SMC Regional BMP Monitoring Network Work Plan 2022-2023 – Version 1.0

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Southern California Coastal Water Research Project
Technical Report 1270

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ACRONYMS

BMP	Stormwater best management practice. In this report, specifically refers to structural BMPs managing urban runoff
EMC	Event mean concentration
MS	Monitoring station
MS4	Municipal separate storm sewer system
QA/QC	Quality assurance/quality control
QAPP	Quality assurance project plan
SCCWRP	Southern California Coastal Water Research Project
SMC	Stormwater Monitoring Coalition
SOP	Standard operating procedure
WQ	Water quality

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BACKGROUND

Stormwater best management practices (BMPs) are an essential component of water quality improvement plans, TMDLs, and other regulatory programs to protect or restore water quality in California. Southern California Stormwater Monitoring Coalition (SMC) member agencies collectively spend hundreds of millions of dollars each year on BMP implementation and maintenance. The importance of BMPs in achieving water quality goals across the region motivated the SMC Steering Committee to prioritize development of a regional BMP monitoring network according to their 2019-2024 Research Agenda.

The current project (2020-2023) aims to develop a work plan and supporting infrastructure for a regional BMP monitoring program to generate robust, statistically relevant data sets covering a range of BMP types, serving multiple land uses, and across a spectrum of operating conditions. Over the long-term, the regional BMP monitoring network is expected to generate data to support guidance for BMP design & selection, annual reporting, maintenance scheduling, asset management programs, Reasonable Assurance Analysis, and Alternative Compliance.

The regional BMP monitoring network pursues field monitoring to achieve initial research objectives. Field monitoring is resource-intensive but gives the best chance to discover the “true” behavior of a BMP. A regional network enables member agencies to leverage resources to tackle some of the major challenges of BMP field monitoring and performance assessment considering:

- Many types of BMPs and scales of implementation are found throughout the region
- Large data sets are needed to overcome high data variability
- There are few storm events in any year
- Instrumentation installation and operation requires substantial effort to ensure data quality
- Data are noisy

This document is an interim product that serves as a roadmap for the SMC agencies who participate in the collaborative structural BMP monitoring projects and is intended for use primarily by the SMC Working Group. The document outlines the work plan for initial field monitoring campaigns and develops an information management system. Standard operating procedures (SOPs) and a quality assurance project plan (QAPP) will be developed for consistent implementation of field monitoring campaigns, raw data management and data processing. These documents will be appended to this work plan as they are developed by the Working Group and approved by the Steering Committee. SCCWRP will provide training to field staff for SMC member agencies where needed. Results of the research program will be compiled into fully documented reports, published by the SMC as appropriate when monitoring campaigns and data processing are completed.

The scope of the SMC Regional BMP Monitoring Network currently includes structural BMPs typically constructed by permittees and co-permittees to manage urban wet weather flows. These BMPs may be regional or site scale. The scope of the SMC regional network does not include non-structural BMPs, certification or verification of proprietary devices, or monitoring of in-stream restoration or rehabilitation projects. It will not create an asset management system. Non-structural BMPs are addressed in another SMC prioritized project.

Initial Research Questions

The initial research questions of the SMC Regional BMP Monitoring Network focus on gathering data to investigate two key aspects of BMP performance (Table 1):

- **Water Quality: Effectiveness of bioretention/biofiltration BMPs at pollutant removal.** The SMC will measure pollutants entering and exiting flow-through bioretention/biofiltration BMPs. The goal is to understand what concentrations and loads of pollutants are removed in the BMP by comparing runoff entering these systems and the runoff exiting via an underdrain pipe.
- **Maintenance: Effect of sediment loading on BMP infiltration rates.** The SMC will measure the rate at which sediment loading into BMPs decreases the infiltration rates of runoff. The goal is to understand how these systems should be maintained to ensure their performance over the long term.

Table 1. Pilot study research question to develop the Regional BMP Monitoring Network.

General Area of Concern	Management Issue	Monitoring Question
BMP Effectiveness	Does my BMP work?	To what extent does the BMP reduce the discharge of contaminant(s)?
Maintenance	How and when do I need to maintain a BMP?	What is the influence of maintenance (or lack thereof) on BMP functions?

Rationale

BMP Effectiveness Question

The initial study aims to kick off in the 2022 with hydrology monitoring (rainfall, BMP inflow, & BMP outflow [underdrain discharge]) for at least 1 BMP per agency. Understanding how a BMP and its drainage area responds to rainfall will facilitate effective future configuration of water quality sampling instrumentation (anticipated to begin wet season 2022-23) and provide the appropriate context for training member agencies or their designated consultants directly in BMP field monitoring. Hydrologic data is also critical to calculating pollutant mass loads and to support most reasonable assurance analysis (e.g., modeling). These data also provide useful diagnostics of a BMP such as helping identify if there are problems with its configuration (e.g., short-circuiting) or construction (e.g., checking for positive drainage throughout the system). Alternatively, semi-controlled testing can be used to assess in-situ instrument configurations, such as with a hydrant or water truck prior to the 2022-23 wet season.

Measuring BMP hydrology is essential to assessing water quality performance for multiple reasons. From a practical standpoint, flow measurement is the input to programming water quality sample collection to generate event mean concentrations (EMCs). Pollutant mass load reductions are critical evaluation metrics for any BMP, which include calculations as per equations 1 & 2.

Volume = Flow x Time   Eq. 1

Mass = Volume x EMC   Eq. 2

Finally, BMP hydrology drives most Reasonable Assurance Analysis (e.g., models). Few existing models have been calibrated for specific BMP types.

Maintenance Question

Sediment clogging in BMPs that rely on infiltration can compromise water quality treatment by increasing the frequency and volume of runoff bypass. Water quality treatment is usually the priority objective for BMP installation. Member agencies scoped two functional issues as monitoring questions that link BMP maintenance to water quality performance:

1. What is the relationship between sediment loading and reduction in infiltration rate?
2. How much deterioration is acceptable?

The monitoring questions aim to identify the BMP conditions that indicate a deterioration or likely deterioration in water quality treatment performance. To identify thresholds indicating a need for maintenance, the research must determine the extent of infiltration rate deterioration that is acceptable. A logical benchmark is to compare measured infiltration rates against the design infiltration rate, while acknowledging that design rates usually incorporate a factor of safety. Finally, the cause of the change in infiltration rates must be investigated to identify appropriate corrective actions (i.e., maintenance activities). For example, infiltration rate decline may be due to sediment load accumulation (clogging), compaction, or some other in-situ condition.

The research is aimed to generate data to support maintenance schedules and activities based on conditions when the potential for BMP water quality treatment performance is compromised. Member agencies are not expected to alter existing maintenance regimes during the course of data collection. The research objective at present does not include assessing the effectiveness of maintenance activities in restoring BMP functions, nor developing an asset management plan or program.

MONITORING DESIGN

BMP Types to Monitor for Pilot Phase

BMP Effectiveness Question

Flow-through or partial capture bioretention/ biofiltration BMPs are prioritized for water quality performance monitoring. Flow-through or partial capture BMPs are identified by the presence of an underdrain that captures treated flow in excess of the system's water storage capacity and discharges it downstream (Figure 1). BMPs which discharge all or a portion of the inflow downstream present scenarios where flow can be collected and analyzed for pollutant removal prior to entering the municipal separate storm sewer system (MS4). Monitoring these systems provides the best opportunity to investigate BMP design features influencing performance in the field under "real-world" conditions, since changes through the system are measured. Full capture BMPs are excluded from the monitoring campaign at this stage because of the challenging logistics of measuring pollutant concentrations of runoff that exfiltrates to the surrounding soils, is harvested, or otherwise used. The utility of monitoring full capture BMPs is primarily limited to generating data for compliance monitoring, which does not contribute meaningfully to advancing BMP design.

Bioretention/ biofiltration BMPs are distinguished as stormwater treatment systems where runoff is filtered through engineered media or soil. The media is likely to be vegetated. Bioswales are acceptable if/when the dominant flow occurs through engineered media along the swale base. There also must be an underdrain or other accessible downstream discharge point for treated runoff.

BMP types that are excluded for this monitoring question include any proprietary device (e.g., modular wetlands) or any full exfiltration BMP (i.e., BMPs where the managed runoff discharges to surrounding soils).

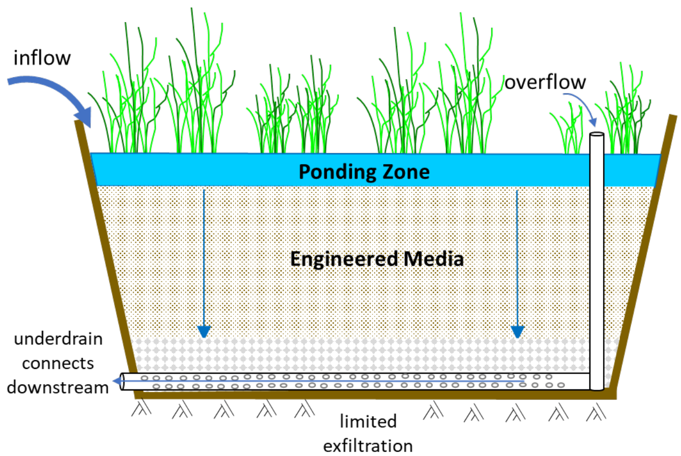

Figure 1. Flow-through bioretention/biofiltration BMP.

Maintenance Question

Any non-proprietary BMP type that incorporates flow from across a media surface, i.e., an infiltration process, is considered a suitable candidate for monitoring, which includes the process whereby runoff flows (Figure 2):

- From a surface such as a ponding zone into an engineered media, including but not limited to bioretention or sand filters. The same biofilter BMPs monitored for the water quality question would qualify. This process is specifically called infiltration.
- From the BMP into the ground, including but not limited to dry wells, infiltration galleries or trenches, unlined biofiltration systems, concrete subsurface infiltration vaults. The process whereby water flows from a BMP into the ground is technically called exfiltration.

The BMP must have either clearly defined inlet(s) where flow monitoring occurs, or a reliable method to estimate flow into the BMP. Whether to pursue monitoring of any BMP as part of the regional BMP network that relies on estimating flow rather than direct measurement shall be considered on a case-by-case basis between the member agency and SCCWRP.

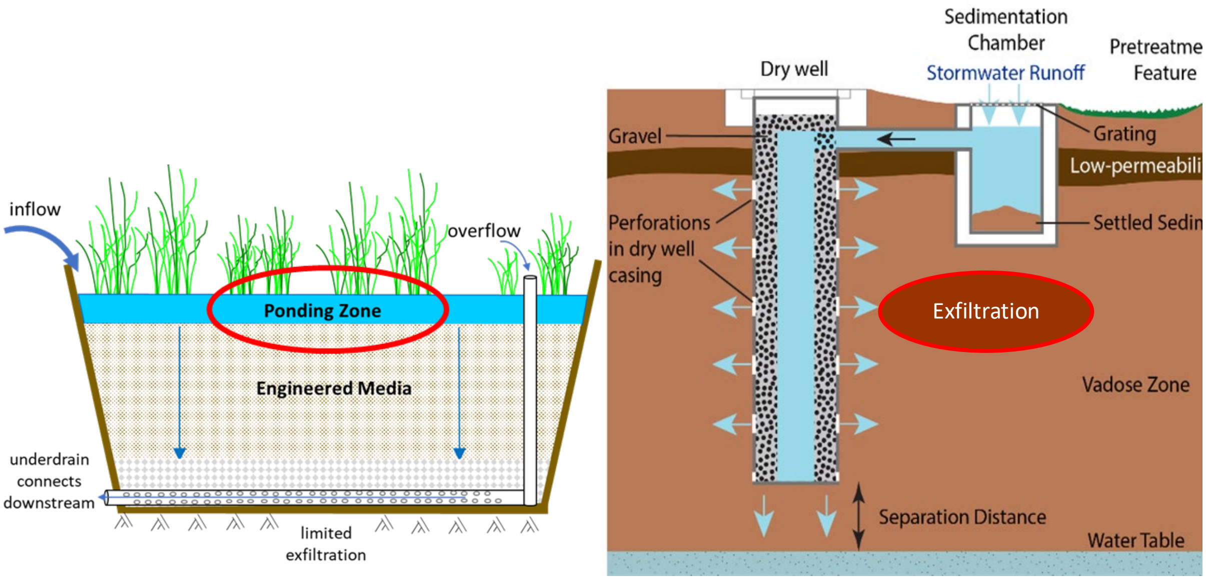

Figure 2. Examples of infiltration in BMPs: (left) infiltration from the ponding zone of a bioretention/biofilter into engineered media; (right) exfiltration from a subsurface dry well into surrounding soils.

Monitoring Approach

BMP Effectiveness Question

Basic assessments for BMP water quality performance measure and compare inflow and outflow water quality. Water quality may be evaluated as changes in concentration through the BMP and/or changes in pollutant mass loads. Mass load analysis requires concurrent measurement or estimation of hydrology (flow) and water quality (chemistry) at multiple locations to characterize runoff that enters (inflow/influent), discharges (outflow/effluent) or bypasses (overflows) the BMP. Figure 3 provides schematics of typical locations of monitoring stations with reference to these data collection objectives.

The description herein provides a generalized approach that will be tailored for each BMP to be monitored. The specific configuration of monitoring stations and equipment are presented in the appendices. During the 2021-2022 wet season, performance data collection is limited to hydrologic parameters only.

Monitoring stations are physical locations where equipment to enable flow measurement and capture water quality samples and/or in-line water quality sonde(s) are installed. Several simplifications of the strategy in Figure 3 are feasible. For example:

- It is often assumed that the water quality of flow that bypasses a BMP is the same as the flow that enters the BMP; thus water quality samples may be physically collected from either the BMP inflow pipe or channel or in the bypass pipe (Figure 3a).
- Flow may be measured at either inflow or outflow for BMPs that are not intended to influence flow rate by design, such as many pre-treatment units that are essentially concrete boxes (Figure 3b).

- Where BMPs operate in series, such as in a treatment train, the outflow from an upstream BMP is the same as the inflow to the downstream BMP, and thus again only one monitoring station is necessary to characterize both BMPs (Figure 3b).

Each of these simplifications are applicable if there are no additional flows or pollutant sources between monitoring stations (e.g., if there is a second inflow to the downstream BMP2 in Figure 2b).

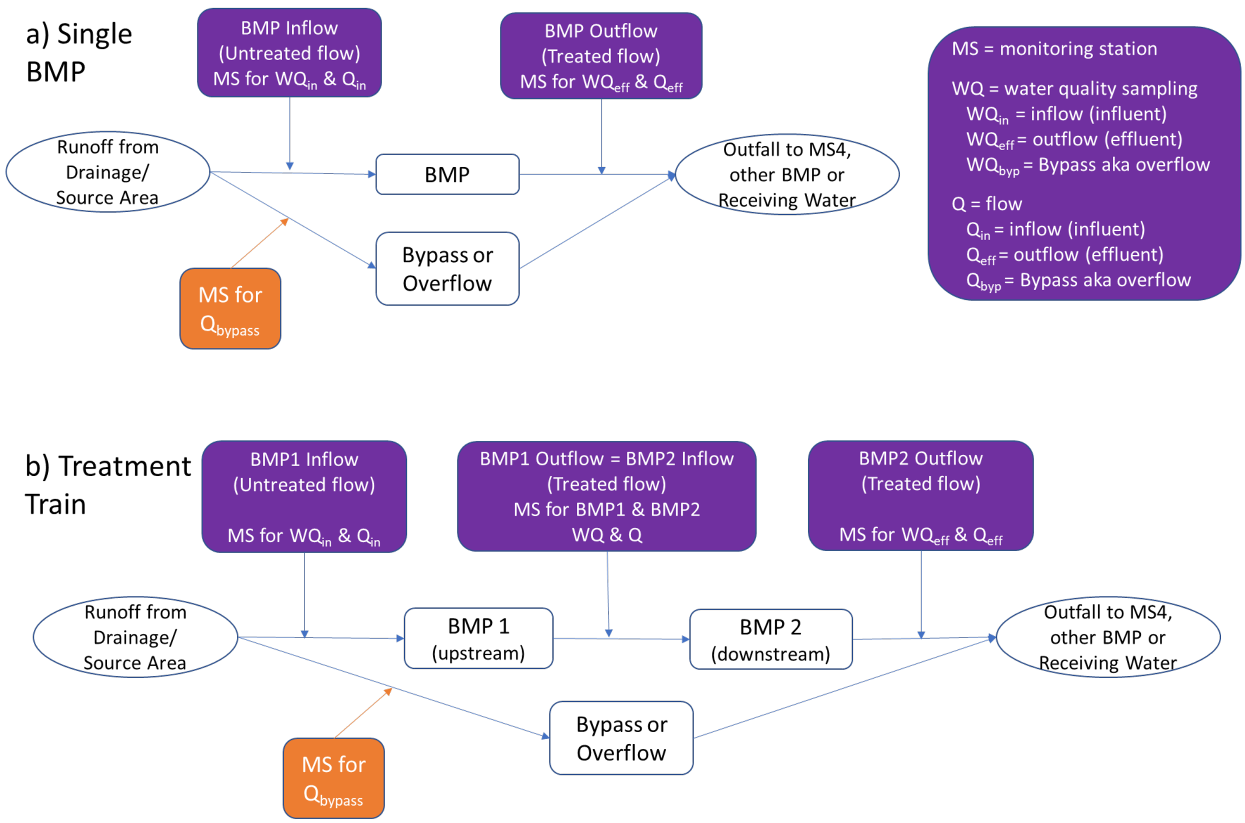

Figure 3. Typical Monitoring Approach for (a) single BMP; (b) multiple BMPs operating in series as a "treatment train". A treatment train may include pretreatment as BMP 1.

Flow cannot be measured directly in the field. Typical equipment configurations rely on instruments to measure water depth or water velocity, which is coupled with channel or pipe geometry to calculate flow, or a rating curve specific to a primary device. Automated water depth instruments commonly used in BMP monitoring include pressure transducers (PTs), bubblers, and ultrasonic sensors. Water velocity instruments include area-velocity meters and acoustic doppler meters. Primary devices may include weirs and flumes. The specific instruments or primary devices (if any) used will be determined at the discretion of the member agency responsible for monitoring each BMP, in consultation with SCCWRP. BMP-specific instrumentation plans are provided in the appendix.

A rating curve describes the mathematical relationship between water level and discharge for a fixed cross-section. Rating curves may be derived from theoretical relationships, with standard equations available from textbooks or reference manuals such as the US Bureau of Reclamation's Water Measurement Manual. Rating curves may also be derived for site-specific application. Work-in-progress by SMC member agencies, SCCWRP, US EPA, and the Riverside County Flood Control and Water Conservation District, suggest that site-specific rating curves differ substantially from theoretical relationships, particularly for small pipes and channels, and may be more appropriate for BMP monitoring. The justification for and ability to develop site-specific rating curves will be investigated on a case-by-case basis for the Regional BMP Monitoring network.

Maintenance Question

Instrumentation for measuring BMP inflow is as described in the previous section. An in-line turbidity sensor with data logging capability should be installed near the location of inflow measurement and deployed for the duration of each storm during the wet season. If/where flow-through BMPs are monitored for this question, an in-line turbidity sensor with data logging capability should also be installed near the location of the outflow measurement. Hand-held devices are not appropriate.

A pressure transducer or comparable device to measure and record the depth of accumulated water above an infiltrating surface will be installed in the ponding zone for surface BMPs such as bioretention or sand filters, or in the storage chamber of a subsurface infiltration system such as a dry well or infiltration gallery. The instrument must be capable of measuring and recording water level at 5-min or less increments. Spatial variation in infiltration rates is anticipated due to heterogeneity of media, plant root density, and pollutant accumulation, among other potential factors. Instrumentation to measure and record the depth of accumulated water at multiple locations within the BMP concurrently is recommended if/where resources allow.

Maintenance activities that may influence the presence or absence of clogging materials include sediment forebay or pre-treatment unit clean-out, weeding, tilling, plant replacement or any other activity that disturbs the surface of media-filled BMPs, mulch removal or replacement, trash or debris removal. The working group recognizes that maintenance plans are often unique to individual BMP installations. The methods used for each activity also likely differs across contractors and agency teams responsible for conducting maintenance, as do terms of existing contracts for reporting activities.

The maintenance plan for each BMP monitored will serve as the baseline assumption of maintenance activity. In other words, it will be assumed that maintenance is executed as planned or contracted. Should a member agency become aware that maintenance is not completed as planned, the agency should discuss issues with SCCWRP, as potential influences on research or alternative data needs can be determined on a case-by-case basis. SCCWRP will develop a mobile app to track completed maintenance activities that may affect sediment accumulation and clogging in monitored BMPs. A range of alternatives from qualitative assessment (e.g., photos) to quantitative measurements (depth of sediment accumulation in forebays or volume of debris or sediment removed) will be incorporated. Member agencies may choose to implement/participate in this type of data collection, as per feasibility within existing contracts.

It is noted that BMPs where sediment is allowed to accumulate during the wet season (i.e., sediment is not removed between storms) are likely to provide the best opportunities for detecting changes in infiltration rate. Opportunities to monitor a BMP where sediment is allowed to accumulate should be discussed with SCCWRP on a case-by-case basis.

Storm Criteria

All storm events are to be monitored for hydrology and infiltration, as applicable.

For water quality sampling using automatic samplers (anticipating beginning wet season 2022-23), the minimum storm size to be eligible for monitoring is set preliminarily at precipitation, $P \geq 0.2$" and an upper bound of the 85th percentile, up to 24-hr event, plus at least one event where bypass occurs (if it occurs). Pilot testing will be used to refine the storm criteria, as each individual catchment and BMP will respond differently to rainfall.

For water quality sampling mobilization, a minimum probability of precipitation of 75% is suggested, according to National Weather Service Quantitative Precipitation Forecast within 2 days of the forecast event. Water quality sampling of flow-weighted composites and sondes is suggested for at least 4 storms per wet season per BMP. Back-to-back storms (i.e., storms with less than a 72-hour antecedent dry period) are eligible for sampling provided:

1. All inflow and outflow, and rainfall from the first event have ceased (i.e., rainfall and flows can be uniquely and entirely attributed to one storm, then the other);
2. Adequate time between storms is available to mobilize crews.

An example interpretation of a precipitation forecast will be developed to support the standard operating procedures (SOPs) and included as an appendix to this work plan.

Parameters to Measure or Calculate

BMP Effectiveness Question

The monitoring plan is designed to characterize pollutant concentrations and loads into and out of the BMP while concurrently gathering information or selecting monitoring sites in a manner that enables an explanation of the results.

Data to be collected during storms in spring 2022 include: rainfall rate (hyetograph) and total depth, inflow rate and volume, outflow (underdrain discharge) rate and volume, and bypass rate and volume.

Data to be collected during storms beginning from autumn 2022 include (depending on the status of individual BMP instrumentation): rainfall rate (hyetograph) and total depth, inflow rate and volume, outflow rate and volume, and bypass rate and volume. Ideally, flow-weighted composite samples will be collected for water quality analysis, preferably using automatic samplers. In some cases, alternative methods for compositing samples may be applied post-sample collection, such as proportionally compositing discrete samples by either flow, time, or rainfall. Pacing of water quality sample collection will be determined on a site-specific basis, pending the results of initial hydrologic monitoring. These details will be developed along with site-specific instrument plans, criteria for determining sampler pacing, procedures for compositing samples, and managing data from the autosamplers will be developed with standard operating procedures (SOPs) and a quality assurance project plan (QAPP). SCCWRP will provide training to field staff for SMC member agencies where needed.

Composite samples are to be analyzed in a laboratory to determine pollutant event mean concentrations (EMCs). In some cases, discrete samples may be analyzed to determine event pollutographs, and the EMC calculated from the pollutograph. Water quality parameters are presented in order of SMC member agency priority in Table 2. Additional parameters may be considered. Final determination of the analyte list is deferred until summer 2022, as more information is collated on cost and effort.

Table 2. Minimum water quality parameters under consideration.

Parameter Group	Specific Analytes	Other Notes
Bacteria	Fecal indicator bacteria	Sample collection method to be determined
Nutrients	Total and ortho-phosphate Total nitrogen Nitrate + nitrite	Flow-weighted composite samples
Heavy Metals	Total and dissolved zinc Total and dissolved copper	Flow-weighted composite samples
Total Suspended Solids	TSS	Flow-weighted composite samples

All hydrologic data should be collected at 5 min or more frequent (1 min) resolution. Specifics of data logging intervals will be developed with QAPP.

Rainfall data is ideally collected on-site, else, data must be obtained from a rain gauge within 1-mile of the monitored BMP. The total rainfall (*P*) is the cumulative precipitation depth measured for each event. The average rainfall intensity (i_{ave}) is the ratio of the total rainfall to the total rainfall duration. The peak rainfall intensity (i_p) is given by the maximum depth of rainfall over a 5-min interval. Precipitation statistics are calculated as:

$$P = \sum_{j=1}^{tp} P_j \times \Delta t \qquad \text{Equation 1}$$

$$i_{ave} = \frac{P}{t_p} \qquad \text{Equation 2}$$

$$i_p = \max\left(\frac{P_5}{5\text{−min}}\right) \qquad \text{Equation 3}$$

Where P = total rainfall during an event (length, e.g., mm or in)

Δt = data logging interval (e.g., min)

t_p = total rainfall duration (time)

i_{ave} = average rainfall intensity over the duration of the event (length/time)

P_5 = 5-min precipitation depth (length)

i_p = maximum depth of rainfall over a 5-min period (length/time)

The peak flow rate is considered the maximum 5-min flow rate (*Q*) at the monitoring station in a single event. Runoff volume (*V*) is determined from the measured hydrograph as:

$$V_i = \sum_{j=1}^{t}\left(Q_j \times \Delta t\right) \qquad \text{Equation 4}$$

Where V = runoff volume (e.g., L)

Q = flow rate over time interval j (volume/time)

Δt = elapsed time of flow measurement

i = indicator for a monitoring station in a unique storm

In most cases, Q is calculated by the autosampler, based on site-specific programming by field staff, while V is a post-hoc calculation performed after data are downloaded.

SCCWRP will work with SMC member agencies to ensure appropriate and consistent application of Equations 1-4, with details documented in the QAPP. Results of calculations will be provided by member agencies to SCCWRP through upload to an online data portal (see Information Management section).

Additional periodic, dry-weather data

It is desirable to link water quality outcomes with BMP characteristics and site influences in order to also use the results to advance design or to choose the "right" BMPs for future site-specific conditions. Four categories of factors influencing bioretention/biofiltration water quality performance are prioritized for investigation:

- Media composition: specifically, indicators for nitrogen and phosphorus leaching
- Age/exposure of the system: specifically, newly built vs. seasoned/established).

Data characterizing each bioretention/biofiltration BMP monitored should include analysis of:

- Vegetation
  - Fraction of surface area covered (method to be determined)
  - Distribution of plant types (method to be determined)
- Media
  - Particle size distribution (or texture as sand/silt/clay fractions)
  - Bulk density
  - Effective porosity
  - Saturated extracts of phosphorus (mg/L as P), nitrate (as N), pH
  - Organic matter (as % mass) by loss on ignition
  - Carbon:nitrogen (C:N)
  - Cation exchange capacity (CEC) and base saturation
  - SAR and ECe

Media testing parameters are routinely conducted by soil physics and soil chemistry laboratories. Contact details for laboratories with appropriate capabilities will be shared with SMC agencies. Media and vegetation data should be collected bi-annually prior to the start and after the end of the wet season. Methods/SOPs for media and vegetation sample and data collection analysis will be developed in summer 2022, along with estimates of cost and effort. In-depth analysis of the influence of vegetation is not considered in the scope of the initial research questions posed.

Maintenance Question

The proposed approach is to use an indicator of cumulative sediment load that can be measured using an in-line sensor, such as turbidity. Turbidity is frequently identified as a surrogate for various measures of solids (e.g., suspended solids). Use of an in-line sensor emerges as a cost-effective approach eliminating the need to physically collect and analyze water samples. A turbidity-TSS relationship is acknowledged as site-specific. If/where in-line turbidity sensors are installed coincident with BMPs that are also subject to water quality sampling, laboratory analysis of flow-weighted composite samples should include TSS and turbidity. Linking sediment load to rainfall (intensity or depth) would be useful for a predictive/scheduling calculator, and will be investigated through this research question.

Data to be collected during storms include rainfall, inflow rate, maximum ponding depth, draw-down rate from ponding depth during storm events (i.e., the change in standing water level vs. time), bypass rate, turbidity of inflow and outflow (where applicable).

$$D_{pond} = \max(h) \qquad \text{Equation 5}$$

$$R_{dd} = \frac{D_{pond}}{t_{dd}} \qquad \text{Equation 6}$$

Where D_{pond} = maximum depth of free/standing water measured above the infiltrating or exfiltrating surface during a storm event (length)

h = depth of free/standing water above the infiltrating or exfiltrating surface during a storm event (length)

R_{dd} = rate of standing water to decrease from D_{pond} to the level of the infiltrating or exfiltrating surface (length/time)

t_{dd} = elapsed time for water level to decrease from D_{pond} to the level of the infiltrating or exfiltrating surface (time)

The duration of standing water (t_{dd}) post-storms can be determined from the same instrument used to measure draw-down rate from ponding depth. The presence/absence of standing water could be also documented by cameras (e.g., wildlife cameras with remote operation).

Data collected during dry weather includes the surface infiltration rate for media-filled BMPs such as bioretention/biofiltration systems, sand filters, bioswales, or permeable pavement. The infiltration rate should be determined using a Turf-tec infiltrometer or comparable device, with data collection occurring prior to and after the wet season during dry weather. Spatial variation in surface infiltration rates is anticipated due to heterogeneity of media, plant root density, and pollutant accumulation, among other potential factors. It is recommended to conduct surface infiltration testing during dry weather in at least 3 locations across the surface of the BMP on the same day: at approximately 25%, 50%, and 75% of the distance along a straight-line transect between the inlet and outlet (assuming there are only one inlet and outlet). Multiple transects may be advised for very large BMPs, or BMPs with multiple inlets or outlets, and will be considered on a case-by-case basis. Conversely, fewer test locations may be warranted for very small BMPs.

The periodic dry-weather media and vegetation data will be applied in post-hoc and trend analysis to attempt to identify causes of changes in in- or ex-filtration rates.

SCCWRP will work with SMC member agencies to ensure appropriate and consistent application of Equations 5 and 6, with details documented in the QAPP. Data will be provided by member agencies to SCCWRP through upload to an online data portal (see Information Management section).

If/where significant or unusual decreases in in- or ex-filtration rates are observed for an individual BMP, evidenced by ponding in excess of 36 hours following a storm, observation of standing water in the absence of a recent storm, or similar, member agencies should work together with SCCWRP to identify the source of the issue, and collect additional data if warranted. Observations may be documented as a "lessons learned" type case study. Corrective action may be required by the member agency to ensure acceptable BMP function in the local jurisdiction.

BMP Metadata

Metadata describing each BMP's configuration, component specification, characteristics of the drainage area, etc., must be reported to support post-hoc data analysis and create context for interpreting data. Metadata requirements and reporting methods are provided in a separate web portal maintained by SCCWRP. Design drawings and site photos should be submitted along with the data detailed in the Appendix.

Member agencies will be provided with a unique login and password for the web portal. All data will be anonymized prior to publication or sharing. Metadata should be submitted to the web portal by June 1, 2022.

DATA ANALYSIS

BMP Effectiveness Question

TMDL and other water quality mitigation objectives are often established in terms of pollutant mass load reductions. Pollutant mass is the product of pollutant concentration (*EMC*s for BMPs) and runoff volume (V). For each storm:

$$M = EMC \times V \qquad \text{Equation 7}$$

Where M = pollutant mass (e.g., mg)

V = runoff volume (e.g., L)

Runoff volume reduction with BMPs may be achieved through exfiltration (enabling/allowing runoff to soak into surrounding soils after entering the BMP), evapotranspiration of runoff retained in a BMP (post-event drying of bioretention/ biofiltration or sand filter media), or stormwater harvesting or use. The current scope of BMP water quality effectiveness monitoring focuses on bioretention/biofiltration BMPs with underdrains; therefore, runoff volume reduction will be attributed to the retention capacity of the fill media (i.e., the ability to store water in the soil). Media water retention capacity may be manipulated to some extent through engineered media specification. Evapotranspiration rates are strongly influenced by climate conditions, and available water (i.e., under the same climate conditions, very wet media will evapotranspire more quickly than drier media).

Decreases in pollutant EMCs indicate that there are mechanisms working to remove pollutants within the BMP, for example, sedimentation on the surface of the ponding zone, or filtration and/or sorption as runoff seeps through the media during a storm event. Increases in EMCs indicate the BMP is contributing pollutants to the runoff that passes through it. Increases in EMCs in media-filled BMPs is often attributed to the materials comprising the media. Pollutant uptake by vegetation, if it occurs, is a slow process that is not typically measurable during the time scale of a storm event.

At a minimum, water quality performance for each BMP for each storm will be evaluated according to:

- Changes in maximum flow rate between the inflow and outflow, and/or across a treatment train, as per:

$$\Delta Q_p\ (\%) = \frac{Q_{p,in} - Q_{p,out}}{Q_{p,in}} \times 100\% \qquad \text{Equation 8}$$

  Where Q_p = maximum 5-min flow rate measured at the monitoring station in a unique event (volume/time)

  In the case of a treatment train, the inflow value is considered the most upstream value, and the outflow value is the most downstream value (i.e., the final discharge from the most downstream BMP of the treatment train).

- Changes in runoff volume between the inflow and outflow, and/or across a treatment train, as per:

$$\Delta V\ (\%) = \frac{V_{in} - V_{out}}{V_{in}} \times 100\% \qquad \text{Equation 9}$$

- Changes in pollutant EMC (if any) between the inflow and outflow, and/or across a treatment train, as per:

$$\Delta EMC\ (\%) = \frac{EMC_{in} - EMC_{out}}{EMC_{in}} \times 100\% \qquad \text{Equation 10}$$

  Where EMC_{in}, EMC_{out} = event mean concentration of the inflow or outflow, respectively (mass/volume, e.g., mg/L).

- Changes in pollutant mass load (if any) between the inflow and outflow, and/or across a treatment train, as per:

$$\Delta M\ (\%) = \frac{M_{in} - M_{out}}{M_{in}} \times 100\% \qquad \text{Equation 11}$$

Where M_{in}, M_{out} = pollutant mass of the inflow or outflow, respectively (e.g., mg). Changes in pollutant mass may be attributed to pollutant removal or additions (indicated by ΔEMC) and/or runoff retention (indicated by positive values of ΔV).

- Consistency of effluent EMC, including the mean, 95% confidence interval, and standard deviation.

Pollutant EMCs are the outcome of laboratory analysis of flow-weighted composite samples, or post-hoc flow weighting of pollutographs. These data will be provided by member agencies to SCCWRP through upload to an online data portal (see Information Management section). Performance analysis calculations, including Equation 7 through Equation 11 at a minimum, will be performed by SCCWRP.

A variety of post-hoc analysis will be conducted to quantify the influence of external factors and design characteristics on performance. External factors such as storm sizes sampled, the range of inflow concentrations and loads experienced, media moisture content (relative saturation), and the duration of the antecedent dry period, and age/exposure of the BMP, at a minimum, may provide context for interpreting performance. Design factors including media and vegetation characteristics are also of interest.

Maintenance Question

Trend analysis is anticipated as the primary method to investigate changes in wet-weather draw-down rates (R_{dd}) over time and duration of ponding (t_{dd}). Free/standing water may not occur during every storm because of high infiltration rates compared to runoff rates.

Statistical approaches are anticipated to evaluate pre- and post- wet season dry weather surface infiltration rates. Where multiple tests are conducted within a single BMP on each testing day, the average infiltration rate will be used for pre- and post- wet season comparisons. These data will also be investigated to determine if the measurement location is significant, potentially signaling useful information regarding maintenance needs or design considerations (e.g., pre-treatment needs or inlet energy dissipation).

There is little precedent in the literature to anticipate the best or most useful way to analyze the proposed data. Additional analytical tools will be developed by SCCWRP in consultation with the Working Group as data become available.

INFORMATION MANAGEMENT

The SMC BMP regional monitoring network is designed to investigate BMPs using consistently collected and reported data. The information management plan creates a shared central database to store these data and information. Standardized data structures and reporting methods have been developed to facilitate data compilation and analysis.

Metadata and monitoring data distinguish data types (Table 3). Metadata are considered "one-time" data, such as BMP design characteristics and location, drawings, photos, etc. These data only need to be submitted once per project. Metadata describing each BMP's configuration, component specification, characteristics of the drainage area, design drawings, site photos, etc., must be reported to support post-hoc data analysis and create context for interpreting data, and maintenance plans. Metadata for BMP maintenance includes the expectations for frequency and/or conditions triggering specific maintenance activities identified in BMP maintenance plans or contracts for maintenance crews.

A web portal designed and maintained by SCCWRP, and reviewed by the working group, to capture BMP metadata is accessible at https://bmp-portal-sccwrp.hub.arcgis.com/. Metadata may be submitted directly to through the web portal, or may be uploaded as an Excel template. Metadata requirements included in the portal to date are detailed in the Appendix. Maintenance plan metadata fields are under development in the web portal. Metadata for all fields except maintenance plans should be submitted to the web portal by June 1, 2022.

Monitoring data are considered "on-going data". These data will include the data collected from various instruments, sensors, water quality laboratory analyses, as well as logs of maintenance activities. Water quality data must be submitted in one of two standardized formats to a centralized database maintained by SCCWRP. CEDEN format water quality data is acceptable with minor modifications, but it is not required. Alternatively, a spreadsheet template will be provided for reporting water quality data; it is currently under development.

Hydrologic data to submit to the centralized database include the results of calculations in Equations 1-4 summarizing precipitation and flow characteristics in each monitored event. Spreadsheet templates will be provided by SCCWRP for data submission. Hydrologic data are not a component of CEDEN reporting. Raw data collected from sensors, and calculations for Equations 1-4 will be maintained by the member agencies.

Monitoring data, especially hydrology data, should be submitted as soon as possible. Hydrologic data are key indicators of instrumentation issues common to field monitoring, easily identifying problems such as dislodged instruments or instruments that have lost calibration, which must be corrected prior to the next storm event. Templates and examples will be provided as appendices to this work plan.

Templates for submitting maintenance data are under development. All participating agencies are expected to submit monitoring data on dry weather infiltration rates, media, and vegetation. Dry weather data collected prior to the start of the wet weather season should be submitted annually by December 1, whereas data collected at the end of the wet weather season should be submitted by July 1. Data documenting maintenance activities may be collected using a live Survey123 app, as feasible per individual member agency.

Templates will evolve to address different data needs as additional research questions are pursued by the SMC BMP Regional Monitoring Network.

Pre-processing of data from most of the instruments is required. For example, water level measurements must be converted to flow rates. Data will likely be recorded from before a storm starts to long after it ends (hydrology data are continuously collected, resulting in many zero-values to be recorded that must be separated from the record). SCCWRP is developing analytical tools to automate data pre-processing (e.g., P, i_{ave}, Q, V) and analysis (e.g., ΔEMC, ΔM) to the extent practical. Member agencies will be responsible for some data processing as every site has unique instrumentation, precluding one-size-fits-all analytical tools. Member agencies are expected to keep records of raw, unedited data.

Member agencies will be provided with a unique login and password for the web portal. Individual agencies can access or modify (e.g., submit corrections) their own data at any time. All data will be anonymized prior to publication or sharing. Committee members may review entire data set once QA/QC is completed. SCCWRP is responsible for QA/QC and initial data analysis. The working group is expected to contribute to the assessment and conclusions after data analysis. The SMC Steering Committee approves all reports prior to publication. No data is publicly released until reports are published.

Table 3. Examples of Metadata and Monitoring Data.

Metadata	Monitoring Data
BMP characteristics, e.g., size, media specification, design assumptions, location, age/exposure	Storm event data: rainfall, flow rates (inflow, outflow), water quality results, turbidity, water level (infiltration during storm)
Drainage area characteristics, e.g., land use, extent, in-situ soil infiltration	Dry weather infiltration tests
Design drawings	Dry weather media analysis (particle size distribution, bulk density, effective porosity, organic matter content)
Photos	Images documenting vegetation condition
Configuration of monitoring stations	Maintenance activities actually conducted (per contract schedule or field records) as relevant to influences on in- or exfiltration
Configuration of treatment trains (if applicable)	
Maintenance plan schedules for: • Sediment and debris removal from forebays or pre-treatment units • Weeding, tilling, or plant replacement • Mulch replacement or replenishment • Any other activity that disturbs the in- or ex-filtrating surface	

ROLES AND RESPONSIBILITIES

The responsibilities by agency and task are outlined in Table 4. SCCWRP will provide assistance to each member agency with site selection and instrument specification, and will provided training as appropriate for installation, operation (e.g., data download, conducting surface infiltration rate with Turf-tec infiltrometers), and raw data quality assurance checks. SCCWRP will be responsible for final data analysis and will provide a data management system to the SMC.

Member agencies are responsible for ensuring access to BMPs, equipment purchase or rental, and field crews (internal or contract) for equipment installation, wet and dry weather data collection, transportation of water quality samples to a laboratory for analysis, cost of laboratory analysis, and inter-storm site visits. Member agencies are responsible for performing raw data quality assurance checks and submitting metadata and monitoring data to the web portal maintained by SCCWRP. A member agency should submit field notes/logs to the web portal when/if maintenance is performed and the number of hours on site performing maintenance at a BMP. The member agency should notify SCCWRP immediately if there is an issue with monitoring equipment or the BMP. SOPs will be developed to conduct and report each of these activities. Member agencies are expected to conduct BMP maintenance activities as per existing maintenance plans.

Table 4. Responsibilities by Agency and Task.

Work Plan Element / Agency	BMP Site ID/ Selection[1]	Instrumentation: Plan	Instrumentation: Purchase or Rental	Instrumentation: Calibration & Installation	Instrumentation: Wet weather season field checks	Work Plan & QA Plan	Training[2]	Conduct Monitoring: Wet Weather	Conduct Monitoring: Water Quality Analysis[3]	Conduct Monitoring: Dry Weather Infiltration Tests	Conduct Monitoring: Dry Weather Media Testing	Conduct Monitoring: Aerial Images of Vegetation	Conduct Monitoring: Maintenance Activities[4]	Information Management: Develop & Maintain Portal & Database	Information Management: Raw Data Processing	Information Management: Data Submission to Portal	Information Management: Data Analysis	Reporting: Writing	Reporting: Review
SCCWRP[5]	✓	✓		✓		✓	✓							✓			✓	✓	
City of San Diego	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓			✓
City of Los Angeles	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓			✓
Riverside County Flood Control and Water Conservation District	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓			✓
County of Los Angeles Public Works	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓			✓
Orange County Public Works	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓			✓
County of San Diego	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓			✓
City of Long Beach	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓			✓
San Bernardino County	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓			✓
County of Ventura	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓			✓
Caltrans	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓			✓

1. Location, design details, permissions/access, etc.
2. Instrument calibration, trouble-shooting, data downloads, infiltrometer testing, etc.
3. Anticipated to begin 2022-23 wet season.
4. As feasible per member agency.
5. Lead agency for tasks indicated. Opportunity for collaboration & cooperation with member agencies.

APPENDICES

Site selection by agency

BMP metadata requirements (excluding maintenance plans as of 4/21/2022)

Site-specific equipment and monitoring station configurations (tbc)

Protocols for bioretention/biofilter media sampling (tbc)

Protocols for bioretention/biofilter vegetation assessment (tbc)

Protocols for Turf-tec surface infiltration testing (tbc)

Procedures for compositing samples (tbc)

Example National Weather Service Quantitative Precipitation Forecast interpretation (tbc)

Site Selection by Agency

Table 5. Monitoring Site Selection as of 05/02/2022.

Agency	Sites	Status
San Diego County Public Works	1 x Campus biofiltration 2 x Otay Mesa Rd Green Street	Site visit completed – instrumentation configuration in progress
City of San Diego	Pacific Highlands Ranch Park	Site visit completed – instrumentation configuration in progress
City of Los Angeles	Garvanza Park	Site visit completed Maintenance question only
Riverside County Flood Control & Water Conservation District	1 x Campus bioretention cell 2 x Campus bioretention planters	Bioretention planters rebuilt & instrumented 9/21. Online/actively collecting data.
County of Los Angeles Public Works	Magic Johnson Park	Site visit completed 9/29/2021. Considering instrumentation.
Orange County Public Works	Glassell Campus bioswale (North County) La Pata Basin (South County) Glassell Campus dry well	Maintenance activities completed. Considering instrumentation Review/compare existing monitoring plan for alignment with SMC Regional Network requirements

Table 6. Candidate Sites Needing Inspection as of 5/2/2022.

Agency	Sites	Status
City of Long Beach	Willow Springs Park	Site visit scheduled 5/3/2022
Caltrans	Irvine Activated Alumina Sand Filter	Currently being monitored per Caltrans permit requirements.

BMP Effectiveness and Maintenance Questions: (left) City of San Diego Pacific Highlands Park.

BMP Effectiveness and Maintenance Questions: (left) San Diego County Otay Mesa Rd Bioswale; (right) County of San Diego Campus.

BMP Effectiveness and Maintenance Questions: Riverside County Flood Control and Water Conservation District Bioretention Planters.

Maintenance: (left) Orange County Glassell St. Campus Dry Well; (right) City of Los Angeles Garvanza Park Infiltration Gallery.

BMP metadata requirements

(excluding maintenance plans as of 5/2/2022)

Field characterize "one-time" data including:

- BMP characteristics, e.g., media specification, size, design assumptions, location, age/exposure
- Drainage area characteristics, e.g., land use, extent, in-situ soil infiltration
- Configuration of monitoring stations

Design drawings and photos are strongly encouraged to be uploaded. Photos from initial construction (if available) and conditions at the start and end of each monitoring season are of interest.

Data may be entered via spreadsheet template, or using https://bmp-portal-sccwrp.hub.arcgis.com/.

1. Test Site Description

The purpose of this table is to identify the general study location and related information. Size refers to the number of characters allowed for the data field.

Table 7. Test Site Table.

Field Name	***Type***	***Required***	***Size***	***Description***
SiteName	Text	yes	100	The Site Name is a unique geographic location where a BMP testing effort has been conducted.
Latitude	Decimal	no	38	Latitude is the North-South coordinate that locates the project to the nearest second on the globe relative to the equator. The latitude should be reported in a decimal degree format.
Longitude	Decimal	no	38	Longitude is the East-West coordinate that locates the project to the nearest second on the globe relative to the selected principal meridian. The longitude should be reported in a decimal degree format.
DataProvider	Text	yes	255	Data Provider helps track the individual submitting the study for future contact purposes. The data provider may or may not correspond to the entity conducting or sponsoring the study.

City	Text	yes	40	City closest to the test site. The site does not have to be within the city limits.
County	Text	no	40	County in which test site is located.
State	Text	no	50	State where test was performed (2 characters).
ZipCode	Text	no	10	Zip code of test site
Country	Text	yes	50	Country
NumberofBMPs	Integer	yes		Number of BMPs located at the test site. This helps alert subsequent users to treatment trains that may be present at the site.
Comments	Text	no	255	General description of study site

2. Watershed Description

Watershed characteristics play a significant role in the types and quantities of pollutants contributed to stormwater runoff as well as hydrologic response of a test site to runoff events. The information requested in the Watershed Table is useful for comparing effectiveness of BMPs under various watershed conditions. Size refers to the number of characters allowed for the data field.

Table 8. Watershed Table.

Field Name	***Type***	***Required***	***Size***	***Description***
SiteName	Text	yes	100	The Site Name is a unique geographic location where a BMP testing effort has been conducted.
WatershedName	Text	yes	100	WatershedName is the name that the watershed is referred to locally. The watershed should contain the drainage area to the BMP.
WatershedHUCCode	Text	no	255	Hydrologic Unit Code is the USGS 8-digit hydrologic unit code (HUC) which represents a geographic area containing part or all of a surface drainage basin or distinct hydrologic feature. The first two digits of the code represent the water resources region; the first four digits represent the subregion; the first six digits represent the accounting unit; and all eight digits represent the cataloguing unit. The HUC can be looked up on the EPA "Surf Your Watershed" web site at http://www.epa.gov/surf/. If the user’s search response is "no results", then higher level tributary names should be tried, or other descriptors such as county name or zip code entered until a HUC is provided.
DrainageAreaCharacterization	Text	yes	100	DrainageAreaCharacterization should be provided for each land use present in the BMP’s contributing drainage area (the area of land that is managed by the BMP) by picking from the lu_drainageareacharacterization list. Land area characterizations excludes area of BMP itself. Additional notes are provided in the lookup list lu_drainageareacharacterization.
DrainagePctLandUse	Integer	yes		Percentage of land area of each type - total must equal 100%
InSituSoilMeasureType	Text	no	28	Indicate the method used for determining or estimating in-situ soil infiltration characteristics. Choose from the lu_insitusoilmeasuretype. Options include: NRCS, Soil Bore, or Measured Infiltration Rate.
InSituSoilValue	Decimal	no		Indicate the in-situ infiltration rate as determined by the NRCS hydrologic soil group (A, B, C, or D), or empirical measurement (measured in-situ or lab hydraulic

				conductivity) or assumption (from interpretation of soil bore data) of infiltration rate. The value must correspond to InSituSoilMeasureType.
InSituSoilUnits	Text	no	5	Enter units as either in/hr or cm/hr corresponding to the empirical measurement or assumed value of in-situ soil infiltration rate. Enter N/A if NRCS is chosen for InSituSoilMeasureType. Options are found in lu_insitusoilunits

3. BMP Information

A structural BMP includes constructed facilities or measures to help protect receiving water quality and control stormwater quantity. Size refers to the number of characters allowed for the data field.

Table 9. BMP Info.

Field Name	Type	Required	Size	Description
SiteName	Text	yes	100	The Site Name is a unique geographic location where a BMP testing effort has been conducted.
BMPName	Text	yes	100	BMP Name must be provided in terms of the common name or code used to identify this BMP locally.
BMPDescription	Text	no	255	Narrative Description
BMPType	Text	yes	5	Type of BMP Being Tested (Enter Code). See lu_bmptype for code list.
BasisOfDesign	Text	yes	255	Basis of Design selected from a lookup list including: 2-yr 24-hr design storm volume, design treatment flow rate, 85th percentile storm volume, other water quality design storm, other. If “other” is selected, please describe in the Comments.
MagnitudeOfDesignBasis	Decimal	yes	10	Indicate the magnitude of the capture volume or maximum flow rate used to design the BMP.
MagnitudeOfDesignUnits	Text	yes	3	See lu_magnitudeofdesignunits for code list.
Purpose	Text	no	8000	Purpose of BMP: Indicate the primary design objective of the BMP selected from lookup list including: pollutant concentration reduction, pollutant mass reduction, flow control (hydromodification), flood control, capture for non-potable reuse or harvesting, capture for potable reuse or harvesting, capture for recharge
InflowCount	Integer	yes		Number of inflow points to the BMP. Each inflow point should be represented by a monitoring station.
OutletDescription	Text	no	255	Description, types, and designs of outlets selected from the lookup list lu_outletdescription including: closed pipe, combo underdrain + exfiltration, exfiltration, harvesting or direct use, perforated underdrain

DesignCriteriaSource	Text	no	255	Source of Design Guidance for BMP identifies the design guidance followed for the BMP design.
BypassOrOverflow	Text	yes	25	BMP Designed to Bypass or Overflow is described by the lookup list lu_bypassoroverflow to indicate whether flows exceeding the design flow are routed around the BMP (“Bypass”), enter the BMP but discharge without treatment (“Overflow”), or “None”.
UpstreamTreatmentIsPresent	Text	yes	3	Indicate “yes” or “no” depending on whether upstream treatment is provided within the Site, for example if a treatment train is present.
PretreatmentDescription	Text	no	255	Narrative description of upstream treatment (if any). Otherwise enter n/a
UpstreamBMPNames	Text	See comments	255	Name of upstream BMP(s). Names should correspond to other BMPName(s) in the SiteName. Must be provided if “UpstreamTreatmentIsPresent” is “Yes” and/or if a treatment train is present.
ConfigInWatershed	Text	no	255	General configuration of BMP in tributary watershed (i.e., end of pipe, source control, off-line, on-line)
DateInstalled	Date	yes		Date facility placed in service (mmddyyyy)
Comments	Text	no	255	Other narrative information not addressed elsewhere.

4. Monitoring Station Description

The Monitoring Station spreadsheet must be completed to identify the monitoring stations in place at each site and the relationship of each monitoring stations to each BMP. This data is the basis for all subsequent data entry and is crucial to allow proper data retrieval. If a monitoring station is shared by two BMPs, the relationship of the monitoring station must be identified for each BMP. Size refers to the number of characters allowed for the data field.

Table 10. Monitoring Station Table

Field Name	***Type***	***Required***	***Size***	***Description***
SiteName	Text	yes	100	The Site Name is a unique geographic location where a BMP testing effort has been conducted.
BMPName	Text	yes	100	BMP Name must be provided in terms of the common name or code used to identify this BMP locally.
StationName	Text	yes	255	Station Name is the user-assigned name for the subject monitoring station. Stations shared by two BMPs should be entered twice (once for each BMP) in this spreadsheet. For example, if a station monitors outflow from one BMP and inflow to another BMP, then the monitoring station should be identified twice.
StationType	Text	yes	255	Monitoring Station Type identifies the function of each monitoring station in relation to each BMP. See lu_monitoringstationtype lookup list. Note Precipitation must be indicated as a unique StationType and MeasurementType.
MeasurementType	Text	yes	50	Code for the type of measurement taken at a monitoring station: See lu_measurementtype lookup list. Use a comma between abbreviations if/where multiple measurements are collected at the same monitoring station. Note Precipitation must be indicated as a unique StationType and MeasurementType.
Comments	Text	no	255	Comments should be used to provide any unique conditions or limitations associated with the monitoring station

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