United States Environmental Protection Agency and the EPA Region III states of Pennsylvania, Maryland, Delaware, District of Columbia, Virginia and West Virginia

# Evaluating the Effectiveness of Municipal Stormwater Programs

EPA 833-F-07-010

January 2008

## Introduction

### NPDES Stormwater Management Programs

EPA stormwater regulations require National Pollutant Discharge Elimination Program (NPDES) permits for stormwater discharges from many municipal separate storm sewer systems (MS4s). Phase I of the stormwater permit program generally addresses municipalities with greater than 100,000 in population, while Phase II addresses smaller jurisdictions within urban areas. Additional information on EPA's stormwater program is available at **www.epa.gov/npdes/stormwater.**

Stormwater Phase II programs address the following program components:

- Public education and outreach
- Public involvement
- Illicit discharge detection and elimination
- Construction Site Runoff Control
- Post-Construction Runoff Control
- Pollution Prevention/Good Housekeeping for Municipal Operations

In addition to the programs above, Stormwater Phase I programs also must address stormwater runoff from industrial facilities.

Operators of regulated MS4s are required to develop a stormwater management plan (SWMP) that includes measurable goals and to implement needed stormwater management controls (BMPs). The process of developing a plan, implementing the plan, and evaluating the plan is a dynamic, iterative process that helps move communities toward achievement of their goals (Figure 1).

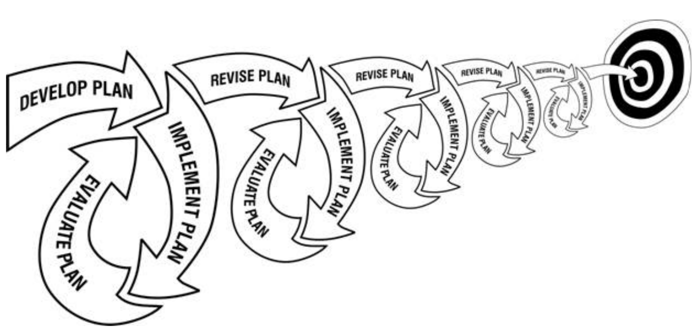


**Figure 1.** The iterative process of stormwater management (Develop, implement, evaluate, repeat).

40 CFR 122.26(d)(2)(v) and 122.34(g) requires MS4s to assess controls and the effectiveness of their stormwater programs. Municipal stormwater programs are also required to reduce the discharge of pollutants to the "maximum extent practicable" and satisfy the water quality requirements of the Clean Water Act. In addition, a number of government and scientific reports have found that better water quality data is needed if MS4s are to evaluate the effectiveness of their program in meeting water quality goals (NRC, 2004; Schwarzenback, et. al, 2006; Vaux, 2005).

This document discusses three approaches to evaluation of municipal SWMP effectiveness:

- Assessing program operations;
- Evaluating social indicators; and
- Monitoring water quality.

Other guidance is available to assist managers in evaluating overall implementation of the SWMP to the maximum extent practicable, e.g., EPA's MS4 *Program Evaluation Guidance* (**www.epa.gov/npdes/pubs/ms4guide_withappendixa.pdf**).

### Purposes of Program Evaluation

- **Meet regulatory requirements.** EPA stormwater regulations require that the effectiveness of the SWMP be evaluated, including assessment of SWMP implementation, evaluation of BMP effectiveness, and the extent to which improvements in stormwater outfall discharge quality have occurred.
- **Document progress toward water quality goals.** Evaluation of SWMP effectiveness is essential to measure progress toward meeting benchmark conditions, complying with water quality standards, or restoring beneficial uses.
- **Justify commitment of resources.** Knowledge of program effectiveness can help justify SWMP expenditures to decision-makers and to the public, and help improve cost-effective implementation and management of the SWMP.
- **Provide feedback to the management program.** Stormwater management is an iterative process and knowledge of program effectiveness is essential for the permit renewal process and for mid-course corrections to improve the program.
- **Assess reductions in pollutants of concern.** If a waterbody is impaired, it may be helpful to assess the effectiveness of the SWMP in reducing the pollutants of concern.

# Stormwater Management Goals

## Setting Goals for SWMPs

Stormwater management plans must be guided by specific measurable water quality-based goals, but also typically include, programmatic, BMP-implementation, and social goals. NPDES permit conditions often serve as minimum goals for a SWMP, but an MS4 may have other goals for restoration or protection of water quality that go beyond minimum permit conditions and reflect local understanding of the storm drain system and receiving water conditions. Guidance on setting measurable goals for SWMPs can be found in EPA's *Measurable Goals Guidance for Phase II Small MS4s* (**www.epa.gov/npdes/pubs/measurablegoals.pdf**).

Programmatic goals might address education and outreach to a range of audiences, establishment of partnerships with business owners, or adoption of ordinances. BMP implementation goals may call for some number of practices to be installed in key locations according to a certain schedule. Goals for public involvement could include targets for number of participants in clean-up or tree-planting activities, number and quality of responses to attitude surveys, or changes in the use of lawn fertilizer.

The ultimate goal of any NPDES stormwater management program is to reduce pollutant discharges to the maximum extent practical, prohibit illicit discharges to the MS4, and protect water quality. Water quality goals may pertain to pollution prevention (reduction of potential pollutants at the source), improvements in stormwater outfall discharge quality, reduction of pollutant loads to receiving waters (e.g., a TMDL), restoration of aquatic resources (e.g., stream channel stabilization, fishery restoration), compliance with water quality standards, or restoration of beneficial uses. Intermediate benchmarks that indicate progress toward meeting water quality standards are important elements of successful long-term SWMPs.

# Matching Evaluation to Management Goals

Evaluation of the effectiveness of a SWMP must relate directly to its goals. Two central questions are: *Are we meeting the municipal SWMP goals?* and *Are we meeting NPDES stormwater regulatory requirements?* If a goal is to keep a swimming beach open, it is often necessary to determine the extent to which water quality criteria for bacteria are being met. If a goal is to reduce nutrient loads by 40% from a watershed, it is then necessary to measure nutrient loads and compare measured loads against the goal. Meeting your water quality goals is the ultimate sign of program success, however, meeting programmatic or social goals can also be indicators of a successful program. Information on how these goals are met will serve as critical feedback in the iterative process of stormwater management.

# Evaluating Stormwater Management Program Effectiveness

Stormwater program evaluation must be more than an exercise in collecting and tabulating data; evaluation data must be analyzed, interpreted, and reported so that results can be applied to such purposes as documenting effectiveness of BMPs, reporting information to government or the public, and planning future management activities.

Stormwater programs address multiple objectives and program evaluation can focus on a variety of desired outcomes that parallel these objectives. Approaches to the evaluation of stormwater program effectiveness may therefore fall on a continuum from basic verification of compliance with regulatory requirements to assessing changes in knowledge and behavior to detecting changes in receiving water quality (Figure 2). The NPDES stormwater evaluation program in Baltimore County, Maryland (**www.baltimorecountymd.gov/Agencies/environment/watersheds/epnpdesmain.html**) is a good example of effective evaluation of an MS4 program.

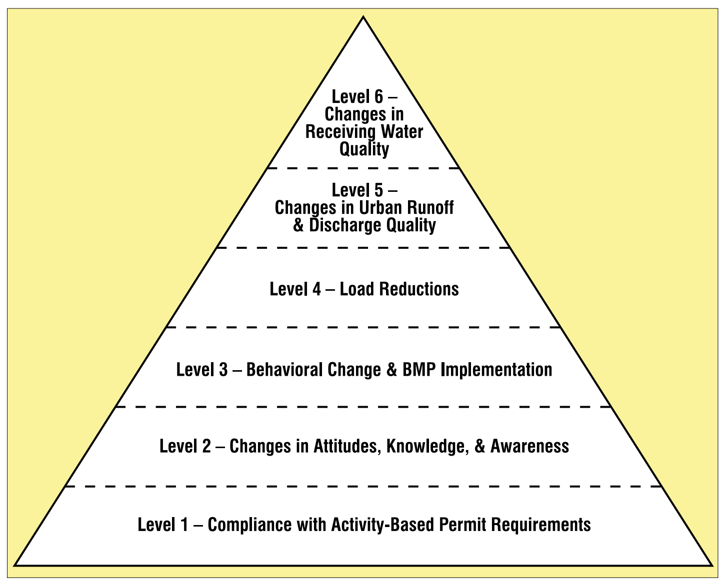


**Figure 2.** Approaches to evaluation of stormwater program effectiveness. (Source: CASQA, 2007)

In this document, we consider the range of evaluation approaches in three groups: program operations, social indicators, and water quality. Every evaluation approach must contain appropriate water quality measures to be meaningful.

## Assess program operations

Assessment of stormwater program operations and activities verifies basic compliance with permit requirements and, more importantly, documents that tangible efforts have been made to reduce the impacts of urban stormwater. This approach to program evaluation can be applied to all of the components of a SWMP.

**Track structural BMP implementation.** Tracking the type and number of structural BMPs installed provides managers with direct feedback on how implementation is progressing and whether goals set forth in the permit are being achieved. Data on BMP specifications, location, date of completion, compliance with permit conditions, and ongoing operation and maintenance may be important to record. See USEPA **Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures: Urban (www.epa.gov/owow/nps/urban.pdf)** for more information on the topic of tracking BMPs implemented in your jurisdiction.

**Document management activities.** Documenting management activities and pollutant source reduction efforts can be as important as tracking structural BMPs. How much material has been collected through street-sweeping and parking lot maintenance? How many site inspections were conducted and what were the results? How many and what type of illicit discharges were identified and eliminated? How many trainings and outreach activities were conducted, and how many people were reached? Baltimore City, Maryland, focuses limited stormwater management resources in a small highly urbanized watershed to demonstrate how making communities more livable can improve water quality. An important part of this effort is to document management activities so that both managers and residents can easily follow progress.

### Evaluate social indicators

Social indicators—changes in knowledge, attitudes, and behavior of people—are important for two reasons. First, some SWMPs may have goals for increasing knowledge and awareness and changing attitudes among groups such as residents, business owners, and municipal employees. Second, social indicators—especially behavior changes—are important intermediate benchmarks in a successful SWMP when many years are needed to measure a water quality response. For more information, see *Developing a Social Component for the NPS Evaluation Framework* (**www.uwex.edu/ces/regionalwaterquality/Flagships/Indicators.htm**). This approach to program evaluation is typically applied to the public education and public participation components of a SWMP.

**Gauge the effects of public education efforts.** Changes in awareness, knowledge, and attitudes can be measured effectively using statistically valid surveys or questionnaires; for example see *Stormwater Knowledge, Attitude and Behaviors: A 2005 Survey of North Carolina Residents* (**www.ncstormwater.org/pdfs/stormwater_survey_12506.pdf**). Other approaches include monitoring attendance at public meetings, tracking requests for information, and counting hits on web sites. Keep in mind that simply reporting the number of meetings held or the number of brochures printed is not an effective method to document changes in stormwater knowledge.

**Assess behavior changes.** Measurement of change in pollution-generating behavior in a watershed can be an important indicator of progress toward achieving SWMP goals. Examples include: changes in lawn fertilizer sales in response to a publicity campaign, pounds of hazardous waste turned in at collection events, participation in streambank clean-up events, and sign-ups for environmental action pledges.

## Monitor water quality

Water quality monitoring is the most direct—and usually the best—approach to evaluating the effectiveness of a SWMP. Program evaluation through water quality monitoring can apply to several of the SWMP components, including illicit discharge detection, construction site runoff control and post-construction runoff control. The collection of water quality data (along with BMP performance data) would be especially useful for discharges to an impaired water body with an approved TMDL. (For more information about the TMDL program, visit **www.epa.gov/owow/tmdl**). Detailed guidance on design and operation of monitoring is available elsewhere, e.g., *USDA-NRCS National Handbook of Water Quality Monitoring* **(ftp://ftp.wcc.nrcs.usda.gov/downloads/wqam/wqm1.pdf)** and *EPA Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (Sept. 1997, EPA 841-B-96-004).

Water quality monitoring approaches range from qualitative observations to highly quantitative measurements, covering areas as small as individual BMPs to large receiving waters such as lakes or estuaries. A good monitoring program for evaluation of SWMP effectiveness will probably contain several elements at various levels of detail and scale. Before embarking on new monitoring, however, it is important to collect and evaluate historic and current data from existing monitoring activities. Data from state 305(b) assessments, 303(d) lists, and published TMDLs, ongoing state and federal agency monitoring programs, water supply intake testing, and watershed volunteer groups, for example, can be useful both in designing a monitoring program and in supplementing program results.

Monitoring can focus on **biological** (e.g., *E. coli*, fish), **physical** (e.g., flow, suspended sediment, streambank stability), or **chemical** (e.g., phosphorus, trace metals) dimensions of the water resource. Measured water quality variables should be directly linked to both the pollutant sources and the BMPs being implemented. In general, a monitoring program should focus on selecting a few good water quality variables to measure well, rather than trying to track a long list of indicators. For example, for a swimming beach impaired by bacteria, it would be appropriate to monitor the swimming area, nearby storm drain outfalls, and tributary flows for *E. coli*. If stream channel blow-outs are an issue and BMPs addressing excessive flows are implemented, monitoring of streamflow and channel cross-section conditions would be a good choice. For algal blooms, monitoring of nutrient concentrations and loads to the receiving water might be appropriate.

Water quality monitoring must take hydrologic variation into account. Most stormwater pollution processes are driven by rainfall that varies from year to year. If several dry years follow implementation of a SWMP, the program may appear to be highly effective in reducing pollutant loads simply because runoff is unusually low. Conversely, several years of wet weather could result in higher pollutant loads simply because of increased runoff volume despite BMP implementation. Consequently, it is important to monitor precipitation and streamflow to help interpret results from all but a few highly qualitative monitoring approaches.

MS4s can take a variety of monitoring approaches to evaluate their SWMP effectiveness. Several common approaches that can be implemented for physical, chemical, and biological dimensions of water quality are listed at the end of this document.

## Feedback: The Iterative Approach to Stormwater Management

Management of stormwater programs is an iterative process, beginning with planning, progressing through implementation and program evaluation, and then returning to the beginning of the cycle with feedback to further program planning. Effectiveness evaluation assesses how well implementation is working and estimates benefits derived from the program for the primary purpose of assessing progress toward program goals and compliance with regulatory requirements. Results can also be used to make practical changes in management strategies. Effective program feedback will enable local governments to guide decisions on shifting priorities to achieve goals more cost-effectively, including modification of activities that need improvement, expansion of effective activities, and cessation of efforts that are no longer productive. Results of SWMP evaluation should be presented to decision-makers in a clear manner that addresses the questions formulated when the evaluation plan was designed.

### Reporting

Annual reports are a good place to summarize evaluation results and to take stock of what is working and what is not. Data gathered throughout the year should be used to answer critical questions such as:

- What is the current status in meeting stormwater goals and NPDES regulatory requirements?
- What are the estimated load reductions and other benefits of BMP implementation?
- What are the costs associated with program implementation?
- How do the costs of program implementation relate to water quality changes?
- What stormwater program changes are necessary to meet the stated goals?

The Baltimore City, Maryland MS4 2005 NPDES permit, for example, requires the permittee to provide an annual narrative summary describing the results and analyses of program data, including monitoring data accumulated throughout the reporting year. Identification of water quality improvements or degradation is a key part of this requirement.

Fourth-year reports are a good opportunity to use data gathered under the entire permit period to guide future management direction. Continuation of a NPDES permit typically requires the permittee to submit with its permit renewal application a summary of its SWMP describing how water quality goals are being achieved. Information in the application would include measured pollutant load reductions resulting from SWMP implementation and achievement of other benchmarks or water quality standards. Analysis of evaluation data is also used to justify or support changes in the permit and SWMP.

### Feedback to the stormwater management program

NPDES regulations require assessment and revision of the stormwater management program in order to continue, to the maximum extent practicable, to not cause or contribute to water quality standards exceedances. As part of the iterative management process, stormwater program activities should be adjusted based on the results of an effectiveness evaluation. If a management goal has been achieved, effort in this area might be reduced to a maintenance level and resources reallocated to another pollutant or goal. If a goal has not been achieved, or satisfactory progress has not been made, additional resources can be applied and new strategies implemented. Such adjustments provide the direction for a municipality's permit renewal and will ensure progress toward program goals.

Effectiveness evaluation can also apply to ongoing stormwater programs through the process of adaptive management. Through this, evaluation results on program operations, social or water quality can provide rapid feedback to guide management activities. For example, an MS4 might establish dry weather action levels—or targets—for water quality constituents such as turbidity, phosphorus, and trace metals in tributaries draining to receiving water. Exceedance of an action level in samples taken from a tributary during dry weather would trigger an immediate investigation upstream to find and eliminate illicit connections and illegal discharges. Dry weather action levels would be reviewed and updated annually based on monitoring data and progress toward meeting SWMP goals.

In another example (Figure 3), coastal beaches and storm drains discharging near them are monitored for fecal bacteria. When compared against storm drain action levels for bacteria (sampled at the storm drain) and bacteria water quality criteria for body contact recreation (sampled in the open coastal receiving water), results of the paired samples guide management decisions on actions needed to protect the beach and follow up on sources of high bacteria counts.

Multi-faceted stormwater management programs can be evaluated as well. Baltimore City's NPDES stormwater permit requires it to restore a watershed or combination of watersheds containing 10% of the City's total impervious area during each five-year permit. The City conducts comprehensive watershed assessments and goals for restoration are developed based on

| | | Beach | |
|---|---|---|---|
| | | **Meets bacteria criteria** | **Fails to meet bacteria criteria** |
| **Storm drain discharge** | Below bacteria action level | No action required | Storm drain discharge not causing beach impairment; continue to monitor and investigate other sources |
| | Above bacteria action level | Storm drain discharge not causing beach impairment; investigate storm drain sources | Storm drain discharge causing beach impairment; investigate storm drain sources ASAP |

**Figure 3.** Decision table for storm drain and beach bacteria levels.

severity of water quality problems, input form local watershed associations, the possibility for inter-jurisdictional cooperation, and the availability of restoration opportunities. One restoration priority is Watershed 263 (**www.cwp.org/RR_Photos/Baltimore_City_profile_sheet.pdf**) where Baltimore City plans to restore a degraded stream system and simultaneously address other social and economic problems associated with older urban environments. The goals in this watershed include; replacing school yard asphalt with green infrastructure to filter stormwater; replacement of sidewalk sections with trees to remove nutrients and reduce the "heat island" effect; conversion of vacant abandoned lots into gardens for local residents to use; reduce the buildup of trash and litter through increased municipal street sweeping; and installing innovative ultra-urban BMPs wherever possible. A catch basin downstream of all of these activities will be monitored for water quality and compared to a similar watershed in the City with no controls. Since the installation of BMPs will be progressive, monitoring data will show the effectiveness of differing management strategies. Information will be fed back into future management plans for this watershed and others across the City to ensure that stormwater is being controlled to the maximum extent practicable.

In summary, a municipal stormwater management program needs to set clear goals and identify appropriate monitoring methods to evaluate those goals in order to assess the effectiveness of the stormwater program in protecting water quality.

## Additional Resources

### Monitoring/Evaluation Guidance or References

California Stormwater Quality Association (CASQA), 2007, *Municipal Stormwater Program Effectiveness Assessment Guidance*. Available at **www.casqa.org**

Southern California Coastal Water Research Project, *Model Monitoring Program for Municipal Separate Storm Sewer Systems in Southern California*. **ftp://ftp.sccwrp.org/pub/download/PDFs/419_smc_mm.pdf**

EPA, 1992, NPDES Stormwater Sampling Guidance Document, EPA 833-B-92-001. **www.epa.gov/npdes/pubs/owm0093.pdf**

Center for Watershed Protection, *Smart Watershed Benchmarking Tool*. Available at **www.cwp.org**

Chesapeake Bay Program, *BMP Efficiencies and Definitions*. **www.chesapeakebay.net/pubs/subcommittee/nsc/uswg/BMP_Pollutant_Removal_Efficiencies.pdf**

International Stormwater BMP Database, *Development of Performance Measures: Determining Urban Stormwater Best Management Practice Removal Efficiencies* (**www.bmpdatabase.org/docs/task3_1.pdf**) and *Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements* (**www.bmpdatabase.org/docs/Urban%20Stormwater%20BMP%20Performance%20Monitoring.pdf**)

Stormwater Manager's Resource Center, *Environmental Indicator Profile Sheet: BMP Performance Monitoring*. **www.stormwatercenter.net/monitoring%20and%20assessment/ind%20profiles/IndPros25.pdf**

### State/Municipal examples of monitoring/evaluation programs

Baltimore County, *Watershed Management and Monitoring*. **www.baltimorecountymd.gov/Agencies/environment/watersheds/ep_watershed_monitoring.html**

City of Hialeah, FL *Stormwater Utility Monitoring Program*. **http://hialeahfl.gov/dept/streets/stormwater/plans/monitoring**

Maryland Watershed Restoration Action Strategy. **www.dnr.state.md.us/watersheds/surf/proj/wras.html**

Ventura, California, MS4 Permit **www.swrcb.ca.gov/rwqcb4/html/programs/stormwater/venturaMs4.html**

## References

National Research Council (NRC), 2004. *Confronting the Nation's Water Problems: The Role of Research*, National Academies Press, Washington, D.C.

Schwarzenbach, R.P., B. I. Escher, K. Fenner, T. B. Hofstetter, C. A. Johnson, U. von Gunten, B. Wehrli. 2006."The Challenge of Micropollutants in Aquatic Systems" Science, volume 313, p1072.

Vaux, H. 2005 "Water Resources Research in the 21st Century", *Journal of Contemporary Water Research and Education*, Issue 131, pp 2-12.

## Contacts

- U.S. EPA—Paula Estornell
  **estornell.paula@epa.gov**
- Maryland—Ray Bahr
  **rbahr@mde.state.md.us**
- Virginia—Douglas Fritz
  **Doug.Fritz@dcr.virginia.gov**

**NOTE:** This document is not law or regulation; it provides recommendations and explanations that MS4s may consider in determining how to comply with requirements of the CWA and NPDES permit requirements.

## Useful Water Quality Monitoring Approaches for Evaluation of SWMPs

**Visual observations.** Some water quality conditions can be assessed by visual (qualitative) observations of controls, outfalls or receiving waters. Searching for and correcting illicit discharges through observation of oil and grease sheens, floatables, or odors at outfalls is one example. Progress in streambank stabilization and channel restoration might be monitored by regular photography of critical locations. In general, qualitative observations should be supplemented by quantitative measurements where possible, such as with dry weather sampling at outfalls or regular surveys of representative stream cross-sections. The City of Albuquerque MS4 Floatable & Gross Pollutant Study (**www.cabq.gov/flood/pdf/FINALREPORT-OCTOBER2005.pdf**) is an example of a systematic approach to qualitative observations of water quality conditions. Examples of survey techniques for streambank assessment can be found in the Maryland Stream Corridor Assessment Survey (**www.dnr.maryland.gov/streams/pubs/surveyprotocols2.pdf**) and the USACE/USEPA Review of protocols for stream assessment (**www.mitigationactionplan.gov/Physical%20Stream%20Assessment%20Sept%2004%20Final.pdf**).

**BMP performance monitoring.** Monitoring of individual BMP performance provides a direct measure of pollutant reduction efficiency of these key components of a SWMP. Conceptually, BMP input/output monitoring is simple—measure pollutant concentrations or loads entering and leaving a wet pond for example, and compute the difference. In practice, BMP monitoring is more complex, requiring careful collection of data concerning storm and runoff characteristics and information on BMP attributes, as well as water quality information. There are several sources of information on BMP performance and on protocols for collecting, storing, analyzing, and reporting BMP monitoring data, including the National Stormwater BMP Database (**www.bmpdatabase.org**) and the USEPA and ASCE *Urban Stormwater BMP Performance Monitoring Manual*. Some examples of individual BMP monitoring studies can be found at the Villanova Urban Stormwater Partnership (**www3.villanova.edu/VUSP/index.html**).

**Probability monitoring.** Monitoring sites can be selected across a broad geographic area according to some statistical design to broadly characterize water quality conditions in a watershed or to identify possible contamination hotspots. Site selection could be random to achieve wide spatial coverage or stratified to focus monitoring on particular environment types or represent specific target populations. Data from a statistical sample of stream riffle sites across a watershed could be used to assess the overall condition of watershed macroinvertebrate communities. A monitoring program addressing sediment toxicity in a bay might geographically direct sampling to ensure that sediments in different depositional environments or with different physical characteristics are sampled, or that samples are collected within the areas affected by discharges from major tributaries. Results of probability monitoring can be used to guide SWMP implementation efforts and to assess long-term trends in response to SWMP implementation. An example of a probability design applied to evaluating sediment toxicity is found in the NOAA report Magnitude and Extent of Contaminated Sediment and Toxicity in Chesapeake Bay (**ccma.nos.noaa.gov/publications/NCCOSTM47.pdf**).

**Short-term extensive network monitoring.** Short-term grab-sampling at the outlets of numerous small watersheds or other drainages within a large MS4 can identify impaired waters and rank areas for implementation priority. Data collected simultaneously across the MS4 can help characterize the geographical distribution of pollutant sources. The City of Los Angeles monitors a network of shoreline stations in Santa Monica Bay for bacteria to identify stormwater impacts on recreational uses of the bay. This approach can apply not only to streams draining small watersheds but also to storm drains during both wet-weather and dry-weather conditions. If continued over several years, this kind of monitoring can be a good opportunity for volunteer groups to participate in the SWMP evaluation process. Data collected by volunteers could be reported separately or incorporated within "official" data sets used for regulatory purposes depending upon the methods used and level of training provided to volunteers.

**Site-specific monitoring.** High-value resources such as popular swimming beaches, important shellfish beds, or high-priority habitats could require specific monitoring to regularly assess the status of use support. Similarly, known high-priority pollutant sources or hotspots of impairment like contaminated aquatic sediments, an eroding stream channel threatening property, or a stream reach with a degraded fish population could be monitored to assess progress in restoration. Depending on the situation, such monitoring can be done in the critical area itself to assess its condition or upstream and downstream of the area to evaluate changes in pollutant stressors. Fairfax County's MS4 program conducts an Industrial and High-Risk Runoff monitoring program to identify and investigate industrial and other high-risk sites to determine if they are contributing substantial pollutant loadings to the MS4. The San Diego Bay MS4 permittees operate a Toxic Hot Spots Monitoring Program to locate and track areas of aquatic sediment contamination related to discharges from MS4s around the Bay.

**Long-term fixed stations.** Permanent monitoring stations at major discharges from an MS4 or on a receiving water above and below an MS4 can be used to measure changes in pollutant loads discharged from the MS4. Such stations are usually located where it is easy to measure flow and collect representative samples. Accurate load measurement requires consideration of many factors including patterns of hydrologic variation, seasonal patterns of pollutant concentrations, and desired statistical power; it is advisable to consult a monitoring expert before setting up a sample program to monitor pollutant loads. Flow, concentration, and load data from long-term fixed stations can be used for many purposes, including assessing compliance with water quality standards, collection of representative data from drainage areas that are undergoing similar activities and where the discharges are expected to be of similar quality as required in some MS4s under Phase I rules, documenting water quality trends, and marking progress toward meeting pollutant load goals, e.g., for a TMDL. The Los Angeles County stormwater monitoring program operates a system of mass emissions stations (**www.ladpw.com/WMD/npdes/Int_report/Section_1.pdf**) to update estimated pollutant loads to the ocean and to document long-term trends in pollutant concentrations. The San Diego region urban runoff monitoring program maintains similar long-term mass loading stations (**www.projectcleanwater.org/pdf/science_mon/2003-2004_monitoring_summary.pdf**) that regular assessment of the biological communities as well as chemical pollutant loads in major drainages.

**Receiving water monitoring.** Protection of a water body receiving discharges from an MS4 is often the ultimate goal of stormwater management. However, an MS4 may not be the only stormwater discharge into a water body, and achievement of the MS4's discharge quality goals may not eliminate the impairment in the receiving water. It may nevertheless be important to monitor water quality in the river, lake, estuary, or bay that receives its discharge, especially if localized impacts can be identified. Evaluation of the effectiveness of a SWMP on maintaining recreational benefits, for example, might involve monitoring both storm drains and swimming beaches for *E. coli*. If a goal of a SWMP is to reduce the impacts of toxic materials delivered in stormwater, a program monitoring a combination of water and sediment chemistry, sediment toxicity, and benthic communities in the receiving water might be appropriate.