant influence on the potential load reduction capability of certain Treatment BMPs. Infiltration rate is measured by the BMP RAM by a Constant Head Permeameter (CHP) that must be used during unsaturated conditions. In reality, infiltration capacity of the unsaturated zone exponentially decays as the system becomes saturated during wet season conditions. The CHP will consistently overestimate the infiltration rate of a Treatment BMP during saturated conditions as it provides a measure at the upper end of the infiltration capability of the specific soil column. Thus, the CHP infiltration rates are not applicable to long-term empirical simulations of Treatment BMP infiltration such as the Pollutant Load Reduction Model (PLRM). However, the BMP RAM and PLRM development teams will utilize existing SNPLMA funding to begin to reconcile the empirical relationships between CHP values and appropriate long-term infiltration values for modeling input purposes. The end goals are to improve PLRM infiltration inputs to align with actual conditions, empirically link PLRM inputs with CHP observed values and recommend representative CHP threshold infiltration values for Treatment BMP types that rely upon infiltration to achieve significant pollutant load reductions.

8. The BMP RAM is the first of several urban stormwater rapid assessment tools to be developed for the Lake Tahoe Basin. The Lake Tahoe Urban Road RAM and other future RAM tools should follow the conventions established by the BMP RAM.

9. The initial project scope called for use of electronic field data collections devices. The field team believes that users of the initial BMP RAM version should work with the simple field datasheets in order to encourage the user to review the protocols in fine detail and develop an intimate understanding of the protocols and rationale. Digital field devices tend to encourage rapid and accurate data entry but can separate the user from the process. The most immediate need of the BMP RAM is to have multiple users engage, and provide suggestions on how the tool can be improved. Once the BMP RAM has been tested by the Lake Tahoe stormwater community, future versions of the BMP RAM tool will include the documentation and incorporation of hand-held field devices.

CHAPTER 12. BMP RAM GLOSSARY

Bed Filter

Treatment BMP Type

- Typically a settling/pretreatment basin followed by a filter bed (e.g., sand filter, activated alumina) with several feet of volume retention above the bed. Filtration is controlled by the rate of infiltration through the filter bed.
- The capture of particles and pollutants is achieved via filtration of stormwater through an activated alumina, sand or other media type.
- Hydraulically similar to infiltration basins except the runoff is filtered through the bed, collected into an under drain, and discharged to an outlet rather than being infiltrated to the local unsaturated zone. Little to no volume loss occurs.
- Stormwater is routed to the structure or they may be strategically placed in an existing runoff path.
- Typically a moderate sized Treatment BMP type constructed in Lake Tahoe.

Benchmark

The desired and achievable Treatment BMP condition. The benchmark equate to a RAM Score of 5. In most instances, benchmark condition may be observed shortly following construction or immediately following appropriate maintenance actions. The exceptions are desired benchmark characteristics that may take some time after construction and/or maintenance to achieve (e.g., benchmark vegetation cover).

Biofilter

Treatment BMP Type

- A pervious substrate with dense vegetation coverage (>80%) to provide a concentration reduction by fixing nutrients via biological processes. Some infiltration may occur during inundation.
- Typically constructed as pervious stormwater conveyance feature.
- Small to moderate sized Treatment BMP type constructed in Lake Tahoe.

BMP RAM

The BMP RAM is a simple and repeatable field observation and data management tool to assist Lake Tahoe natural resource managers in determining the relative condition of an urban stormwater Treatment BMP. The tool consists of six distinct BMP RAM STEPs implemented by the user and a supporting database

BMP RAM Database (database)

The database is a customized Microsoft Access 2007 file that stores and manages all catchment information necessary to implement, track and maintain BMP RAM inventory and results over time. The BMP RAM user generates data and/or information and enters it into the database.

Field Observations (BMP RAM STEP 4)

Compilation of distinct rapid observations and/or measurements made at Treatment BMPs over time to evaluate and track condition.

BMP RAM Score

The BMP RAM Score is a 0-5 value that represents the Treatment BMP condition at the time of observations. The BMP RAM Score is a weighted integration of field observation results based on Treatment BMP type. A BMP RAM Score of 5 is the achievable benchmark. A BMP RAM Score of 2 is a trigger for maintenance or other action to improve condition.

Cartridge Filter

Treatment BMP Type

- 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.

Confined Space

BMP RAM observation to evaluate the condition of Cartridge Filters. The confined space observations include qualitative visual observations to simply infer if there is evidence to suggest the confined Treatment BMP may not be operating properly. The BMP RAM results of confined space observations will merely indicate that additional observations, requiring access and testing of the Treatment BMP is warranted and the manufacturer may need to be contacted.

Constant Head Permeameter (CHP)

BMP RAM observation to measure the infiltration rate in inches per hour (in/hr) of a surface soil substrate in Dry Basins, Infiltration Basins and Bed Filters. This simple instrument has been developed by the NRCS and is well-accepted in the Lake Tahoe Basin to measure the infiltration capability of Tahoe soils.

Conveyance

Conveyance is the physical process that transports stormwater downgradient in a manner that mitigates, and does not induce, localized flooding. All Treatment BMPs must be able to convey stormwater both in and out, but conveyance alone provides no water quality benefit. Clear evidence of operating inflow and outflow must be present for Treatment BMPs to function as designed.

Data Reporting

Database function. The data summaries generated by the database to track the condition of Treatment BMPs over time. Reports include the STEP 2 INVENTORY data, STEP 3 Report of benchmark and threshold values, and STEP 5 BMP RAM Scores.

Drop Inlet

- Stormwater feature placed strictly to collect and convey stormwater.
- A drop inlet that includes a sump to capture sediment is termed a **Sediment Trap**.
- Typically connected to a culvert and provides no water quality benefit downgradient.

Dry Basin

Treatment BMP Type

- 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.

Failure

The BMP RAM Score equating to a 1, indicating that the BMP condition is 20% worse than the required maintenance threshold and the Treatment BMP is assumed to be in a failure state relative to any water quality improvement capabilities. Maintenance is required immediately.

Fine Sediment Particles (FSP)

FSP refers to the mass fraction of the TSS (Total Suspended Solids) concentration that consists of particles 16 µm or smaller, expressed as a % TSS by mass and allowing a concentration of FSP to be simply calculated.

Infiltration

Treatment process: Reduction of stormwater volume by infiltration through soil. Pervious soils capture stormwater runoff, reducing pollutant loads primarily due to volume reductions of stormwater that continues downgradient of the Treatment BMP. However, some pollutants contained within the infiltrated volumes, such as dissolved nutrients and fine sediment particles, are captured and trapped within the pore spaces of the unsaturated zone.

Infiltration Basin

Treatment BMP Type

- Constructed basin with little to no treatment storage, meaning stormwater that continues downgradient has the same pollutant concentrations as introduced to the infiltration basin.
- Highly permeable substrate designed to rapidly infiltrate significant volumes of stormwater into unsaturated zone. Pollutant load reductions realized due to significant volume reductions.
- Vegetation distribution should be minimal, but preferably absent.
- Stormwater is typically routed to the BMP and any excess stormwater is expected to be conveyed downgradient as bypass.
- Typically a larger sized Treatment BMP type constructed in Lake Tahoe.

Infiltration Feature

Treatment BMP Type

- Land surface modified to sustain maximum infiltration rates, typically consisting of vertical excavation of native soils and filling with coarse drain rock or other highly permeable material.
- Stormwater is typically not routed to infiltration features, but rather implemented to reduce volumes generated from adjacent impervious surfaces.
- Small sized Treatment BMP type constructed in Lake Tahoe.

Infiltrometer

BMP RAM observation to measure the infiltration rate in inches per hour (in/hr) of a pervious surface using a single-ring infiltrometer.

Inventory (BMP RAM STEP 2)

The user creates a mapped inventory of Treatment BMPs within the subject urban planning catchment using available maps and information and field verification efforts. The inventory includes unique IDs, spatial locations and relevant Treatment BMP characteristics.

Material Accumulation

BMP RAM observation to quantitatively track the relative loss of the Treatment BMP storage capacity. A permanent staff plate is installed near the outlet of Treatment BMP and the lowest visible value is recorded during BMP RAM field observation.

Media Filtration

Improvement of stormwater quality through the use engineered flow-through systems. Flow-through systems can be designed to (1) physically trap, separate, and/or sieve particulate matter and/or (2) use active media to treat dissolved constituents as stormwater is transported downgradient.

Nutrient Cycling

A stormwater treatment process. Concentration reductions of biologically available nutrients in stormwater due to uptake by growing vegetation, during photosynthesis. Fall and winter respiration of vegetation can result in increased biologically available nutrient release due to vegetation decay.

Observation Score

The BMP RAM Score is determined by the integration of observation scores. Each observation value (obtained by the user in BMP RAM STEP 4) is converted to an observation (0-5) score based on the pre-determined benchmark (5) and threshold (2) values set by the user and stored in the DATABASE. The BMP RAM user enters the field observation values per the protocols outlined in Chapter 8, and the DATABASE internally calculates individual observation scores, as well as the overall BMP RAM Score. (See Chapter 8 for scoring calculations.)

Observation Type

The BMP RAM scoring approach includes 5 distinct observation types that have been lettered A-E. Each observation type has a different combination of user input requirements during the BMP RAM STEP 3 and internal database calculations to determine the observation scores.

Particle Capture Treatment Process: Removal of particulate matter in stormwater through flow attenuation. Decreasing flow velocity limits the transport capacity of stormwater, allowing particle settling and retention.

Porous Pavement Treatment BMP Type

- Porous pavement consist of a durable, pervious surface overlaying a crushed stone base that stores rainwater before it infiltrates into the underlying soil.
- Porous pavement can include an underlying reservoir to increase infiltration rates.
- Local stormwater is typically not routed to a porous pavement surface, but rather constructed to minimize the volume of stormwater generated and routed downgradient from a previously impervious surface.
- Footprint of Treatment BMP type can vary greatly, typically used for parking lots or other impervious surfaces.

Runoff Observation BMP RAM observation to quickly evaluate the infiltration capacity of an Infiltration Feature or Biofilter. A known volume of water is applied to the soil substrate of the Treament BMP and a simple observation is made as to whether the water is infiltrated into the soil or not.

Sediment Trap Treatment BMP Type

- Typically constructed on site using low cost vertical corrugated metal (CMP) and trash rack placed in stormwater flow path to capture sediment, debris, coarse particles and associated pollutants in a deep (>5 ft) sump.
- Minimal to no volume loss occurs due to vertical accumulation of road side particulates and relatively small footprint.
- Typically located on road shoulder stormwater flow paths.
- Small sized Treatment BMP type constructed in Lake Tahoe.

Sediment Trap Capacity BMP RAM observation to quantitatively track the relative loss of Sediment Trap storage capacity. Field personnel use a stadia rod to measure the remaining distance from top of the accumulated sediment to the invert of the outlet during BMP RAM field observation.

Settling Basin Treatment BMP Type

- Structures typically placed at the inlet of other treatment BMPs to pre-treat inflowing stormwater and retain coarse sediment loads prior to stormwater entering subsequent Treatment BMP.
- Load reductions are realized by concentration reductions. Minimal to moderate volume loss occurs.
- Typically small to moderate sized Treatment BMP type constructed in Lake Tahoe.

Total suspended sediment (TSS) TSS is the mass of sediment contained in a known volume of water, and stormwater samples analyzed for TSS can be used to quantify the suspended sediment loads transported in runoff.

Threshold The Treatment BMP condition that the user has determined to be no longer acceptable from a water quality treatment perspective. The threshold equate to a RAM Score of 2. Typically, threshold values for each of the field observations are determined by the user relative to benchmark values. The integration of field observations are calculated by the database to determine the Treatment BMP RAM Score (i.e. condition) at the time of observations.

Threshold Value The threshold value for a specific observation equates to a BMP RAM score of 2, indicating maintenance is required to preserve the intended water quality benefits. Depending upon the observation type, the threshold value is either directly determined by the user, calculated as a result of the threshold criteria determined by the user, or a default value. In some instances, the observation type requires the user to set the threshold value, which is either an actual value or a relative % decline in the benchmark value. The BMP RAM User Manual V.1 details the user steps necessary to determine and input threshold values as required (BMP RAM STEP 3). The BMP RAM development team provides recommended threshold values for each observation type (Table 5 of the User Manual v1). See Chapter 8 BMP RAM Scoring for empirical scoring details.

Treatment BMP Structural BMPs that accept, attenuate, and treat urban stormwater. Treatment BMPs are implemented to reduce pollutant loads in stormwater by either removing pollutants and/or by reducing surface water volumes. The BMP RAM defines Treatment BMP Types by the processes relied upon for water quality improvements. Users of the BMP RAM must define the Treatment BMP type by these processes, rather than rely on previous naming conventions.

Treatment BMP Condition The condition is defined as a continuum of the water quality performance capability of a Treatment BMP. A Treatment BMP is considered at benchmark following installation and/or after adequate maintenance. As pollutant loading and treatment occurs during subsequent storm events, the condition of a Treatment BMP gradually declines. At some point, the operational performance of the specific Treatment BMP falls below the pre-determined acceptable condition (i.e., threshold) and maintenance is required.

Treatment Process Physical, chemical, or biological means employed by a Treatment BMP to remove/retain the pollutants of concern and/or reduce stormwater volumes that ultimately reach Lake Tahoe. Treatment BMPs in Lake Tahoe rely on 4 primary, passive processes to reduce the load of pollutants in stormwater: infiltration, particle settling, media filtration and nutrient cycling.

Treatment Vault

Treatment BMP Type

- Flow-through confined space structure that separates sediment, debris and other particulate pollutants from the water volumes via various settling techniques.
- Water quality improvements of stormwater continuing downgradient expected as a result of particle capture. No volume loss occurs due to impervious base, thus pollutant load reductions realized by concentration reductions due to particle capture.
- Typically manufactured and proprietary structures.
- 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.

Treatment Vault Capacity

BMP RAM observation to quantitatively track the relative loss of Treatment Vault storage capacity. Field personnel use a stadia rod to measure the remaining distance from top of the accumulated sediment to the invert of the outlet during BMP RAM field observation.

User Data Entry

Database function. The data inputs entered by the user to populate the database with the required information to calculate and track BMP RAM Scores.

Vegetation Cover

BMP RAM observation to characterize the vegetation types and percent cover within the frequently inundated area of a Treatment BMP. Vegetation types include: wetland species, riparian species, grass species, and terrestrial trees.

Wet Basin

Treatment BMP Type

- 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

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