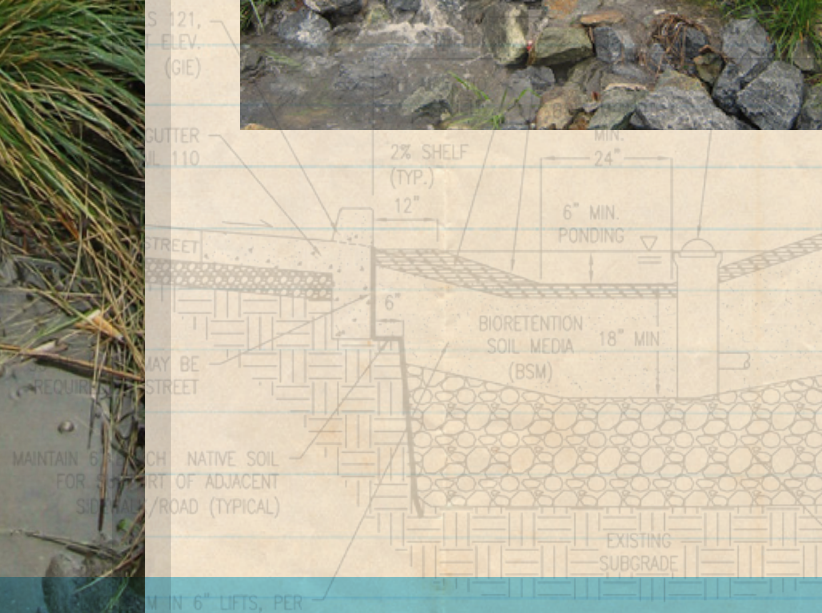


BEST MANAGEMENT PRACTICES  
RAPID ASSESSMENT METHODOLOGY

# BMP RAM TECHNICAL DOCUMENT V3.1

NOVEMBER 2016



**2NDNATURE**  
ecosystem science + design



# Best Management Practices Rapid Assessment Methodology (BMP RAM)

Technical Document v 3.1

November 2016

Developed by:



[www.2ndnaturellc.com](http://www.2ndnaturellc.com)

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BMP RAM technical approach and data management platform will continually be improved and maintained to meet the needs of stormwater managers, funders, regulators and the community within the concise mission defined for the tool. There are many individuals and organizations that have provided technical and usability input since 2009 and 2NDNATURE will continue to solicit users, encourage feedback and incorporate useful and feasible improvements to BMP RAM over time.

## TERMS AND CONDITIONS FOR USE

The Best Management Practices Rapid Assessment Methodology (BMP RAM) is a comprehensive and repeatable field observation and data management tool to simplify how municipalities inventory, assess the effectiveness, and determine maintenance intervals of structural BMPs. There are many individuals and organizations that have provided technical and usability input since 2009 and BMP RAM has been continually improved based on user feedback. Platform use is available to all current subscribers via a secure login. Please contact 2NDNATURE to obtain a license for use.

As with all 2N stormwater platforms, there is a long-term commitment to continue to refine and improve these tools as necessary to meet the needs of municipal users. 2NDNATURE will continue to iteratively implement the highest priority improvements and the updates will be automatically provided to all registered users.

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## EXECUTIVE SUMMARY

The Best Management Practices Rapid Assessment Methodology (BMP RAM) is a comprehensive and repeatable field observation and data management tool to simplify how municipalities inventory, assess the effectiveness, and determine maintenance intervals of structural BMPs. Anyone with a day of training can proficiently complete all aspects of BMP RAM. The primary product of BMP RAM is a customized web-based data management system ([www.bmpram.com](http://www.bmpram.com)) where users inventory structural BMPs, enter standardized and consistent field observations, and simply review mapped and tabular results of the relative condition of structural BMPs. Structural BMP condition is expressed as a meaningful continuous 0-5 score that directly indicates the relative performance and urgency of maintenance to ensure each BMP is managed to provide the stormwater treatment benefits intended.

A logical and consistent linkage is defined between the BMP RAM structural BMP types and the physical, chemical or biological processes relied upon to treat stormwater and reduce downslope pollutant loading. The result is 14 structural BMP types that can be used to define any existing stormwater structural BMP that provides some water quality benefit to stormwater runoff. Each structural BMP type has a unique set of characteristics and treatment processes that a BMP RAM user evaluates in the field. BMP RAM field protocols are designed as precise and repeatable proxies to evaluate the relative performance of the treatment processes relied upon for water quality treatment. The rapid nature of the field observations allow repeat observations following maintenance actions to document the restored water quality benefits. The inventory and assessment functions of BMP RAM also provide a standardized and consistent data management system to meet annual MS4 structural BMP tracking and reporting permit requirements. BMP RAM can also be used to track and report progress toward state and regional permit requirements regarding full trash capture by simple inclusion of trash capture device installation and maintenance within BMP RAM.

The consistent and repeatable terminology, data generation, data management and reporting formats of BMP RAM provide an invaluable and very cost-effective stormwater asset management tool for municipalities. The consistency of BMP RAM can also focus monitoring and modelling efforts to assess the effectiveness of one or many structural BMPs. By creating a standardized and useable terminology to define structural BMP types based upon their functional elements, BMP RAM concepts provide clarity to better define the water quality improvement expectations as a result of BMP interactions with stormwater and inform more focused and comparable water quality effectiveness monitoring of structural BMPs. In addition, for BMP RAM users who choose to use the stormwater Tool to Estimate Load Reductions (TELRL; [www.swtelr.com](http://www.swtelr.com)) all of their structural BMP inventory and effectiveness data generated in BMP RAM will automatically populate TELRL inputs. TELRL integrates available BMP RAM data within each urban catchment to quantify the cumulative pollutant load reductions to receiving waters. TELRL and BMP RAM together can be used to greatly improve the information available to inform stormwater program decisions. The communication power will increase a municipality's ability to compete for implementation funding by having a means to easily communicate, track and report the environmental benefits of stormwater investments. BMP RAM and TELRL are two in a suite of valuable decision support tools developed by 2NDNATURE for resource managers to simply and consistently evaluate, track and report the effectiveness of improvement actions in a format easily communicated to regulators, funders and the public.

# 1 INTRODUCTION

The Best Management Practices Rapid Assessment Methodology (**BMP RAM**<sup>1</sup>) is a comprehensive asset management tool for stormwater managers to **inventory** and evaluate the relative **structural BMP** condition to determine the maintenance urgency to ensure the water quality benefit is being sustained at an acceptable condition over time. BMP RAM facilitates the rapid field evaluation of any structural BMP. The capability of a structural BMP to perform its treatment function and provide water quality benefits will typically decrease over time unless maintenance actions are performed. At a certain **threshold** of pollutant accumulation, which varies from one structural BMP to another, the functional efficiency of passive **treatment processes** in the BMP will be drastically decreased. Poorly maintained structural BMPs have been observed to become so degraded that they simply provide a temporary storage of pollutants of concern where they can be easily entrained by subsequent storm flows (Mihevc 2004, 2NDNATURE 2005, 2NDNATURE 2006a, Green Nylan and Kiparsky 2015). 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 structural BMPs.

BMP RAM is a customized web-based BMP assessment and data management tool for users to quickly inventory and simply determine and track the condition of structural BMPs. RAM results can be used to track structural BMP distribution and conditions over time, prioritize BMPs for maintenance and report programmatic progress. BMP RAM is directly applicable for stormwater managers to evaluate and track the condition of stormwater structural BMPs in any location with minimal subjective decision making or local calibration. 2NDNATURE (2N) is committed to continual improvements to all aspects of BMP RAM to add to the technical validity, usability and feasibility of BMP RAM adoption into stormwater programs throughout the country.

## 1.1 Why 2N RAMs?

Natural resource management suffers from a lack of standardization and focus when it comes to quantifying the effectiveness of actions to protect and improve water quality. Countless watersheds across the nation have been added to the 303(d) list as impaired under the Clean Water Act, spurring the requirement of local public entities to develop TMDLs (Total Maximum Daily Loads) to identify the sources of pollutants and define a plan to protect the beneficial uses of local waters. Municipal Separate Stormwater Sewer Systems (**MS4**) permits place additional requirements on municipalities to implement actions to mitigate the impacts of urban **land uses** on receiving water quality. We collectively continue to struggle with how to prioritize where to invest resources and then quantify the benefits of our actions to improve water quality. 2NDNATURE believes this struggle is due, in part, to inconsistent sampling and assessment approaches that greatly limit the spatial and temporal comparability of results. These ambiguities combined with the substantial flow variability endemic to urban hydrologic systems creates a situation that, given available monitoring data, confounds **catchment** scale detection of any signal of water quality changes due to management actions. Consequently, we reside in a highly uncertain state regarding the effectiveness of water quality protection measures, and have a poor knowledge base from which to make decisions regarding how and where to implement management actions and consistently report their water quality benefits over time.

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<sup>1</sup> The first appearance of terms defined in the glossary (Section 7) is bolded.

Given decades of struggling with these issues alongside regulators and the regulated entities, 2N is at the leading edge of a paradigm shift towards a more holistic view of natural resource and water quality assessment that uses our best understanding of catchment mechanics in conjunction with monitoring design and analysis that make the most of the data collected. Generally, we want to know where problems are, whether things are changing and if those changes can be attributed to effective management actions. Monitoring data provide good ways to validate management effectiveness, but typical monitoring is expensive and therefore highly spatially and temporally limited. We cannot monitor everywhere all of the time, but we can reduce the time and cost while expanding the spatial application of useful data collection.

2NDNATURE has developed customized data collection and data management 2N RAM™ tools to rapidly evaluate the effectiveness of specific actions at the location on the landscape where improvement actions are implemented to provide an environmental benefit, whether it be water quality, water supply, ecological function, etc. 2N RAMs™ are customized monitoring tools purposely designed to consistently quantify the likely benefits of management actions. The 2N RAM™ approach focuses on the visible, physical and/or biological structure of the site attributes that vary across the range of expected conditions and uses simple proxies to infer the physical, chemical or biological state, process and/or function. The underlying philosophy behind the 2N RAM™ is that the relative condition of a site can be reliably and consistently quantified using a select number of objective, standardized and simple observations. 2N RAMs™ allow users to consistently evaluate the relative condition of specific locations where resources have and/or will be expended to improve water quality, providing a site specific and reliable assessment of the effectiveness of our actions. The 2N RAM™ tools translate all user inputs into a clearly defined numeric scale to communicate existing condition and relative site improvement priority easily to a wide array of audiences.

2N RAMs™ allow a much more cost-effective application of existing scientific knowledge by implementing repeatable, targeted observations or measurements over a much greater spatial extent than would be feasible with monitoring data collection on time frames relevant to management decision making. Because changes at the catchment scale that are detectable in monitoring data often occur over many years, there is an important information feedback lag to managers. 2N RAMs provide a mechanism for generation of resource status and trends intelligence that can drive decision making in the interim. RAM observations can be precisely implemented by anyone with a small amount of training, allowing comparable data to be collected by many over a large area. Trained volunteer groups or interns provide a great labor force to implement RAMs of all kinds.

RAM results do not replace the need for more rigorous evaluations, site design and effectiveness studies by experts. RAMs provide focus and consistency to monitoring efforts, and the specific framework by which each is created can be used to articulate our current technical theory in a quantitative and useful platform. The development of RAMs also greatly improves focus on where additional data is needed to continue to improve our understanding. For example, BMP RAM assessments do not supplant the need for or role of professionals to design or assess structural BMPs and implement appropriate improvements to ensure continued function as intended. Rather, 2N RAMs™ simplify and standardize the assessment approach so that more users can assess more structural BMPs to identify issues consistently and reliably. The standardization of BMP type definitions provides much needed clarity on expected functions and performance of different BMPs. Annual re-assessments of structural BMPs allow tracking of condition and can greatly guide maintenance priorities. Once maintained, reassessment demonstrates the restoration of the structural BMP water quality benefit.



## 1.2 Why BMP RAM?

Structural BMPs are a primary strategy to mitigate the impacts of urban development on receiving water quality (USEPA 1994, NRC 2008, USEPA 2016) and this strategy is inherent in MS4 stormwater permits throughout the United States. Low impact development (LID), green infrastructure, stormwater flood management, etc. are all strategies to mitigate the impacts of urban runoff on receiving waters that comprise the implementation of structural BMPs to reduce, retain and/or treat urban runoff and associated pollutants. These structural BMPs are stormwater assets that require maintenance over time to provide the intended water quality benefits (2NDNATURE 2011). However, the timing and actions necessary to maintain each structural BMP varies, making it challenging and costly to create standard maintenance schedules. BMP RAM v1 was first released in 2009 (2NDNATURE *et al.* 2009) and since that time dozens of stormwater managers, stormwater BMP engineers and designers, environmental scientists, field personnel and regulators have reviewed, tested and provided improvement suggestions to all aspects of BMP RAM. BMP RAM v3 includes the majority of the technical, functional and usability recommendations provided over the past decade.

BMP RAM is a simple and repeatable assessment method that can be used by trained volunteers or staff to document the condition of all structural BMPs on annual intervals and the results can be used to focus staff efforts only in the locations where maintenance is required. The condition history of each structural BMP can be used to inform design performance, identify locations where additional source control solutions may be warranted, or provide other valuable assessment data on the lifespan performance of various stormwater assets to improve program decisions.

BMP RAM provides municipalities with a comprehensive assessment and data management tool that addresses a number of prevalent challenges faced by stormwater managers throughout the country. These challenges include:

- Improving consistency and communication of structural BMP purpose and performance expectations by defining any existing structural BMP as one of the 15 types defined by the combination of processes relied upon to treat stormwater.
- A standardized, precise and repeatable approach to iteratively inventory, assess and track structural BMP function, prioritize maintenance and document the effectiveness of improvement actions.
- A cost effective and technically defensible alternative to costly and complex traditional approaches of high resolution water quality monitoring to quantify structural BMP water quality performance.

## 1.3 RAM Products

All 2N RAMs™ include three related products. A technical document provides the justification and technical approach underlying the data collection, management, analysis and reports provided by the respective RAM tool. A detailed user guide provides step by step instructions on how to complete all necessary RAM steps. The web-based data management system that provides users with a secure platform to collect, manage, and analyze their data.

BMP RAMv3 field observations are designed to be measureable proxies for one or more of stormwater treatment processes each unique structural BMP type is designed to provide. Continued testing and refinements to BMP RAM field techniques has tightened the precision by which RAM users can reliably complete each observation or measurement. The BMP RAM scoring rubrics have been informed by

existing and available structural BMP monitoring data, hydrologic modeling, research and best professional judgement of experts in the field of structural BMP design and hydrologic and water quality performance.

2N has developed a standard web-based RAM data management and visualization platform, and applied this template to create [www.bmpram.com](http://www.bmpram.com). Help menus are provided throughout the website to guide users through the data entry and data evaluation steps. The current BMP RAM Technical Document and User Guidance are available for download at [www.bmpram.com](http://www.bmpram.com). BMP RAM v 3.0 includes all of the technical, database functionality and user improvements iteratively made to BMP RAM over the last decade.

## 1.4 Document Structure

The primary RAM deliverable is the fully functional, customized web-based data management system located at [www.bmpram.com](http://www.bmpram.com). All BMP RAM user guidance, including field assessment protocols, is available for view and direct download by registered users. This technical document provides supplemental information of the development decisions and technical assumptions behind BMP RAM. *Chapter 2* provides an overview of user steps to assess structural BMP condition and track progress. *Chapter 3* includes the technical approach, definitions of the four treatment processes relied upon to reduce stormwater pollutant loads, and a presentation of the BMP RAM definitions of structural BMP types based on the processes outlined. *Chapter 3* also details how the development team leveraged available structural BMP effectiveness studies, theory and available data to develop the **field observation** methods. *Chapter 4* describes the scoring approach and results generation for each structural BMP type. *Chapter 5* summarizes the many applications and benefits of using BMP RAM as a structural BMP asset management tool and providing well needed consistency to structural BMP monitoring and modelling approaches. *Chapter 6* documents the limitations of BMP RAM v3 and identifies potential next steps. *Chapter 7* provides the BMP RAM glossary and a complete list of references is provided in *Chapter 8*.

## 2 BMP RAM USER WORK FLOW

2NDNATURE has a proven user workflow, terminology and development process to create user friendly and technically defensible rapid assessment methods (2N RAMs™). The BMP RAM structure and function is similar to other 2N RAMs™, while incorporating distinct changes to ensure the workflow, field observations and scoring rubrics are directly applicable to evaluating and tracking the condition of structural BMPs by stormwater managers, public works employees, resource managers, funders and regulators. The primary product of a 2N RAM™ is the customized web-based data management platform with a simple and standardized user workflow to inventory sites, conduct RAM field assessments, and evaluate results. 2N has designed a general RAM workflow template and common software functionality that is applicable to any future RAM we develop. We started with these templates and software functionality to create the BMP RAM located at [www.bmpram.com](http://www.bmpram.com).

Below we briefly summarize the BMP RAM user steps listed Table 2.1 from a technical perspective and the associated rationale for inclusion. The detailed BMP RAM user guidance is embedded within the online tool in HELP menus located throughout the website to assist users, and can be viewed in its entirety under Downloads. It is recommended that BMP RAM users review this document as well as the help and guidance materials at [www.bmpram.com](http://www.bmpram.com). Should users wish to conduct RAM field assessments accurately, it is recommended they attend a 1-day BMP RAM training hosted by a supporting organization.

**Table 2.1** Summary of BMP RAM steps implemented by the user.

STEP	Name	Description and Frequency
1	INVENTORY Structural BMPs	Inventory site location, site type, and assign unique site ID. Conduct 1 time per site.
2	Set BENCHMARK and THRESHOLD Values	Set observation expectations for best achievable and threshold values to inform at what condition maintenance is required. Complete following inventory and repeat following substantial maintenance actions.
3	Conduct FIELD OBSERVATIONS	Conduct RAM field observations and enter data by site. Repeat as frequently as desired.
4	Obtain BMP RAM SCORES	View RAM results for a time period of interest. Evaluate structural BMP conditions over time. Repeat as frequently as desired.
5	TRACK PROGRESS	Evaluate structural BMP presence and condition in area of interest. Track program progress toward goals. Repeat as frequently as desired.

### 2.1 Create BMP Inventory

The user inventories the spatially explicit location of structural BMPs where RAM field observations will be conducted. The user selects from one of the 15 types of BMPs, which are defined based on the treatment process they employ to treat stormwater (see Chapter 3.1) and general design specifications. Each structural BMP type has a set of required characteristic information that is both applicable to all types (e.g., number of inlets, land use treated) and specific to the type (e.g., **footprint**, **treatment capacity**). This data can be obtained through site observation or review of as-built plans or other data

sources. Using a mobile device, the user can document the location of a structural BMP on site and assign the structural BMP a unique ID code. Existing structural BMP databases and spatial data can be translated into BMP RAM database formats using provided templates and bulk uploaded to BMP RAM. Any structural BMP only has been inventoried once, and all inventoried BMPs are easily viewed in both map and tabular summaries.

BMP RAM users are encouraged to delineate and integrate the municipal urban drainage catchments into the BMP RAM online data management platform. The delineation of urban catchments provides an invaluable level of watershed scale organization to any MS4 area to improve prioritization of stormwater improvements and tracking of progress over time. Detailed guidance to complete such delineation is available to municipalities (2NDNATURE 2016a). If catchments are available, BMP RAM will automatically assign the catchment, receiving water, MS4 and other spatial context for each structural BMP inventoried in the tool. Should the user also use **TELRL** (2NDNATURE 2016b) to quantify and track catchment pollutant loading receiving waters, the urban catchment delineations will already be available to BMP RAM.

## 2.2 Set Benchmark and Threshold Values

**BENCHMARK** and **THRESHOLD** are critical values that are necessary to express structural BMP condition at the time of assessment as a 0-5 RAM score, and these values are updated only when deemed necessary by the user. Benchmark and threshold values are set by the user for each structural BMP to quantitatively define the structural BMP condition on a continuous 0-5 scale ranging from the best achievable (RAM score = 5; benchmark) to the condition when maintenance is required to maintain an acceptable water quality benefit (RAM score = 2; threshold). The details of how RAM scores are calculated for each BMP are provided in Chapter 4. Depending upon the BMP type, the benchmark values for each specific structural BMP are either assigned based on existing design standards or observed by the user at a time when the specific structural BMP is at its best achievable condition. Structural BMPs are typically at best achievable condition shortly following construction or immediately following complete maintenance actions. When benchmark values are observed by the user, these values may not align with design recommendations, but do represent the benchmark values by which performance decline over time will be tracked. When in benchmark condition the structural BMP will have a RAM Score of 5. Threshold values define the value at which the associated process(es) represented are no longer providing the intended benefit, and are set as default values in the application. When the observations are beyond the threshold values 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. Benchmark values can be updated over time as maintenance actions or BMP improvements are performed.

## 2.3 Conduct Field Observations

All BMP RAM observations are proxies, either independently or in combination, for the current condition of the structural BMP to perform the respective treatment process(es). For each structural BMP type, the user performs a series of standardized and rapid field observations defined by the BMP RAM field observation protocols. Common to all BMP types are inspection and observation that each inlet, outlet and bypass feature, including any trash capture device, is functioning appropriately and conveying water into and out of the respective BMP in order to provide the intended water quality benefit. The results of the individual observations are compared to the benchmark and threshold conditions and computationally integrated to determine the current condition (i.e., BMP RAM score) at the time of observations. Using a mobile device to complete field observations and directly enter data into the



database while at the BMP is recommended. Alternatively, field datasheets are available and hard copy data can later be transferred into the database in the office.

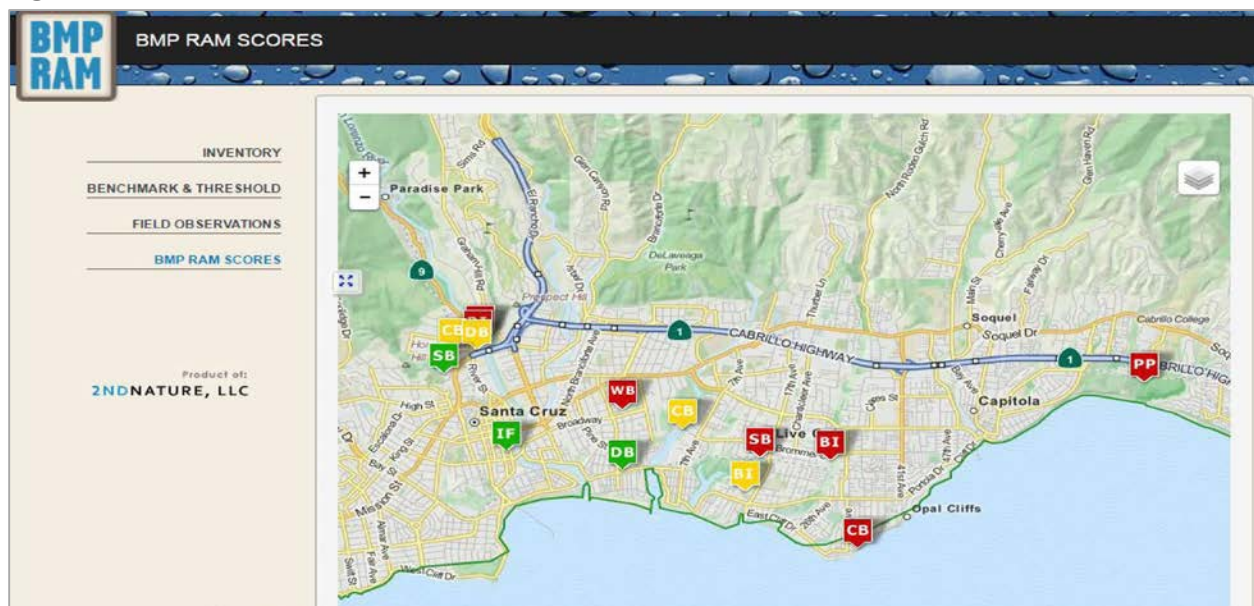
## 2.4 Obtain BMP RAM Score

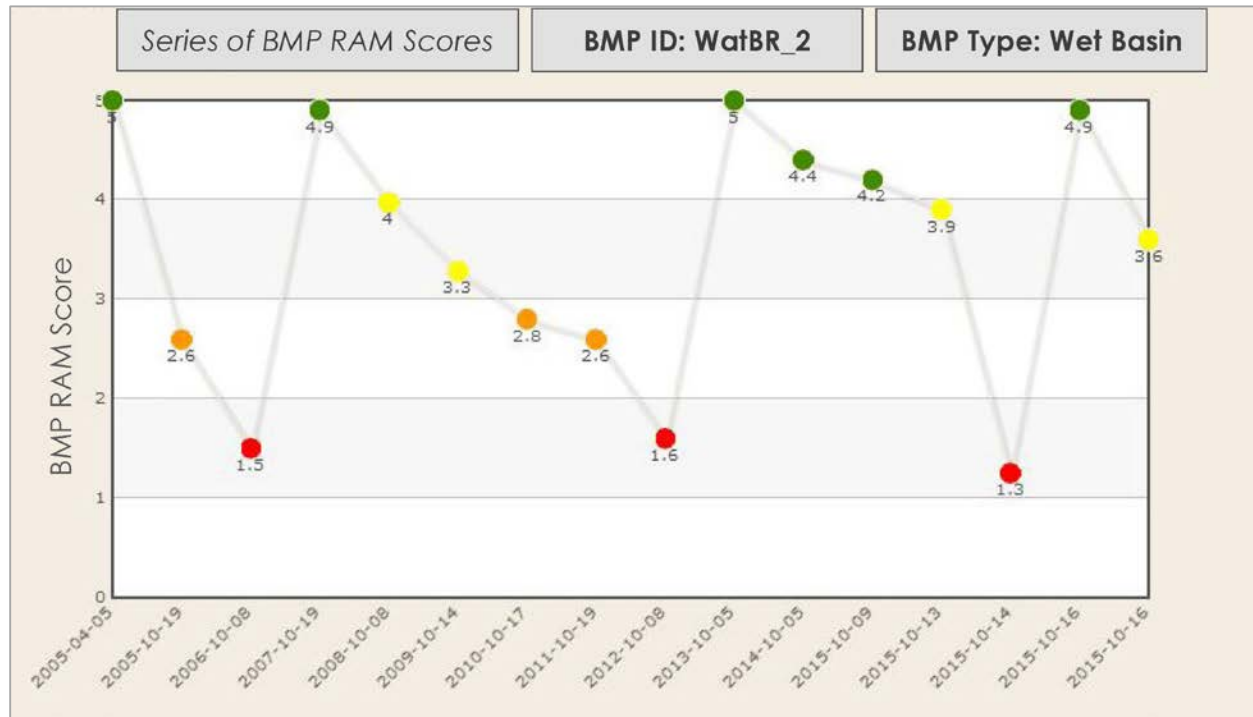
Using the scoring rubrics outline in Chapter 4, the field observation results are translated into the 0-5 BMP RAM Score (Table. 2.2) using a continuous scale in 0.1 increments. BMP RAM scores can be viewed spatially in the auto-generated map and in tabular form using filters and user defined queries (Figure 2.1). A graphical history of all BMP RAM scores for any BMP is readily available (Figure 2.2). The mapped results can guide maintenance priorities or be used to communicate structural BMP progress over time. If a mobile device is used in the field, the BMP RAM score is readily available to the user providing immediate verification that the obtained BMP RAM score aligns with the user's impression of BMP condition. This immediate feedback provides a tremendous data QA/QC opportunity that is more challenging to achieve with field datasheets. All results can be exported for further analysis outside of the database.

**Table 2.2** BMP RAM Scores relative to structural 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. Downgradient water quality may be adversely affected due to failure of structural BMP function. Maintenance required immediately.
>1.0 - 2.0	Below acceptable		Structural BMP pollutant load reduction potential is below acceptable condition. Maintenance is required prior to next runoff event.
>2.0 - <3.0	Fair	MODERATE	Acceptable downgradient water quality benefit, but structural BMP condition is closer to threshold than benchmark. Perform maintenance if time and resources permit.
3.0 - <4.0	Acceptable	LOW	Acceptable downgradient water quality benefits. No immediate maintenance recommended.
4.0 - 5.0	Desired	NONE	BMP providing desired water quality benefit. No maintenance actions needed.

**Figure 2.1** Spatial comparison of structural BMP condition.



**Figure 2.2** Structural BMP Condition Chronology.

## 2.5 Track Progress

The BMP RAM consistency of data generation and data management provides an invaluable stormwater asset management tool for municipalities. The individual structural BMP scores, color coded catchment maps and database information can be used to identify areas of high maintenance priority, develop appropriate maintenance schedules, and assist jurisdictions to more easily meet MS4 stormwater permit requirements.

The customized data management platform allows simple spatial and temporal summaries of BMP RAM data to quantify progress within an urban catchment, a subwatershed, or a municipality over a defined time period. The automated reporting functionality will prove invaluable for stormwater managers to quickly summarize, for instance, the number of BMPs installed or acres of **impervious area treated** over a grant funding cycling. The inventory and assessment functions of BMP RAM also allow the use of BMP RAM to demonstrate MS4 permit requirements related to the inventory and effectiveness requirements of any structural BMPs. BMP RAM can also be used to track and report progress toward state and regional permit requirements regarding trash capture.

The cumulative benefit of structural BMPs installed and maintained within an urban catchment can be quantified using the tool to estimate load reductions (TEL<sub>R</sub>; 2NDNATURE 2016b). If a user subscribes to both BMP RAM and TEL<sub>R</sub>, BMP RAM structural BMP sizing and condition data is automatically integrated into TEL<sub>R</sub> catchment volume and pollutant loading estimates. See Chapter 5 for more details.

## 3 TECHNICAL APPROACH

BMP effectiveness is critical information needed by managers to inform structural BMP design and maintenance to maximize the water quality treatment benefits. BMP RAM was created to provide a repeatable and defensible structural BMP assessment tool that quantifies anticipated relative water quality treatment benefits of any existing structural BMP based on well-established pollutant fate and transport principles. Pollutant load reduction estimates made using traditional water quality monitoring data are strongly influenced by hydrologic and sampling variability. Catchment heterogeneity in the relationships between flow metrics, pollutant concentrations, and pollutant loads makes it difficult to quantify loading in such a way that uncertainty is constrained to allow confident discernment of change from one time or location to another. BMP RAM is designed to quantify expected water quality changes due to the primary treatment processes providing load reductions irrespective of these other sources of variability.

All of the technical concepts and decisions incorporated into BMP RAM are driven by the goal to create a repeatable and defensible structural BMP assessment tool that is rapid and implementable by anyone with a day of training. Such a tool can greatly increase the amount of informative and directly comparable structural BMP data available to municipalities, regulators, funders, researchers and other interested stakeholders.

BMP RAM is based on a progression of four concepts that represent the best scientific understanding of structural BMPs installed to mitigate the water quality impacts of urban land uses and impervious surfaces. The primary pollutants derived from urban land uses and typically transported in stormwater runoff include a wide range of organic and inorganic pollutants. Structural BMPs rely upon varying physical, chemical and biological processes to reduce these pollutants in urban stormwater. We consolidate these processes into 4 simple categories that are precisely defined. These processes and the relative configuration of the structure are then used to define a small number of BMP types. BMP RAM field observations serve as proxies to rapidly and repeatedly assess and track the relative performance of the fundamental processes that each structural BMP relies upon to reduce stormwater volumes and loads to receiving waters.

### 3.1 Treatment Processes

The installation and maintenance of structural BMPs is a common and potentially effective strategy to reduce the impacts of the urban landscape and associated pollutant generation on receiving water quality. Using the basic equation:

$$\text{Pollutant concentration (mass/volume)} * \text{stormwater runoff (volume/time)} = \text{pollutant load (mass/time)}$$

Structural BMPs can reduce pollutant loads in stormwater by removing pollutants via concentration reductions and/or by reducing surface water volumes. We simplify the processes performed by structural BMPs into 4 distinct treatment processes:

- Infiltration
- Particle settling
- Biogeochemical cycling
- Media filtration

In reality, these primary treatment processes are interdependent with multiple physical, chemical and biological processes acting in unison to provide either volume or concentration reductions downslope as a result of stormwater interaction with any given structural BMP. The degree to which any single process dominates stormwater treatment depends largely on the designed function of the structural BMP. To simplify and focus discussions, we define how we define and apply these four processes in the context of a structural BMP and how effectiveness of each process would be measured using water quality effectiveness monitoring with a robust experimental design.

### 3.1.1 INFILTRATION

**Infiltration** is the most common process of structural BMP designs to treat urban stormwater and reduce downslope pollutant loads. Given that impervious surface coverage has greatly reduced the spatial distribution of infiltration, an effective strategy at mitigating urban development is the disconnection of impervious areas and an increase in areas that can infiltrate runoff.

The ability of a surface to infiltrate stormwater is primarily controlled by infiltration capacity, which is dominated by porosity, saturated hydraulic conductivity, degree of saturation, and hydraulic head. In addition to enhancing infiltration via native soils, fabricated surfaces such as porous pavement can infiltrate rain and runoff at relatively high rates. During infiltration, all pollutants suspended in stormwater, both dissolved and particulate, are transported into the unsaturated zone. Conservative dissolved compounds, such as nitrate ( $\text{NO}_3^-$ ), chloride ( $\text{Cl}^-$ ) or MTBE (methyl tert-butyl ether; banned in California in 2004) may continue with the infiltrating water to the shallow groundwater table. However, the majority of pollutants of concern derived from urban land practices are non-conservative or hydrophobic, including hydrocarbons, trace metals, phosphate and bacteria. These hydrophobic pollutants will preferentially bind to soil particles in the unsaturated zone, reducing the concentrations of these pollutants as the stormwater water infiltrates through the subsurface (Stumm and Morgan 1996, Barraud *et al.* 1999, Weiss *et al.* 2008, Leahy and Colwell 1990). Infiltration of urban stormwater, therefore, is a very effective water quality treatment approach to reduce non-conservative pollutant loads from reaching receiving waters.

*Infiltration is defined as the physical process by which water enters the soil or subsurface. Infiltration is used to indicate stormwater volume reductions, although infiltration will also result in soil-water interactions, filtration and other pollutant concentration benefits. While it is assumed that any pollutants contained within infiltrating volumes are introduced to and, when hydrophobic, retained within the unsaturated zone, effective infiltration is measured as a stormwater volume reduction as result of BMP interaction.*

Particulate matter contained within infiltrating waters will be captured and trapped within the pore spaces of the surface soils. Over time, the accumulation of sediment and fine particles in an infiltration structural 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 structural BMP to decline as stormwater and associated pollutants are infiltrated through the unsaturated soil layer.

The infiltration performance of larger centralized structural BMPs can be greatly influenced by seasonally elevated shallow groundwater tables that exist either regionally during winter/spring conditions or locally as a result of structural BMP presence and the creation of a localized mounding effect (2NDNATURE 2006b, Susilo *et al.* 2009, Machusick and Traver 2009).



### 3.1.2 PARTICLE CAPTURE

**Particle capture** is used to define the sequestering of particulate pollutants through flow attenuation, coagulation, and settling. One common mechanism to enhance particle capture is decreasing lateral flow velocities through detention or retention of volumes. This ponding will reduce the particle transport capacity and allow particle settling and retention within a structural BMP. Key characteristics that increase a structural BMP's ability to capture particles are longer flow path lengths and longer hydraulic residence times or brim full draw down times. Increasing the contact time between particles also increases aggregation (clay particles have a slight electric charge), thereby increasing particle size that have higher settling velocities and thus increasing the magnitude of the pollutant loads captured. Coagulation and adsorption of other hydrophobic pollutants to particulates can also occur and can result in pollutant concentration reductions as result of adsorption and subsequent settling. Correlations between total suspended solid (TSS) concentrations and other urban pollutants such as dissolved and total trace metals and phosphorous, total nitrogen, and *E. coli* have been documented in highway runoff (Kim *et al.* 2005, Kayhanian *et al.* 2006, Han *et al.* 2006), storm runoff (Anderson and Rounds 2003, Hamilton and Luffman 2009) and urban stormwater (Lee *et al.* 2004, Chen and Chang 2014). Effective removal of particulates can be assumed to have some commensurate reduction in associated total pollutant fractions. Outlet risers that restrict outflow to the surface of the water column increase the particle capture effectiveness of a structural BMP.

*Particle capture is defined as the physical process by which particulates, trash, or debris are physically removed from stormwater. Particle capture can occur via flow attenuation, vertical settling, flow separation, or other physical or abiotic processes that result in capture and retention within a BMP. Effective particle capture would be measured as pollutant concentration reductions for particulate pollutants as result of BMP interaction.*

Vegetation presence can both enhance and reduce particle capture within a structural BMP. Vegetation can attenuate flow velocities and provide a substrate for particulate pollutants to aggregate and/or adhere. In these cases, the presence and role of vegetation and/or biota as a treatment process is defined separately as **biogeochemical cycling** (see below). However, high density wetland and riparian vegetation within a structural BMP can also greatly diminish the treatment capacity over time. Loss of capacity due to vegetation growth can shorten hydraulic residence times and lessen the particle settling and retention capability within the BMP.

BMP types that rely upon both infiltration and particle settling will require regular assessment to track the loss in infiltration capacity of the bed as a result of material capture. Infiltration capacity of the BMP will be controlled by the soil horizon with the lowest relative permeability, which will likely exist at the base of the BMP. High particulate pollutant loading can clog the interstitial pores within the organic soil media, greatly reducing infiltration capacity (2NDNATURE and nhc 2013).

### 3.1.3 BIOGEOCHEMICAL CYCLING

**Biogeochemical cycling** involves the reduction in concentration of pollutants as a result of biological interactions. This interaction may be physical, such as adherence of fine particles to surface vegetation provided by stems and leaves, filtration of water through an organic soil substrate to promote biogeochemical transformations, or uptake of nutrients by plants. Biogeochemical cycling is assumed to occur in any structural BMP that relies upon a persistent vegetation presence or passive filtration through an organic rich soil substrate.

Vegetation uptake via photosynthesis is most pronounced in structural BMPs that are seasonally or frequently inundated with stormwater containing a relatively elevated concentration of phosphorous and nitrogen or where dry weather flows provide a year round water source for vegetation to persist. Structural BMPs that include persistent vegetation provide surfaces to which microparticles can adhere, thereby removing these particles and associated pollutants from stormwater. Microbial respiration of the organic matter during the fall and winter will release inorganic nutrients back into the BMP. Reducing (anaerobic) conditions where dissolved oxygen is limited can occur in structural BMPs with dense wetland plant communities and can be very effective at removing biologically available nitrogen via denitrification. However, effective phosphorous species removal may require annual fall harvesting of vegetation to prevent decomposition and the re-release of biologically available nutrients.

*Biogeochemical cycling is defined as the biologically-induced physical or chemical processes by which compounds or pollutants are retained, transformed and removed from stormwater. Biogeochemical cycling can occur either as result of vegetation or microbial presence in the soils or media within a structural BMP. Effective biogeochemical cycling would be measured as pollutant concentration reductions as result of BMP interaction for a range of pollutant types.*

Biogeochemical cycling is not limited to nitrogen or phosphorous reductions in stormwater. Biofiltration through soil media with high organic content provides opportunities for adsorption and detainment of any hydrophobic pollutants in urban stormwater and promotes bacterial decomposition and transformations of both organic and inorganic pollutants (Hinman 2009). Hsieh and Davis (2005) tested laboratory column rain gardens and found greater than 96% removal of oils and grease (introduced as used motor oil through synthetic stormwater). The results of their field study found that removal efficiency of oils and greases from a synthetic stormwater was nearly 100 percent and 99% removal was observed during a natural rain event. The right biota for biofiltration media enhances the microorganism community that contribute to the capture and conversion of pollutants and nutrients into a form that can be easily consumed by the vegetation. The microorganisms work in a symbiosis with the plants to capture and uptake the pollutants and nutrients in the stormwater runoff. Via biogeochemical processes, microorganisms convert nutrients and pollutants from their stable insoluble form into ones that are easily utilized by vegetation. Urban pollutants including particulates, hydrocarbons, nutrients, and trace metals and other urban pollutants adhere to the soil horizon in the unsaturated zone (Barraud *et al.* 1999, Legret *et al.* 1999, Dierkes and Geiger 1999).

BMP types that rely upon both infiltration and biogeochemical cycling require vegetation distribution and density to be balanced such that infiltration capacity of the soil media is not compromised by excessive vegetation rooting and organic debris and decomposition. Similarly, high particulate pollutant loading can clog the interstitial pores within the organic soil media, greatly reducing infiltration capacity. Excessive vegetation growth can also impact the treatment capacity of the structural BMP, diminishing particle capture performance and pollutant retention.

### 3.1.4 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 hydrophobic compounds and/or (2) use active abiotic media to adsorb and remove dissolved constituents as stormwater is transported downgradient. The type of media installed in any particular structural BMP should be carefully selected based on the targeted pollutants of concern in the contributing drainage catchment. 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 and the remaining adsorption capacity of the media through which the stormwater is filtered.

*Media filtration is defined as the physical filtration process by which particulates and dissolved pollutants are physically removed from stormwater. Media filtration results in pollutant removal through physical or abiotic chemical processes through engineered flow through systems. Media filtration that includes any vegetation or organic microbial component is defined by BMP RAM as biogeochemical cycling. Effective media filtration would be measured pollutant concentration reductions as result of BMP interaction for a range of pollutant types.*

## 3.2 Structural BMP Types

The BMP RAM technical approach is designed to be simple, consistent and applicable to the range of structural BMP types implemented throughout urban areas to mitigate urban water quality impacts. Using the 4 treatment processes defined above, 15 structural BMPs types are precisely defined based on the functional physical, chemical and biological processes they rely upon to reduce surface water volumes and/or urban pollutant concentrations. BMP RAM structural types preserve traditional names to the extent possible, while minimizing the total number of types. In some instances, two different structural BMP types rely upon the same treatment processes for water quality improvement, but their respective physical characteristics are distinctly different. In most instances these physical characteristics can be categorized into centralized and decentralized structural BMPs. **Centralized BMPs** are larger in size, have larger drainage areas that can include a mixture of urban land uses and are more hydrologically complex and costly to design and install. **Decentralized BMPs** are installed to treat stormwater from a relatively smaller drainage areas, typically comprised of single land use such as a high traffic road or a commercial parking lot.

Table 3.1 lists BMP RAM structural BMP types, provides other common names, a narrative description and the defined primary treatment process(es) relied upon to improve water quality as defined in Chapter 3.1. The first task of a BMP RAM user when inventorying a BMP is to identify its structural BMP type. Users must define the structural BMP type as one of 15 types by applying the intended processes the BMP relies upon to treat urban stormwater, rather than relying on previous naming conventions.

The placement of trash capture devices at the inlet or outlet of structural BMPs or at drop inlets are becoming common practices to meet State Trash Reduction requirements (CA SWRCB 2015). Both drop inlets and trash capture devices are included in Table 3.1 for simplicity, though by definition they are not structural BMPs. A drop inlet does not provide any water quality benefit and merely conveys stormwater, and trash capture devices are placed at the inlet or outlet of a drop inlet or any structural BMP and thus always associated with a specific structural BMP in BMP RAM.

For peak flow management, structural BMPs may be designed to only receive stormwater during high flow events for the purposes of retention to avoid flooding downstream. The stormwater is then released to the receiving water after the high flows have receded. Due to the conveyance design, these BMPs are not providing treatment during the majority of stormwater flow events and are by definition therefore not considered treatment BMPs in BMP RAM. However, municipal stormwater managers still desire to inventory these structures and regularly assess their condition, particularly with respect to changes in capacity. Any of the 14 treatment BMPs can be designated as a low flow bypass in the inventory step, and a definition is provided in Table 3.1 for simplicity.

**Table 3.1** BMP RAM structural BMP types.

CENTRALIZED BMPs			
STRUCTURAL BMP TYPE	OTHER NAMES	DESCRIPTION	TREATMENT PROCESSES
Bed Filter		A flow-through structure that uses granular media (e.g. sand or activated alumina) to actively filter stormwater to remove stormwater pollutants.	MEDIA FILTRATION
	Underground Sand Filter	Filtration is controlled by the flow rate through the media and discharge via an underdrain or outlet. Little to no volume loss occurs.	
	Surface Sand Filter	May be confined space but not always.	
	Perimeter Sand Filter	Pollutant load reductions achieved by reduced concentrations in effluent.	
	Organic Media Filter	Typically, moderate sized centralized BMPs but can be small decentralized BMPs treating small areas of imperviousness.	
Detention Basin	Detention Pond	A flow through basin with discrete inlets and outlets designed to detain stormwater runoff for some minimum time to reduce peak flows. Design treatment capacity and draw down time will vary across specific BMPs.	PARTICLE CAPTURE
		One or more outflow offices may exist but there is at least one at base of basin to allow complete draining between storms. Increased draw down times can increase particle capture via settling within the basin.	
		Little to no volume loss via infiltration either due to impervious or highly impermeable base.	
		Vegetation may or may not be present.	
		Moderate to large sized centralized BMPs that accept runoff from mixed land use drainage areas.	
Dry Basin	Extended Detention Basin  Dry Pond	A flow through basin with discrete inlets and outlets designed to detain stormwater runoff for some minimum time to reduce peak flows. Design treatment capacity and draw down time will vary across specific BMPs.	INFILTRATION  PARTICLE CAPTURE
		One or more outflow offices may exist but there is at least one at base of basin to allow complete draining between storms. Increased draw down times can increase particle capture via settling within the basin.	
		Footprint is pervious and infiltration capacity of base maintained to consistently infiltrate some fraction of volumes detained to unsaturated zone.	
		Wetland and riparian vegetation species distribution is minimal to absent. Moderate distribution of grass and/or tree species likely and acceptable.	
		Moderate to large sized centralized BMPs that accept runoff from mixed land use drainage areas.	



STRUCTURAL BMP TYPE	OTHER NAMES	DESCRIPTION	TREATMENT PROCESSES
<b>Infiltration Basin</b>	<i>Large-Scale Infiltration Feature</i>	A flow through BMP with highly permeable substrate (aggregate or rock) designed to store and infiltrate significant volumes of stormwater into unsaturated zone.	INFILTRATION
		Little to no surface detainment storage.	
		Vegetation distribution should be minimal and preferably absent.	
<b>Media Filter</b>	<i>Proprietary Subsurface Filtration Systems:  Stormfilter®  Perk Filter™  Jellyfish®  Tree Box Biofilter (TreePod™)</i>	A proprietary subsurface flow-through structure that uses a membrane or other media to actively filter stormwater to remove pollutants.	MEDIA FILTRATION
		Proprietary models include media or membranes that may be selected to target the specific removal of the pollutants of concern, resulting in downgradient stormwater concentration reductions.	
		May be confined space but not always.	
		Pollutant load reductions achieved by reduced concentrations in effluent. No stormwater volume reduction occurs.	
		Typically moderate to large sized centralized BMP, accepting runoff from a mixed land use drainage area.	
<b>Treatment Vault</b>	<i>Hydrodynamic Separator (Vortechs, CDS®, DVS)  Wet Vault  Detention Vault  Flow Separation Vault  Gross Solids Retention Devices  Large Scale Settling Basins</i>	A subsurface flow-through structure that physically separates sediment, trash, leaf litter, debris and other particulate pollutants from stormwater via various water separation or settling techniques.	PARTICLE CAPTURE
		Pollutant load reductions are realized by concentration reductions. No volume reduction occurs due to impervious base.	
		Many available manufactured and proprietary models employ various physical techniques to separate and capture debris and particulate.	
		Accumulation of material at base of BMP can be observed and measured via manhole access.	
		Moderate sized centralized structure accepting runoff from either a large single or mixed land use drainage area.	
<b>Wet Basin</b>	<i>Wet Pond  Retention Pond  Wetland Swale  Wet Extended Retention Pond  Stormwater Wetlands  Constructed Wetlands</i>	A flow through basin with discrete inlets and outlets designed to retain some volume stormwater runoff in a persistent pool of surface water. Designs may include additional detainment storage of stormwater for some minimum time to reduce peak flows.	BIO- GEOCHEMICAL CYCLING  PARTICLE CAPTURE
		Wet pool capacity, treatment capacity and draw down time of treated volumes will vary across specific BMPs.	
		One or more outflow offices may exist at different elevations. Lowest outlet elevation sets wet pool capacity.	
		Dense vegetation is common. Dominant vegetation is wetland species and can be supplemented with riparian species with very high densities.	
		Substrate is typically fine organic matter and silt, making volume reductions via infiltration negligible. Volume reductions occur primarily by evapotranspiration.	
		Moderate to large sized centralized BMPs that accept runoff from mixed land use drainage areas.	

## DECENTRALIZED BMPs

STRUCTURAL BMP TYPE	OTHER NAMES	DESCRIPTION	TREATMENT PROCESSES
<b>Bio- filtration</b>	<i>Lined rain garden with no exfiltration</i>	Vegetated BMP where stormwater is filtered through a specialized soil media and discharged via an underdrain.	
		BMP may or may not be lined but little to no exfiltration of volumes.	
		Outlet design requires surface ponding prior to surface outflow typically with a maximum ponding depth of 6 inches.	BIO- GEOCHEMICAL CYCLING
		Site designed biofiltration systems use specialized soil media ideally 18-24 inches in depth to enhance biogeochemical processes to retain and transform pollutants.	PARTICLE CAPTURE
		Proprietary biofilter designs vary and specialized soil media may or may not be accessible for inspection.	
		Small to moderate sized decentralized BMP accepting runoff from a single land use drainage area.	
<b>Bio- retention</b>	<i>Rain garden with exfiltration</i>	Vegetated retention structure where the base of the BMP is not lined and must infiltrate volumes and allow exfiltration to unsaturated zone. Designs may or may not include an underdrain to route some fraction of treated waters to stormwater system.	
		Outlet design requires surface ponding prior to surface outflow typically with a maximum ponding depth of 6 inches.	INFILTRATION
		Outlet design either passive surface outlet (e.g., curb cut) or piped overflow (e.g., overflow inlet and underdrain) used to allow retention and ponding.	BIO- GEOCHEMICAL CYCLING
		Constructed with specialized soil media ideally 18-24 inches in depth to enhance biogeochemical processes to retain and transform pollutants.	PARTICLE CAPTURE
		May include rock or aggregate subsurface layer under the soil media to enhance storage/infiltration.	
		Designs may include settling forebay at inlet(s) to remove sediment.	
		Vegetation types include species that can tolerate stormwater ponding and drought conditions.	
		Small to moderate sized decentralized BMP accepting runoff from a single land use drainage area.	
<b>Bioswale</b>	<i>Biofilter, Grass Swale, Grass Filter Strips, Vegetated Buffer Strips, Bioslopes</i>	Flow through areas with dense vegetation coverage (>80%). Flow surface topography allows inundation of adjacent vegetated areas during storm runoff.	BIO- GEOCHEMICAL CYCLING
		Design includes gentle sloped flow paths and dense vegetation to promote primary stormwater surface filtration, adsorption to vegetation and settling. Biological processes include geochemical transformation and plant uptake. Infiltration performance and volume reductions may vary.	INFILTRATION
		Size and application of bioswales can vary.	

STRUCTURAL BMP TYPE	OTHER NAMES	DESCRIPTION	TREATMENT PROCESSES
<b>Catch Basin</b>		A small decentralized BMP designed to capture and retain sediment, leaf litter, trash, coarse particles and/or other stormwater pollutants.	
	<i>Sediment Trap,</i>	Capture of material may occur through variable flow modifications or passive settling, but result is vertical accumulation of material at base of BMP reservoir with regular material cleanout required.	PARTICLE CAPTURE
	<i>Sediment Chamber,</i>		
	<i>Vertical CMP,</i>	Minimal to no stormwater volume reduction occurs.	
	<i>Small Hydrodynamic Separators</i>	Water quality improvement downgradient expected as result of concentration reduction due to material capture within BMP.	
		Typically accepts runoff from road or a single land use parking lot.	
<b>Infiltration Feature</b>	<i>Infiltration Trench,</i>	A small scale structure designed to retain stormwater from small impervious drainage area and infiltrate into unsaturated zone. 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.	INFILTRATION
	<i>Dry Well,</i>		
	<i>Exfiltration Trench</i>		
	<i>Percolation Trench,</i>	Vegetation is absent.	
	<i>French Drain,</i>	Typically a small sized decentralized BMP, accepting runoff from a single land use drainage area.	
	<i>Roof Drip-Line</i>		
<b>Porous Pavement</b>		Use of sustainable materials to create a durable, pervious surface overlaying a crushed stone base that allow stormwater to percolate and infiltrate into the underlying soil.	INFILTRATION
	<i>Permeable Pavement,</i>		
	<i>Porous Asphalt,</i>	Porous pavement can include an underlying reservoir to increase infiltration rates.	
	<i>Pervious Concrete,</i>	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.	
	<i>Porous Aggregate,</i>	Footprint of structural BMP type can vary greatly, typically used for parking lots, sidewalks, driveways or other impervious surfaces.	
	<i>Pervious Pavers,</i>		
	<i>Permeable Pavers</i>		
<b>Settling Basin</b>		Open flow through structures used to detain stormwater volumes and settle particulate pollutants prior to outflow.	PARTICLE CAPTURE
		Pollutant load reductions are realized by concentration reductions with no volume reduction via infiltration due to impervious or highly impermeable base.	
	<i>Settling Pond,</i>	Size and application of settling basins can vary.	
	<i>Sediment Basin</i>	Settling basins are common at the inlet of another structural BMPs to pre-treat inflowing stormwater prior to stormwater entering subsequent structural BMP. If inventory and assessment of the settling basin is desired independent from the next structural BMP in the treatment train, there are two options:	
	<i>Decant Pond</i>	large scale settling basin draining a mixed land use area can be classified and assessed as a treatment vault	
	<i>Concrete Forebay</i>	smaller sized settling basins draining a single land use area can be classified and assessed as a catch basin.	

## CONVEYANCE BMP

STRUCTURAL BMP TYPE	OTHER NAMES	DESCRIPTION	TREATMENT PROCESSES
<b>Drop Inlet</b>	<i>DI</i>	Stormwater feature placed strictly to collect and convey stormwater.	NO WATER QUALITY BENEFIT
	<i>Storm Drain</i>	A drop inlet that includes a sump to capture particulate pollutants is termed a Catch Basin.	
	<i>Culvert</i>	Typically conveying water from a roadway, parking lot or other impervious surface to a culvert or storm drain and provides no water quality benefit downgradient.	

## TRASH CONTROL

STRUCTURAL BMP TYPE	OTHER NAMES	DESCRIPTION	TREATMENT PROCESSES
<b>Trash Capture Device</b>	<i>Connector Pipe</i>	Structures placed at the inlet of a drop inlet or structural BMP to capture and detain trash, litter or debris < 5 mm in size to prevent discharge of trash into the stormwater system or the structural BMP.	TRASH CAPTURE
	<i>Screen</i>		
	<i>Insert Filter</i>		
	<i>Retractable Screen</i>		
	<i>Pipe Netting</i>		

## PEAK MANAGEMENT

STRUCTURAL BMP TYPE	OTHER NAMES	DESCRIPTION	TREATMENT PROCESSES
<b>Low Flow Bypass</b>	<i>Flood Control</i>	Large retention areas designed to receive stormwater inflows only during large (10-year) events in order reduce flows to the receiving waters and lower the likelihood of flooding.	N/A
	<i>Peak Management</i>	The structural design of the inlet is set to an elevation that only allows water into the BMP during high flow events. Low flows will bypass the BMP entirely and continue directly downstream.	
	<i>Retention Basin</i>		
	<i>Floodwater Storage</i>	The design of the flood control area may vary with respect to vegetation cover, substrate, etc.	

### 3.3 BMP RAM Field Observations

Each of the 15 BMP types are defined by their physical characteristics and the processes they rely upon to improve stormwater quality (see Table 3.1). Different combinations of BMP RAM field observations are used to collectively track and assess the performance of the respective processes performed by each structural BMP based on type. RAM observations were developed and continue to be refined to ensure they are rapid, repeatable and can be precisely implemented by a wide array of users with 1 day of training. The observations or measurements are translated into a meaningful 0 to 5 ( $\pm 0.1$ ) BMP RAM scores by the custom online data management system available at [www.bmpram.com](http://www.bmpram.com).

Table 4.1 summarizes the BMP RAM field observations by structural BMP type. In many instances, an observation may be used to assess the performance of more than one process. A total of 9 **observation types** are used in combination to assess the condition of all 15 different BMP types. In some instances,



the application of the observation results are integrated into the BMP RAM score differently, depending upon BMP type. Each of the observations were developed to ensure the results are sensitive to expected changes in structural BMP attributes over time as stormwater and pollutants are loaded into the structure. Development of the field observations included the chemical, physical or biological processes relied upon, typical BMP sizing and design, substrate conditions, hydrologic functions, vegetation characteristics, and other considerations. The BMP RAM User Guidance v3.0 (2NDNATURE 2016a) contains the detailed protocols to conduct BMP RAM field observations by BMP type.

**Table 3.2** BMP RAM field observations for each BMP type. Some observations are proxies for more than one process to assess overall BMP function.

Structural BMP Type			Field Observations			Structural BMP Type			Field Observations		
Centralized BMPs	Bed Filter	Runoff			Biofiltration	Remaining Capacity					
		Conveyance				Substrate Type					
	Detention Basin	Material Accumulation				Runoff					
		Conveyance				Conveyance					
	Dry Basin	CHP or Infiltrometer			Bioretention	Remaining Capacity					
		Veg Cover				Substrate Type					
		Material Accumulation				Runoff					
		Conveyance				Conveyance					
	Infiltration Basin	CHP or Infiltrometer			Bioswale	Veg Cover					
		Veg Cover				Runoff					
		Conveyance				Conveyance					
	Media Filter	Confined Space			Catch Basin	Remaining Capacity					
		Conveyance				Conveyance					
	Treatment Vault	Remaining Capacity			Infiltration Feature	Veg Cover					
		Conveyance				Runoff					
	Wet Basin	Material Accumulation				Conveyance					
		Veg Cover			Porous Pavement	Runoff					
		Conveyance				Conveyance					
Decentralized BMPs	Settling Basin	Material Accumulation			Drop Inlet	Material Accumulation					
		Conveyance				Conveyance					

### 3.3.1 INFILTRATION OBSERVATIONS

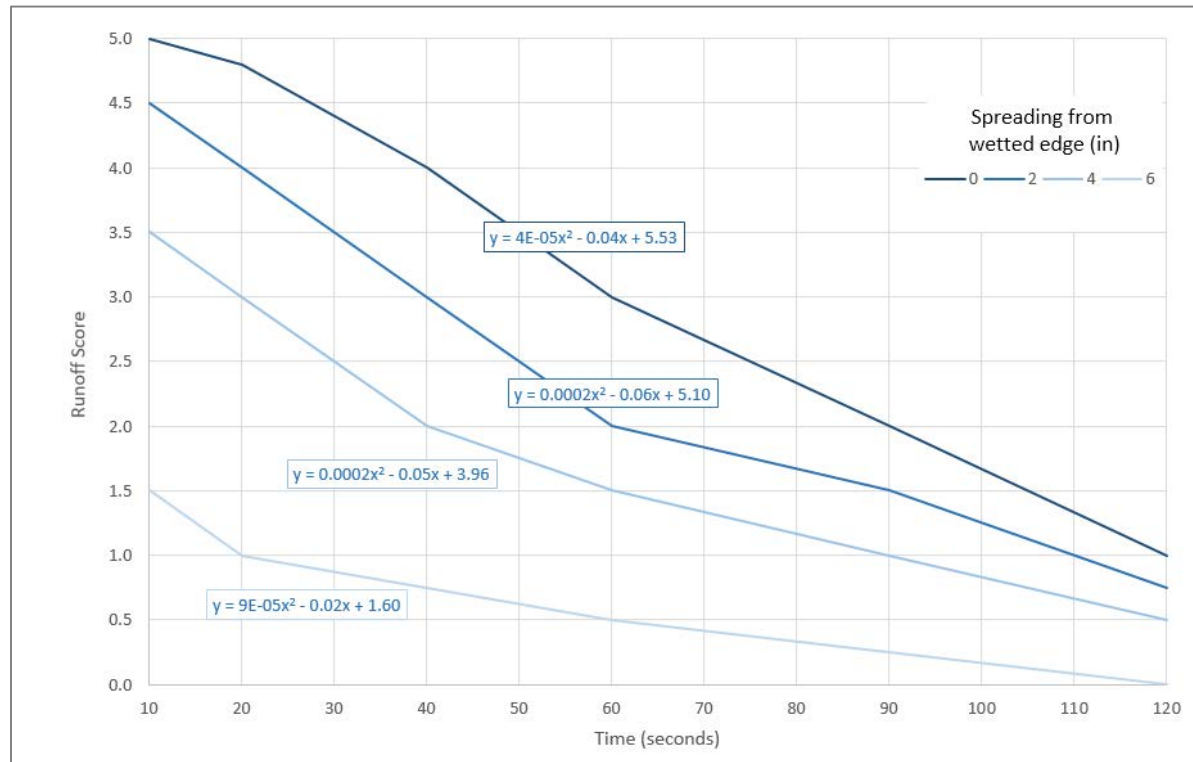
As defined in Section 3.1, infiltration is explicitly defined as the vertical exfiltration of stormwater through either the native soil horizon or a fabricated abiotic media, such as porous pavement. Particulate matter contained within infiltrating waters will be captured and trapped within the pore spaces of the surface soils. Over time, the accumulation of sediment and fine particles in an infiltration structural 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 structural BMP to decline as stormwater and associated pollutants are infiltrated through the unsaturated soil layer.

BMP RAM employs 3 different methods to measure the relative infiltration performance of a structural BMP. The infiltration rate (in/hr) of dry basins and infiltration basins is recommended to be performed using the 6-in diameter double ring **infiltrrometer** following NRCS well-accepted methods (Johnson 1963). Another acceptable approach developed by the NRCS is the **constant head permeameter** (CHP) to measure the saturated hydraulic conductivity ( $K_{sat}$ ) of a surface soil substrate (NRCS 2011). The BMP RAM user can choose whether an infiltrrometer or CHP is preferred, but once selected for a specific BMP the infiltration method cannot be changed. The number of infiltration measurements recommended is dependent upon the structural BMP footprint and the precision of the values obtained.

Precise and repeatable CHP and infiltrrometer measurements are not possible in decentralized BMPs that infiltrate stormwater, due to their smaller surface areas and/or the footprint substrate of these BMP types. 2NDNATURE developed and refined the 'runoff' method to measure infiltration performance in decentralized BMPs. The runoff test has been designed to be a rapid and repeatable measure to assess the relative degree to which a surface is capable of rapidly infiltrating stormwater. A series of controlled experiments have been conducted to determine the relative behavior of surfaces within these types of BMPs to infiltrate a small volume of water in a focused location over a short period of time (Figure 3.1 next page). Experiments across a range of **substrate types** and degree of infiltration performance have illustrated that a surface with some infiltration capacity will infiltrate 400mL over an approximately 30 in<sup>2</sup> surface in less than 20 seconds. A poorly infiltrating surface will take longer than 2 minutes to infiltrate the same volume over the same area. Different types of equipment are used to minimize leaks depending upon the footprint material of the BMP, but the surface area of infiltration, volume of water and starting head is consistent whether the BMP base is soil, cobble, pavers, or permeable pavement. In those cases when leaks cannot be prevented, the degree of the leaking and spreading from the equipment edge is included in the **runoff observation** scoring (see Figure 3.1). The number of runoff measurements recommended is dependent upon the structural BMP footprint and the precision of the values obtained.

In BMP RAM, infiltration observations commonly are integrated with visual observations of vegetation type and cover or substrate type to evaluate the infiltration ability of the structural BMP. **Vegetation cover** can be a potential indication of reduced infiltration capacity, where dense vegetation cover of riparian or wetland species can indicate the presence of dense rooting structures and fine grained material possessing a lower infiltration capability than coarse or un-compacted substrate. Similarly, observations of the type and distribution of the BMP substrate material within the functional footprint can indicate infiltration capacity, where the presence of coarse, crumbly, organic material will have a higher infiltration capability than compacted, fine-grained material.

**Figure 3.1** Time required to infiltrate 400mL of water and spreading of water from wetted edge of field equipment are integrated to estimate the relative infiltration ability of the structural BMP on a 0-5 scale. The equations are informed by a controlled experiment across a number of different BMP types in a range of conditions.



### 3.3.2 PARTICLE CAPTURE OBSERVATIONS

Some particle capture structural BMPs retain and sequester particulate pollutants by detaining stormwater to allow settling. Efficiencies in particle capture will increase with longer hydraulic residence time, lengthening the stormwater flow path from the inlet to outlet, and/or reducing lateral flow velocities. Other proprietary BMPs that rely upon particle capture, such as hydrodynamic separators, can promote capture and retention of debris, trash, leaf litter and other material through physical flow separation. Regardless of how the material and pollutants are separated from stormwater, effective particle capture will result in accumulation of material within the BMP that must be removed to restore performance at necessary intervals. Thus within a specific structural BMP, particle capture capability can be tracked over time by the relative amount of storage capacity remaining or the amount of material accumulated since benchmark (best achievable) conditions. **Material accumulation** and **remaining capacity** protocols have been developed to rapidly evaluate the reduction in particle capture efficiency as the capacity of a structural BMP declines from the accumulation of retained material.

Particle capture observations are designed to quantitatively track the relative loss of the structural BMP storage capacity as a result of material accumulation. In larger centralized BMP types like dry or wet basins, the amount of material accumulation is tracked using one or more permanent staff plates installed at representative locations within the structural BMP to make observations more precise and rapid. The lowest visible value on the staff plate is noted during the BMP RAM field observations. The number of staff plate measurements recommended is dependent upon the structural BMP footprint.

Remaining capacity observations require the user to use a stadia rod, tape measure or ruler to repeatedly measure the distance from the top of the accumulated material to the invert of the outlet. Guidance is given to the user to determine the most appropriate locations to conduct the remaining capacity measurements based on BMP type and available access.

For dry and wet basins, observations of the distribution of wetland and riparian vegetation species within the structural BMP footprint are also used to evaluate the treatment capacity performance. A higher density of wetland and riparian species within the BMP than designed can reduce the treatment capacity, reducing the residence time and associated the particle capture efficiency of the BMP.

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### 3.3.3 BIOGEOCHEMICAL CYCLING OBSERVATIONS

Biogeochemical cycling involves the reduction in concentration of pollutants through biological interactions. Biological communities may include live vegetation, bacteria or microbes. Through uptake, increased microbial activity in organic detritus, and adsorption on plant material, vegetation can reduce stormwater concentrations of a variety of pollutants, including biologically available nutrients, hydrocarbons, organic compounds, fine particulates and heavy hydrocarbons. Both bioretention and biofiltration BMPs require an organic unconsolidated soil media through which stormwater is filtered to reduce pollutant loads, and to support plant growth. BMP RAM observations of the distribution of vegetation cover and substrate type and texture are proxies to determine if the BMP attributes necessary to support biogeochemical cycling are present within the structural BMP.

BMP RAM field observations to assess relative performance of pollutant retention via biogeochemical cycling include the density and type of vegetation present and surface soil or substrate characteristics. The BMP RAM characterizes vegetation type into 3 general categories: wetland/riparian species, grass species, and terrestrial trees. Each of these categories requires a decreasing amount of water to survive within a structural BMP. The RAM observer conducts rapid observations of the % cover of each vegetation type within the potentially inundated area of the structural BMP being evaluated. Substrate type include a determination of the quality, compaction and type of substrate at the base of the structural BMP to assess if the fundamental design characteristics of the BMP soil is appropriate and being maintained. Uncompacted soils with some organic material will provide more pollutant retention capacity than very fine, compacted soils.

As discussed Sections 3.3.1 and 3.3.2, the vegetation cover and substrate observations are also used to inform infiltration and particle capture performance. The observation protocols are the same, but the database analyzes the user inputs differently depending upon the structural BMP type.

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### 3.3.4 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 are instructed to follow the **confined space observation** for any structural BMPs that meet these criteria. The confined space observations include qualitative visual observations to simply infer if there

is evidence to suggest the confined structural 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 structural BMP is warranted and the manufacturer may need to be contacted.

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

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### 3.3.5 CONVEYANCE OBSERVATIONS

While **conveyance** of stormwater does not provide any water quality improvement downgradient, verification of proper water routing into, within and out of a structural BMP is a vital characteristic of function. If a structural 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 structural BMP is conveying water adequately and that basic design elements of the inlet, outlet and bypass relationships are present. It is assumed that a non-functional inlet or outlet will directly impair the operational condition of a structural BMP.

Users can inventory the presence of trash capture devices installed at the inlet or outlet of any structural BMP, including a drop inlet. The conveyance performance of each structure is verified by the user based on a series of considerations and documented by the user.

## 3.4 Timing of BMP RAM Observations

2N RAMs™ are targeted products to simplify and focus implementation and effectiveness monitoring for natural resource managers. With all monitoring, there is a need to focus resources both temporally and spatially to ensure resources expended to obtain monitoring data will be as valuable as possible. Like all 2N RAMs™, BMP RAM greatly increases the spatial extent of observations. Repeated measurements are prescribed at times when the information acquired will be most useful to managers.

In the instance of structural BMPs, within the Mediterranean climate of the western U.S., annual rainfall is highly variable with 65-95% of the annual precipitation falling from October to May (Wallace 1991). These seasonal variations in climate influence soil moisture, chemical transformation rates, vegetation growth and other biological processes and associated rates. Since BMP RAM field observations are used as means to track condition of each inventoried BMP over time, we want observations to be conducted at times when the seasonal influence on the BMP attributes is minimized.

By minimizing the introduction of seasonal variability to the observations, the procedure is designed to reduce measurement uncertainty and capture changes in BMP status in the most precise manner possible. For example, an infiltration measurement taken in Santa Cruz County, CA on a wet January day will result in a very different value than one taken on a day in July on the same soil in the same condition, due the antecedent moisture present in the soil. From a structural BMP asset management perspective, stormwater infrastructure and maintenance should be intensive in late summer and early fall in preparation for the upcoming winter runoff events. Therefore, it is recommended to perform a complete BMP RAM assessment of all municipal structural BMPs in May and June each year, following the wet months. This late spring data will inform public works and other maintenance teams where to prioritize summer maintenance activities and can greatly reduce visits to BMPs that do not require maintenance. To track condition improvements, either the maintenance teams can repeat BMP RAM



observations once maintenance actions are completed, or a subsequent assessment effort can be conducted on all degraded BMPs that were maintained in early fall, prior to first rains of the water year.

For new structural BMPs, it is recommended that stormwater managers or site inspection personnel inventory structural BMPs in BMP RAM as soon as construction is completed and they are ready for stormwater treatment. Having each BMP inventoried by personnel with knowledge of the intent and design of the specific BMP will ensure the most accurate information is entered into BMP RAM. However, an existing BMP can be inventoried at any time and the determination of the appropriate BMP type should be based on the intent moving forward as to how the structural BMP will be maintained (i.e., exactly what processes will the BMP rely upon to provide stormwater treatment in the future). In some instances, this may differ from the original intent of the structural BMP design and construction.

*It is recommended that municipalities use BMP RAM to do a complete annual assessment of all existing structural BMPs annually between May 1 and June 30. These early summer results can guide upcoming structural BMP maintenance priorities. Any maintained BMPs should be reassessed using BMP RAM by the end of September to document the improved conditions of all structural BMPs where maintenance actions were performed and demonstrate MS4 permit compliance.*

## 4 BMP RAM RESULTS

2N RAMs™ are intended to standardize and focus the data obtained to inform and improve effective land management, making the inclusion of the experts in the 2N RAM™ development critical to ensure the RAM outputs (i.e., scores) are relevant and useful for resource managers. The creation of the technical components unique to BMP RAM has been iterative, working in tight collaboration with stormwater managers, structural BMP designers, engineers and regulators throughout California and Nevada since 2008. A wide array of structural BMP hydrologic and water quality monitoring data, structural BMP design handbooks and structural BMP effectiveness models (Miller and Gunsalus 1997, NRC 2008, CNPS 2004, Tomer and Locke 2011) have been valuable resources to inform BMP RAM scoring rubrics.

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 by which pollutant load reductions in stormwater are achieved. It is a fundamental hypothesis of the BMP RAM that a reduction in the performance of the primary treatment process(es), as measured by field observation proxies, corresponds to a simultaneous reduction in stormwater pollutant load reduction potential of a specific structural BMP for any given runoff event. The technical development team considered the application of universal design standards for each BMP type, by which the condition of each inventoried BMP was compared during each assessment. This approach was rejected due to the extreme variability in sizing and design specifications for any particular BMP that must be created to suit site specific opportunities and constraints. A universal benchmark condition for all BMPs is not applicable to the majority of structural BMPs that exist on the ground. A number of fundamental design elements for specific BMP types are integrated into BMP RAM observations and scoring to the extent practical while ensuring flexibility in BMP designs of the same type. Users enter field observation results directly into [www.bmpram.com](http://www.bmpram.com) and the database compares each observation result to the benchmark and threshold values and generates a 0-5 score for each observation. The **observation scores** are then integrated using a predefined weighting based on functional elements of each BMP type. The results are expressed as a BMP RAM score using a continuous and meaningful 0-5 scale ( $\pm 0.1$ ) to indicate the structural BMP condition at time of observation (see Table 2.2).

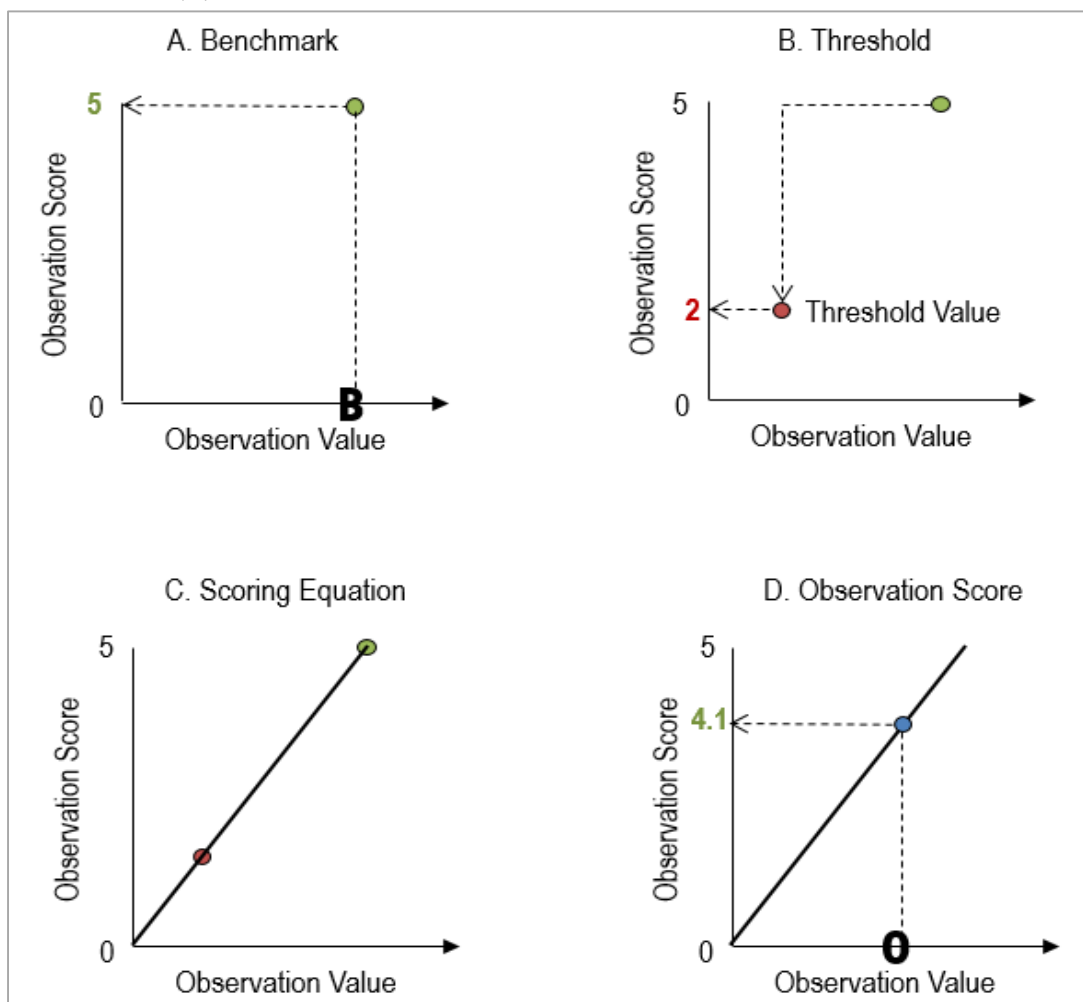
The quantification of the numeric pollutant load reduction benefits achieved by each BMP is not the objective of this tool, but BMP RAM users can also subscribe to TELR ([www.swtelr.com](http://www.swtelr.com); 2NDNATURE 2016b). TELR uses the design parameters and BMP RAM condition results as inputs to the urban pollutant loading model to quantify the pollutant load reductions to receiving waters achieved as a result of all of the structural BMPs contained within an urban catchment. TELR also includes the benefits of non-structural BMPs such as desired parcel scale site design attributes and road sweeping programs.

*A BMP RAM 0-5 ( $\pm 0.1$ ) score reflects the condition of a specific structural BMP at time of observation. Condition is defined as the relative water quality treatment potential of a specific structural BMP compared to its built design. The best achievable condition is immediately following construction of effective maintenance actions and condition is expected to gradually decline as stormwater and associated pollutants are loaded into the respective BMP.*

## 4.1 BMP RAM Scoring Rubric

The benchmark and threshold can be considered the bookend values that define the condition of each structural BMP. Following the creation (or inventorying) of a BMP in BMP RAM, benchmark and threshold values for each required observation must be entered prior to any field assessments. The benchmark value for each observation 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 structural BMP, equating to an observation score of 5 (Figure 4.1A). Benchmark values may need to be measured by the user or be default values that are a universal standard for all BMPs of the respective type. The threshold is the lowest acceptable value for each respective observation type and is defined as the observation value that equates to an observation score of 2 (see Figure 4.1B). Thresholds may be absolute values or % deviations from benchmark. The determined threshold for each observation may be based on a universal standard for all BMPs of the same type or a recommended deviation tolerance below which the respective process is no longer adequately functioning. Some threshold values require user input, while other default values may be modifiable by the user when design variations across BMPs of the same type is common.

**Figure 4.1** Linear scoring approach and use of benchmark and threshold values to generate observation score (O).



The benchmark and threshold values (observations scores of 5 and 2, respectively) are used to calculate the observation equations. In most instances the equations are the defined linear trend for each observation as illustrated in Figure 4.1C. In cases where both a minimum and maximum threshold value exists for an observation, 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 and multiple choice observations, no linear trend relationship is necessary. All subsequent field observations conducted at a specific BMP are compared to the observation equations defined by the existing benchmark and threshold values in BMP RAM. Should a BMP be maintained and new benchmark values are established, the date is noted in the database and all subsequent observations are compared to the most recent (i.e., most applicable) equations for each observation.

Field observation results are entered by the user during BMP assessment. In the instances where the observation is scored using a linear observation equation, the field value is compared against the existing observation equation to generate an observation score (Figure 4.1D).

The following are exceptions to the linear trend:

- The conveyance observation results are binary. Non-functioning inlets are scored at 0 and an average inlet score is calculated. Non-functioning outlets are scored as a 2 and set the outlet observation score. The lowest conveyance score is assigned to the observation.
- Confined space observation results are binary, making the associated confined space score either a 5 or 2.
- The substrate observations are multiple choice. The substrate observation score is based on user inputs of the relative ranking and presence of bioretention soil (desired), various coarse inorganic materials (acceptable), and fine grained compacted soils (unacceptable).

The possible maximum BMP RAM score for any BMP at time of observation is set by the conveyance score, supporting the assumption that a structural BMP that is not getting water, or routing water downslope appropriately, is a high priority for maintenance. If the inlets and outlets are functioning as intended the BMP RAM score is determined as weighted-average of the observation scores defined in Table 4.1. The relative weighting of each observation is unique by structural BMP type and is based on the relative contribution of the processes or attributes that indicate treatment performance decline based on existing design standards and functional requirements. The confidence, repeatability and rigor of each observation to serve as a proxy of BMP treatment performance were also considered in the weighting. It is acknowledged that individual structural BMP designs will vary, but the relative weightings presented in Table 4.1 are expected to be the most common prioritizations for each structural BMP type. The relative weightings for each structural BMP observation are fixed to maintain scoring consistency across structural BMP types and users. This consistency increases comparability and power of future BMP RAM data analysis by structural BMP type. Future structural BMP water quality with appropriate experimental designs can inform the weights in Table 4.1 and improve our understanding of the linkage between structural BMP observation results, condition and quantitative water quality benefits (i.e., characteristic effluent concentration (CEC's) and pollutant load reductions).

**Table 4.1** Relative weighting of each observation result into the BMP RAM Score for each structural BMP type.

	Structural BMP Type	Observation(s)	Observation weighting to determine structural BMP RAM Score
Centralized BMPs	Bed Filter	Runoff	100%
	Detention Basin	Material Accumulation	100%
	Dry Basin	Infiltrometer or CHP	50%
		Veg Cover	15%
		Material Accumulation	35%
	Infiltration Basin	Infiltrometer or CHP	80%
		Veg Cover	20%
	Media Filter	Confined Space	100%
	Treatment Vault	Remaining Capacity	100%
	Wet Basin	Material Accumulation	60%
		Veg Cover	40%
Decentralized BMPs	Biofiltration	Runoff	40%
		Substrate	40%
		Remaining Capacity	20%
	Bioretention	Runoff	40%
		Substrate	40%
		Remaining Capacity	20%
	Bioswale	Veg Cover	60%
		Runoff	40%
	Catch Basin	Remaining Capacity	100%
	Infiltration Feature	Runoff	75%
		Veg Cover	25%
	Porous Pavement	Runoff	100%
	Settling Basin	Material Accumulation	100%

The field observation results are translated into BMP RAM scores as defined in Table 2.2 and that reflect the relative ability of the treatment processes to provide downgradient water quality improvements, with distinct scoring ranges corresponding to maintenance urgency.



## 4.2 BMP RAM Results

The priority uses of BMP RAM data have been automated either in BMP RAM or TELR.

BMP RAM result summaries include:

- Automated mapped comparisons of BMP condition to identify maintenance priorities (Figure 2.1). This map can be generated for any time interval, allowing simple screenshots of mapped comparisons of BMP condition over time and space.
- Chronological summaries for all BMP RAM scores for each BMP (Figure 2.2) that can be used to identify where BMP maintenance is relatively frequent and inform exploration of contributing drainage areas. Screenshot comparisons of BMP chronologies across BMPs of either the same or different types can inform future designs or BMP type selections.

TELR integrates BMP RAM design characteristics and BMP RAM scores with local precipitation, soils and catchment physical characteristics to quantify the average annual runoff volume and load reductions provided by the network of structural BMPs existing and maintained within the municipality. The quantitative aggregation provides a measurable and comparable estimate of the water quality benefit that the structural BMPs provide to local receiving waters.

In addition to the automated reporting functions, all user data and associated results are available for download from the user's account at any time. Full data downloads can provide users with a complete record of all data inputs and BMP RAM assessment results. Customized data download queries are also provided to focus data extractions by BMP type, catchments, or date range to allow users to analyze or communicate BMP RAM data outside BMP RAM.

Municipal BMP RAM results can be exported and used to:

- summarize total impervious area treated by land use, catchment or BMP type;
- compare average BMP condition by land use, catchment or BMP type;
- compare or summarize the number of different BMP types installed across different time periods, or
- various other potential useful analysis of structural BMP design and condition data that may exist.

Suggestions and feedback from BMP RAM users to 2NDNATURE is encouraged to identify other priority data analysis or reporting functions that would improve the utility of BMP RAM to stormwater managers, funders, regulators or others. An online spreadsheet can be accessed through the BMP RAM website or at [www.tinyurl.com/bmpram](http://www.tinyurl.com/bmpram).

## 5 BMP RAM PROGRAMMATIC INTEGRATION

Any MS4 can utilize BMP RAM as a structural BMP inventory and assessment tool to meet a number of programmatic needs.

### 5.1 Stormwater Asset Management

BMP RAM is an online customized data management and visualization tool ([www.bmpram.com](http://www.bmpram.com)). Structural BMPs can be inventoried and assessed directly in the field with a phone or tablet. Similarly, field observations no longer require field datasheets, greatly reducing the data entry errors and other QA/QC challenges associated with other assessment methods. The location, design and water quality treatment expectation of each structural BMP is documented and stored, providing a consistent communication tool of the extent, characteristics and condition of municipal stormwater BMP assets. The website tool automatically generates a series of maps, tables and graphics to make spatial comparisons and tracking of BMP condition over time simple and consistent across all users. This standardized data management and analysis system allows simple transfer or collaboration across municipal staff and greatly improves communication of resource needs and priorities to maintenance staff as well as managers.

The BMP RAM enables flexibility and measurement 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 structural 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 structural BMPs achieve the goal of reducing pollutant loading to receiving waters.

Over time, BMP RAM results will show which structural 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 resources. 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.

The use of BMP RAM will generate a dataset of typical operating conditions for common BMP types implemented within or across municipalities (should municipalities wish to compare BMP RAM results). Such a dataset creates the potential for regional studies and synergistic exchange of ideas between municipalities and academic scientists. The structural BMP performance chronologies will help project designers and stormwater engineers understand the likely operational conditions of structural BMPs, which can be used 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 structural BMPs with varying design parameters.

### 5.2 MS4 Annual Permit Compliance

BMP RAM data and results can be inserted directly into annual reports to illustrate MS4 permit compliance with a series of regulatory requirements. The majority of Phase I and Phase II MS4 permits across the country include some requirement to inventory, maintain and monitor the effectiveness of

structural BMPs that include catch basins, detention basins, bioretention, etc. Through the use of BMP RAM as a structural asset management tool, an MS4 permittee can automatically integrate the information and data into annual reports, greatly reducing the time and complexity of typical annual reporting practices. Annual reporting to demonstrate progress toward MS4 trash controls and reduction requirements can also be easily generated from BMP RAM datasets. BMP RAM standardizes and simplifies structural BMP management and annual reporting. Stormwater program personnel can spend less time generating annual reports to demonstrate compliance and are free to spend more time implementing stormwater improvements and maintaining existing infrastructure.

### 5.3 Maintenance Contract Compliance

BMP RAM provides a data collection and data management system that can be used to demonstrate compliance with either grant or regulatory structural BMP maintenance contracts. Capital implementation funds typically include long-term maintenance requirements of the assets built with the resources provided. Similarly, large scale new or redevelopment projects are subject to post construction requirements (PCRs) to minimize stormwater impacts of developed parcels. The construction of structural BMPs to achieve these volume and pollutant load reductions is and will continue to be common, and may require stormwater control plans and long term maintenance agreements.

Annual inspection and maintenance reports are required by the municipality to show continued compliance with the PCRs. BMP RAM allows stormwater managers to inventory, assess, inform maintenance and demonstrate performance of structural BMPs. BMP RAM results can clearly demonstrate compliance with maintenance requirements and is simple enough for land owners to be trained to use competently.

### 5.4 Stormwater BMP Effectiveness Monitoring

Reliable and accessible water quality monitoring data are a critical tool for resource managers to identify problems and track changes over time. Monitoring data is the most direct way to determine overall effectiveness of programs and quantify their benefits. Data are essential for the calibration and validation of hydrologic and water quality models that provide estimation of conditions where we are not able to measure. Empirical understanding of relationships between water quality parameters and landscape factors, such as land use, impervious cover, road condition, and hydrologic connectivity, are required for building simple tools to prioritize the locations and timing of management actions. Monitoring data can also inform design specifications, treatment capabilities for different pollutants, necessary maintenance intervals, life expectancy, etc. of structural BMPs.

Typical stormwater monitoring of structural BMP effectiveness is conducted to quantify pollutant load reductions achieved by a specific structural BMP over a short period of time, with little attention to other sources of variation or BMP performance changes. These data, which may be reported in large data repositories like the International BMP Database (IBMPdb; <http://www.bmpdatabase.org/>) or CEDEN (<http://www.ceden.org>), are usually inappropriate for a robust quantification of BMP effectiveness over time:

- ❖ There are poorly defined definitions of BMP types by which monitoring data is aggregated and compared. This lack of standardized nomenclature introduces uncertainty in the analysis and application of the datasets. BMP RAM provides this nomenclature clarity and refinement to structural BMP types (see Table 3.1) and identifies critical design parameters for each BMP

type that are necessary for completing reasonable modelling of BMP performance. Nationwide adoption of such consistent nomenclature would be a simple step toward more powerful aggregation of structural BMP monitoring data in formats that could more directly inform application of data to other BMPs of the same type but of varying designs.

- ❖ It is well understood that structural BMP water quality performance is variable, and that periodic maintenance actions are necessary to restore design performance of these structures that are constructed to treat urban runoff. The lack of maintenance will result in significant reductions in the functional performance of a structural BMP, and this decline will influence the quantified volume and load reductions from monitoring data. However, typical monitoring approaches fail to document where the structural BMP is currently on the trajectory of condition. The largest available database of structural BMP monitoring (IBMPdb) includes no mention of design parameters or the state of structural BMP (i.e., defined by BMP RAM as condition). BMP RAM provides both the recommended design parameters for each BMP type, as well as simple and repeatable method to assess and report the condition of any BMP. Consistent documentation of structural BMP condition that can be directly related to design parameters at the time of monitoring would significantly expand the use and application of a dataset to inform maintenance intervals, performance decline algorithms, and future optimization of design standards for each BMP type.
- ❖ Hydrologic and water quality monitoring protocols have important differences across monitoring agencies and researchers based on expertise, resources, site opportunities and constraints, etc. Sampling methods and data formats are project specific and can be difficult to translate from one site or time to another. Inconsistent sampling methods add variability to the datasets that reduce their utility for detecting changes over time.
- ❖ Most available BMP effectiveness monitoring is temporally limited from a few weeks to a few months, and a few years in rare cases. Short-term sampling will result in measurements taken at a variety of runoff event magnitudes and intensities, which will influence the load reduction estimates. Robust detection of water quality changes over time generally requires long-term datasets, as the high degree of hydroclimatic variability inherent in the urban catchment system reduces the statistical power for detecting water quality changes.

Demonstration of progress towards pollution reduction goals at the urban catchment scale is more meaningful than at the individual BMP scale. Ultimately, we would expect the cumulative effects of functioning structural BMPs to improve catchment scale water quality conditions and for those changes to be reflected in monitoring data. With BMP RAM used as an interim proxy for individual BMP effectiveness, there is an opportunity to free up resources for longer term monitoring of a catchment scale network to quantify cumulative BMP effectiveness. Such a dataset could be collected in a consistent, directly comparable way that minimizes sampling variation and collects concurrent flow measurements, improving the statistical power in a change detection analysis. Data collection should be accompanied by a strategic standardization of the sampling, data management, data analysis and results reporting protocols. These steps would ensure that those data collected at individual structural BMPs align with catchment scale data and can inform the management needs while minimizing costs to allow collection over longer time frames.

## 5.5 Quantification of Water Quality Benefits

By definition, each structural BMP installed is designed to treat a specific sized storm generated from the impervious area draining to the BMP. Each structural BMP inventoried in BMP RAM includes the BMP specific sizing and design parameters input by the user. When these design parameters are used with local precipitation data, the designed treatment capacity at benchmark condition of the BMP can be quantified and tracked. As sediment and other pollutants accumulate, BMP performance declines at a rate that depends on BMP, site, and catchment characteristics. The available BMP performance monitoring and research has informed development of performance adjustment curves based on observed BMP RAM condition for all structural BMP types. Treatment capacity is adjusted according to the empirical BMP performance decline curve and catchment factors.

2NDNATURE has taken this structural BMP effectiveness one step further and linked the BMP RAM online database with our online urban stormwater pollutant loading model: Stormwater Tool to Estimate Load Reductions (TELRL) ([www.swtelr.com](http://www.swtelr.com), 2NDNATURE 2016). TELRL estimates the pollutant load reductions to receiving waters as a result of BMP implementation and condition on an urban drainage catchment scale. When users subscribe to both BMP RAM and TELRL, the data management system assigns each structural BMP inventoried and assessed in BMP RAM to a specific urban catchment and the cumulative water quality benefit of all structural (and some non-structural BMPs) is quantified by TELRL. TELRL load reduction estimates can be easily and consistently produced on an annual basis for all municipal urban drainage catchments and the results aggregated to track and report municipal stormwater program water quality benefits to receiving waters over time.



## 6 CONTINUED IMPROVEMENTS AND NEXT STEPS

BMP RAM version 3.0 is the product of many technical and user discussions to identify and implement the highest priority improvements and create a simple and repeatable tool to inform structural BMP management decisions. As with all 2N RAM™ tools, there is a long-term commitment by 2NDNATURE to refine and improve these tools as necessary to meet user needs. All functional improvements identified by users are cataloged and freely available to all BMP RAM users via a Google spreadsheet document (available through [www.bmpram.com](http://www.bmpram.com) or at [www.tinyurl.com/bmpram](http://www.tinyurl.com/bmpram)). This list is reviewed biannually, with improvements prioritized by 2NDNATURE staff and BMP RAM users. 2NDNATURE will continue to iteratively implement the highest priority improvements and updates will be automatically provided to all registered users. Check back at [www.bmpram.com](http://www.bmpram.com) to view the current platform and features or contact 2NDNATURE for a demonstration.

All of the BMP RAM desired improvements noted in version 1.0 of the Technical Document have been completed and integrated into BMP RAM v3.1. While changes and improvements will continue to be made, below are a collection of current priority improvements not yet implemented in BMP RAM v3.1.

- Implement field protocols and track structural BMP condition on select structural BMPs where high resolution water quality monitoring studies are conducted over many years. A well designed and targeted structural BMP effectiveness study conducted concurrently with BMP RAM field observations would provide invaluable data to:
  - Refine to BMP RAM field protocols and threshold values,
  - Validate long-term performance of specific BMP design elements, and
  - Inform development of urban pollutant loading models, including the stormwater Tool to Estimate Load Reductions (TELRL)
- Develop a mobile application to allow field data collection in locations where cellular service is not available. This would include caching map data to be used offline and the ability to synch data from a mobile device to the BMP RAM database remotely.
- Fully integrate the BMP RAM website with Parcel RAM ([www.parcelram.com](http://www.parcelram.com)) and TELRL ([www.swtelr.com](http://www.swtelr.com)). Parcel RAM is a parcel-scale data management system to track post construction requirements (PCR), maintenance agreements, owner information, and parcel condition inspections. With full integration, these parcel data will be available for review in BMP RAM, and inventoried BMPs can be cataloged by APN to facilitate data management and reporting.
- The potential for a manager's module has been suggested. Such functionality would allow more BMP specific information to be added and stored in the BMP RAM database. This information may include the addition of photos into inventory and field observation steps, addition of BMP as built plans, construction or maintenance costs, maintenance agreements or other BMP specific records. A manager's module will facilitate the completion of other data management and reporting tasks required by stormwater managers.

## 7 BMP RAM GLOSSARY

<b>Bed Filter</b>	<p>A Structural BMP type:</p> <ul style="list-style-type: none"> <li>• A flow-through structure that uses granular media (e.g. sand or activated alumina) to actively filter stormwater to remove stormwater pollutants. Filtration is controlled by the flow rate through the media and discharge via an underdrain or outlet. Little to no volume loss occurs.</li> <li>• May be confined space but not always.</li> <li>• Pollutant load reductions achieved by reduced concentrations in effluent. No stormwater volume reduction occurs.</li> <li>• Typically moderate sized centralized BMPs but can be small decentralized BMPs treating small areas of imperviousness.</li> </ul>
<b>Benchmark</b>	<p>The desired and achievable condition of any structural BMP. The benchmark equates to a RAM Score of 5. In most instances, benchmark condition may be observed and measured 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).</p>
<b>Biofiltration</b>	<p>A Structural BMP type:</p> <ul style="list-style-type: none"> <li>• Vegetated BMP where stormwater is filtered through a specialized soil media and discharged via an underdrain.</li> <li>• BMP may or may not be lined but little to no exfiltration of volumes.</li> <li>• Outlet design requires surface ponding prior to surface outflow typically with a maximum ponding depth of 6 inches.</li> <li>• Site designed biofiltration systems use specialized soil media ideally 18-24 inches in depth to enhance biogeochemical processes to retain and transform pollutants.</li> <li>• Proprietary biofilter designs vary and specialized soil media may or may not be accessible for inspection.</li> <li>• Small to moderate sized decentralized BMP accepting runoff from a single land use drainage area.</li> </ul>
<b>Biogeochemical cycling</b>	<p>A stormwater treatment process. Concentration reductions of pollutants in stormwater through interaction with vegetation or biological processes. These processes may include, but are not limited to uptake by vegetation, adsorption, desorption, reduction etc. by vegetation or bacteria. Decomposition of vegetation or native debris within a structural BMP can result in increased concentrations of nutrients, trace metals and other pollutants in outflow volumes.</p>

<b>Bioretention</b>	<p>A Structural BMP type:</p> <ul style="list-style-type: none"> <li>• Vegetated retention structure where the base of the BMP is not lined and must infiltrate volumes and allow exfiltration to unsaturated zone. Designs may or may not include an underdrain to route some fraction of treated waters to stormwater system.</li> <li>• Outlet design requires surface ponding prior to surface outflow typically with a maximum ponding depth of 6 inches.</li> <li>• Outlet design either passive surface outlet (e.g., curb cut) or piped overflow (e.g., overflow inlet and underdrain) used to allow retention and ponding.</li> <li>• Constructed with specialized soil media ideally 18-24 inches in depth to enhance biogeochemical processes to retain and transform pollutants.</li> <li>• May include rock or aggregate subsurface layer under the soil media to enhance storage/infiltration.</li> <li>• Designs may include settling forebay at inlet(s) to remove sediment.</li> <li>• Vegetation types include species that can tolerate stormwater ponding and drought conditions.</li> <li>• Small to moderate sized decentralized BMP accepting runoff from a single land use drainage area.</li> </ul>
<b>Bioretention Soil</b>	<p>Soil media mix used recommended in Bioretention and Biofiltration BMP design to ensure adequate drainage, reduce pollutant loads, and support plant growth. Mixture includes sand, clay and silt fines, and organic material.</p>
<b>Bioswale</b>	<p>Structural BMP type:</p> <ul style="list-style-type: none"> <li>• Flow through areas with dense vegetation coverage (&gt;80%). Flow surface topography allows inundation of adjacent vegetated areas during storm runoff.</li> <li>• Design includes gentle sloped flow paths and dense vegetation to promote primary stormwater surface filtration, adsorption to vegetation and settling. Biological processes include geochemical transformation and plant uptake. Infiltration performance and volume reductions may vary.</li> <li>• Size and application can vary.</li> </ul>
<b>BMP RAM</b>	<p>BMP RAM is a standardized and repeatable field observation and data management tool to allow resource managers in inventory, assess and track the performance of structural BMPs over time. The standardized 0-5 scoring and mapped results are used to simply communicate the relative condition of any stormwater structural BMP. The customized online data management system is available at <a href="http://www.bmpram.com">www.bmpram.com</a>. BMP RAM can be used by municipalities to satisfy annual structural BMP inspection and reporting requirements.</p>
<b><a href="http://www.bmpram.com">www.bmpram.com</a></b>	<p>The customized web-based data management and reporting asset management system that stores and manages all information necessary to implement, track and maintain BMP RAM inventory and results over time. The mobile application allows users to assess BMPs in the field and enter the observations directly into the database, eliminating the time and QA/QC challenges with using field datasheets.</p>
<b>BMP RAM Score</b>	<p>The BMP RAM score is a 0-5 (<math>\pm 0.1</math>) value that represents the structural BMP condition at the time of observations. The BMP RAM score is a weighted integration of field observation results based on structural BMP type. A BMP RAM score of 5 is the achievable benchmark. A BMP RAM score of 2 is a trigger that maintenance or other actions are required to restore performance of the structural BMP to an acceptable condition.</p>
<b>Bypass Outlet</b>	<p>The outlet of a large scale centralized BMP at which stormwater exits the BMP when the storage capacity of the BMP is exceeded. BMP RAM conveyance observations are made at all bypass outlets of a structural BMP.</p>

<b>Catch Basin</b>	<p>Structural BMP Type:</p> <ul style="list-style-type: none"> <li>• A small decentralized BMP designed to capture and retain sediment, leaf litter, trash, coarse particles and/or other stormwater pollutants.</li> <li>• Capture of material may occur through variable flow modifications or passive settling, but result is vertical accumulation of material at base of BMP reservoir with regular material cleanout required.</li> <li>• Minimal to no stormwater volume reduction occurs.</li> <li>• Water quality improvement downgradient expected as result of concentration reduction due to material capture within BMP.</li> <li>• Typically accepts runoff from road or a single land use parking lot.</li> </ul>
<b>Catchment</b>	A contiguous planning unit that represents the hydrologic routing of urban lands within the MS4.
<b>Centralized BMP</b>	<p>One of two structural BMP categories:</p> <ul style="list-style-type: none"> <li>• Designed to reduce urban stormwater volumes and/or pollutant concentrations from a concentrated stormwater flow path draining a mixed land use catchment.</li> <li>• Contributing drainage areas typically exceed 1 acre of impervious area.</li> <li>• More typically publically installed and maintained but can be privately owned.</li> <li>• Few may be needed to measurably reduce catchment loading</li> </ul> <p>Large scale centralized BMPs include Dry Basins, Detention Basins, Wet Basins, Infiltration Basins, Treatment Vaults, Media Filters, and Bed Filters.</p>
<b>Confined Space Observation</b>	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 structural 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 structural BMP is warranted and the manufacturer may need to be contacted.
<b>Constant Head Permeameter (CHP)</b>	BMP RAM observation to measure the infiltration rate in inches per hour (in/hr) of a surface soil substrate in Dry Basins and Infiltration Basins. This simple instrument has been developed by the NRCS and is well-accepted in the Lake Tahoe Basin as one method to measure the infiltration capability of soils.
<b>Conveyance</b>	Conveyance is the physical process that transports stormwater downgradient in a manner that mitigates, and does not induce, localized flooding. All structural 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 structural BMPs to function as designed.
<b>Decentralized BMP</b>	<p>One of two structural BMP categories:</p> <ul style="list-style-type: none"> <li>• Designed to reduce urban stormwater volumes and/or pollutant concentrations generated from a single land use.</li> <li>• The contributing drainage areas are typically less than 1 acre of impervious surface.</li> <li>• Installed on private parcels or on public property (typically roads).</li> <li>• Typically structural BMPs that meet design requirements of treating the 85<sup>th</sup> or 95<sup>th</sup> percentile 24-hour storm event.</li> </ul> <p>Small scale decentralized BMPs include Infiltration Features, Bioretention, Bioswales, Biofiltration, Porous Pavement, and Catch Basins.</p>

<b>Detention Basin</b>	<p>A Structural BMP type:</p> <ul style="list-style-type: none"> <li>• A flow through basin with discrete inlets and outlets designed to detain stormwater runoff for some minimum time to reduce peak flows. Design treatment capacity and draw down time will vary across specific BMPs.</li> <li>• One or more outflow offices may exist but there is at least one at base of basin to allow complete draining between storms. Increased draw down times can increase particle capture via settling within the basin.</li> <li>• Little to no volume loss via infiltration either due to impervious or highly impermeable base.</li> <li>• Vegetation may or may not be present.</li> <li>• Moderate to large sized centralized BMPs that accept runoff from mixed land use drainage areas.</li> </ul>
<b>Drawdown Time</b>	<p>A BMP RAM inventory field:</p> <ul style="list-style-type: none"> <li>• Time it takes for the treatment capacity volume to completely drain through the treatment outlet without consideration of the infiltration rate.</li> <li>• Entered as hours (hrs) for Dry Basins, Detention Basins, and Wet Basins.</li> </ul>
<b>Drop Inlet</b>	<p>A Structural BMP type:</p> <ul style="list-style-type: none"> <li>• Stormwater feature placed strictly to collect and convey stormwater.</li> <li>• A drop inlet that includes a sump to capture particulate pollutants is termed a Catch Basin.</li> <li>• Typically conveying water from a roadway, parking lot or other impervious surface to a culvert or storm drain and provides no water quality benefit downgradient.</li> </ul>
<b>Dry Basin</b>	<p>A Structural BMP type:</p> <ul style="list-style-type: none"> <li>• A flow through basin with discrete inlets and outlets designed to detain stormwater runoff for some minimum time to reduce peak flows. Design treatment capacity and draw down time will vary across specific BMPs.</li> <li>• One or more outflow offices may exist but there is at least one at base of basin to allow complete draining between storms. Increased draw down times can increase particle capture via settling within the basin.</li> <li>• Footprint is pervious and infiltration capacity of base maintained to consistently infiltrate some fraction of volumes detained to unsaturated zone.</li> <li>• Wetland and riparian vegetation species distribution is minimal to absent. Moderate distribution of grass and/or tree species likely and acceptable.</li> <li>• Moderate to large sized centralized BMPs that accept runoff from mixed land use drainage areas.</li> </ul>
<b>Field Observations</b>	<p>Compilation of distinct rapid observations and/or measurements made at structural BMPs over time to evaluate and track condition.</p>
<b>Footprint</b>	<p>A BMP RAM inventory field:</p> <ul style="list-style-type: none"> <li>• Surface area that will typically be inundated; approximately the area at the average design depth.</li> <li>• Entered as square feet (sq-ft) for Dry Basins, Detention Basins, Wet Basins, Infiltration Basins, Treatment Vaults, Media Filters, Bed Filters, and Settling Basins.</li> </ul>
<b>Impervious Area Treated</b>	<p>The impervious area treated is the impervious area a structural BMP was sized and designed to treat and is input by the BMP RAM user.</p>



<b>Infiltration</b>	<p>A stormwater treatment process:</p> <p>The physical process by which water enters the soil or subsurface. Infiltration is used to indicate stormwater volume reductions, although infiltration will also result in soil-water interactions, filtration and other pollutant concentration benefits. While it is assumed that any pollutants contained within infiltrating volumes are introduced to and those hydrophobic are retained within the unsaturated zone. Effective infiltration is measured as a stormwater volume reduction as result of BMP interaction.</p>
<b>Infiltration Basin</b>	<p>A Structural BMP type:</p> <ul style="list-style-type: none"> <li>• A flow through BMP with highly permeable substrate (aggregate or rock) designed to store and infiltrate significant volumes of stormwater into unsaturated zone.</li> <li>• Little to no surface detainment storage.</li> <li>• Vegetation distribution should be minimal and preferably absent.</li> <li>• Moderate to large sized centralized BMP, accepting runoff from a mixed land use drainage area.</li> </ul>
<b>Infiltration Feature</b>	<p>A Structural BMP type:</p> <ul style="list-style-type: none"> <li>• A small scale structure designed to retain stormwater from small impervious drainage area and infiltrate into unsaturated zone. 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.</li> <li>• Vegetation is absent.</li> <li>• Typically a small sized decentralized BMP, accepting runoff from a single land use drainage area.</li> </ul>
<b>Infiltration Rate</b>	<p>A BMP RAM inventory field:</p> <ul style="list-style-type: none"> <li>• Characteristic rate of infiltration expected over the life span of the structural BMP while factoring in assumptions for anticipated maintenance.</li> <li>• Entered as inches per hour (in/hr) for Dry Basins and Infiltration Basins.</li> </ul>
<b>Infiltrometer</b>	<p>BMP RAM observation to measure the infiltration rate in inches per hour (in/hr) of a pervious surface using a double-ring infiltrometer.</p>
<b>Inventory</b>	<p>The user maps a structural BMP using the drop pin feature in a handheld device with GPS capabilities, such as phone or tablet, via <a href="http://www.bmpram.com">www.bmpram.com</a>. The inventory data for each BMP includes unique ID, lat/long and relevant structural BMP characteristics that vary by BMP type. Data can also be bulk uploaded from another source (such as GIS) into the online application.</p>
<b>Land Use</b>	<p>The land use type where a structural BMP is constructed to treat respective runoff is a BMP RAM inventory field. BMP RAM defines 10 land uses: Industrial (IND), Commercial (COM), Multi-family Residential (MFR), Single Family Residential (SFR), Cultivated (CUL), Other/Open Space (OTH), High Traffic Roads (HTR), Medium Traffic Roads (MTR), Low Traffic Roads (LTR), and Low Traffic Unpaved Roads (rdsUL).</p>
<b>Material Accumulation</b>	<p>BMP RAM observation to quantitatively track the relative loss of the structural BMP storage capacity over time in select structural BMP types. A permanent staff plate is installed near the outlet of structural BMP and the lowest visible value is recorded during BMP RAM field observation.</p>

<b>Media Filter</b>	<p>A structural BMP type:</p> <ul style="list-style-type: none"> <li>• A proprietary subsurface flow-through structure that uses a membrane or other media to actively filter stormwater to remove stormwater pollutants.</li> <li>• Proprietary models include media or membranes that may be selected to target the specific removal of the pollutants of concern, resulting in downgradient stormwater concentration reductions.</li> <li>• May be confined space but not always.</li> <li>• Pollutant load reductions achieved by reduced concentrations in effluent. No stormwater volume reduction occurs.</li> <li>• Typically moderate to large sized centralized BMP, accepting runoff from a mixed land use drainage area.</li> </ul>
<b>Media Filtration</b>	<p>A stormwater treatment process:</p> <p>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.</p>
<b>MS4</b>	<p><b>Municipal Separate Storm Sewer System</b> includes ditches, curbs, gutters, storm sewers, and similar means of collecting or conveying urban derived stormwater runoff that do not connect with a wastewater collection system or treatment plant. An MS4 is typically operated by a public agency such as a city, county, municipal utility district, or state or federal agency.</p>
<b>Observation Score</b>	<p>The BMP RAM Score is determined by the integration of observation scores. Each field observation value 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 online application. The BMP RAM user enters the field observation values per the protocols provided and the data management system internally calculates individual observation scores, as well as the overall BMP RAM Score.</p>
<b>Observation Type</b>	<p>The BMP RAM scoring approach includes 9 distinct observation protocols and each is a rapid proxy for one or more treatment processes performed by a BMP type.</p>
<b>Particle Capture</b>	<p>A stormwater treatment process:</p> <p>The physical process by which particulates, trash, or debris are physically removed from stormwater. Particle capture can occur via flow attenuation, vertical settling, flow separation, or other physical or abiotic processes that result in capture and retention within a BMP. Effective particle capture would be measured as pollutant concentration reductions for particulate pollutants as result of BMP interaction.</p>
<b>Porous Pavement</b>	<p>Structural BMP type:</p> <ul style="list-style-type: none"> <li>• Use of sustainable materials to create a durable, pervious surface overlaying a crushed stone base that allow stormwater to percolate and infiltrate into the underlying soil.</li> <li>• Porous pavement can include an underlying reservoir to increase infiltration rates.</li> <li>• 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.</li> <li>• Footprint of structural BMP type can vary greatly, typically used for parking lots, sidewalks, driveways or other impervious surfaces.</li> </ul>
<b>Remaining Capacity</b>	<p>BMP RAM observation to quantitatively track the relative loss of the structural BMP storage capacity over time in a Treatment Vault, Bioretention, Biofiltration, and Catch Basin. A stadia rod is used to measure the remaining distance from top of the accumulated sediment to the invert of the outlet during BMP RAM field observation.</p>

<b>Runoff Observation</b>	BMP RAM observation to quickly evaluate the infiltration capacity of a Bed Filter, Infiltration Feature, Bioretention, Biofiltration, Bioswale or Porous Pavement. A known volume of water is applied to the soil substrate of the structural BMP and a simple observation is made as to whether the water is infiltrated into the soil or not.
<b>Settling Basin</b>	<p>Structural BMP type:</p> <ul style="list-style-type: none"> <li>• Open flow through structures used to detain stormwater volumes and settle particulate pollutants prior to outflow.</li> <li>• Pollutant load reductions are realized by concentration reductions with no volume reduction via infiltration due to impervious or highly impermeable base.</li> <li>• Size and application of settling basins can vary.</li> <li>• Settling basins are common at the inlet of another structural BMPs to pre-treat inflowing stormwater prior to stormwater entering subsequent structural BMP. If inventory and assessment of the settling basin is desired independent from the next structural BMP in the treatment train, there are two options: <ul style="list-style-type: none"> <li>○ Large scale Settling Basin draining a mixed land use area can be classified and assessed as a Treatment Vault</li> <li>○ Smaller sized Settling Basins draining a single land use area can be classified and assessed as a Catch Basin.</li> </ul> </li> </ul>
<b>Structural BMP</b>	Structural BMPs that accept, attenuate, and treat urban stormwater. Structural BMPs are implemented to reduce pollutant loads in stormwater by either removing pollutants and/or by reducing runoff volumes. The BMP RAM defines 14 distinct structural BMP types by the processes relied upon for water quality improvements. Users of the BMP RAM must define the structural BMP type by these processes, rather than rely on previous naming conventions.
<b>Structural BMP Condition</b>	The condition is defined as a continuum relative water quality performance capability of a structural BMP using 0-5 scoring range. A structural BMP is considered at benchmark condition following installation and/or after adequate maintenance. As stormwater and pollutant loading to the BMP occurs during subsequent storm events, the condition of a structural BMP gradually declines. At some point, the operational performance of the specific structural BMP falls below the pre-determined acceptable condition (i.e., threshold) and maintenance is required to sustain the intended function of the BMP.
<b>Substrate Type</b>	BMP RAM observation to determine the biogeochemical cycling capacity and infiltration ability of the substrate material of the structural BMP of a Bioretention and Biofiltration BMP. BMP RAM user performs qualitative assessment of the quality, compaction and type of substrate at the base of the structural BMP to assess if the fundamental design characteristics of the BMP soil is appropriate and being maintained.
<b>Threshold</b>	The structural 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 stored as default values relative to benchmark values based on a universal standard for all BMPs of the same type or a recommended deviation tolerance below which the respective process is no longer adequately functioning. The integration of field observations are calculated by the database to determine the structural BMP RAM score (i.e. condition) at the time of observations.

<b>TELRL</b>	The stormwater <b>Tool to Estimate Load Reductions</b> ( <a href="http://www.swtelr.com">www.swtelr.com</a> ) is an urban hydrology and pollutant loading model that quantifies the cumulative pollutant load reductions to receiving waters as a result of structural and non-structural BMP implementation on an urban catchment scale. BMP RAM inventory and condition results are direct inputs into the TELR data management system to estimate load reductions from the implementation and maintenance of centralized and decentralize structural BMPs.
<b>Trash Capture Device (TCD)</b>	Structures placed at the inlet of a drop inlet or structural BMP to capture and detain trash, litter or debris < 5 mm in size to prevent discharge of trash into the stormwater system or the structural BMP.
<b>Treatment Capacity</b>	<p>A BMP RAM inventory field:</p> <ul style="list-style-type: none"> <li>Storage capacity below the bypass outlet, designed for water quality treatment</li> <li>Entered as cubic-feet (cu-ft) for Dry Basins, Detention Basins, Wet Basins, Infiltration Basins, Treatment Vaults, Media Filters, Bed Filters, and Settling Basins.</li> </ul>
<b>Treatment Process</b>	Physical, chemical, or biological means employed by a structural BMP to remove/retain the pollutants of concern and/or reduce stormwater volumes that ultimately reach receiving waters. Structural BMPs rely on 4 primary, passive processes to reduce the load of pollutants in stormwater: infiltration, particle settling, media filtration and biogeochemical cycling.
<b>Treatment Rate</b>	<p>A BMP RAM inventory field:</p> <ul style="list-style-type: none"> <li>Maximum flow rate through the structural BMP that provides effective treatment.</li> <li>Entered as cubic feet per second (cfs) for Treatment Vaults, Media Filters, and Bed Filters.</li> </ul>
<b>Treatment Vault</b>	<p>A Structural BMP Type</p> <ul style="list-style-type: none"> <li>A subsurface flow-through structure that physically separates sediment, trash, leaf litter, debris and other particulate pollutants from stormwater via various water separation or settling techniques.</li> <li>Pollutant load reductions are realized by concentration reductions. No volume reduction occurs due to impervious base.</li> <li>Many manufactured and proprietary models are available that employ various physical techniques to separate and capture debris and particulate.</li> <li>Accumulation of material at base of BMP can be observed and measured via manhole access.</li> <li>Moderate sized centralized structure accepting runoff from either a large single or mixed land use drainage area.</li> </ul>
<b>Vegetation Cover</b>	BMP RAM observation to characterize the vegetation types and percent cover within the frequently inundated area of a structural BMP. Vegetation types include: wetland and riparian species, grass species, and terrestrial trees.

<b>Wet Basin</b>	<p>A Structural BMP Type</p> <ul style="list-style-type: none"><li>• A flow through basin with discrete inlets and outlets designed to retain some volume stormwater runoff in a persistent pool of surface water. Designs may include additional detainment storage of stormwater for some minimum time to reduce peak flows.</li><li>• Wet pool capacity, treatment capacity and draw down time of treated volumes will vary across specific BMPs.</li><li>• One or more outflow offices may exist at different elevations. Lowest outlet elevation sets wet pool capacity.</li><li>• Dense vegetation is common. Dominant vegetation is wetland species and can be supplemented with riparian species with very high densities.</li><li>• Substrate is typically fine organic matter and silt, making volume reductions via infiltration negligible. Volume reductions occur primarily by evapotranspiration.</li><li>• Moderate to large sized centralized BMPs that accept runoff from mixed land use drainage areas.</li></ul>
<b>Wet Pool Capacity</b>	<p>A BMP RAM inventory field:</p> <ul style="list-style-type: none"><li>• Wet pool water quality volume used for flow through treatment. The wet pool can be depleted through evaporation and is regenerated by incoming flows.</li><li>• Entered as cubic feet (cu-ft) for Wet Basins.</li></ul>

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