This PDF file is an excerpt from the EPA guidance document entitled *National Management Measures to Control Nonpoint Source Pollution from Urban Areas* (November 2005, EPA-841-B-05-004). The full guidance can be downloaded from http://www.epa.gov/owow/nps/urbanmm/index.html.

National Management Measures to Control Nonpoint Source Pollution from Urban Areas

Management Measure 2: Watershed Assessment

November 2005

MANAGEMENT MEASURE 2
WATERSHED ASSESSMENT

2.1 Management Measure

Develop and implement a watershed assessment program to:

- Characterize watershed conditions
- Establish a set of watershed indicators

2.2 Management Measure Description and Selection

2.2.1 Description

Watershed assessment and monitoring are tools used to characterize water quality and to identify trends in water quality over time (USEPA, 1998c). This management measure describes methods that can be used to determine the health of water bodies by using watershed indicators that measure physical, chemical, and biological conditions.

2.2.2 Management Measure Selection

2.2.2.1 Overview

Watershed assessment is a critical component of a watershed-based approach to managing receiving waters. Watershed assessment is needed to develop both protection and restoration strategies, identify priorities, and adjust management prescriptions based on trend analyses. Both rapid and extensive assessments can be performed to determine water body status and trends. Numerous metrics, such as EPA's *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*; *Lake and Reservoir Bioassessment and Biocriteria*; and *Estuarine and Coastal Marine Waters:Bioassessment and Biocriteria Guidance,* are available for determining water body status. In general, the objectives, available funding, and expertise of the assessors will determine the level of assessment conducted.

An assessment and monitoring program is important for effective watershed management because it provides a basis for decisions and actions, and allows managers to continually reassess progress and redefine goals and priorities. Monitoring enables water quality managers to identify existing or emerging problems. Monitoring also facilitates responses to emergencies such as spills and floods, and helps water quality managers target specific pollution prevention or remediation programs to address these problems. Assessment and monitoring can be used to determine whether program goals, such as compliance with pollution regulations and implementation of effective pollution control actions, are being met. Monitoring programs should be established based on indicators of human health and aquatic life. A large number of documents and case studies are available to use as resources (see Information Resources at the end of this chapter).

2.2.2.2 Examples of monitoring and assessment programs and methodologies

State pollution control agencies, Indian tribes, local governments, and federal agencies typically are responsible for watershed assessment and monitoring activities. These entities monitor water quality and identify waters and watersheds that do not meet clean water goals through various programs, which include the following:

- Unified Watershed Assessments (UWAs), developed by states in 1999 to assess the health of watersheds and identify watersheds in need of restoration (i.e., watersheds that do not currently meet clean water and other natural resource goals). UWAs also identified watersheds that need preventive action to sustain water quality using ongoing state, tribal, and federal programs, as well as pristine or sensitive watersheds on federal lands that need an extra measure of protection. The results of these assessments can be obtained from state environmental protection departments.

- Water Quality Reporting Program, established under CWA section 305(b), which mandates the collection of water quality information and reporting on the condition of waters every two years.

- 303(d) program, established under CWA section 303(d), which mandates the use of monitoring and other water quality information to develop lists of waters that do not meet water quality standards.

- Nonpoint Source Program, established under CWA section 319, which involves identifying waterbodies that are impaired by nonpoint sources.

- Source Water Protection Program, established under the Safe Drinking Water Act, which involves assessments of drinking water sources that form a basis for actions to protect such sources.

- State Revolving Fund (SRF) Program, which involves developing and prioritizing clean water projects.

- Federal Emergency Management Agency's National Flood Insurance Program, which involves conducting floodplain studies and developing mitigation plans.

- Marine pollution control programs, which include identification of coastal water quality problem areas as part of efforts to reduce polluted runoff to coastal waters.

- Wetlands Program, which involves developing assessments of wetland areas that need special attention or protection.

One example of a state assessment program comes from the Commonwealth of Pennsylvania. The state's Act 167 requires that watershed assessments consider the following objectives (Pennsylvania DEP, 1999):

- Implement nonpoint source pollutant removal methodologies
- Maintain ground water recharge
- Reduce channel erosion
- Manage overbank flood events
- Manage extreme flood events

The state established four subtasks to achieve these objectives:

- Determine the water quality design storm
- Determine the runoff capture design storm (recharge/retention)
- Establish streambank erosion requirements
- Establish overbank/extreme event requirements (release rates)

To accomplish these subtasks, Pennsylvania developed a process that will ultimately lead to the development of standards for stream bank erosion, infiltration, water quality, overbank flooding, and extreme storm events. The assessment fits into a larger framework for integrated watershed resource management, which includes the following steps:

- Watershed assessment/prioritization
- Watershed evaluation
- Restoration/protection plan development
- Financial resources secured
- Restoration/protection plan implementation
- Results compared to goals

2.3 Management Practices

2.3.1 Characterize Watershed Conditions

2.3.1.1 Establish a reference condition

It is important to establish a reference that characterizes the relatively unimpaired condition of the water body. The reference condition establishes a basis for making comparisons between sites, and is essential for detecting impairment. Conversely, if a water body is found to be impaired, it is important to have an understanding of natural background concentrations before undergoing costly efforts to mitigate anthropogenic inputs.

There are two types of reference conditions—site-specific and regional. Site-specific reference conditions are determined from one or more sites in a watershed or stream from a point where discharges (nonpoint source, point source, or a combination) are occurring. Regional reference conditions typically are established from a population of relatively unimpaired sites within a relatively homogeneous region and habitat type. An ecoregional framework based on land surface form, soil, potential natural vegetation, and land use has been developed by Omerink (1987) to interpret spatial patterns in data (USEPA, 1999); these ecoregions can be used to help develop a reference condition for a relatively homogeneous region. Regional reference conditions are often preferable to site-specific conditions because they are more widely applicable, they produce a larger sample of unimpaired sites, and they allow more robust statistical comparisons.

The U.S. Geological Survey (USGS) developed a model for determining ecoregional background concentrations of nitrogen and phosphorus as a function of annual runoff, basin size, atmospheric nitrogen deposition rate, and region-specific factors. Background total nitrogen (TN) concentrations ranged from 0.02 mg/L in the western United States to more than 0.5 mg/L in the southeastern United States. Background total phosphorus concentrations ranged from less than 0.0006 mg/L in the western United States to more than 0.08 mg/L in the Great Plains (Smith et al., 2003).

2.3.1.2 Model pollutant sources and loads

Watershed managers can use models to estimate storm water pollutant loads in receiving waterbodies. Modeling of pollutant loadings can help watershed managers target specific areas for nonpoint source control. More specifically, runoff models can accomplish one or more of the following:

- Simulate the generation and movement of water and pollutants from their point of origin to a place of treatment or disposal into receiving waters
- Perform frequency analyses on water quality parameters to determine the return periods of concentrations or loads
- Provide input for an analysis of receiving water quality
- Determine the relative effects of pollution control options
- Determine optimal locations and combinations of management practices
- Provide input to cost-benefit analyses

Selecting the model that is most appropriate to fulfill watershed management goals requires careful consideration of trade-offs with respect to level of detail, data requirements, cost, and accuracy. For example, a high level of detail requires a more complex model. Data requirements are also important: a complex model might require more data than one has or is willing to collect. Sometimes published data can be substituted for field-collected data. The advantage of using published data is avoidance of costly, labor-intensive fieldwork. A major data source is the USEPA National Urban Runoff Program (NURP) database, which contains concentration values measured for 30 cities (USEPA, 1983). Information generally required for models includes the following:

Quantity Parameters

- Rainfall information
- Catchment area

- Imperviousness
- Runoff coefficient

Quality Parameters

- Constant concentrations (event mean concentrations or EMCs)
- Constituent median and coefficient of variation (CV)
- Regression relationships
- Buildup and wash-off parameters

Calibration/Verification Parameters

- Measured rainfall
- Measured runoff
- Water quality samples

While model calibration is beneficial, models generally used for watershed assessments do not strictly require calibration and precision to determine compliance with permit requirements or Clean Water Act requirements. Therefore, these models can be simpler and less expensive, while still providing watershed managers with information on pollutant loadings and sources.

Another consideration when choosing a model is its reputation. Watershed managers should become familiar with the model's concepts, assumptions, and limitations, as well as the experiences of other users. In choosing the most appropriate model, watershed managers should:

- Use the simplest model that will satisfy the project's objectives
- Use a model that is consistent with available data
- Predict only the water quality parameters of interest
- Make predictions over the broadest time scale that will satisfy the objectives
- Become familiar with the characteristics and assumptions of the model

Using pollutant loading models has advantages and disadvantages. Measured data are preferable to simulated data, especially when characterizing the magnitude of a pollution problem, because accurate concentration values are important. Models cannot substitute for good field-sampling programs, but they can be used to extrapolate and to augment field-sampling results.

To ensure quality results from a modeling effort, sensitivity analyses should be performed when uncertainty exists regarding data quality or model assumptions. Also, if possible, models should be calibrated and validated using measured values (field monitoring). This process is labor-intensive and can add to the expense of the modeling effort, but it is worthwhile to ensure accuracy when making management decisions.

A detailed description of water quality models of all types can be found in the *Compendium of Tools for Watershed Assessment and TMDL Development* (USEPA, 1997a). In general, watershed managers can choose from several different methodologies depending on the specific goals of the modeling effort, including the following:

– *Constant concentration or published yield values*. This method involves calculating loads as the product of the proportion of land area in a particular land use and the published loading rates for that land use. A disadvantage is that the catchments from which the published values are derived may not represent the catchment of interest. However, the calculations are very simple and easy to use for general loading assessments. Options include coupling constant concentrations with a hydrologic model so that loading will vary with flow, or calculating a confidence interval for loading to determine the level of uncertainty that can be tolerated before conclusions change. This method might be robust enough to answer straightforward management questions despite assumptions.

– *Unit loads.* This method involves calculation of the mass of the pollutant of interest per area of watershed per unit of time. It is site-specific (demographic and hydrologic factors are important determinants) and is based on average runoff volume (not coupled to a hydrologic model). Also, loading rates are variable and difficult to extrapolate from one area to another. This is a relatively simple method that does not require a great deal of data collection. Published values can be used at the expense of some accuracy.

– *Simple empirical model*. This method uses spreadsheet calculations to combine precipitation data with a runoff coefficient and land use-specific constant concentrations. This method easily simulates a mixture of land uses, allowing the study area to extend over a large area without compromising the quality of results. The model can quantify relative contributions from different land uses, and can be expanded readily to incorporate more complex calculations. The hydrologic modeling is very simple, however, and the model does not necessarily work well for short-term predictions. Also, using published constant concentrations in the model introduces errors; locally measured concentrations would greatly improve the model's performance.

– *Statistical method*. The statistical method uses a derived, usually lognormal frequency distribution of estimated mean concentrations (EMCs) of pollutants. This method is useful for assessing the frequency of exceedance of water quality standards, but it has weak hydrologic assumptions. The model can be coupled with stream flow, storage, and treatment data to improve accuracy and estimate the effects of management practices on water quality. Estimates can be improved by using measured EMC values rather than published ones. EMCs can vary widely because of seasonal and watershed land use variations, and might require at least one year and often two years of field verification to be statistically significant.

– *Regression equations.* Regression equations are published equations from the U.S. Geological Survey (USGS) (Driver and Tasker, 1990) that relate loads and EMCs to catchment, demographic, and hydrologic characteristics. They usually incorporate total storm loads and runoff flows or volumes. They require neither preliminary estimates of EMCs nor local monitoring data, and standard errors are provided for a measure of uncertainty. They are more or less accurate depending on the pollutant of interest and the level of precipitation (arid vs. humid). The equations predict only the mean rather than a frequency distribution of EMCs or loads, and they are subject to error when extrapolating to conditions that are different from those used to derive the equations. A related approach uses rating curves to relate pollutant loads or EMCs to flow rates or volumes, thereby allowing quantification of intra-storm variations in these measures.

- *Buildup and washoff.* This method is used to determine loadings by estimating the buildup of pollutants during dry weather and estimating washoff during rainfall events. This method quantifies intra-storm variations in pollutant loading and is good for comparing the relative effects of management practices. However, processes of sediment transport and erosion that are fundamental to this method are still poorly understood. Moreover, this method requires averaging the extent of pollutant buildup on heterogeneous urban surfaces. This averaging can result in erroneous predictions because actual values vary widely over relatively small areas. Assumptions include linear buildup and generic washoff coefficients that might or might not represent actual conditions. Estimates can be improved by using local monitoring data such as site-specific buildup and washoff estimates for model calibration.

- *Mechanistic models*. Mechanistic models contain hydrologic and water quality components and use mathematical algorithms to represent the mechanisms that generate and transport runoff and contaminants. They are the most comprehensive models in that they incorporate many variables to produce the best estimations of the numerous mechanisms that affect pollutant loading. However, they require substantial local data to set and verify parameters, and they demand both skill and commitment from staff. Users must ensure that the models are documented, supported, and proven through the experience of other users. There are several commercially available mechanistic models, including STORM by the U.S. Army Corps of Engineers and SWMM and HSPF by EPA. (See Web references and resources below.)

The confounding factors for load estimation models are:

- Inputs from atmospheric deposition (H_2SO_4, NO_3, etc.)

- Ground water inputs

- Pervious surfaces that confound runoff estimates

- Sediment transport and erosion

- Pollutants adsorbed to solids. These pollutants, namely metals and organics, can be estimated as a proportion of the total suspended solids concentration or annual load.

- Point sources in the watershed (e.g., industrial and commercial sources and publicly owned treatment works)

All of these factors can be included in the surface runoff model at the expense of time and simplicity and can improve the accuracy of loading estimates. Before they are included, consideration should be given to the level of detail needed for the analysis.

Application of a GIS Decision Support Tool to Urban Watershed Management in Fulton County, Georgia

The high density of development in Sandy Springs, a suburban area northwest of Atlanta, reduces the opportunities for new, areawide management practices such as regional detention ponds. Instead, multiple on-site or local management practices are recommended. In response to the need for developing storm water and water quality plans, a GIS application called LORELEI was developed (Slawecki et al., no date). LORELEI allows users to rapidly develop and compare watershed management alternatives for catchments with hundreds of management practices. It was developed to

- Keep track of hundreds of candidate management practice sites.
- Develop management scenarios using different combinations of management practices.
- Evaluate the practices' impact on water quality.
- Compare scenario results.
- Present the information to a wide range of people.

LORELEI provides decision support through data management, scenario development and evaluation, and enhanced involvement in and understanding of the watershed management process. LORELEI stores data about potential management practice locations and associated costs, practice types, and effectiveness data, as well as standard geographic information such as natural features, watershed delineations, and property ownership. Through scenario development, the program allows for rapid selection of individual projects and entire categories of management practices to build various scenarios. LORELEI then evaluates the scenarios to estimate and compare their costs and benefits. Finally, with enhanced involvement and understanding, LORELEI uses GIS to give decision makers an opportunity to participate directly in the watershed management process and to clearly understand issues, components, and cost and benefit implications of different management scenarios. GIS linkages allow for fine-tuning of the scenarios to determine the cost and performance effects of different suggestions made by participants at public meetings.

2.3.1.3 Model receiving water quality

Receiving water quality models identify impacts from runoff inputs and help watershed managers determine whether receiving waters meet water quality standards. Usually, computer models are used because of the complexity of calculations. Models are available for streams, lakes, reservoirs, estuaries, bays, and coastal segments. Most models couple quantity (hydrodynamic) and quality parameters, but some consider these parameters separately.

A useful water resource impact model is the Long-Term Hydrologic Impact Assessment (L-THIA), which was developed by Purdue University (2000) for land use planners to provide site-specific estimates of changes in runoff, recharge, and nonpoint source pollution resulting from past or proposed land use changes. The model uses regional climate data and user-provided location, land use, and soil group data for up to three different scenarios (past, present, and future). The results are in the form of tables, bar charts, and pie charts. The model is available at http://danpatch.ecn.purdue.edu/~sprawl/LTHIA7.

The best sources of information for receiving water quality models are either government agencies or product vendors. The following is a list of government agencies that can provide the information needed to choose the most appropriate model:

- USEPA Center for Exposure Assessment Modeling, Athens, Georgia
- US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi
- US Army Corps of Engineers, Hydrologic Engineering Center, Davis, California
- USGS, Reston, Virginia
- National Oceanic and Atmospheric Administration (NOAA), Silver Spring, Maryland—estuaries and bays
- Tennessee Valley Authority (TVA), Knoxville, Tennessee—rivers and reservoirs

Additional guidance regarding load estimation and receiving water quality modeling is provided in *Compendium of Tools for Watershed Assessment and TMDL Development* (USEPA, 1997a), which supports the watershed approach by summarizing available techniques and models that assess and predict physical, chemical, and biological conditions in water bodies. This document is intended to provide watershed managers and other users with information helpful for selecting models appropriate to their needs and resources. The *Compendium* includes information on the following:

- A wide range of watershed-scale loading models
- Field-scale loading models
- Receiving water models, including eutrophication/water quality models, toxics models, and hydrodynamic models
- Integrated modeling systems that, for example, link watershed-scale loading with receiving water processes
- Ecological techniques and models that can be used to assess and/or predict the status of habitat, single species, or biological communities

An additional modeling resource is *Modeling of Nonpoint Source Water Quality in Urban and Non-Urban Areas*, which is a major nonpoint source model review effort published by EPA in 1991. It focuses on nonpoint source assessment procedures and modeling techniques for both urban and non-urban land areas (Donigian and Huber, 1991). The report provides detailed reviews of specific methodologies and models, as well as overview discussions and model comparison tables. Simple procedures, such as regression and loading function approaches, are also described in the report, along with complex models like SWMM, HSPF, STORM, CREAMS/GLEAMS, SWRRB, AGNPS, and others. Brief case studies of modeling efforts are summarized, with emphasis on the use of nonpoint and comprehensive watershed models for watershed management activities. This publication can be found at http://yosemite.epa.gov/water/owrccatalog.nsf/0/b28aec046488178585256fc700700b24?OpenDocument.

EPA has assembled a Web site with information about and links to water quality models. This site includes basic information, EPA-supported models, other federal government-supported models, technical guidance for models, and model training and meetings. The Web site can be accessed at http://www.epa.gov/waterscience/wqm/.

2.3.2 Assess Cumulative Effects

A watershed assessment should include an evaluation of cumulative effects, which are combined effects of multiple activities over space or time. Such effects can be difficult to assess because a large number of resources can be affected and often there are multiple pathways through which these effects can occur. In addition, the appropriate spatial and temporal scales for the analysis usually are uncertain. Because many environmental assessments do not take cumulative effects into account, most likely because there is no explicit process for analyzing them, MacDonald (2000) developed a conceptual process to guide their assessment and management. The process is divided into three phases: the scoping phase, the analysis phase, and the implementation and management phase. Within each phase are a group of interrelated steps that, if followed, typically lead to a complete analysis of the cumulative effects on a watershed. The three phases and their steps are shown in Figure 2.1.

2.3.3 Estimate the Effectiveness of Treatment Programs

A useful tool to estimate the effectiveness of treatment practices on water quality is the Watershed Treatment Model (WTM), which was developed by the Center for Watershed Protection (Caraco, 2001). The WTM is a simple model for rapidly assessing how various management programs influence pollutant loadings and/or habitat quality in urban watersheds. It incorporates many simplifying assumptions that allow watershed managers to assess various programs and sources that are not typically tracked in more complex models. The WTM consists of two basic components: pollutant sources and treatment options. The pollutant sources component estimates the load from a watershed without treatment measures in place. It assesses two broad categories of pollutant sources: primary land uses and secondary sources. The treatment options component estimates the reduction in the uncontrolled load resulting from a wide range of treatment measures. Treatment options are broadly defined in the model as storm water treatment practices and storm water management programs. The most current version of the WTM, version 3.0, can track sediment, nutrients, and bacteria. The WTM can be a useful tool for managers who are analyzing the effectiveness of current watershed restoration programs, preparing Total Maximum Daily Loads (TMDLs), or evaluating the watershed benefit of National Pollutant Discharge Elimination System (NPDES) storm water programs. For more information about the WTM, contact the Center by e-mailing center@cwp.org or visit their Web site at http://www.cwp.org.

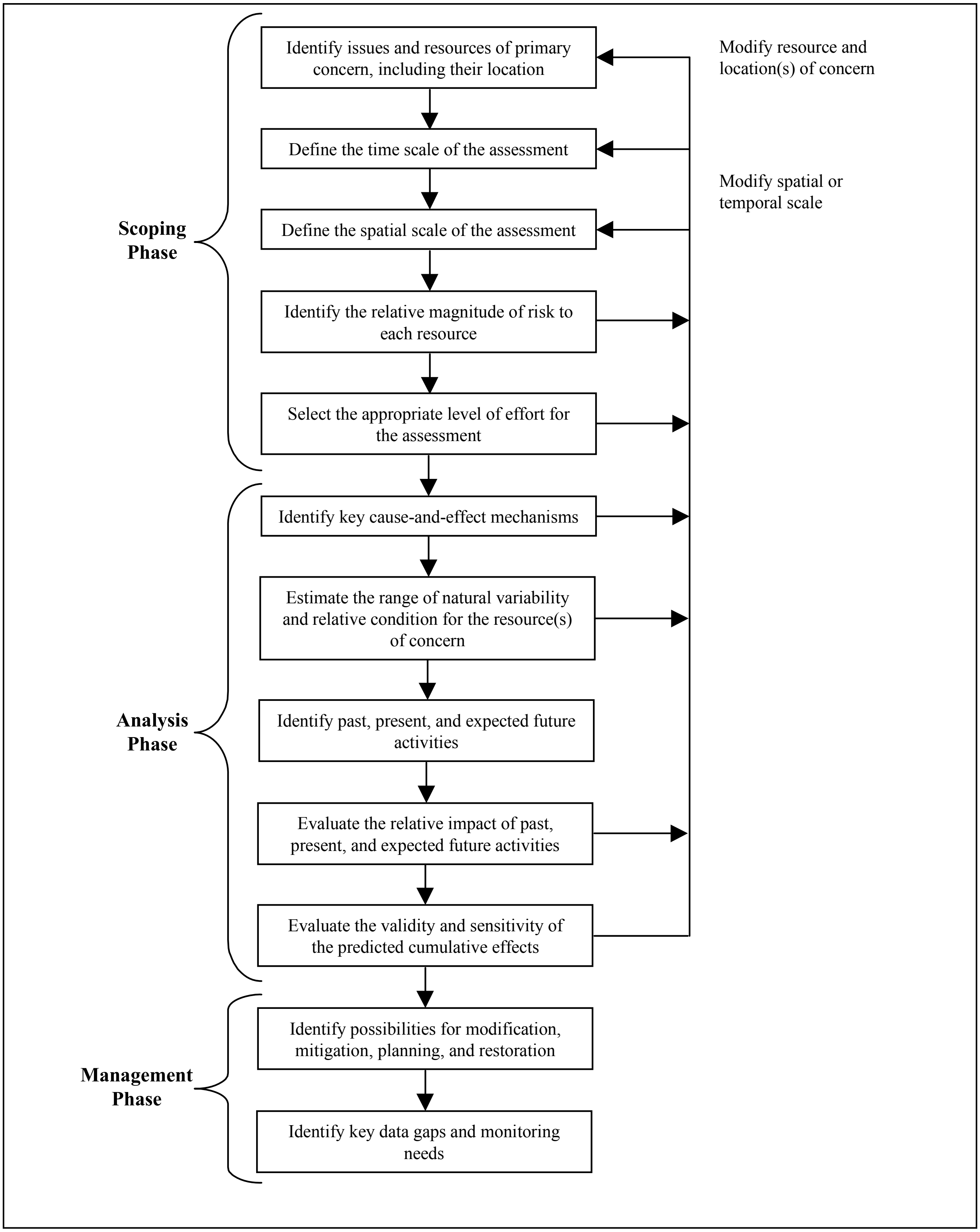

Figure 2.1: Conceptual process for assessing cumulative effects (MacDonald, 2000).

Indicators of Storm Water Program Effectiveness

The Hampton Roads Planning District Commission in Chesapeake, Virginia, has developed a database to track and evaluate various indicators of the effectiveness of the storm water program. The indicators fall into four basic categories: water quality, physical & hydrological, socioeconomic, and programmatic. This database tracks the indicators as listed below (Hillegass, 2003):

- *Water quality*: pollutant loadings for nutrients
- *Physical and hydrological*: acres of open space land protected from development
- *Socioeconomic*: inventory of public education efforts, such as number of publications produced and distributed, Web site hits, media campaigns, stream cleanup activities
- *Programmatic*: the following are programmatic indicators:
  - Number of approved erosion and sediment control plans and disturbed acreage
  - Number of inspections and enforcement actions for erosion and sediment controls
  - Number of citizen calls about flooding and drainage problems, and number of responses
  - Cost and number of flooding and drainage projects
  - Investigative and corrective actions for illicit discharge detection and elimination
  - Operation and maintenance activities
  - Number of approved site and subdivision plans, and acreage served
  - Number and type of BMPs installed, the number of acres served by each BMP, and installation and maintenance information

Under the Phase II Storm Water Rule, communities are required to go beyond chemical pollutant monitoring to track the implementation of storm water management programs. This database can serve as a useful tool in fulfilling this requirement and can be used as a model for the development of varied indicators of program success (Hillegass, 2003).

2.3.4 Establish a Set of Watershed Indicators

Watershed indicators are monitoring parameters or techniques used to measure the effectiveness of management practices in meeting watershed and subwatershed goals and objectives. Indicators range from complex chemical or toxicity testing methods to simple public perception surveys. Watershed managers can choose one or more of these indicators to better focus their monitoring efforts. Regardless of the parameters or technique, to be effective, an indicator must accomplish the following:

- Reflect a measurable attribute of a watershed goal or subwatershed management objective
- Be measured using scientifically valid protocols, quality controls, and assessment techniques to ensure that results are replicable, consistent, compatible with other data collection efforts, and statistically valid
- Be measured at one or more locations that will adequately characterize “typical” conditions in the management unit and establish reference conditions against which future data comparisons can be made

- Be monitored over a long enough period to establish observable trends
- Be compatible with available finances, personnel, and other resources. The cost of implementing the watershed indicator is an important consideration.

The Center for Watershed Protection and EPA published a reference to help municipalities select a suite of indicators that will most effectively measure conditions in their watershed (Claytor and Brown, 1996). This publication, *Environmental Indicators to Assess Stormwater Control Programs and Practices*, presents profiles with information such as advantages, disadvantages, cost, and applicability for 26 indicators, which include water quality, physical/hydrological, biological, social, programmatic, and site indicators. The document is available online at http://www.cwp.org.

2.3.5 Establish Water Quality Indicators

Conduct water quality monitoring. This type of monitoring involves measuring pollutants in both runoff and baseflow conditions. The most commonly measured constituents are oxygen demand, nutrients, metals, pH, temperature, flow or discharge, solids (e.g., total suspended solids or turbidity), fecal coliform, and a measure of oil and hydrocarbons (e.g., total petroleum hydrocarbons [TPH] or polycyclic aromatic hydrocarbons [PAHs]). Measurements can be taken at management facilities or in receiving waters. This method allows for the identification of trends in water quality over time and can identify areas that are degraded relative to low-impact reference sites. Changes in water quality that result from changes in land use or from the implementation of management practices can be detected to prioritize future conservation or restoration efforts. The specific constituents found in receiving waters can aid in identifying the source of the pollution problem and help target management practices effectively. The methodology for water quality monitoring is well-outlined in specific protocols, and results are quantitative and easy to present and compare to other monitoring databases. However, the monitoring effort must be long-term because of the high variability in constituent concentrations, and it might be expensive because of labor requirements or equipment costs for automation. Volunteer monitoring programs can reduce some of the expense of monitoring while providing the additional benefit of educating the public. EPA's Volunteer Monitoring Web site has more information about volunteer monitoring (http://www.epa.gov/owow/monitoring/volunteer).

(1) *Conduct toxicity testing*. These methods, often called whole effluent toxicity (WET) tests, involve exposing standardized freshwater, marine, and estuarine vertebrates, invertebrates, and plants to water samples to directly measure the adverse effects of effluents. Both acute and short-term chronic effects can be assessed. The test organisms can be either resident species or species that will be restocked or reintroduced. Toxicity reduction evaluation (TRE) can be used to identify the agent of toxicity, which helps to identify the pollutant source and indicates which management practices would be appropriate to treat the problem. Although this method allows managers to distinguish among a range of conditions and chemicals, species' responses vary substantially with respect to the choice of species, location (laboratory or in situ), and duration of the test. Also, chronic toxic effects, which may take a long time to manifest, are not measured with this type of testing. The TRE process can be expensive and is often used to specifically identify pollutants when receiving waters have previously been identified as impaired through other, less-expensive methods.

More information on WET methods is available at http://www.epa.gov/OST/WET. Descriptions and guidance on other analytical methods are provided at http://www.epa.gov/ost/methods (USEPA, 2000d).

(2) *Measure the frequency at which water quality standards are exceeded*. This method is usually based on chemical standards and can be derived from existing data or as part of the biennial 305(b) reporting process. It can identify long-term trends in water quality, storm water impacts, and the effectiveness of management practices. However, because the ability to detect exceedances is highly dependent on the frequency and timing of sample collection, brief periods of exceedance might be missed (during storm flow) and long-term conditions inaccurately represented. Also, exceedance frequencies provide little information about causes and sources of pollution. Costs associated with this method are minimal because data are usually collected through other programs. Guidance and information on EPA and state water quality standards and criteria can be found at http://www.epa.gov/ost/standards (USEPA, 2001c).

(3) *Determine sediment pollutant levels*. This type of monitoring involves the determination of pollutant load carried by sediments and deposited in slow-moving receiving waters. Analysis is usually conducted using spectrophotometry and chromatographic tests of samples from natural or artificial water bodies. The extent of toxicity in sediments can be determined by comparing sample results to reference samples that are known to be relatively unimpacted. Measured pollutant levels can also be compared to existing standards for typical contaminants in sediment (USEPA, 2000d). Using sediment contamination as an indicator of water quality is often confounded by uncertainty related to levels of concern and long-term impacts, the inability to identify pollutant sources, and lag time between discharge and settling. However, long-term trends in sediment pollutant loading can be detected if monitoring is conducted over a long period.

(4) *Measure microbial contamination*. This type of monitoring involves measuring concentrations of microbes such as fecal coliform or *Escherichia coli* to ascertain the probable presence of pathogens in the water column. These pathogens result in the closure of beaches, fishing areas, and shellfish beds. Tracking the frequency of such closures may indicate contamination in effluent from industrial or municipal facilities or septic systems, or runoff from agricultural areas. In areas where no treatment facilities or septic systems are present, runoff can be identified as the main source of pathogens. Measuring microbe concentrations can help determine the effectiveness of management practices in removing this type of contamination from receiving waters.

Trends in beach or shellfish closures over time may indicate a developing problem if high concentrations or counts become more frequent, or they may demonstrate the effectiveness of management efforts if decreasing trends occur. However, many of the bacteria measured have a variety of nonhuman sources, making it difficult to identify the source of the pollution. In addition, they are short-lived in the water column, so depending on when samples are collected, the occurrence of high bacterial concentrations may not be detected even though they are present at certain times (e.g., during storm flows).

Bacterial source tracking refers to a family of methods that can be used to distinguish among sources of fecal contamination and can aid in tracking illicit discharges to storm sewer systems. Bacterial source tracking requires development of a database of known sources against which samples can be compared (Zhang et al., 2003). The methods can be molecular (e.g. DNA fingerprinting, or more specifically, ribotyping, pulsed-field gel electrophoresis [PFGE], polymerase chain reaction, terminal restriction fragment length polymorphism) or non-molecular. Non-molecular procedures can be biochemical (e.g., antibiotic resistance analysis, carbon utilization, F-specific coliphage typing, cell wall fatty acid methyl ester) or chemical (e.g., caffeine detection, optical brightener detection). In general, molecular methods can offer the most precise identification of specific types of sources, but they also have the highest unit costs and the most time-consuming procedures. Biochemical procedures are simpler, less expensive, and faster, and allow a larger number of samples to be analyzed in a shorter period of time (USEPA, 2002). The technology in this subject area is constantly evolving and new procedures and more refined methods may be available as research progresses.

Zhang et al. (2003) described the use of the PFGE method of bacterial source tracking analysis on *E. coli* samples from Four Mile Run in Northern Virginia, which is a highly urbanized watershed with approximately 40 percent impervious surface. Four Mile Run is impaired due to bacterial contamination and has a TMDL in place to control bacterial sources. The PFGE analysis identified that waterfowl contribute 38 percent of the bacteria, humans and pets (combined) accounted for 26 percent, and raccoons contributed 25 percent. Deer (9 percent) and rats (11 percent) also contributed bacteria to Four Mile Run.

DNA testing is an expensive but effective molecular method for identifying the primary animal or animals (human, duck, dog, etc.) that contribute microbes to the water column. More information about bacterial source tracking can be found in a two-part article in *Stormwater* available at http://www.forester.net/sw_0105_detecting.html (Hager, 2001).

Antibiotic resistance analysis (ARA) is the most commonly used non-molecular method for tracking sources of bacteria. ARA is used to distinguish among sources by looking at patterns of antibiotic resistance found in bacteria from human and animal sources. Fecal bacteria from humans can exhibit greater resistance to certain antibiotics than bacteria from wildlife feces (Hager, 2001; USEPA, 2002). However, this method may be confounded by the presence of bacteria from agricultural operations such as feedlots or poultry operations where antibiotics are used.

EPA's Office of Research and Development's National Risk Management Research Laboratory (NRMRL) is working to develop an integrated system for screening fecal bacteria contamination from various animal sources. NRMRL is working to match the best molecular method to its target bacteria for rapid screening and identification of sources of fecal contamination in watersheds (Simpson, 2003).

(5) *Measure nonpoint source loadings.* It is possible to estimate the amount of pollutants transported in storm water runoff from various land uses by using empirical monitoring data, land use imperviousness and cover, area, and rainfall volume. Modeling of pollutant loads can establish baselines that can be used to determine whether changes have occurred as a

Maryland's Environmental Indicators

The state of Maryland has compiled several indicators to characterize environmental quality (MDE, 1999). These indicators embody a range of environmental attributes, from air quality to drinking water quality to public understanding and community support. The Non-Tidal Aquatic Systems category, which encompasses the range of plants and animals found in free-flowing rivers, streams, lakes, and most wetlands, includes several indicators that appropriately address Maryland's habitat and land uses and include physical, chemical, and biological measures:

- Miles of Streams Degraded by Abandoned Mine Drainage.
- Stream Miles Open to Migratory Fish.
- Physical Habitat Index (Non-Tidal).
- Benthic Macroinvertebrate Index of Biotic Integrity (Non-Tidal).
- Fish Index of Biotic Integrity (Non-Tidal).
- Riparian Forest Buffers.

The biological indicators consider communities of living organisms as found throughout the water column rather than any individual species, and their values reflect the physical and chemical water quality conditions described by other indicators. The Riparian Forest Buffers indicator was chosen because of its importance to physical and chemical habitat and its contribution in cycling nutrients to aquatic species and because a statewide benchmark had already been established through the Chesapeake Bay Program. More information on Maryland's environmental indicators is available at http://www.mde.state.md.us/enpa/ 2000_enpa/envi_indicators.

result of land use changes or implementation of management practices. Loadings can be calculated for small-scale studies using the Simple Method as described in *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs* (Schueler, 1987), which is available for purchase at http://www.mwcog.org. Alternatively, several computer simulation models are available to model changes in nonpoint source loads under different scenarios.

Another source of information for estimating pollutant releases is the Healthy Community Environmental Mapping program, called HUD E-MAPS (HUD and USEPA, 2000). HUD E-MAPS, which was developed by the Department of Housing and Urban Development (HUD) and EPA, combines EPA environmental data with information on HUD's community development and housing programs. The program provides location, type, and performance information on HUD-funded activities throughout the country, and select EPA pollution release information. The maps help communities to plan by allowing them to identify areas of pollutant releases when planning economic development and housing projects. The HUD E-MAPS program can be accessed at http://www.hud.gov/emaps.

2.3.6 Establish Physical and Hydrological Indicators

EPA's *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (USEPA, 1999) and *Volunteer Stream Monitoring: A Methods Manual* (USEPA, 1997c) provide guidance on how to conduct assessments of a water body's physical, habitat, and hydrological characteristics. Both documents are available on the Internet: the former can be found at http://www.epa.gov/owow/monitoring/rbp, and the latter is located at http://www.epa.gov/owow/monitoring/volunteer/stream.

EPA also provides guidance for lake and reservoir monitoring in *Lake and Reservoir Bioassessment and Biocriteria* (USEPA, 1998b), which is available at http://www.epa.gov/owow/monitoring/tech/lakes.html. Monitoring guidance for estuarine and coastal marine waters can be found in *Estuarine and Coastal Marine Waters: Bioassessment and Biocriteria Guidance* (USEPA, 2000a), located at http://www.epa.gov/ost/biocriteria/States/estuaries/estuaries1.html.

Additional monitoring guidance can also be obtained from EPA's Environmental Monitoring and Assessment Program (EMAP), a research program designed to develop the necessary tools for monitoring and assessing the nation's ecological resources. The objective of the program is to guide national monitoring initiatives and activities with improved scientific understanding of ecosystem integrity and dynamics. Information about the EMAP program is available at http://www.epa.gov/emap.

Methods for characterizing streams are contained in *Applied River Morphology* (Rosgen, 1996). Rosgen discusses geomorphic characterization of streams, which helps to differentiate between degraded and stable stream systems. This book also contains methods used to assess the current conditions of a stream and the departure from its potential. The Bank Erodibility Hazard (BHI) Rating Guide can be used to quickly determine bank erosion potential.

(1) *Measure stream widening/downcutting*. Measurements of stream width, depth, and bank characteristics taken over time can be used to indicate changes in the magnitude and frequency of storm flows caused by land use changes that affect stream geometry. Such measurements are also useful in identifying stream segments that are especially susceptible to erosion and areas where habitat is degraded to target areas for implementation of management practices. Many stream channels are already modified, so baseline conditions need to be established. This method cannot be used to predict changes, but it can help to diagnose a problem after it has occurred. Booth (1994) presents excellent guidance for conducting measurements of stream cross-sectional area.

(2) *Conduct physical habitat monitoring*. Monitoring of physical habitat is used to assess the potential of the stream to support different kinds of biota. Parameters such as weather, stream type and origin, land use, erosion, reach width and depth, canopy, proportion of stream morphological type (pool, riffle, and run), and presence or absence of large woody debris and aquatic vegetation can be measured easily and inexpensively and can provide information about which taxa would likely be found in the stream without water quality impacts (reference condition). If conducted over time, monitoring can provide information about past, present, and future changes in channel morphology. Although this method detects impacts from relatively low levels of development, it is not useful in pinpointing sources of degradation, nor does it offer insight into other water quality impacts.

(3) *Assess dry weather flows*. This method is used to assess the impact of urbanization on base flows, either as compared to a non-urbanized stream in the same ecoregion, or as a change over time. Impacted streams in humid areas show decreased flow, whereas perennial streams in arid regions show increased flow, as a result of urbanization. Evaluating pipe installations and impervious surfaces in humid regions and water use in arid regions allows this method to be used to identify causes of baseflow alteration. This method works well in conjunction

with stream widening/downcutting studies. It cannot be used to distinguish between urbanization and other causes of stream flow alteration such as irrigation, long-term drought, and the like, unless these factors are taken into account explicitly. Also, it is difficult to establish trends without extensive long-term data and knowledge about certain geologic conditions.

(4) *Measure flooding*. It is important to quantify changes in stream morphology over time because alterations in stream size or shape or in floodplain boundaries indicate that hydrologic changes have resulted from development in the watershed. These changes can be identified by comparing historical floodplain records to current floodplain maps, called Flood Hazard Boundary Maps (FHBMs). They are official maps issued by a community administrator that detail the boundaries of the flood, mudslide, and related erosion areas having special hazards that have been designated (FEMA, 2000). The maps can be obtained from local community map repository sites, from the Federal Emergency Management Agency (FEMA) online at http://msc.fema.gov, or through FEMA by phone, fax, or mail from the Map Service Center, P.O. Box 1038, Jessup, Maryland 20794-1038; telephone 800-358-9616; fax 800-358-9620.

(5) *Monitor stream temperature*. This method identifies areas where stream temperature has increased as a result of urbanization and loss of shading and buffers. Stream temperature can be measured over time or compared to other, low-impact watersheds. This monitoring method can be used to identify areas that would potentially benefit from riparian buffer enhancement and to measure the effectiveness of management practices used to regulate stream temperature. Changes in stream temperature can be an early warning sign that sensitive species will be lost without intervention. Climatic conditions can cause variability in stream temperature that is extraneous to trends caused by urbanization and can confound analyses. In addition, in should be noted that some management practices, such as ponds and wetlands, can result in increased temperature.

2.3.7 Establish Biological Indicators

Bioassessments are useful for detecting aquatic life impairments and identifying the causative agents and possible mitigation strategies. Additional bioassessments can indicate whether mitigation was successful and can direct further management activities. Monitoring of biological communities offers the following advantages:

- Biological communities reflect overall ecological integrity and directly relate to the primary goal of the Clean Water Act.

- Biological communities integrate the effects of different stressors and provide a broad measure of their aggregate impact.

- Biological communities provide an ecological measure of changes in environmental conditions.

Development and Evaluation of Ecosystem Indicators for Urbanizing Midwestern Watersheds

Researchers at Purdue University are undertaking a study to develop predictive indicators of urbanization that are applicable to midwestern watersheds (Spacie et al., 2000). The objectives of this study are as follows:

- Quantify impacts on hydrologic regimes, water quality, and habitat structure of stream ecosystems using paired experimental watersheds.
- Develop linked models to accurately predict these impacts.
- Use the models to generate and test indicators of urbanization and hydrologic change with respect to biological responses to these changes.
- Use these indicators with the models to assess biological responses to alternative urbanization scenarios on larger scales.

Data from satellite imagery, intensive water quality and biological sampling, stream cross-section measurements, and physical habitat assessments will be used to develop and test the models. A dynamic hydrology model that can simulate cross-sectional averaged velocities, shear stress velocities, and water depth variability during storm peaks has been developed. Functional biological metrics and habitat quality indices will be correlated not only to land use but also to channel morphometry and flow variability.

For more information contact Anne Spacie, Department of Forestry and Natural Resources, Purdue University, 1159 Forestry Building, West Lafayette, Indiana 47907-1159; telephone 765-494-3621; e-mail aspacie@purdue.edu.

- Routine biological monitoring is inexpensive compared to chemical monitoring and toxicity tests.
- Biological monitoring is useful for evaluating impairment when criteria for specific ambient impacts do not exist.

Bioassessments can include evaluation of fish populations, benthic macroinvertebrate communities, periphyton, and single species monitoring. EPA's *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (USEPA, 1999) contains descriptions of various methods for each community type. EPA (2000b) also published the *Stressor Identification Guidance Document*, which outlines a process to identify causes of biological impairment. The stressor identification process is outlined in Figure 2.2 and includes three major steps: (1) listing candidate causes of impairment; (2) analyzing new and existing data to generate evidence for each candidate cause; and (3) producing a causal characterization with the evidence generated in step 2 to draw conclusions about the stressors most likely to have caused the impairment. The *Stressor Identification Guidance Document* is available for download in PDF format at http://www.epa.gov/waterscience/biocriteria/stressors/stressorid.html or can be ordered through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

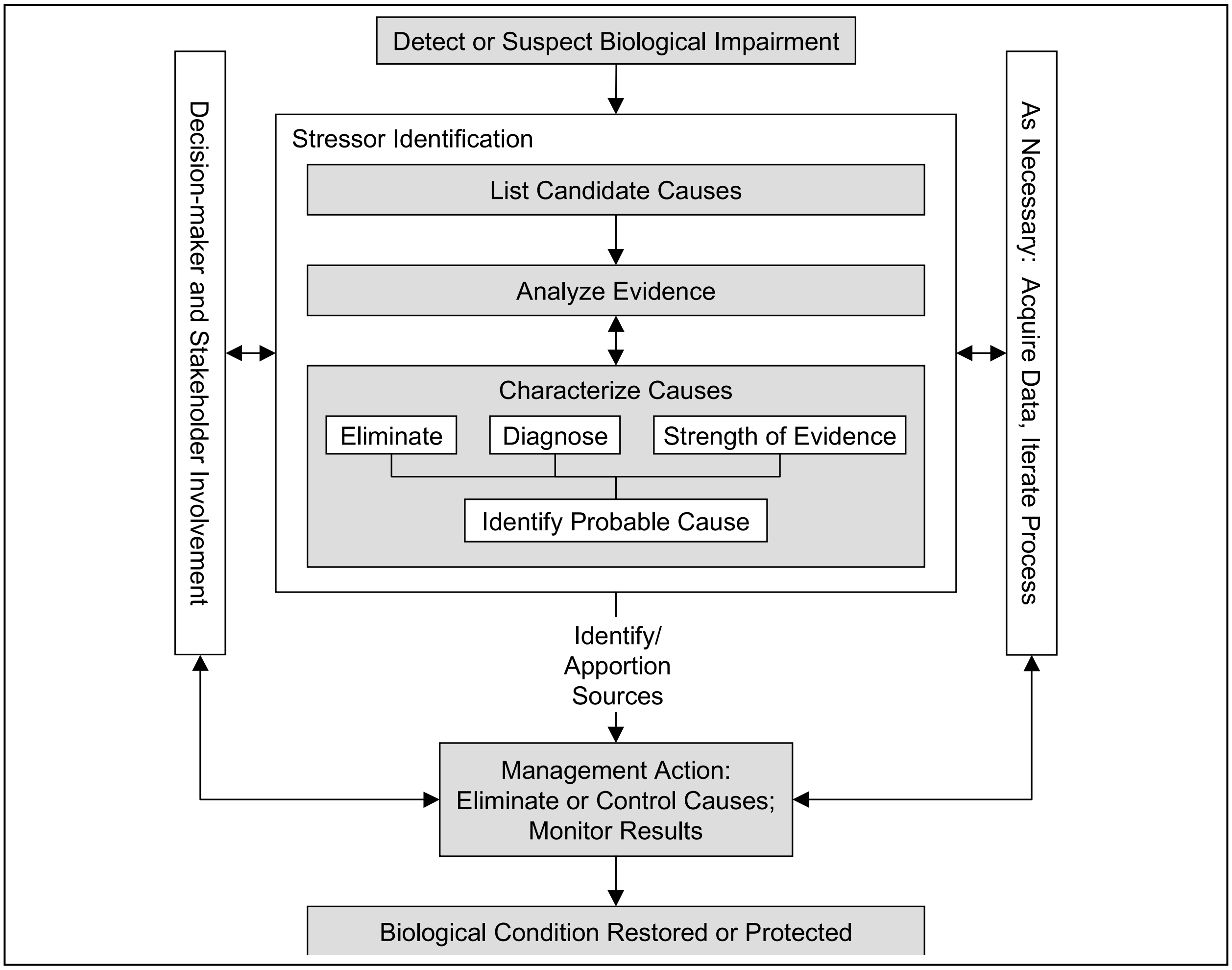

Figure 2.2: Conceptual diagram of the stressor identification process (USEPA, 2000b).

The Biological Assessment of Wetlands Workgroup (BAWWG) (USEPA, 2001b) provides information for establishing monitoring protocols for wetlands through its series of "state of the science" reports. These reports include introductory modules on wetland bioassessments and modules on specific methods, such as bioassessments for macroinvertebrates. Although the reports do not provide specific prescriptive guidance, they summarize current knowledge and provide options and recommendations to states for developing wetland bioassessment methods and programs. The modules also point out limitations of current methods and identify research needs. Information from BAWWG is available at http://www.epa.gov/owow/wetlands/bawwg/index.html.

(1) *Assess periphyton populations*. Changes in periphyton or plankton community structure and distribution patterns can indicate a water quality problem stemming from thermal pollution, toxic chemicals, nutrients, and sedimentation. Because periphyton have a short life cycle, they are especially good indicators of short-term impacts. Measurements of chlorophyll, a chemical common to all periphyton, can also be used as an indicator of eutrophication. Although there are several levels of sampling and analysis of periphyton populations, rapid sampling can be relatively easy and inexpensive and has little impact on the ecosystem.

Also, standardized methods (biomass, chlorophyll) can be used to analyze and interpret algal communities without doing an extensive taxonomic evaluation, which requires specialized training. One problem with these indicators is that plankton populations vary seasonally and are highly transient, making them a poor indicator of site-specific conditions.

(2) *Assess macroinvertebrate assemblages*. Macroinvertebrates are relatively immobile and are good indicators of site-specific effects. They have a short life cycle and therefore are good indicators of short-term stress. Measurements of invertebrate populations are usually compared to populations from a reference condition to determine the severity of pollutant impacts. The presence or absence of particular species can be used to infer poor aquatic integrity because macroinvertebrate assemblages typically cover a broad range of trophic levels and pollution tolerances that allow interpretation of multiple effects. Macroinvertebrate sampling has some drawbacks, including the fact that populations are highly habitat-dependent and vary with season, stream flow, and region, which can confound results. In addition, taxa identification requires training and can be complex and time-consuming. Despite these drawbacks, volunteer monitoring programs can be used to collect macroinvertebrate data. Both *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (USEPA, 1999) and *Volunteer Stream Monitoring: A Methods Manual* (USEPA, 1997c) provide guidance on how to conduct benthic macroinvertebrate assessments.

(3) *Assess fish assemblages*. Measurements of fish diversity, species richness, species pollutant tolerance, disease prevalence, and a variety of other metrics can be used to identify the nature and extent of a pollution or habitat problem. Measurements are taken in several different habitats within the stream or other water body and are usually compared to a regional reference condition to determine the extent of impairment. The methods can also be used to evaluate the success of management practices. Because fish have a relatively long lifespan, they often react to chronic levels of pollutants and long-term impacts. Fish are also easy to collect and identify. However, fish populations are influenced by many other variables, such as stream size, region, season, temperature, and flow conditions, that need to be taken into account when analyzing the data. Also, fish that migrate may be affected by conditions in another area that is not the area of interest. It is sometimes difficult to identify the source of problems in fish populations because of the prevalence of confounding factors that make interpretation of results difficult.

Biodiversity information on the Web via NatureServe

NatureServe, a nonprofit organization, partners with a network of natural heritage programs and conservation data centers to conduct expert local biodiversity inventories and analyze the results both nationally and internationally. Their Web site offers such data products as the NatureServe Explorer, which compiles conservation data on more than 50,000 plants, animals, and ecological communities in the United States and Canada. Users can search the database by any combination of name, location, and conservation status. The Web site also links to online data resources available from natural heritage programs and conservation data centers via the “Local Program Data” link. NatureServe provides links to ecology, animal, and plant data for download and provides links to other biodiversity resources on the Web. The NatureServe Web site can be accessed at http://www.natureserve.org.

(4) *Assess single species indicators*. Trout, salmon, and freshwater mussels are often used for this type of assessment. Some species are popular with the public, and their popularity can help in rallying support for better management. Measuring only one species is relatively easy and inexpensive and might provide early diagnosis of degradation, which can facilitate remediation efforts. However, natural population fluctuations in a single species can skew results, and without corroborating evidence there is no way to prove conclusively that degradation has occurred. It should be noted that focusing on protecting a single species may decrease protection of other threatened species.

(5) *Measure composite indicators*. This method typically involves developing an index that incorporates the results of several different bioindicators. Several metrics can be combined into a single integrity index, such as the number of native fish species or the number of intolerant macroinvertebrate taxa. Composite indicators provide a more comprehensive evaluation of storm water impacts than fish, macroinvertebrate, or single species indicators alone. Both long-term and short-term effects can be evaluated by using this type of metric. As with the other biological methods, populations are dependent on region, season, and flow. Reference site measurements are essential for valid comparisons when determining the extent of storm water impacts. Note: other measurements may be needed to identify sources of degradation.

2.3.8 Establish Programmatic Indicators

It is important to assess the effectiveness of a runoff management program. Claytor and Brown (1996) present several programmatic indicators that can be used to estimate the success of a management program and help to direct future efforts. These include:

- Number of illicit connections identified or corrected
- Number of management practices installed, inspected, and maintained
- Permitting and compliance
- Growth and development

Management Measure 12 discusses other ways to determine the effectiveness of runoff management programs.

2.3.9 Develop a Suite of Social Indicators

Watershed managers can use several methods to gauge public perception of water quality issues and nonpoint source programs. These “social indicators” include:

- Public attitude surveys
- Industrial/commercial pollution prevention
- Public involvement and monitoring
- User perception

More information about these indicators can be found in *Environmental Indicators to Assess Stormwater Control Programs and Practices* (Claytor and Brown, 1996).

2.4 Information Resources

USGS's NAWQA Data Warehouse provides online access for invertebrate community data from 1,700 stream sites in more than 50 major river basins across the nation. Data from more than 5,000 invertebrate community samples that were collected from 1993 through 2002 can be found here. The data warehouse also provides data on fish communities from more than 1,000 stream locations, as well as data from thousands of water quality samples from approximately 6,400 stream sites, 7,000 wells, and streambed sediment and aquatic animal tissue. Samples have been analyzed for a number of constituents. The NAWQA Data Warehouse can be accessed at http://water.usgs.gov/nawqa/data.

The Caltrans *Guidance Manual: Storm Water Monitoring Protocols* (Caltrans, 2000a) provides step-by-step descriptions of the processes used to plan and implement a successful water quality monitoring program specific to runoff from transportation-related facilities. Although the guidance manual emphasizes uniform policies and procedures for monitoring, the *Statewide Storm Water Management Plan* (Caltrans, 2000b) describes minimum procedures and practices Caltrans uses to reduce pollutants discharged from storm water drainage systems. These documents, along with other storm water-related documents, can be downloaded in PDF format http://www.dot.ca.gov/hq/env/stormwater/special/index.htm.

Donigan and Huber (1991), in *Modeling of Nonpoint Source Water Quality in Urban and Non-Urban Areas*, reviewed nonpoint source assessment procedures and modeling techniques for both urban and non-urban land areas. Detailed reviews of specific methodologies and models are presented, along with overview discussions focusing on both urban and non-urban methods and models. Brief case studies of ongoing and recently completed modeling efforts are described and recommendations for nonpoint runoff quality modeling are presented. This document can be ordered from the National Technical Information Service at *www.ntis.gov* or by calling 800-553-6847.

EPA has assembled a Web site with information about and links to water quality models. This site includes basic information, EPA-supported models, other federal government-supported models, technical guidance for models, and model training and meetings. The Web site can be accessed at http://www.epa.gov/waterscience/wqm/.

Patten et al. (2000) have undertaken a study to develop improved indicators and innovative techniques for assessing and monitoring ecological integrity at the watershed level in the western United States. Their objectives are to develop practical, scientifically valid indicators that span multiple resource categories, are relatively scale-independent, address different levels of biological organization, can be rapidly and cost-effectively monitored by remote sensing, and are sensitive to a broad range of anthropogenic and natural environmental stressors. More information about this project can be found at http://es.epa.gov/ncer_abstracts/grants/99/ecological/patten.html (NCER, 2001).

Compendium of Tools for Watershed Assessment and TMDL Development (USEPA, 1997a) supports the watershed approach by summarizing available techniques and models that assess and predict physical, chemical, and biological conditions in water bodies. The publication contains descriptions of three major categories of models: watershed loading, receiving water, and ecological. Watershed loading models can be used to simulate the generation and movement of pollutants from the source to discharge into receiving waters. Receiving water models can be used to simulate the movement and transformation of pollutants through lakes, streams, and rivers. Ecological models can be used to simulate plant and animal communities and their response to pollutants and habitat modification. This document is available through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

EPA's *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls* (USEPA, 1997b) contains an overview of nonpoint source pollution and covers the development of a monitoring plan, data analysis, quality assurance/quality control, and biological monitoring. The manual was written to assist users in the design of water quality monitoring programs to assess both impacts from nonpoint source pollution and the effectiveness of control practices and management measures. It is available through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

Volunteer Stream Monitoring (USEPA, 1997c) serves as a tool for program managers who want to launch a new stream monitoring program or enhance an existing program. It contains methods that have been adapted from those used successfully by existing volunteer programs. The guidance is available in HTML and PDF formats at http://www.epa.gov/owow/monitoring/volunteer/stream.

The *Lake and Reservoir Bioassessment and Biocriteria* (USEPA, 1998b) guidance was developed through the experience of existing state, regional, and national lake monitoring programs and is oriented toward practical decision-making rather than research. Its primary target audiences are state and tribal natural resource agencies. It is intended to provide managers and field biologists with functional methods and approaches that will facilitate the implementation of viable lake bioassessment and biocriteria programs that meet their needs and resources. The document can be obtained in HTML format at http://www.epa.gov/owow/monitoring/tech/lakes.html.

Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish (USEPA, 1999) is a practical technical reference for conducting cost-effective biological assessments of lotic systems. This guidance is intended to provide basic, cost-effective biological methods for states, tribes, and local agencies that: (1) have no established bioassessment procedures; (2) are looking for alternative methodologies; or (3) may need to supplement their existing programs (not supersede other bioassessment approaches that have already been successfully implemented). The scope of this guidance is considered applicable to a range of planning and management purposes, i.e., the methods may be appropriate for priority-setting, point and nonpoint source evaluations, use-attainability analyses, and trend monitoring, as well as initial screening. The guidance is available in HTML and PDF formats at http://www.epa.gov/owow/monitoring/rbp.

The *Estuarine and Coastal Marine Waters: Bioassessment and Biocriteria Guidance* (USEPA, 2000a) provides an extensive collection of methods and protocols for conducting bioassessments in estuarine and coastal marine waters, as well as the procedures for deriving biocriteria from the results. Several case studies illustrate the bioassessment process and biocriteria derivation procedures. This document can be downloaded in PDF format at http://www.epa.gov/ost/biocriteria/States/estuaries/estuaries1.html.

The *Stressor Identification Guidance Document* (USEPA, 2000b) leads water resource managers through the process of stressor identification and evidence assembly. The guidance can be used whenever biological impairment is present in an aquatic ecosystem and the cause is unknown. The stressor identification process combines multiple methods to determine the causes of impairment, and the methods are presented in order of the kinds of evidence used, from site-specific to more general information. The *Stressor Identification Guidance Document* is available in PDF format at http://www.epa.gov/waterscience/biocriteria/stressors/stressorid.html.

Techniques for Tracking, Evaluating, and Reporting the Implementation of Nonpoint Source Control Measures: Urban (USEPA, 2000c) was written to assist local officials in focusing limited resources by using statistical sampling methods to assess, inspect, or evaluate a representative set of management practices, erosion and sediment controls, and onsite wastewater treatment systems. The document can be downloaded in PDF format at http://www.epa.gov/owow/nps/urban.pdf, or it can be ordered through EPA's National Service Center for Environmental Publications at http://www.epa.gov/ncepihom/index.htm.

EPA's Web site titled "An Introduction to Water Quality Monitoring" contains a wide variety of resources for those interested in learning more about water quality monitoring, automated data management, and geographic information systems (USEPA, 2001). Many EPA guidance documents, fact sheets, and final reports are available from this site, which can be accessed at http://www.epa.gov/owow/monitoring/monitor.html.

EPA's Web site, "Water Quality Criteria and Standards Plan" (USEPA, 1998d), describes six new criteria and standards program initiatives that EPA and the states and tribes will take over during the next decade. The plan presents a "vision" and strategy for meeting these important new initiatives and improvements and will guide EPA, states, and tribes in developing and implementing criteria and standards that provide a basis for enhancements to the TMDL program, NPDES permitting, nonpoint source control, wetlands protection, and other water resource management efforts. The Web site is located at http://www.epa.gov/ost/standards/quality.html.

EPA's Volunteer Monitoring Program provides technical assistance, serves as a regional contact for volunteer programs, manages grants to state agencies that undergo volunteer water monitoring and conduct public participation programs, and provides information exchange services for volunteers. The program's Web site (http://www.epa.gov/owow/monitoring/volunteer) provides a link to a listserver is available for volunteer monitoring program coordinators, as well as a national newsletter for volunteer monitors, a directory of volunteer monitoring programs, and manuals on volunteer monitoring methods and on planning and implementing volunteer programs.

EPA's Watershed and Water Quality Modeling Technical Support Center provides information and services to federal agencies, state and local governments, businesses, and individuals to help support implementation of the Clean Water Act. Support includes reviewing proposed TMDLs, providing oversight to TMDL development nationwide, serving as technical advisors, applying models for TMDL development, assisting in data acquisition and analysis, assisting in TMDL implementation, analyzing BMP design and performance, and researching models for regulatory applications. The center's Web site can be accessed at http://www.epa.gov/athens/wwqtsc/index.html.

The P8—Urban Catchment Model by Walker (2000) is designed to predict the generation and transport of runoff pollutants in urban watersheds. The model was developed to design and evaluate runoff treatment control combinations in developments for pollutant removal efficiency. The most recent version of this DOS-based program (Version 2.4, published in February 2000), as well as data files and program documentation, is available for download from http://wwwalker.net/p8.

A useful water resource impact model is the Long-Term Hydrologic Impact Assessment (L-THIA), which was developed by Purdue University (2000) for land use planners to provide site-specific estimates of changes in runoff, recharge, and nonpoint source pollution resulting from past or proposed land use changes. The model uses regional climate data and user-provided location, land use, and soil group data for up to three different scenarios (past, present, and future). The results are in the form of tables, bar charts, and pie charts. The model is available at http://danpatch.ecn.purdue.edu/~sprawl/LTHIA7.

Vermont's Water Resources Board developed "A Scientifically Based Assessment and Adaptive Management Approach to Stormwater Management" as an appendix to the *Investigation into Developing Cleanup Plans for Stormwater Impaired Waters* (Docket No. INV-03-01). The assessment paper describes a framework for identifying storm water runoff problems and providing adaptive management to address controls for and treatment of runoff in problem areas. The framework represents a balance of the interests of many diverse constituents, focusing on surface water impairments and improvements to identify problems due to runoff and improvements due to runoff controls. The report, part of the Vermont Water Resources Board's Stormwater Docket, can be accessed at http://www.state.vt.us/wtrboard/docs/inv-03-01report.pdf.

NatureServe, a nonprofit organization, partners with a network of natural heritage programs and conservation data centers to conduct expert local biodiversity inventories and analyze the results both nationally and internationally. Its Web site offers such data resources as the NatureServe Explorer, which compiles conservation data on more than 50,000 plants, animals, and ecological communities in the United States and Canada. Users can search the database by any combination of name, location, and conservation status. The Web site also connects to online data resources available from natural heritage programs and conservation data centers via the "Local Program Data" link. NatureServe provides links to ecology, animal, and plant data for download and to other biodiversity resources on the Web. The NatureServe Web site can be accessed at http://www.natureserve.org.

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