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Handbook for Developing Watershed Plans to Restore and Protect Our Waters

Chapter 11. Evaluate Options and Select Final Management Strategies

March 2008

11. Evaluate Options and Select Final Management Strategies

Chapter Highlights

- Approaches used to evaluate management practice performance.
- Estimating management performance and comparing to objectives
- Cost considerations
- Evaluating options
- Selecting final strategies

Read this chapter if...

- You want to evaluate potential management strategies to select the final strategy for your watershed plan
- You want to learn about approaches to quantify the effectiveness of management practices
- You want to understand the capabilities of available models for evaluating management practices
- You need examples of applications for quantifying the effectiveness of management practices
- You need to identify criteria for ranking and selecting your final management strategy

11.1 How Do I Select the Final Management Strategy?

In chapter 10 you conducted an initial screening to determine the feasibility of using various management practices in your implementation program. The screening was based on factors like the critical areas in the watershed, estimated pollutant removal efficiencies, costs, and physical constraints. In this chapter you'll take those candidate options and refine the screening process to quantitatively evaluate their ability to meet your management objectives in terms of pollutant removal, costs, and public acceptance (figure 11-1).

You'll work with your stakeholders to consider various strategies that use a combination of management practices, to rank and evaluate the strategies, and finally to select the preferred strategies to be included in your watershed plan.

This chapter presents various techniques to help you to quantify the potential of the management actions to meet the watershed objectives, thereby providing the information you'll need to make final selections. There are five major steps to selecting your final management strategies:

1. Identify factors that will influence selection of the preferred management strategies.
2. Select the suitable approach to evaluate the ability of the management techniques to meet the watershed objectives.
3. Quantify the expected load reductions from existing conditions resulting from the management strategies.
4. Identify capital and operation and maintenance costs and compare initial and long-term benefits.
5. Select the final preferred strategies.

Before you conduct detailed analyses of the management strategies, you should first identify the factors that will influence which approach you'll use and then select the actual approach or method you'll use to evaluate the effectiveness of the proposed management practices in meeting your objectives. The factors that will influence the selection of your approach are discussed below, followed by a discussion of various approaches.

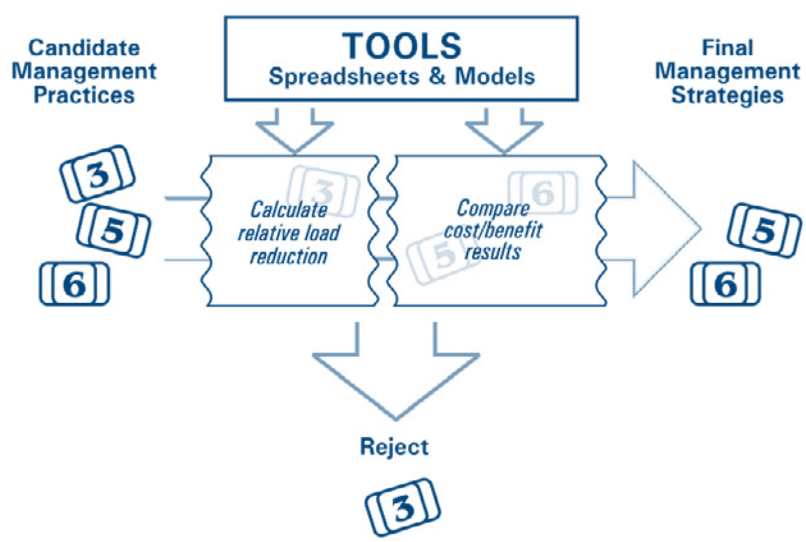


Figure 11-1. Evaluate Candidate Management Practices to Select Final Strategies

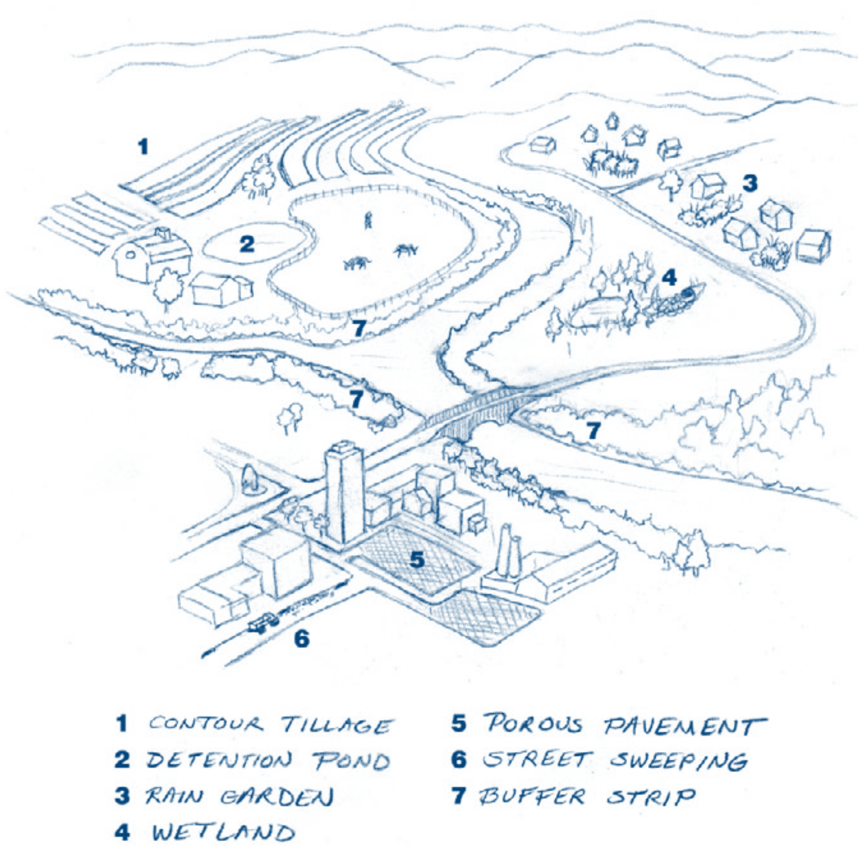
11.2 Identify Factors that Influence the Selection of Approaches Used to Quantify Effectiveness

You should consider several factors before you select an approach to evaluate your candidate management strategies. These include identifying the general and specific types and locations of management practices that will be used, what indicators you'll use to evaluate their performance, and the appropriate scale and detail of the analysis to assess the cumulative benefit of multiple practices.

> *Tip* While you're setting up your evaluation of management practices, you might find it helpful to develop metrics or measures that can be combined readily with your cost evaluation to facilitate the cost-effectiveness analysis (discussed further in section 11.5). For instance, pounds per acre per year of pollutant removal can be combined easily with dollars per acre of cost to produce dollars per pound removed.

11.2.1 General Types of Management Practices

Which approaches you choose to evaluate the performance of the management practices depends in part on the location of the sources being managed and the types of management practices used. A source in an upland area (e.g., cropland erosion) is different from a source in a stream (e.g., streambank erosion). To evaluate upland loading management, you could use a tool that estimates sediment loading (on an area basis) from land uses in your watershed and could calculate a load reduction from changes in land use management practices. For streambank erosion, you might need to evaluate the effectiveness of stream restoration measures in terms of reduction in tons of sediment per linear foot of stream.



When selecting the approaches used to assess management, consider the general characteristics of the management practices. One way to group the various practices is to consider how they are applied. Are the practices applied across a land area, along a stream corridor, or at a specific location? Some types of management practices, such as tillage and fertilizer management techniques, are applied over large land areas.

These land area-based practices are measured by the area affected and often include large regions of the watershed. Practices applied along a stream corridor are linear practices that stretch across long areas, such as riparian or stream buffer zones. By instituting a stream buffer zone, some water from uphill areas can be filtered; the vegetation might also provide additional shade and improved habitat. Practices installed at a point or specific location provide treatment for runoff from a specific drainage area. Point practices include detention ponds, bioretention areas, and many other practices that collect and treat runoff through settling or infiltration of water and pollutants. These types of practices require slightly different assessment techniques and have different data collection needs for evaluating their pollutant removal benefits.

11.2.2 Identify the Types of Indicators You're Using to Measure Performance

In chapter 9 you developed indicators to help measure progress toward meeting your watershed goals and management objectives. Your indicators and associated targets might be based on pollutant loads, hydrologic factors, concentration values, or habitat measures. The types and expression of your indicators will affect the types of analyses you can use to assess your management practices and strategies.

If your indicator is a pollutant load, performance measures for practices are easy to find. For concentration- or value-based indicators, you should take greater care to ensure that the information you find is applicable to your situation. Assume, for example, that your watershed has been listed as impaired because of frequent exceedances of fecal coliform counts during storm events. When locating data about management practice performance, you should make sure that the information you find applies to storm event performance, not to base flow performance.

If you have more than one indicator to address, note how each management practice performs for all of your indicators. Practices that benefit multiple indicators might have greater overall benefit as part of a watershed-wide management strategy.

11.2.3 Consider the Scale of Your Watershed

Understanding how to develop your management strategy will depend in large part on how big and complicated the watershed is and how expensive the management will be. When looking at how to evaluate a management plan, scale is a major concern. A management strategy for a small urban watershed (e.g., approximately 1,000 acres) might include hundreds or even thousands of individual actions such as changes in fertilizer applications, increased street sweeping and vacuuming, retrofit of existing detention ponds, or restoration of shoreline areas. In large watersheds, both urban and rural, the effect of multiple actions is often generalized to get an estimate of the overall impact. For a smaller-scale watershed, you might conduct a more detailed analysis of the benefit of specific management practices or restoration activities. These studies might include examining what will happen if practices are installed or adopted in defined locations within the watershed. Practices can also be evaluated at the smallest scale, such as an individual development or lot. At that level, however, analyses typically focus on meeting regulatory requirements or design requirements of a funding program. Individual practices provide a cumulative benefit when considered as part of a larger program of implementation, but their individual benefit might be more difficult to discern.

How to bridge the various scales is an ongoing issue in watershed planning. Tools are needed to evaluate the cumulative benefit of management strategies to select the best alternatives, evaluate the most cost-effective solutions, and ultimately be assured that restoration will be successful. But it's not always appropriate or necessary to use models or perform detailed analyses of each management practice. In subsequent sections the capabilities of available models to assess the benefits of management practice installation are discussed. In applying models to management analysis, keep in mind that sometimes simplifying or generalizing the impacts of management practices is appropriate. Sometimes very detailed simulation or testing of land use practices and small-scale practices can be performed and the results extrapolated to a larger scale. Such studies can be described as “nested” modeling studies. For example, a detailed evaluation of fertilizer and tillage practices can be performed at the field scale using modeling or monitoring. The results from the study can be used to evaluate the implications of using similar practices on similar fields in the region. Similar approaches can be used to examine the implications of urban development and redevelopment practices.

In larger watersheds there are also additional considerations in aggregating results to the entire watershed and accounting for physical and chemical processes that occur on a large scale (e.g., instream nutrient uptake, the timing and duration of storm event peak flow at the mouth of the watershed). If the upstream conditions of your watershed significantly influence the downstream portions, it might be necessary to use models to evaluate the link between upstream and downstream indicators.

11.2.4 Consider the Synergistic Effects of Multiple Practices

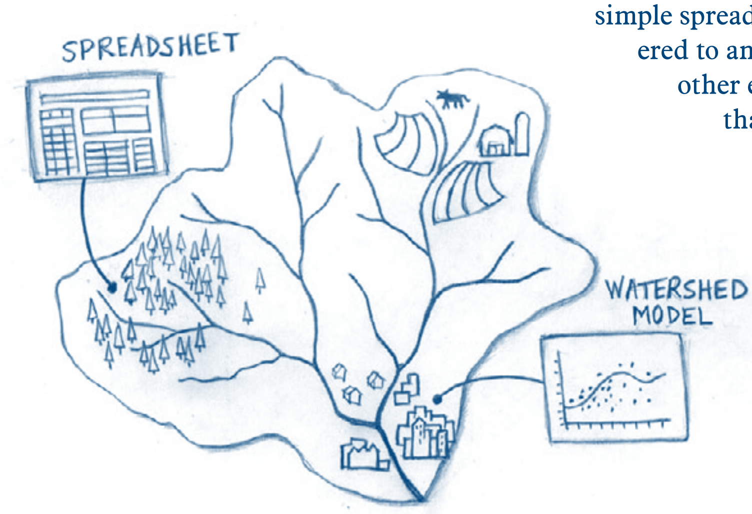
The combined effects of all management practices implemented in a watershed should be considered to determine whether water quality goals will be achieved. In watersheds with easily characterized problems (e.g., where bacterial contamination is due to a few obviously polluting animal operations in a watershed that has no other identifiable sources of pathogens), it might be very easy to project that water quality benefits will be achieved by implementing, for example, management practices for nutrient management, erosion and sediment control, and facility wastewater and runoff. However, in a watershed with multiple land uses where agriculture is considered to contribute only a portion of the pollutants, it is more difficult to estimate the combined impacts of various management practices on a fairly large number of diverse farming operations. Further complicating the assessment is the possibility that historical loading of pollutants has caused the water quality impairment and several years might be required for the water resource to recover fully.

If you need to evaluate the interaction of multiple management practices simultaneously, you’ll want to evaluate the degree to which they complement or conflict with one another. Their combined effect could be different from their individual influence. The cumulative effect of management practices spread throughout a large watershed might need to be assessed with complex tools. Sometimes multiple management activities at the site scale are evaluated simultaneously within a single watershed. Most commonly, individual sites are evaluated in a watershed framework to investigate the downstream effects. An example of a downstream effect is the magnitude of peak flows at the junction of the main stem and the tributary on which the management practice is located. Though unlikely, it is possible that the reduced peak outflow hydrograph from a proposed stormwater management practice could exacerbate the peak flow in the main stem channel because of differences in timing. The only way that this unintended, and likely undesirable, downstream effect could be discovered is through a watershed-scale evaluation. On the other hand, it is possible that multiple management practices could work in concert to cumulatively reduce peak flows more than the sum of their individual contributions.

The next section discusses various approaches for quantifying the effectiveness of management practices, including the role of modeling and the types of models available.

11.3 Select an Approach to Quantify the Effectiveness of the Management Strategies

You can use various approaches to evaluate the performance of management practices and strategies. Choosing the one that is right for you will depend on several factors, including the objectives and targets you need to achieve, the types of sources and management practices, the scale of the analysis, and the cost of implementation. Some of the technical considerations associated with modeling are the types of models that were used for loading analysis, the availability of data or resources to collect management practice information, and the availability of the appropriate modeling techniques. A wide variety of approaches can be used to evaluate management strategies. At one end, you can use published literature values and a simple spreadsheet-based tool that calculates loads delivered to and removed by management practices. At the other end, you can use a detailed watershed model that requires substantial amounts of input on each management technique. Sometimes a combination of approaches are used to address various indicators and management practices that might need to be addressed. Very simple approaches can be appropriate for planning and alternatives analysis and can provide relative comparisons of various management strategies. The common limitations of simplified techniques include a lack of sensitivity to precipitation, seasonal patterns, and storm events.



11.3.1 Using Literature Values

One of the most commonly used methods for predicting the performance of management strategies is the use of literature values of the removal percentage typically associated with each type of management practice and pollutant (e.g., detention pond and sediment). The removal percentage is typically estimated from one or more monitoring studies in which the performance of practices was measured using flow and chemical monitoring.

The percentages from various literature sources and studies can include ranges or variations in the expected reductions from practices. This is because the effectiveness of management practices in removing pollutants depends on many factors, including local climate and conditions, design specifications, and type of pollutant. Some monitoring studies have detailed data for only part of the year, such as a few storms, and do not fully consider what the annual load reduction might be for one or more years. When you use studies that document removal percentages, consider the location and climate of the study area (e.g., arid, wet region, cold weather) and the amount of data collected. If you have data that range in values (e.g., from 20 to 80 percent), consider using a range of values in your analysis.

Note that the effectiveness of a series of management practices is not necessarily cumulative. The removal percentage is typically calculated on the basis of monitoring of an individual practice. Management practices are frequently combined on a site to provide enhanced performance. If the same runoff is treated by more than one practice, the configuration is referred to as a treatment train. One common pitfall is that people add the performance results for all the management practices to obtain a combined performance (e.g., 65 percent load removal plus 25 percent load removal equals 90 percent removal). This method of calculation is not accurate and overestimates reduction.

Questions to Ask Before You Select a Management Evaluation Approach

- What is the time frame for your analysis? Determine whether the management practice performance is compared to indicators on an annual, seasonal, or storm basis. Determine whether you have to perform calculations daily, or even hourly.
- Is your analysis continuous through time, or can you evaluate discrete events? For instance, you might need to look at only large storm events, not a continuous hydrologic record.
- Are you calculating loads, concentrations, flow, or some other measure? Make sure that your approach reflects the units of measure of your indicator(s).
- Do you need to account for variation in environmental conditions in your analysis, such as weather, wet versus dry years, and so forth?

Management practice combinations have some cumulative benefit; however, depending on the pollutant type and the removal mechanism (e.g., settling), the removal percentages can change for subsequent practices. If the removal is cumulative, the removal rate is calculated as follows. If the first practice removes 65 percent of the load, 35 percent of the total load is passed to the second practice. The second practice removes 25 percent of the remaining 35 percent, or 8.75 percent of the total load. The overall performance is 65 percent plus 8.75 percent, or 73.75 percent. If the process is not cumulative, the second practice might be slightly less effective than the first, resulting in a cumulative reduction of less than 73.75 percent. Typical practices that are not cumulative include those which rely on settling. For instance, the first practice might remove coarse, heavy sediment, but the second practice might be less efficient in settling the remaining fine-grained sediment.

It might be tempting to apply more than two practices in a series to achieve better results, but the mechanisms of pollutant removal suggest that additional removal is not likely to be achieved. Pollutants are often composed of components with different physical properties; for example, ammonia, nitrate/nitrite, and organic nitrogen make up total nitrogen. Frequently, a practice can remove only one component of a pollutant well. If the next practice in the treatment train removes the same component, less removal results. What is left over is often difficult for any practice to remove. For this reason, you should usually consider using no more than two practices in a given treatment train.

Watershed-scale reductions can be calculated by using simple spreadsheets to provide an accounting of the estimated loading, areas treated, and the percent reductions (or ranges of reductions) expected. Through the use of spreadsheets, multiple scenarios or combinations of load reduction practices can be easily evaluated. Figure 11-2 shows a simple spreadsheet analysis that evaluates one management practice at one site and then broadens the analysis to the watershed scale.

11.3.2 Using Models to Assess Management Strategies

Watershed models or management practice-specific models can also be used to evaluate individual management practices or watershed-scale management strategies. These approaches can build on models developed previously to assess source loads, or they can be set up to supplement other approaches used to estimate source loading. Watershed management modeling is an active research and development area. The goal is to make existing models more flexible and to develop new tools for assessing the placement, selection, and cost of management practices. You're encouraged to check EPA Web sites, publications, and journal articles for ongoing research on management practice analysis.

Currently available models have significant capabilities to represent management practices. The practices they represent, however, vary depending on the specialities of the models. Some agriculture-oriented models have excellent tools for assessing area-based management

A rural/agricultural watershed is listed as impaired because of the impacts of sedimentation on fish communities. During the watershed characterization portion of the study (↳ chapters 7 and 8), you determined that upland sources are a major source of sediment. Much of the load originates from fields planted in conventional-till row cropland. One of the potential management practices you identified in chapter 10 is implementing no-till in areas currently farmed with conventional till. You want to evaluate the effectiveness of the no-till practice on a 120-acre field. During your modeling analysis of sources, you determined that conventional-till row cropland at this site has a sediment loading rate of 1.6 tons/ac/yr. According to your local extension agent, no-till practices are expected to reduce sediment loading by 75 percent. You perform the following calculation to determine the pre-practice and post-practice sediment load:

Conventional till: 120 ac x 1.6 tons/ac/yr = 192 tons/yr

No-till: 120 ac x 1.6 tons/ac/yr x (1 - 0.75) = 48 tons/yr

Your net reduction is 144 tons/yr for the selected site.

If you want to evaluate this practice on a larger scale for several sites throughout the watershed, you can use a spreadsheet to facilitate the calculation. For example, suppose your watershed has 10 potential sites where conventional till could be converted to no-till. Each site has a unique area, of course, but you have also calculated loading rates for each site, based on variations in slope and soil composition:

Site	Area (ac)	Loading Rate (tons/ac/yr)	Load (tons/yr)	Removal Percentage	Load Removed (tons/yr)	Net Load (tons/yr)
1	120	1.6	192	75	144	48
2	305	1.8	549	75	412	137
3	62	1.9	118	75	88	30
4	245	1.7	417	75	312	105
5	519	1.6	830	75	623	208
6	97	2.1	204	75	153	51
7	148	1.9	281	75	211	70
8	75	1.5	113	75	84	28
9	284	2.0	568	75	426	142
10	162	1.8	292	75	219	73
Total	2,017	N/A	3,564	N/A	2,672	892

From this analysis, you estimate that altogether converting to no-till on 10 sites will remove 2,672 tons of sediment. The spreadsheet provides a powerful tool for testing and combining results for various scenarios. For example, you might test combinations of other management practices, with varying percent removal at each site.

Figure 11-2. Using a Spreadsheet Analysis to Evaluate One Management Practice at a Single Site such as fertilizer and tillage practices. Others that specialize in urban areas include techniques for assessing structural solutions like detention ponds. Similar to the watershed modeling discussions highlighted in chapter 8, which model you use depends on what questions you need to answer and the strategies under consideration. The modeling approach you select should provide a process for assessing pollutant loads, evaluating management practices, and ultimately testing the recommended approach for the watershed plan.

The following sections discuss how you can use the seven models highlighted in chapter 8 to evaluate management strategies. The capabilities, strengths, and weaknesses of each model are summarized. In addition to the selected models, descriptions are provided for additional models, supplementary tools, or specialized techniques that can be used to assess management practices. Key data needs and technical considerations in applying the models for management analysis purposes are also discussed.

Summary of Management Practices Simulated by the Seven Models

- **AGNPS**—agricultural practices, tillage, nutrient application
- **STEPL**—removal percentages for multiple practices
- **GWLF**—agricultural practices, tillage, simplified nutrient/manure applications
- **HSPF**—urban and agricultural practices, nutrient applications, detention, and buffer areas
- **SWMM**—urban practices, including detention and infiltration
- **P8-UCM**—urban practices, including detention
- **SWAT**—agricultural practices, tillage, nutrient applications

Modeling Management Strategies with the Selected Models

The models discussed in chapter 8 have various capabilities for representing management practices (table 11-1). As shown in the summary table, each model can assess a variety of practices and each has associated strengths and weaknesses. The models tend to specialize in the following areas:

- Agricultural practices: SWAT, AGNPS, GWLF, STEPL
- Urban practices: P8-UCM, STEPL, SWMM
- Mixed land use: STEPL, HSPF

For agricultural practices, the SWAT model provides the ability to examine specific practices and specialized agricultural techniques like irrigation, drainage, and ponds. STEPL includes a generalized capability to include management practices and assign a removal percentage of pollutant loading. The P8-UCM model provides a flexible set of tools for evaluating specific urban management practices such as ponds and infiltration structures. For mixed-land-use watersheds, STEPL or similar spreadsheet-based models can provide a generalized description of the load reductions from a variety of sources. HSPF can provide a more detailed representation of agricultural, forested, and urban areas, although it is more limited than SWMM in representing structural practices. Chapter 8 provides additional information on the selected models.

Each model has a slightly different approach for including management practices, as summarized in table 11-2. For example, the agricultural techniques in SWAT, AGNPS, GWLF, and STEPL are already recognized during model setup by the selection of parameters for predicting runoff (e.g., curve number equation) and sediment loading (e.g., Universal Soil Loss Equation [USLE]). Other practices might need to be specifically identified and separately input into the model. Some of the agricultural models provide a continuous evaluation of the availability of nutrients in the active soil layer or root zone. This feature provides for tracking of nutrient loading, fertilizer applications, crop uptake, and leaching of nutrients. The HSPF model, with its AGCHEM module, provides a similar ability to track nutrients in the soil.

Table 11-1. Summary of Management Practice Representation Capabilities of the Selected Models

Model	Types of Practices Considered	Strengths	Limitations
STEPL	• Contour farming • Filter strips • Reduced-tillage systems • Streambank stabilization and fencing • Terracing • Forest road practices • Forest site preparation practices • Animal feedlot practices • Various urban and low-impact development (LID) practices (e.g., detention basin, infiltration practices, swale/buffer strips)	• Easy to use; good for giving quick and rough estimates • Includes most major types of management practices	• Simplified representation of management practices using long-term average removal percentage does not represent physical processes • Developed based on available literature information that might not be representative of all conditions
GWLF	• Agricultural area management practices (e.g., contouring, terracing, no-till)	• Easy to use • Long-term continuous simulation	• Does not have structural management practice simulation capabilities
HSPF	• Agricultural practices • Impoundment • Buffer	• Can simulate both area and point management practices • Provides long-term continuous simulation • Land and management practice simulation are linked	• Weak representation of structural point practices • Requires moderate to high effort to set up
SWMM	• Detention basin • Infiltration practices	• Can simulate both area and point management practices • Long-term continuous simulation • Physically based simulation of structural management practices • Management practice simulation is coupled with land simulation	• Limited representation of non-urban area practices • Requires moderate to high effort to set up
P8-UCM	• Detention basin • Infiltration practices • Swale/buffer strip • Manhole/splitter	• Tailored for simulating urban structural practices • Long-term continuous simulation • Process-based simulation for structural practices • Management practice simulation is coupled with land simulation, which provides dynamic input to drive practice simulation	• Cannot simulate nonstructural and area practices
SWAT	• Street cleaning • Tillage management • Fertilizer management • Pesticide management • Irrigation management • Grazing management • Impoundment • Filter strips	• Strong capabilities for simulating agricultural area practices • Ability to consider crop rotation • Long-term continuous simulation	• Limited urban and structural practice simulation
AnnAGNPS	• Feedlot management • Tillage management • Fertilizer management • Pesticide management • Irrigation management • Impoundment	• Strong capabilities for simulating agricultural area management practices • Long-term continuous simulation	• Limited urban and structural practice simulation

Table 11-2. Summary of Management Practice Simulation Techniques of the Selected Models

Model	Management Practice Evaluation Techniques	Water Quality Constituents
AnnAGNPS	• Sediment - RUSLE factors • Runoff curve number changes • Storage routing • Particle settling	• Sediment • Nutrients • Organic carbon
STEPL	• Sediment - RUSLE factors • Runoff curve number changes • Simple percent reduction	• Sediment • Nutrients
GWLF	• Sediment - USLE factors • Runoff curve number changes • User-specified removal rate	• Sediment • Nutrients
HSPF	• HSPF infiltration and accumulation factors • HSPF erosion factors • Storage routing • Particle settling • First-order decay	• Sediment • Nutrients
SWMM	• Infiltration • Second-order decay • Particle removal scale factor • Sediment - USLE (limited)	• Sediment • User-defined pollutants
P8-UCM	• Infiltration - Green-Ampt method • Second-order decay • Particle removal scale factor	• Sediment • User-defined pollutants
SWAT	• Sediment - MUSLE parameters • Infiltration - Curve number parameters • Storage routing • Particle settling • Flow routing • Redistribution of pollutants/nutrients in soil profile related to tillage and biological activities	• Sediment • Nutrients • Pesticides

Note: MUSLE = Modified Universal Soil Loss Equation; RUSLE = Revised Universal Soil Loss Equation; USLE = Universal Soil Loss Equation.

Urban models use representation of impoundments to represent a variety of point practices that collect runoff and remove pollutants through infiltration and settling. Most of the urban models use settling of sediment and decay as the primary removal mechanisms. SWMM can emulate the major management practice processes—storage, infiltration, first-order decay, and sediment settling. The recently added overland flow rerouting (land-to-land routing) options can be used to mimic riparian buffers or infiltration areas.

Modifying a watershed modeling application using any of the reviewed models typically includes the following additional steps:

1. Identify the specific or general practices to be included.
2. Identify the practices that were included in the existing conditions.

3. Incorporate each practice as appropriate into the model.
4. Vary the adoption of the practices according to the management strategy.
5. Summarize the results.

Typical data needs for simulating management strategies using the selected models include specific information for area, point, and linear management practices. For modeling purposes, you'll need information on the existing and proposed management practices, including location, drainage area for each practice, size, type, and key characteristics. Consider carefully the current adoption of management practices in the watershed and what might change in the future. Make sure that you include the current practices in areas where significant restoration has already taken place.

If you're using the same model or approach from your watershed characterization, you might need to add new land use categories. For instance, if you defined urban development in terms of low intensity and high intensity, you might need to break out urban categories in greater detail (e.g., low-density residential, high-density residential, commercial, industrial, institutional). Some of your management practices might be suited for only certain land uses.

You might also need to add a layer of complexity to an existing approach. For instance, your assessment might have been based on generic land use classes, but the evaluation of your management practice is driven by land cover (impervious surface, lawn, forest). In this case, you should provide direct measures of land cover or estimate proportions of land cover for each land use class.

Table 11-3 lists typical information needs for each of the selected models and major practices. The specific information might vary depending on the level of detail of the modeling tools used. For example, a detailed simulation of detention ponds in SWMM might require detailed characteristics of the pond design (e.g., depth-volume relationship, depth-outflow rate relationship), in addition to information on location and the drainage area contributing to the pond.

In general, area-based practices require information on area affected and land use management practices (e.g., tillage, fertilizer/manure applications), including application date, amount, and technique. Simulating point practices generally requires information on the drainage area to each practice and the design specifics for each practice. Detention ponds would generally require information on storage volume, shape, outlet structure, and retention time. Bioretention structures might require information on the infiltration rate, volume of storage, soil media, and pollutant removal rate.

The performance of the model with management practices is typically tested for the existing conditions, where historic monitoring data are available. However, because management practices are dispersed across the watershed and are adopted sporadically over time, the available monitoring data might not provide a distinct response at the watershed scale. One solution to this problem is to use smaller-scale pilot studies that simulate individual practices or combinations of practices for more detailed small-scale testing. In addition, management practice simulations can build on the available data on removal effectiveness. These results are used to build the best estimates of the potential benefits of implementing management practices. Ultimately, these forecasts can be tested or evaluated for accuracy only through monitoring after implementation. Once implementation has begun, a post-audit can include monitoring of management effectiveness and a reassessment of modeling results.

Table 11-3. Data Needs for Management Strategy Modeling

Model	Data Needs for Management Practices
AnnAGNPS	• Tillage area, type and date, crop rotation • Fertilizer application rate, method, and dates • Manure application rate, method, and dates • Strip cropping location and area • Impoundment size and discharge rate • Sediment settling rate
STEPL	• Land use type and condition • Practice type
GWLF	• Crop type and condition • Manure application rate and date • Runoff nutrient concentration
HSPF	• Land use type and pollutant accumulation rates • Nutrient and pathogen application rates and dates • Impoundment size and discharge rates • Settling rate and pollutant decay rate
SWMM	• Land use type and pollutant accumulation rates • Impoundment size, shape, and discharge rate • Settling rates and pollutant decay rates • Street cleaning frequency and areas affected
P8-UCM	• Point practice drainage area • Impoundment size and discharge rate, pollutant decay rate • Bioretention size and infiltration rate • Street cleaning frequency and area affected
SWAT	• Tillage area, type and date, crop rotation • Fertilizer and pesticide application rate, method, and dates • Manure application rate, method, and dates • Filter strip width • Grazing dates and vegetation biomass affected • Street sweeping pollutant removal rate, date, and curb length

Other Models Available for Analysis of Management Practices

Although the selected models consider various management practices, sometimes you might need an additional model or models that specialize in a particular type of management practice simulation. In some cases, models are used to perform a detailed small-scale (small representative watersheds or fields) analysis of management practices. Some of the specialized management practice models available today are the Site Evaluation Tool (SET), the Prince George's County [Maryland] BMP Module (PGC-BMP), Model for Urban Stormwater Improvement Conceptualization (MUSIC), and Integrated Design and Evaluation Assessment of Loadings (IDEAL). SET provides a simplified spreadsheet-based approach for assessing management practices and is used in several examples throughout this chapter. PGC-BMP,

Build on Existing Model or Perform Separate Analysis

When evaluating modeling approaches for evaluating management practices, consider the following alternatives:

- Modify original loading model to incorporate management practices.
- Add supplemental analyses for specific management practices.
- Perform alternative analyses for management practices using spreadsheet or other simplified tools.

MUSIC, and IDEAL provide options for more detailed simulation of multiple management practices. These systems are oriented to examining networks of one or more management practices.

Many models, however, do not include ways to evaluate the benefits of buffer zones. The models that specialize in the representation of buffer strips include the Vegetative Filter Strip Model (VFSMOD) and Riparian Ecosystem Management Model (REMM). Options for reducing sediment loading, including forest and agricultural area management, can be evaluated using Water Erosion Prediction Project (WEPP); the Erosion Productivity Impact Calculator (EPIC) also provides evaluation of agricultural area management. WETLAND and Virginia Field Scale Wetland Model (VAFSWM) provide the capability to evaluate wetlands. These specialized models are summarized in table 11-4 and described in more detail below.

Table 11-4. Specialized Models for Analyzing Management Practices

Model	Types of Management Practices Considered	Management Practice Evaluation Techniques	Water Quality Constituents
SET	• Detention basin (e.g., wet pond, extended dry detention, conventional dry detention) • Infiltration practices (e.g., infiltration trench, dry well, porous pavement, sand filter) • Vegetative practices (e.g., wetland, swale, buffer/filter strip, bioretention, green roof) • Wetland • Storage (e.g., cistern/rain barrels)	• Simple percent reduction • Simple regression	• Sediment • Nutrients (total nitrogen and total phosphorus)
GC-BMP	• Detention basin • Infiltration practices (e.g., infiltration trench, dry well, porous pavement) • Vegetative practices (e.g., wetland, swale, filter strip, bioretention)	• Infiltration: Holtan's equation • Storage routing • Weir/orifice flow • First-order decay	• User-defined pollutants
MUSIC	• Detention basin • Infiltration practices • Vegetative practices	• Infiltration • Settling • First-order decay (k-C* model)	• User-defined pollutants
IDEAL	• Vegetative filter strip • Detention/retention basin	• Infiltration • Storage routing • Settling • Trapping efficiency • Bacteria die-off rate	• Sediment • Nutrients • Bacteria
VFSMOD	• Vegetative filter strip	• Infiltration: Green-Ampt equation • Kinematic wave • Sediment deposition and resuspension	• Sediment
REMM	• Riparian buffer strip	• Infiltration: Green-Ampt equation • Sediment: USLE parameters • Storage routing • Nutrient cycling: Century Model • Nitrification: First-order Weir/orifice flow • Sediment transport: Einstein and Bagnold equations	• Sediment • Nutrients • Organic matter

Table 11-4. Specialized Models for Analyzing Management Practices (continued)

Model	Types of Management Practices Considered	Management Practice Evaluation Techniques	Water Quality Constituents
WEPP	• Impoundment • Tillage management • Irrigation management • Grazing management • Filter strips • Forest roads • Forest and rangeland fire management	• Infiltration: Green-Ampt Mein-Larson equation • Erosion: Steady-state sediment continuity equation • Kinematic wave • Subsurface: Kinematic storage-discharge	• Sediment
EPIC	• Tillage management • Fertilizer management • Irrigation management • Feedlot management (lagoons)	• Infiltration: Curve number equation or rational formula • Six variations of USLE equation for soil erosion and sediment delivery • Storage routing • Nitrogen and phosphorus cycling	• Sediment • Nutrients • Pesticides
WETLAND	• Detention basin • Wetland	• Water budget • Monod kinetics • Nutrients cycling (carbon, nitrogen, phosphorus) • Constant vegetative growth rate • Freundlich isotherms for phosphorus sorption/desorption • First-order mineralization	• Nitrogen • Phosphorus • Carbon • Dissolved oxygen • Sediment • Bacteria
VAFSWM	• Detention basin • Wetland	• Water budget • Infiltration • Particle settling • Continuously stirred tank reactors in series • First-order kinetics (adsorption, plant uptake)	• User-defined • Sediment

SET was developed to assess the impacts of development, including sediment and nutrient loading, on a site scale. It provides a more robust environment for testing multiple management practices and site configurations than simple export calculations, and it incorporates several principles discussed previously in this section. The tool lets the user define pre- and post-treated land use/land cover, allowing for multiple drainage areas and various combinations of practices. An important benefit of SET is that the user can test management practices in combination with each other, in the context of a site or small catchment. In addition, both structural and nonstructural practices can be represented, offering a suite of options for evaluation.

PGC-BMP is an example of a more detailed management practice simulation tool. It evaluates the effect of management practices or combinations of management practices on flow and pollutant loading. It uses simplified process-based algorithms to simulate management practice control of modeled flow and water quality time series generated by watershed models like HSPF. These simple algorithms include weir and orifice control structures, storm swale characteristics, flow and pollutant transport, flow routing and networking, infiltration and saturation, and a general loss/decay representation for pollutants. The tool offers the flexibility to design retention-style or open-channel management practices; define flow routing through a management practice or management practice network; simulate integrated management practices (IMPs), such as reduced or discontinued imperviousness through flow networking; and compare management practice controls against a defined benchmark, such as a simulated pre-development condition. Because the underlying algorithms are based on physical processes, management practice effectiveness can be evaluated and estimated over a wide range of storm conditions, management practice designs, and flow routing configurations.

MUSIC (Wong et al. 2001, Wong et al. 2005) was developed by the Cooperative Research Center for Catchment Hydrology in Australia. It was developed to evaluate small- and large-scale (0.01 km^2 to 100 km^2) urban stormwater systems using modeling time steps that range from 6 minutes to 24 hours. MUSIC provides an interface to help set up complex stormwater management scenarios. The interface also allows the user to view results using a range of graphical and tabular formats. The stormwater control devices evaluated by MUSIC include ponds, bioretention, infiltration buffer strips, sedimentation basins, pollutant traps, wetlands, and swales. The major techniques used to evaluate management practices are settling in ponds and decay of pollutants (first-order). For more information go to the MUSIC Web site at **www.toolkit.net.au/music**.

IDEAL (Barfield et al. 2002) provides a spreadsheet-based technique for assessing the beneficial effects of urban management practices on flow, sediment, nutrients, and bacteria. The model predicts watershed runoff, concentrations, and loads based on your selection of vegetative filter strips, dry detention ponds, and wet detention ponds. Urban areas are defined as pervious, impervious connected, and impervious unconnected areas. Flow and loads can be directed to a pond that can be dry (no permanent pool) or wet (permanent pool). The model then calculates the pollutant removal efficiencies of the practices using empirical equations. The model predicts single storm values and converts them to average annual storm values using a statistical process. IDEAL is designed to help managers estimate long-term management practice pollutant removal efficiencies and is not designed for evaluating individual storms.

VFSMOD (Muñoz-Carpena and Parsons 2003) provides specialized modeling of field-scale processes associated with filter strips or buffers. This model provides routing of storm runoff from an adjacent field through a vegetative filter strip and calculates outflow, infiltration, and sediment-trapping efficiency. The model is sensitive to the characteristics of the filter, including vegetation roughness or density, slope, infiltration characteristics, and the incoming runoff volume and sediment particle sizes. VFSMOD includes a series of modules—Green-Ampt infiltration module, kinematic wave overland flow module, and sediment filtration module. The model can also be used to describe transport at the edge of the field when flow and transport are mainly in the form of sheet flow and the path represents average conditions across the vegetative filter strip. VFSMOD uses a variable time step that helps to more accurately solve the overland water flow equation. The model inputs are specified on a storm basis, and the model summarizes all the information after each event to generate storm outputs. For more information go to the VFSMOD Web site at **http://carpena.ifas.ufl.edu/vfsmod**.

REMM is used to simulate hydrology, nutrient dynamics, and plant growth for land areas between the edges of fields and a waterbody. Output from REMM allows watershed planners to develop buffer systems to help control nonpoint source pollution. USDA's Agricultural Research Service (ARS) developed REMM at the Southeast Watershed Research Laboratory, Coastal Plain Experiment Station, in Tifton, Georgia. For more information go to the REMM Web site at **www.cpes.peachnet.edu/remmwww**.

WEPP (Flanagan and Nearing 1995) simulates water runoff, erosion, and sediment delivery from fields or small watersheds. Management practices, including crop rotation, planting and harvest date, tillage, compaction, stripcropping, row arrangement, terraces, field borders, and windbreaks, can be simulated. WEPP has been applied to various land use and management conditions (Liu et al. 1997, Tiscareno-Lopez et al. 1993). For more information go to the Web site **http://topsoil.nserl.purdue.edu/nserlweb/weppmain/wepp.html**.

EPIC (Sharpley and Williams 1990) simulates the effect of management practices on edge-of-field water quality and nitrate nitrogen and pesticide leaching to the bottom of the soil profile. The model considers the effect of crop type, planting date, irrigation, drainage, rotations, tillage, residue, commercial fertilizer, animal waste, and pesticides on surface water and shallow ground water quality. EPIC has been used to evaluate various cropland management practices (Edwards et al. 1994, Sugiharto et al. 1994).

WETLAND (Lee 1999, Lee et al. 2002) is a dynamic compartmental model used to simulate hydrologic, water quality, and biological processes and to assist in the design and evaluation of wetlands. WETLAND uses the continuously stirred tank reactor prototype, and it is assumed that all incoming nutrients are completely mixed throughout the entire volume. The model can simulate both free-water surface and subsurface-flow wetlands. WETLAND is modular and includes hydrologic, nitrogen, carbon, dissolved oxygen, bacteria, sediment, vegetation, and phosphorus submodels. The strength of this model lies in the linked kinetics for the water quality variables and the consideration of seasonal variation (variable user-defined parameter by season/time period). The weaknesses include the completely mixed assumption, which overlooks the effect of the system shape, and the need for extensive kinetic parameters.

VAFSWM (Yu et al. 1998) is a field-scale model for quantifying the pollutant removal in a wetland system. It includes a hydrologic subroutine to route flow through the treatment system and precipitation, evapotranspiration, and exchange with subsurface ground water. VAFSWM simulates settling, diffusion, adsorption to plants and substrate, and vegetative uptake for a pollutant in dissolved and particulate forms in a two-segment (water column and substrate), two-state (completely mixed and quiescent) reactor system by employing first-order kinetics. The governing equations for the quiescent condition are identical to that for the turbulent condition; however, far lower settling velocities are assumed to account for the greater percentage of finer particles during the quiescent state. VAFSWM is a relatively simple model that includes the most dominant processes within the wetland system. However, the user needs to provide and calibrate the requisite kinetics parameters.

Considerations in Modeling of Management Strategies

Whether you use simplified approaches, one of the selected models, or a combination of supplementary tools, there are some common considerations in developing your approach to model management practices. Summarized below are some of the key issues in the emerging area of watershed management practice simulation. It's important to recognize that simulating management practices can make the modeling process much more complicated and data-intensive, primarily because of scale and the amount of information needed. For example, in a 1,000-acre watershed, hundreds of management practices could be used. Some management practices, such as cropping practices that affect a percentage of corn fields, cover large areas. Others, such as an individual pond that drains part of a watershed, are at specific locations.

Others, such as a riparian buffer zone on either side of several miles of a river, might stretch across part of the watershed. For large watersheds, the information collection needs can quickly become formidable. In addition, there are often issues related to privacy and protecting information related to management practices installed on private lands. Collecting some information on current management practice adoption, however, is very important for the purposes of estimating benefits and evaluating needs for future management.

When setting up models, some approaches involve identifying and inputting information on each management practice. This is appropriate for small watersheds and can provide a system for evaluating the benefit of management actions and new initiatives. For large watersheds, modelers use a variety of techniques to extrapolate or estimate the benefits of management. One technique is a "nested" modeling approach, in which a more detailed model is applied to a smaller representative area. The results of the detailed modeling are then used to define the land use characteristics used for the large-scale watershed model. For example, a detailed model might be used to evaluate new residential development techniques. The results of the detailed small-scale assessment would be used to create a new alternative "new residential development" land use that would then be used in the watershed-wide simulation. Sample or pilot studies can be used to test and evaluate a variety of management techniques on a small scale before initiating a large, more complex and time-intensive application. Sometimes watershed-wide or large-scale applications can be adjusted by using simple percentage reductions at the subwatershed or land use level to reflect estimates of load reduction due to management practices.

Tip Regardless of the technique used, you should record the rationale and justification for why the various changes were made. This will provide documentation for what was done and give you a basis for future updates or improvements in the methodology as more information becomes available.

Consider carefully what areas are really being treated by the management practices. The drainage area or treatment area is used for calculations of loading and percent removal. Site constraints usually prevent 100 percent treatment of a particular development. Assume, for example, that a residential development will be treated by a stormwater wetland. Site topography prevents 10 percent of the site from draining to the wetland. If you're using an ordinance to require a set-aside of undisturbed open space, the untreated area increases because the open space cannot be graded. In this example, complementary practices result in a change in the evaluation of one of the practices.

Another consideration might be the drainage area for a buffer zone. The buffer is located laterally along a channel and receives runoff from the drainage adjacent to the channel. In an urban setting, however, runoff from storm events tends to accumulate into concentrated flow within a short distance, probably no more than 150 feet (Schueler 1995). These concentrated flows will likely bisect or cross a buffer without treatment. In the eastern United States, this area of concentrated flows usually translates to less than 10 percent of a watershed for perennial streams. The pollutant removal rates in the literature reflect runoff received as overland flow. Removal performance is therefore limited by the proportion of a site draining to it.

11.3.3 Example Model Applications to Assess Management Strategies

Using the approaches discussed in the previous section, you will now quantify the effectiveness of the proposed management practices in meeting watershed goals and objectives. This section presents three examples that reflect various management objectives, such as addressing multiple indicators using a variety of practices, assessing sediment loading reductions, and improving habitat.

Quantify the Effectiveness of Multiple Management Practices

You can use a spreadsheet tool to assist with quantifying multiple practices. This example demonstrates how a management strategy can be assessed for multiple indicators using a simplified spreadsheet tool, SET. The example includes a suite of structural management practices, nonstructural management practices and detailed site layout, and a need to define multiple drainage areas and management practice combinations, including treatment trains (figure 11-3).

Quantify the Effectiveness of Management Practices in Reducing Sediment Loading

When reducing sediment loading is the management objective, rates of sediment generation from channel enlargement can provide a tool for quantifying effectiveness. A monitoring approach is a good strategy for assessing longer-term sediment loading and stream channel characteristics. Historical aerial photographs allow comparison of channel width and location over discrete points in time, and translating changes to an average annual rate can provide an estimate of the rate of sediment loading due to instream sources. A more direct method of calculating erosion rates is to install and monitor bank pins in the reach of interest. Stakes or pins can be driven into channel banks flush with the surface. The amount of pin exposed due to erosion is the amount of change at the streambank erosion site between your times of observation. (↳ Note: This would have been done during the earlier data collection phase; refer to chapter 6). Reductions in sediment loading can then be quantified by comparing the estimated erosion rates with the rate for a stable reach (figure 11-4).

Quantify the Effectiveness of Management Practices in Improving Aquatic Habitat

For stream reaches where instream habitat is degraded, habitat sampling can provide a gauge for quantifying the effectiveness of a management action. A straightforward comparison of conditions before and after implementation can numerically quantify the improvement in aquatic habitat. State agencies typically have habitat evaluation forms that provide numerical rankings for observed conditions for various components of aquatic habitat. By using such forms, some of the subjectivity of visual interpretations can be reduced, leading to better evaluations of effectiveness (figure 11-5). Also, evaluation of community assemblages (e.g., macroinvertebrates, fish, periphyton) is a critical measure of the overall effectiveness of habitat protection management measures. ↳ EPA's *Rapid Bioassessment Protocols (RBPs) for Use in Wadeable Streams and Rivers* (Barbour et al. 1999) provides more information about evaluating habitat (**www.epa.gov/owow/monitoring/rbp/index.html**). ↳ Additional descriptions of state protocols for assessing habitat quality can be found in EPA's *Summary of Assessment Programs and Biocriteria Development for States, Tribes, Territories, Interstate Commissions: Streams and Wadeable Rivers* at **www.epa.gov/bioindicators**. (↳ See section 6.5.6 for more information on assessing habitat quality.)

Modeling can be used where nutrient reductions associated with improving vegetation in riparian areas are the management goal. Loading rates for constituents of concern within a limited distance of riparian areas can be coupled with the removal efficiencies of the buffers to evaluate how effective the management action is at reducing contaminant input to the stream. However, the benefits of nutrient reduction associated with riparian revegetation are typically limited, especially in locations where stormwater outfalls or drainage ditches result in concentrated flow through the buffer.

Mecklenburg County, North Carolina, is home to rapidly growing Charlotte and other surrounding communities. It has several watersheds listed as impaired in part due to the impacts of upland sedimentation. In addition, nutrient loading from much of the county affects several reservoirs on the Catawba River. The following example explores how the SET might be used to evaluate various combinations of management practices. The team located sites in the watershed that were publicly owned, were larger than 5 acres, and could be adapted for retrofit of possible management practices. The selected 10-acre site contains a public school and lends itself well to placement of a structural practice to capture most of the runoff. Three scenarios are being tested—a stormwater pond, a combination of bioretention cells in series with an extended dry detention basin, and the conversion of 2 acres of lawn into forest. Thirty percent of the site is impervious surface, and the remainder is lawn or managed herbaceous. The site configuration for each scenario is as follows:

Stormwater Pond: The pond is at the lowest point on the site, and it captures all runoff except that from 1 acre of lawn area.

Bioretention Cells and Extended Dry Detention Basin: Bioretention cells treat all the impervious area and 2.75 acres of the lawn area; all bioretention cells are configured to drain completely to the extended dry detention basin. Another 3.25 acres of the site drain to the extended dry detention basin only. One acre of lawn is not treated.

Forest Conversion: Two acres of lawn area are planted with saplings, fenced off, and no longer mowed. Modeled conditions reflect brush/immature forest.

The amount of land in each of the three land cover types is summarized below for existing conditions and the three proposed management alternatives:

Treatment	Land Cover in Drainage Area (acres)		
	Lawn	Impervious	Forest
Existing Site			
Untreated	7	3	
Stormwater Pond Scenario			
Stormwater pond	6	3	
Untreated	1		
Bioretention and Extended Dry Detention Scenario			
Bioretention + dry detention	2.75	3	
Dry detention only	3.25		
Untreated	1		
Forest Conversion Scenario			
New land cover	5	3	2

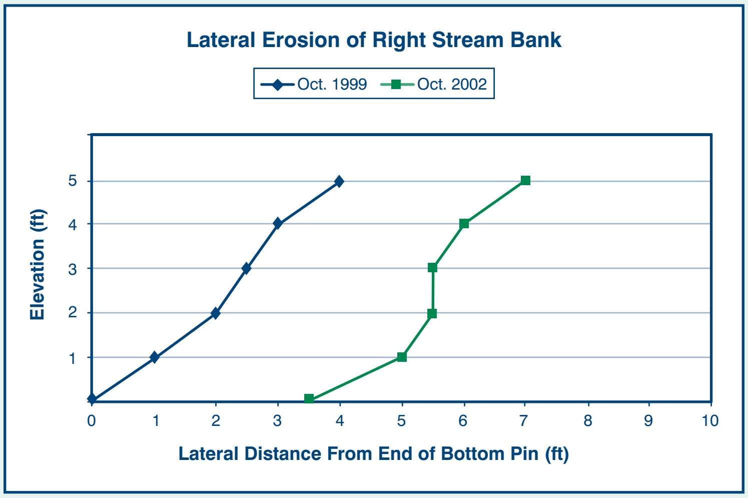
The SET calculates annual loads from the site under each scenario for total suspended solids, total phosphorus, and total nitrogen and shows the percent reduction in load between the existing site and each scenario. The forest conversion scenario by itself performs poorly, but results suggest it might be a good candidate as a complementary practice. The two structural management practice scenarios perform better for pollutant reduction. Note that the bioretention/extended dry detention scenario performs better than the stormwater pond for nutrient removal but worse for sediment removal.

	TSS		TP		TN	
	tons/yr	% red.	lb/yr	% red.	lb/yr	% red.
Existing Site	5.11		11.5		70	
Stormwater Pond	1.79	65%	6	48%	50	29%
Bioretention/Ext. Dry Detention	1.97	61%	4.6	60%	36	49%
Forest Conversion	4.1	20%	10.6	8%	66	6%

Figure 11-3. Analysis of Multiple Management Practices Using Multiple Indicators

Bank pins (e.g., rebar with painted ends) were installed in a streambank in October 1999 to determine the rate of streambank erosion. In October 2002, three years after the pins were installed, the distance that the pins extended from the streambank was recorded. The streambank profiles are illustrated in the figure. Six bank pins were installed at approximately one-foot vertical intervals between the toe of the bank and top of the bank.

This location along the stream is representative of nearly 400 feet of channel. If the streambank along this reach were stabilized, what would be the effect on the average annual contribution to the total sediment load, at current erosion rates?



The lengths that the six bank pins extended from the bank at the October 2002 measurement, from the lowest pin to the highest, were 3.5, 4.0, 3.5, 3.0, 3.0, and 3.0 feet, respectively.

Average amount of erosion = (3.5 + 4 + 3.5 + 3 + 3 + 3) / 6 = 3.3 feet

Conversion to average annual rate = 3.3 feet / 3 years = 1.1 feet per year

Average annual volumetric loading (using length of 400 feet and average bank height of 5 feet)
= 1.1 ft/yr * 400 ft * 5 ft = 2,200 cubic feet per year

To convert to a weight-based sediment loading, a unit weight of the streambank soil is needed.

Assume a unit weight of 100 pounds per cubic foot for this streambank soil.

Average annual weight of sediment loading
= 2,200 cubic feet per year * 100 pounds per cubic foot = 220,000 pounds per year
= 110 tons per year.

Unimpacted, stable channels tend to have negligible rates of streambank erosion, so an eroding channel that is stabilized can be assumed to have a negligible rate of erosion as well. Thus, stabilization efforts along this reach of stream can be expected to reduce average annual sediment loading by about 110 tons per year. Caution should be exercised to determine the overall effects of any streambank stabilization work, to ensure that erosive forces are not simply transferred to another—possibly unprotected—location downstream.

Figure 11-4. Quantifying the Effectiveness of Stabilization Practices in Reducing Sediment Loads

In this section you were shown how to quantify the effectiveness of various management practices to evaluate how well they achieve the management goal. Next, you'll compare the estimated costs of various management actions to identify the most cost-effective opportunities.

11.4 Identify Costs and Compare Benefits of Management Practices

Now that you've quantified the effectiveness of various management practices in achieving your goals and objectives, you should incorporate cost considerations into your evaluation. Economics is always a consideration in the evaluation and formulation of management strategies. Stakeholders might offer insights and concerns regarding the cost of various management options. This is why an ongoing dialogue with stakeholders is critical to selecting management alternatives that they will support. Cost considerations can also help to identify opportunities for collaboration or leveraging practices with existing programs.

A stream reach that is classified as impaired because of the condition of the instream aquatic habitat is being considered for rehabilitation efforts. A few rehabilitation options are under consideration because of various levels of effort and the associated costs. How can the effectiveness of the rehabilitation efforts be evaluated?

A physiographic region-specific instream aquatic habitat evaluation method can be used to characterize habitat condition, and the numeric score linked to a functional level of support for the aquatic community. In this example, the overall score can range from 0 (most impaired conditions) to 200 (capable of fully supporting a diverse and abundant aquatic community). The functional levels of support are provided in table A.

Table A. Habitat Quality and Use Classifications by Habitat Score

Habitat Assessment Score	Habitat Quality	Use Classification
170–200	Excellent	Supporting
145–169	Good	Supporting
95–44	Good–Fair	Partially Supporting
50–94	Fair	Not Supporting
0–9	Poor	Not Supporting

The field form used for the example reach includes 10 key habitat parameters with a numeric scale for each parameter for assigning 0–20 points. An example breakdown of possible points for the degree of physical channel alteration is shown in Table B. Under the current conditions, the example reach scores a total of 90 points, corresponding to *Fair* habitat quality and *Not Supporting* its use. Of the 90 points, 3 points were assigned to the parameter for Physical Channel Alteration because of historical channelization (i.e., 100 percent of the reach is disturbed, but no embankments are present).

For the proposed full-scale rehabilitation effort, a new natural channel will be excavated on the existing floodplain. Because of the location of a sanitary sewer line along the right side of the floodplain, the sinuosity of the new channel will be limited and channel bends will be no tighter than 45 degrees. Therefore, if the full-scale restoration effort is pursued, the scoring for the Physical Channel Alteration is expected to increase from 3 points to 18 points.

Figure 11-5. Quantifying the Effectiveness of Management Practices in Improving Aquatic Habitat

To fully evaluate the effectiveness of the full-scale rehabilitation option, the anticipated conditions will need to be compared with the existing scores. Although the scores for many parameters will be expected to increase, decreases are possible and need to be realistically evaluated. (For example, if the existing canopy cover is dense and scores high, but the restoration effort would result in clearing and revegetation that would not provide dense cover until the vegetation had time to grow, the result would be a lower score.) In this manner, the effectiveness of the various rehabilitation efforts can be quantified.

Table B. Scoring Thresholds for Physical Channel Alteration

Stream follows a normal and natural meandering pattern; alteration is absent	
No evidence of disturbance; bend angles greater than 60 degrees	20
No evidence of disturbance; bend angles between 40 and 60 degrees	18
No evidence of disturbance; bend angles less than 40 degrees	16
Some stream alteration present but NO evidence of recent alteration activities	
Bridge abutments present but older than 20 years; no other disturbances	15
10% of reach or less has channel disturbance other than bridge	14
20% of reach has channel disturbance	13
30% of reach has channel disturbance	12
40% of reach has channel disturbance	11
Somewhat altered; 40%–80% of reach altered; alterations might be within past 20 years	
40% of reach has channel disturbance	10
50% of reach has channel disturbance	9
60% of reach has channel disturbance	8
70% of reach has channel disturbance	7
80% of reach has channel disturbance	6
More than 80% of reach altered; instream habitat highly affected	
90% of reach has channel disturbance	5
100% of reach disturbed; straightened with no artificial embankments	3
100% of reach disturbed; straightened with artificial embankments	2
100% of reach disturbed; straightened with natural and artificial embankments	1
100% of reach disturbed; concrete or gabion lining	0

Figure 11-5. Quantifying the Effectiveness of Management Practices in Improving Aquatic Habitat (continued)

To the extent possible, a cost estimate should consider all future costs of the management strategy, including design and engineering, construction, labor, and operation and maintenance. The following sections explain what to consider when estimating the cost of management options and how to conduct a cost/benefit analysis. Most of the guidelines center on structural management practices, but the discussions of labor, inflation, discounting, and information sources are applicable to nonstructural management options as well.

11.4.1 Identify Cost Considerations

Construction Costs

The construction costs of various management practices can be estimated in one of two ways: (1) with a total per unit cost or (2) with a detailed breakdown of individual cost components. Total per unit costs are more appropriate when you're considering a large number of management practice sites or management practices that would be applied throughout the watershed but at no specific location. If you need to estimate the size of a specific practice, use published design guidelines or consult with a stormwater engineer to ensure the accuracy of the cost estimate.

If you're comparing a few specific management practices, using a detailed cost estimate would be more accurate than using a total per unit cost estimate. For example, if you were comparing the use of a stormwater wetland with the use of a wet pond for a single site, you should consider how the costs of these management practices would differ on that particular site. You would estimate the cost of each construction component (e.g., excavation, grading, outlet structure) and then sum the component costs to arrive at a total cost estimate. Use guidance from a stormwater engineer when determining preliminary quantities and costs of individual management practice components.

Whether you're looking for total per unit costs or component costs, look for local cost estimates that use the same design guidelines that your project will require. It's also important to use costs that represent soil, climatic, and geographic conditions similar to those of your future project. Check several sources to determine whether cost estimates vary geographically.

The accuracy of cost estimates depends on how unit costs are used to translate management practice design quantities into management practice costs. Although your management practice might be appropriately sized, you can describe the management practice size in many different ways. For example, a detention pond has at least three volumes: a permanent pool, a detention volume, and a volume up to the emergency spillway. You should determine to which measurements the unit cost refers. Table 11-5 shows example formats of management practice unit costs and the information you need before using the unit costs.

Table 11-5. Considerations for Applying Management Practice Unit Cost Measures

Example Management Practice	Example Cost Units	Issues to Consider Before Using Unit Costs
Grass swale	$ per linear foot	Find out the width of swale assumed in the unit cost, and make sure the width is appropriate for your project. You will overestimate the cost if you use a unit cost based on a swale that is wider than your proposed swale.
Water quality swale (dry swale)	$ per square foot	Find out whether the width should be measured across the filter media or across the entire swale. You will overestimate the cost if you measure across the entire swale and the unit cost refers to only the filter media width.
Wet detention pond	$ per cubic foot	Determine the height at which to measure the pond volume. If the cost estimate assumes the volume up to the emergency spillway, using the volume of the permanent pool would underestimate the pond cost.
Bioretention	$ per impervious acre treated	This cost estimate format might not be appropriate for all uses. If your bioretention cell is treating a large amount of pervious area (e.g., grass lawn), this unit cost would not accurately represent the size of the bioretention cell needed.
Stormwater wetland	$ per acre of drainage area treated	This unit cost would not account for how drainage areas vary in the amount of impervious surface. Before using this type of estimate, you should make sure that it assumes a level of imperviousness similar to that of your stormwater wetland's drainage area.

Management practice retrofit costs can differ from the costs of management practices used in new development. Check whether the cost information refers to new construction or retrofit sites. If you're estimating costs for a retrofit site and can't find information on retrofit costs, consider how your project will differ from new construction. A retrofit on an agricultural site is likely to be similar in cost to a management practice on a new construction site, whereas a management practice retrofit on a highly developed site could have a much higher cost than new construction. For highly developed sites, you should estimate costs for demolition, regrading, and other components in addition to new construction management practice costs.

Overall, construction cost information can be an important deciding factor for targeting management practices in a watershed. Figure 11- 6 shows a comparison of the costs of different treatment trains for a mixed-use development. Each treatment train achieves a 70 percent total phosphorus removal objective, and the cost analysis shows that treating runoff with water quality swales leading to a wet detention pond is the least expensive option for this development. Although this treatment train is the least expensive for one development, a different combination of management practices might be more economical for a different type of development or treatment objective.

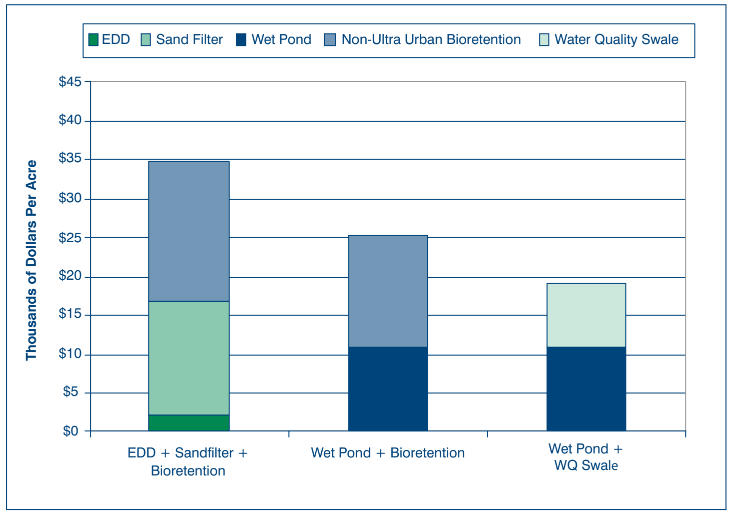


Figure 11-6. Cost Comparison of Alternative Treatment Trains to Meet Specific Water Quality and Detention Performance Standards

Labor and Nonstructural Management Options

When estimating construction costs, check that the cost information includes labor. Most total construction cost estimates include labor. If you're estimating costs for a nonstructural management practice like training programs or site-specific nutrient management plans, most of the costs will be labor. Request cost information from local agencies that have recently developed a similar policy or plan. Also consider how project costs vary by the site acreage or type of watershed being managed. If no local information is available, you can check Internet references that provide cost estimates for nonstructural management practices. For example, the EPA Web site provides cost information for agricultural management practices, including a number of nonstructural management options: **www.epa.gov/owow/nps/agmm**. Information is also available for management practices for other source types, including forestry (**www.epa.gov/owow/nps/forestrymgmt/**), marinas and recreational boating (**www.epa.gov/owow/nps/mmsp/index.html**), and urban areas (**www.epa.gov/owow/nps/urbanmm/index.html**).

Design and Engineering Costs

When researching construction cost estimates for various management practices, determine whether the cost estimates include design and engineering. Typical design and engineering costs represent an additional 25 to 30 percent of the base construction cost. Use a local estimate if available; otherwise, consult a national management practice reference for the approximate design and engineering costs of your specific management practices. See appendix A for example management practice reference guides.

Operation and Maintenance Costs

Operation and maintenance costs vary by the type of management practice and local requirements. Use local cost estimates when available; otherwise, use the most recent estimates from national sources. Reference sources might report operation and maintenance costs as average annual costs or as a percentage of the base management practice construction cost. For example, *Post-Construction Storm Water Management in New Development & Redevelopment* (USEPA 2003b) estimates that the annual routine maintenance cost for a wet detention pond ranges from 3 to 5 percent of the pond's construction cost. Maintenance for a $150,000 wet detention pond would therefore cost about $4,500 to $7,500 per year.

Inflation Adjustment

Prices of goods and services increase every year because of inflation. You should adjust cost estimates for inflation if they are reported before the first year of your project. You need to adjust only historical prices; maintenance and other costs after the first project year do not have to be adjusted because your estimate should be in the perspective of the first project year, or in "real" terms. The U.S. inflation rate averages about 3 percent per year. Inflation rates for specific products are available but are probably not necessary for preliminary cost estimates.

To adjust historical costs, increase the cost by the inflation rate for every year that the historical cost differs from the first project year. For example, a cost of about $4 per cubic foot for an infiltration trench in 1997 would be converted to a cost of about $5 per cubic foot in 2005 according to the following calculation:

$$2005 \text{ cost} = \$4.00 \times (1 + 0.03)^{(2005-1997)} = \$5.07$$

Discounting

The costs that occur after the first project year should be estimated in "present value" terms. The present value is the current value of the projected stream of costs throughout a project's lifetime. The process of calculating present value is known as discounting. Discounting is important because the money allocated to future costs could earn an average return in another investment. For example, assume that the first project year is 2005 and your project will require maintenance after construction. If you can invest the project's maintenance funds in another project or fund and earn at a return of r, consuming one unit of maintenance in 2006 would have a present value of $1/(1+r)$ in 2005. One unit consumed in 2007 has a present value of $1/(1+r)^2$ in 2005, and so on. The r at which future returns are discounted to the present value is called the discount rate (Helfert 1997; Sugden and Williams 1981). Discounting simply reflects the time preference for consumption. Although not synonymous with the interest rate, for governments it often reflects the rate at which funds can be borrowed and loaned. Discounting is especially important if you're comparing projects with different maintenance costs and frequencies.

Project costs should be discounted if they are incurred after the first project year. Costs are discounted according to the following formula:

$$PV = C / (1+r)^{(Y^C - Y^0)}$$

where PV = present value, C = cost, r = discount rate, Y^C = year of cost, and Y^0 = first year of cost.

After discounting, costs for all years should be summed to calculate the total present value cost.

The U.S. Office of Management and Budget (OMB) publishes the discount rates required for use in federal project evaluations. OMB currently requires a 7 percent discount rate for projects evaluated in real terms (USOMB 2005). A discount rate of 7 percent would be appropriate to use with a government-funded project; a higher discount rate should be used if the project is privately funded.

Table 11-6 gives a hypothetical example of discounting costs for two management practices, in which MP 1 is $2,000 more expensive to construct than MP 2. Over 20 years, the present value of maintenance costs for MP 1 is $2,000 less expensive than that of MP 2. When construction and maintenance are considered together, MP 1 is about $100 less expensive than MP 2. Although MP 1 is the more expensive management practice to construct, the present value calculation shows that it is the less expensive management practice when construction and maintenance are considered.

Table 11-6. Example of Discounting Management Practice Cost for Comparison Purposes

Management Practice	Construction Cost	Annual Maintenance	Present Value of Maintenance Costs over 20 Years, r = 7%	Total Present Value of Costs
MP 1	$12,000	$300	$3,178	$15,178
MP 2	$10,000	$500	$5,297	$15,297

11.4.2 Compare Costs and Effectiveness of Management Practices

Choosing the most beneficial management practices for your watershed involves comparing the costs and pollution reductions of the available options. At a minimum, you should compare the total costs and effectiveness of the management practices. First, compare the total benefits and determine which management practices achieve the goals of your project. Then, compare the total costs of the management practices that achieve your goals and determine which ones are the least expensive. If you wish to prioritize further, calculate a cost-effectiveness ratio to determine which management practice is the most cost-effective for achieving your goals.

Buffer$:
A Conservation Buffer Economic Tool

Buffer$, a Microsoft Excel-based tool, can be used to analyze the cost benefits of buffers compared to those of traditional crops. To download the tool, visit **www.unl.edu/nac/conservation** (right click on the picture and click "save target as"; the file size is 6.0 Mb, so it might take a while to download). To request a CD with the tool, contact Gary Bentrup at **gbentrup@fs.fed.us**.

The following example illustrates how a cost-effectiveness ratio can be calculated. Assume that you're proposing a treatment train of bioretention cells draining to an extended dry detention pond for a residential development. The total present value cost of the management practice construction, operation, and maintenance is about $200,000. The estimated annual reduction in total phosphorus load is 7 pounds per year. Assuming a project lifetime of 20 years, the total reduction in phosphorus load would be 7 lb × 20, or 140 lb. The cost per pound of phosphorus removed is $200,000 divided by 140, or about $1,430. In this example, the pounds of phosphorus removed are not discounted over the project lifetime. If you are comparing practices with differing benefits over time, you might consider discounting pollution load reduction and other nonmonetary benefits as prescribed by OMB (USOMB 2005).

You can determine which options are the most cost-effective by comparing the cost- effectiveness ratios of your management options. The management option with the lowest cost-effectiveness ratio provides the most benefit for the least dollars spent. However, you also need to evaluate whether the most cost-effective options are adequate to meet your management goals. Sometimes you need to select less cost-effective options because they represent the only way to achieve the required load reductions or other specific goals. For example, in a watershed targeted for sediment reduction that has significant sediment contribution from eroding banks, more expensive structural stream restoration might be the only way to achieve the necessary reduction; more cost-effective upland management practices might not be able to achieve targets by themselves.

The examples above assume that you're comparing management options for one type of development or condition. Comparing costs and benefits is also useful when targeting management practices across different types of land uses. Figure 11-7 compares the costs and pollutant loadings across 14 types of developments; the percentage on the horizontal axis refers to the average percentage imperviousness of the developments. A simplified spreadsheet, SET, was used in this example to estimate the pollutant loading with and without management practices, and each management practice treatment train achieved 70 percent phosphorus removal. The figure shows that developments with a higher percentage of impervious area can cost substantially more to treat than developments with lower levels of imperviousness.

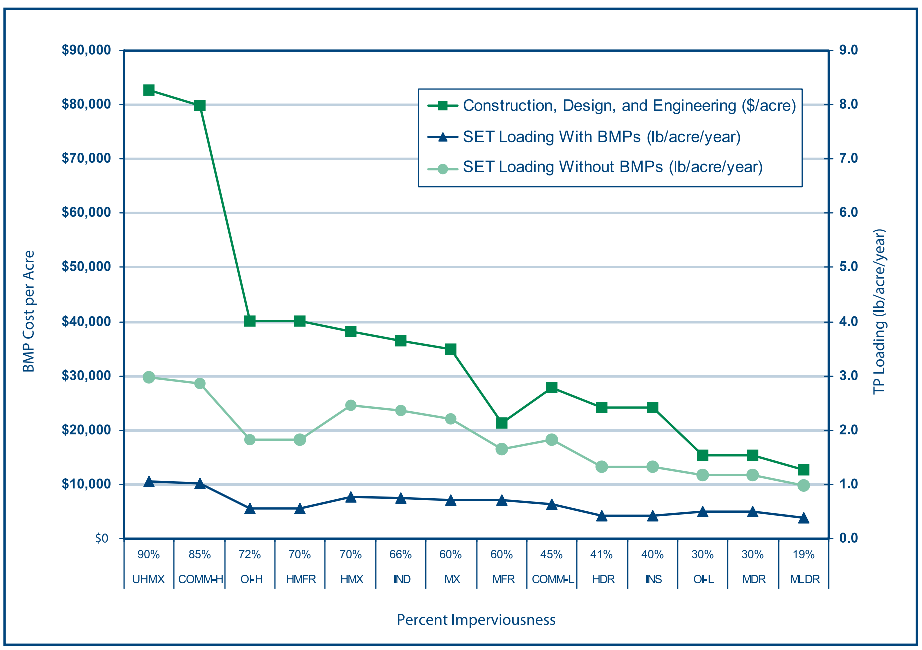


Figure 11-7. Example Comparing Construction Cost and Pollutant Loading for Different Urban Land Use Types with Decreasing Levels of Imperviousness

Figure 11-8 compares the management practice construction cost per acre with the cost per pound of total phosphorus removed. At below 70 percent imperviousness, the cost-effectiveness ratio is fairly constant for the developments, but above that level the cost-effectiveness ratio increases substantially. In this situation, you should consider how much impact the developments with high imperviousness have on the water quality of your watershed. You might find that these land uses are a small percentage of your watershed and that a less-expensive treatment option for these land uses could achieve your watershed-wide water quality objectives. When certain land uses are found to be the least cost-effective, stakeholders can be consulted to determine the importance of treating all land uses versus saving on costs. Beyond cost-effectiveness, stakeholders might be concerned about localized impacts on water quality from highly impervious developments.

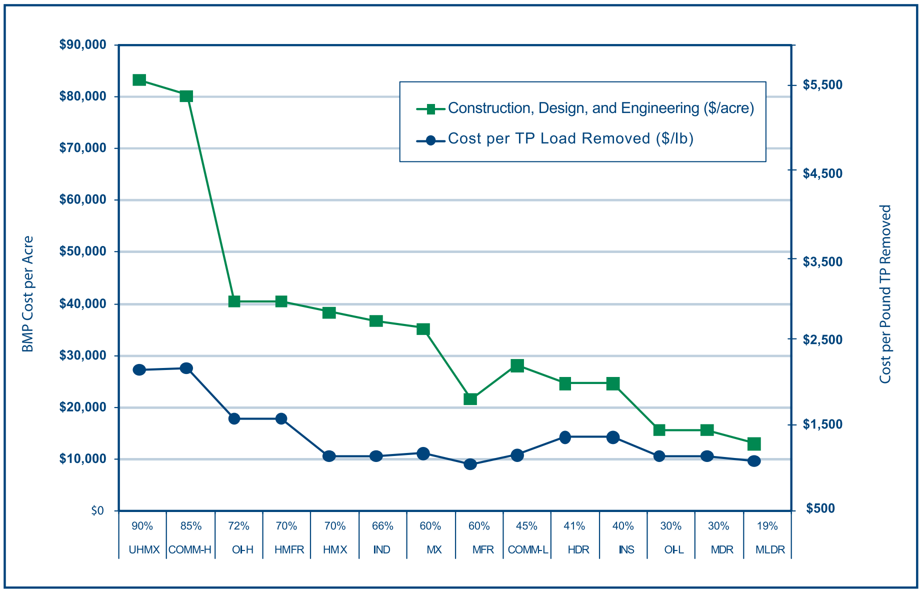


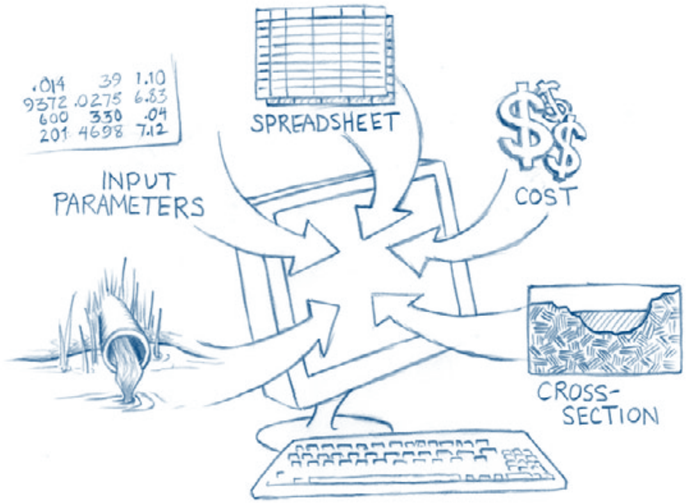
Figure 11-8. Example Showing Increased Cost per Pound of Total Phosphorus Removed for Urban Land Uses with Highest Levels of Imperviousness

When used in combination with an assessment of the project objectives and stakeholder concerns, a comparison of costs and benefits can be useful in management decisionmaking. The examples and strategies outlined above do not cover all the possible watershed conditions and issues to be considered. With each project, look at the situation critically and ensure that you've covered the most important factors before making a decision on management practices.

11.5 Select Final Management Strategies

The process of narrowing down possible management options involves ultimately matching the best candidate practices to your needs.

When you screened management options (chapter 10), you used worksheets to summarize promising alternatives, noting potential pollutant removal efficiencies, identifying constraints in using the practice, and so forth. In this chapter, you've refined those worksheets, quantified estimates of the total potential pollutant removal, and identified which combinations of management practices meet your load reduction or hydrology targets. You've also



estimated costs for these different watershed management strategies (or different combinations of management practices). Now it's time to pull together information from the environmental and cost analysis and select the preferred strategies.

11.5.1 Decision Process

In general, you'll work through a process using established decision criteria to identify the management strategies that are most likely to succeed. The process is likely to follow some variation of the following steps:

- Develop decision criteria.
- Summarize evaluation results and present to stakeholders.
- Obtain feedback from stakeholders.
- Rank preferences and select management strategy(ies).

Develop Decision Criteria

In such watershed planning efforts, you should address not only the state or local water quality or hydrology targets but also such issues as

- Fiscal impact on local governments
- Cost to the development community
- Benefits that will be realized
- Overall regulatory feasibility of the strategy
- Compatibility with other local planning objectives and policies
- Overall political feasibility

Pulling together the "big picture" for watersheds is critical for those trying to select the preferred management strategies, but it can also be challenging. Most likely you'll select indicators and objectives that include both quantifiable indicators (Does it meet the target? How much will it cost the development community?) and more subjective indicators (Is it compatible with local policies? Is it politically feasible?).

Summarize Evaluation Results and Present to Stakeholders

Before meeting with the stakeholder committee, develop a summary chart that can convey the big-picture evaluation, noting which indicators you are able to quantify versus those which must be evaluated subjectively. Fill in the chart for the indicators you are able to quantify and evaluate (in absolute numbers or in relative percentages). For more subjective indicators, you can use a "straw man" or "blank slate" approach with the committee. The straw man approach involves conducting a preliminary evaluation (e.g., evaluating how compatible the differing strategies are with local planning policies) and presenting your evaluation to the committee for review, discussion, and final evaluation. The blank slate approach allows the committee to jointly or independently evaluate the criteria and develop a response. This evaluation could be conducted through a survey of committee members, deliberations of the committee, or both.

Obtain Feedback from Stakeholders

If stakeholders have concerns about a particular management strategy, determine whether there is information that is already available or could be readily obtained that would address their concerns. For example, if the stakeholders are not familiar with a particular management practice and are therefore hesitant to implement it, consider bringing in an extension agent familiar with the practice who can further educate concerned stakeholders about the practice and answer questions credibly. Perhaps increasing familiarity and confidence is all that will be required for the stakeholders to support the practice.

Stakeholders

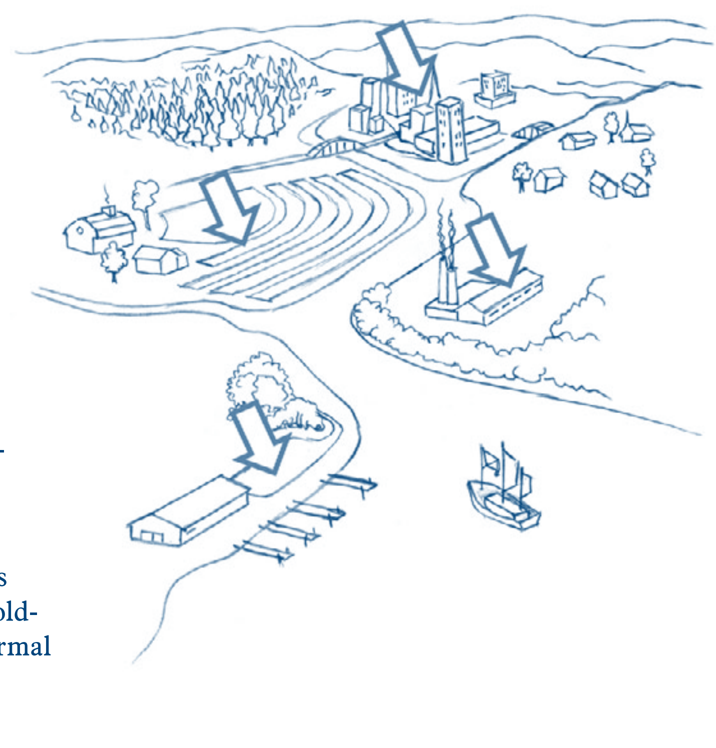
Refer to appendix A for additional resources concerning stakeholders.

Where cost feasibility is an issue, present information regarding cost-sharing sources or other funding options that might make implementation feasible. Consider accessing technical support from organizations like Cooperative Extension, NRCS, or other resource agencies or nonprofit organizations that can offer technical assistance or cost-sharing dollars. Always keep the end in view, reminding those around the table of the loading that you are trying to achieve and the load reduction needed. Then focus on the solutions—practices that landowners are willing to implement and can implement on their own or with assistance of agencies, nonprofit groups, or other stakeholders. The more that you ensure that initial questions and concerns are adequately addressed, the more buy-in you're likely to have when the time for implementation arrives.

Rank Preferences and Select Final Strategies

The process for selecting preferred strategies can be very straightforward if you have a small watershed with a limited number of landowners and a limited number of problems or issues to resolve. Cost-effective choices might be quite clear, and there might not be many other issues to work through.

In a small watershed or a watershed with a limited number of landowners and parameters of concern, your management practice worksheets can be used as the basis for evaluating management strategies and making a final selection. The task might be as simple as sharing the information regarding the effectiveness and cost of the different practices with the landowners, explaining how practices could be combined in complementary ways to address the problem, and then discussing which management practices they would be willing and able to implement. Discussions about feasible options also need to address a reasonable timetable for implementing the options.



A more complex process is often needed when managing larger watersheds or small watersheds with multiple issues and a broader set of stakeholders. In such cases it can be helpful to develop formal criteria and methods for ranking stakeholder preferences to support final decisions on selection. These formal methods can include weighting some criteria as more important than others to best represent stakeholder preferences. In addition, it might not always be necessary for stakeholders to agree on exactly the same practices; if different stakeholders are willing to implement separate practices that still achieve the objectives, there is no reason to force a single ranking or preference.

The degree to which you feel the need to formally rank the candidate strategies will depend on the circumstances. ↳ You can use a ranking process similar to the one you conducted in section 10.3.8. The ranking factors and assumptions will change, however.

In reality, there are many more ways you can use to rank and select management practices than can possibly be covered here. The following section provides two examples in the range of options for selecting the preferred strategies.

11.5.2 Example Procedures for Selecting Final Management Strategies

The following two examples are provided to help illustrate the range of methods for selecting the preferred strategies. The first example represents a simple case in which a less formal process was used to select preferred practices; the second example includes a more formal process in which evaluation criteria and objectives were established and results were weighted before making final selections.

Muddy Creek Selects Final Strategies to Implement TMDL

Watershed planners in the Muddy Creek watershed went through a ranking process to select management practices to implement their portion of the Virgin River Total Maximum Daily Load (TMDL). Table 11-7 lists the management techniques evaluated. Note that each is categorized by the level of engineering intensity. A separate worksheet was developed for each technique during the screening and then refined during the evaluation process. Table 11-8 lists the final selection of management practices that the landowners plan to use to meet the load reduction requirement, along with the estimated load reduction of the practices and a timeline for implementation.

Table 11-7. Selected Management Techniques for the Muddy Creek Subwatershed, Virgin River TMDL Implementation

Level A Management Changes	1	Rotational grazing
	2	Seasonal grazing
	3	No-till farming techniques
Level B Management Practices and Altruistic Techniques	1	Installation of cross-fencing
	2	Use of sprinkler irrigation system
	3	Decreased water usage
Level C Mild Engineering	1	Stream grade stabilization structures
	2	Revegetation of streambanks
	3	Replacement of open ditches and diversions with piped systems
Level D Moderate Engineering	1	Installation of stream barbs
	2	Installation of weirs
	3	Stabilization of road cuts
Level E Intensive Engineering	1	Slope stabilization
	2	Change in meander and profile of stream sections

Table 11-8. Summary of Load Reduction Requirements and Expected Removal Efficiencies for Selected Management Practices for Muddy Creek Subwatershed

TMDL Target Values	Total Dissolved Solids (lb/day)	Implementation Technique(s)	Estimated Percent Load Reduction (%)	Timeline for Implementation Reductions (mo)
Overall load allocation	12,320	A1	4	4–12
		B2	8	6–12
		B3	8	6–12
Current measured load	20,550	C1	10	9–24
		C2	15	36–120
		C3	15	12–36
Overall required load reduction	8,230	D2	20	24–48
		E1	20	24–48

Town of Cary, North Carolina, Selects Final Strategies to Manage Stormwater Runoff

The Town of Cary used a summary chart to evaluate different options and criteria for managing future stormwater runoff from its Town Center area. The town had adopted a redevelopment plan that encouraged urban redevelopment along a planned rail corridor in the Town Center and the use of smart growth principles. However, the planned redevelopment needed to meet a number of stormwater management regulations, including an existing nutrient TMDL and drinking water supply protection regulations and pending National Pollutant Discharge Elimination System (NPDES) Phase II stormwater requirements.

At the *beginning* of the planning process, the stakeholder committee was instrumental in developing and adopting the evaluation criteria in the box at right for different management options. Easily understood consumer report symbols were then used to convey how well each option met the evaluation criteria (figure 11-9). The options being compared by Cary included onsite stormwater water quality and volume/peak detention controls, an off-site shared facility (e.g., constructed wetlands) for local control, regional controls to meet volume and water quality performance standards, and combinations, including a buy-down allowance for achieving nitrogen reductions.

When presenting and discussing the results of the evaluation of management options, the stakeholder committee prioritized two of the criteria:

1. Meets state Nutrient-Sensitive Water TMDL and Phase II requirements
2. Supports the Town Center Area Plan and preferred growth areas

Criteria Used to Evaluate Management Options

State Regulations

- Meets state Nutrient-Sensitive Water TMDL and Phase II requirements
- More protective than state regulations
- Comparable to existing Swift Creek watershed drinking water supply protection rules
- Regulatory feasibility

Town Plans and Policies

- Supports Town Center Area Plan and preferred growth areas
- Provides adequate infrastructure
- Preserves and protects natural resources
- Encourages attractive development

Fiscal Impact

- Cost-effectiveness in meeting targets

Overall Feasibility

Although the other criteria were important in the evaluation, these two became the most important in selecting the preferred management option. Therefore, option 1 was selected as the final management strategy (figure 11-9).

Now that you've selected the recommended management strategy that will meet the objectives of your program, the more detailed implementation planning can begin. In the next chapter implementation plans, schedules, and funding are discussed in more detail.

Criteria	Meets State TMDL	More Restrictive than State TMDL			
	Option 1 On-site/ Shared	Option 2 On-site/ Shared	Option 3 Regional Volume, TSS, TN	Option 4 Regional Volume, TSS, N Buy-Down	Option 5 On-site/ Shared Water Quality Control; Regional Volume
State Regulations					
Meets State Nutrient-Sensitive Water and Phase II Requirements—*High Priority*	●	●	◗	◗	◗
More Protective than State Regulations	—	●	—	—	◗
Swift Creek Watershed: Comparable to Existing Swift Creek Land Management Plan	●	●	●	●	●
Regulatory Feasibility	●	●	◗	◗	◗
Town Plans and Policies					
Supports Town Center Area Plan (Urban Form/ Preferred Growth Areas)—*High Priority*	●	—	◗	◗	—
Provides Adequate Infrastructure	●	●	●	●	●
Preserves/Protects Natural Resources	●	●	◗	◗	●
Encourages Attractive Development	●	●	◗	◗	●
Fiscal Impact					
Cost-Effectiveness of Mitigation Target	●	●	◗	◗	●
Overall Feasibility (Counts ●/◗/—)	8/0/1	7/1/1	2/6/1	2/6/1	5/3/1
Percent that Option Meets Criteria	90%	85%	55%	55%	72%
Meets Both High-Priority Criteria	Yes	No	No	No	No

● Meets Criteria ◗ Partially Meets Criteria — Does Not Meet Criteria

Figure 11-9. Evaluation of Stormwater Management Options for the Town of Cary