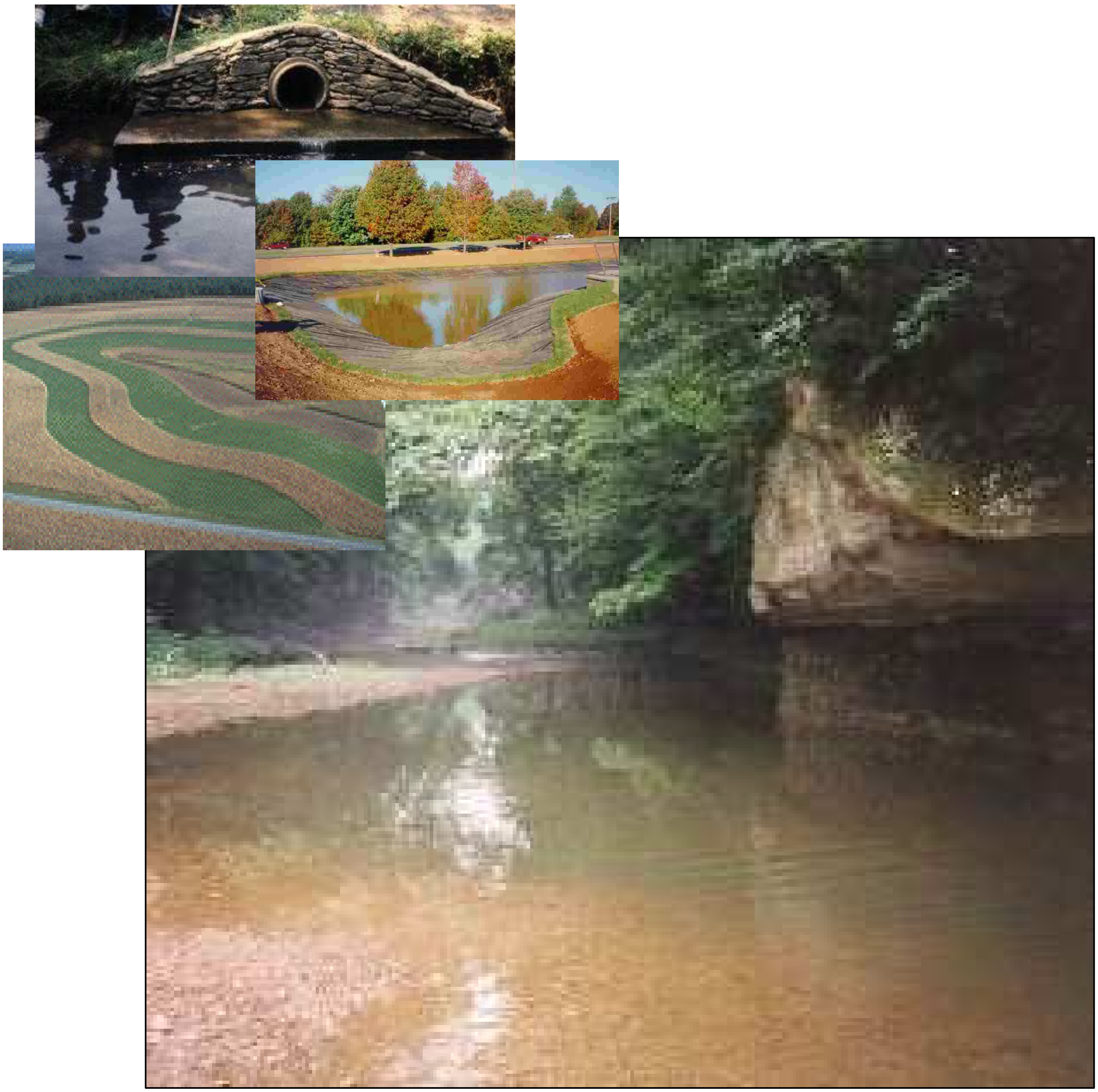
Best Management Practices
Stormwater Management Manual
for Southern Indiana



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PREFACE

This manual contains specific recommendations and criteria to be considered when implementing Best Management Practices within your community; however, it should not be confused with a design document. The manual does not contain complete detailed design information for all practices that are referenced.

The examples, recommendations and criteria highlight some of the major principles and notable points related to the practices based upon the best information available from a variety of sources. These sources should be used with caution since you must demonstrate the appropriateness and applicability of the practice to Indiana, your community and to your project in particular.

Some of the examples shown in this document represent projects which, under state or federal laws, may require permits or design by a registered design professional. This manual, the source references and professional integrity should be seen as three legs providing a stable foundation for the community's project BMPs.

Acknowledgements

The Stormwater Management Manual of Best Management Practices was created with the shared input of all who participated in the Southern Indiana Stormwater Advisory Committee. This manual would not be complete without the collaborative effort between Clark County, Clarksville, Jeffersonville, Sellersburg, Oak Park Conservancy District, and Floyd County with assistance from Stantec Consulting Services, Inc. (formerly Fuller, Mossbarger, Scott and May Engineers, Inc.) and Jacobi Toombs and Lanz, Inc. It was developed based upon the review and consideration of a number of other existing manuals including related materials from IDEM, the City of Nashville, TN, the National Association of Home Builders, the City of Knoxville, TN, the State of Georgia, the Minnesota Pollution Control Agency and related ASCE and APWA documents.

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Section 1
INTRODUCTION

1.1 Background and Purpose

The intent of this manual is to provide guidance on BMP selection, design, and implementation to developers, engineers, reviewers, construction site operators, and site inspectors. There is special emphasis on Erosion Prevention and Sedimentation Control (EPSC) during construction and long-term (or permanent) stormwater quality treatment devices and facilities after construction is complete. There are also guidance materials for activities at commercial and industrial facilities.

The fact sheets are categorized, focused, and concise so that they may be used as quick references for design, inspection, and maintenance guidance. In this way, the fact sheets are designed to be stand-alone documents that may be distributed to facilitate focused discussion about design and/or implementation of the management practice. Many of the practices are considered structural practices in that they involve construction. However, several of the BMPs cover non-structural practices where normal activities are performed in a different manner with stormwater quality in mind.

1.2 Stormwater Quality and Quantity Management

Many of the communities in Southern Indiana, including Clark County, Floyd County, Clarksville, Jeffersonville, Sellersburg, Madison and Oak Park Conservancy District require that stormwater quality management techniques be applied to new development and redevelopment in the form of structural and non-structural Best Management Practices (BMPs). Stormwater quality management involves pollutant control, capture, and/or treatment. Some of the pollutants are referred to as “point sources” and appear in the form of regulated discharges, spills, dumping, illicit connections, etc. This manual briefly discusses minimizing the chance of unregulated point sources, but primarily focuses on nonpoint source pollution.

Nonpoint source pollution comes in the form of particulate or dissolved pollutant matter conveyed by runoff over surfaces and conveyed to separate storm sewer system, creeks, and waterways. This principally includes sediment eroded from denuded areas during construction and other pollutants from impervious surfaces after construction. Nonpoint source pollution is most prevalent in runoff from small very frequent storm events. Typically these events are less than 1.25-inches of rainfall and that fact was used in preparing the selection, sizing, approach, and maintenance criteria presented in the BMP fact sheets.

1.3 Construction Site Management for Stormwater Quality

1.3.1 Erosion Process

Stormwater quality management predominately focuses on erosion prevention and sedimentation control (EPSC) for construction sites. However, for some fully developed sites EPSC can also be a concern. Soil erosion is the process by which soil particles are removed from land surfaces by wind, water or gravity. Natural erosion generally occurs at slow rates. However, the rate of erosion increases when land is cleared or altered and left disturbed. Erosion rates will increase when flow rates and velocities discharged from a site exceed the erosive range.

Clearing and grubbing activities during construction remove vegetation and disrupt the structure of the soil surface, leaving the soil susceptible to rainfall erosion, stream and channel erosion, and wind erosion, if left untreated. Ultimately, the sediment suspended by erosion settles in downstream reaches. This process, termed sedimentation, can lead to increased maintenance needs and flooding problems.

1.3.1.1 Water Erosion

The rainfall erosion process begins when raindrops impact the soil surface and dislodge minute soil particles. These soil particles then become suspended in the water droplet. Sediment laden water droplets accumulate on the soil surface until a sufficient quantity has developed to begin flowing under the forces of gravity.

The initial flow of sediment-laden water generally consists of a thin, slow-moving sheet, known as sheet flow. While sheet flow is generally not highly erosive on its own, it does begin the transport of previously suspended sediment. Due to irregularities in the soil surface and uneven topography, sheet flow will usually begin to concentrate into rivulets, where the flow picks up velocity, and erosive energy increases as a result of gravitational forces.

The increasing erosive energy of water flowing in rivulets will cut small grooves, or rills, in the soil surface. Rill erosion of the soil surface tends to concentrate more flows, which then flow faster and gain erosive energy as a result of gravitational forces. In turn, the rills become deeper and larger, and join adjacent rills. Typically, rills run parallel with the slope and each other, are small enough to be stepped across, and are generally enlarged by direct erosion of the rill's sides and bottom by the action of flowing water.

The communion of several adjacent rills, or sufficient enlargement of a single rill, begins gully erosion. Gully erosion of the soil surface tends to concentrate more flows, which then flow faster and gain erosive energy as a result of gravity. Typically, gullies running parallel with the slope, may have one or more lateral branches, and are enlarged by four key actions. First, gullies often have a "head cut" at the upstream end which progresses its way upstream as water flowing into the gully erodes the lip of the head. This mechanism is similar to a waterfall working its way upstream. Second, the flow in a gully tends to under cut the banks. Once sufficiently under cut, the banks collapse into the gully where the collapsed soil is then washed away. Third, when banks collapse into the gully, flowing water is diverted around the temporary blockage of soil. This temporary blockage increases velocities along one or both banks, which results in increased bank erosion. Fourth, the concentration of flows in the gully can result in scour of the gully floor until a stable slope is obtained.

1.3.1.2 Stream and Channel Erosion

One or more of the following factors that disrupt the delicate balance required for stable streams and channels generally precipitate erosion within streams and channels.

1. Disturbing the banks of streams and channels is often required during construction. Once vegetation or other bank protection measures are disturbed, flows may begin to erode the unprotected soil.

2. Disturbing the flow within a stream or channel is often necessary to facilitate construction activities. However, this should only be allowed when traversing banks such as temporary stream crossing, culvert installation, bridge construction, etc. By diverting flows within the channel, velocities are increased in some areas to compensate for decreases in other areas. The increases in velocity may exceed those normally experienced by the channel, resulting in bank erosion and bottom scour.

3. Increasing the quantity and rate of flow to streams and channels often results from construction activities and construction of facilities that increase the quantity and rate of runoff as well as how runoff is conveyed to the discharge point. The increased quantity and rate of flow can cause bank erosion and bottom scour.

1.3.1.3 Wind Erosion

Dust is defined as solid particles or particulate matter small enough to remain suspended in the air for a period of time and large enough to eventually settle out of the air. Dust from a construction site originates as inorganic particulate matter from rock and soil surfaces and material storage piles. The majority of dust generated and emitted into the air at a construction site is related to earth moving, demolition, construction traffic on unpaved surfaces, and wind over disturbed soil surfaces.

1.3.1.4 Factors Influencing Erosion

There are five primary factors that influence erosion: soil characteristics, vegetative cover, topography, climate, and rainfall.

1. Soil characteristics that determine the erodibility of the soil include particle size, particle gradation, organic content, soil structure, and soil permeability. Soil characteristics affect soil stability and infiltration capacity. The less permeable the soil, the higher the likelihood for increased runoff and erosion. Soils with a high percentage of silt and clays are generally the most erodible.

The soil characteristics play a different role for channel flow. The tractive-force or shear stresses developed by flowing water over the channel banks and bottom can cause the soil particles to move and become suspended into the runoff. The "permissible shear" stress indicates the stress that the channel banks and bottom can sustain without compromising stability. Protecting the channel bottom and banks with a variety of "soft/green" or "hard" armoring increases the permissible shear stress in the channel.

2. Vegetative cover plays an important role in controlling erosion by shielding the soil surface from the impacts of falling rain, and slowing the velocity of runoff. This permits greater infiltration, maintains the soil's capacity to absorb water, and holds soil particles in place. Vegetative root structures create a favorable soil structure, improving its stability and permeability.

3. Topography, including slope length and steepness are key elements in determining the volume and velocity of runoff. As slope length, and /or steepness increases, so does the rate of runoff and the erosion potential.

4. Climate is a key factor that influences erosion. High rainfall areas and areas with freeze/thaw cycles have significant effects on soil stability and structure.

5. Wet weather frequency, intensity, and duration are fundamental factors in determining the amounts of erosion produced. When storms are frequent, intense, or of long duration, erosion risks are high. In Southern Indiana, the erosion risk period is typically highest in the wet season (typically December through May) which coincides with the period of minimal vegetative cover.

1.3.2 Sedimentation Process

Once soil particles are eroded by and suspended in water or wind, they can be carried from a few inches or feet to many miles before conditions are such that gravity will force soil particles to settle. The settling of soil particles is known as the process of sedimentation. Excessive levels of sedimentation can plug storm drains, block streams and channels, damage habitat, and in some cases result in formation of habitats in undesirable locations. Generally, sedimentation can be forced to occur by creating conditions that slow the flow of water or air, allowing particles to settle. Conversely, creating conditions of rapid and/or turbulent flow that prevent particles from settling can prevent sedimentation.

1.3.3 Other Stormwater Pollutants and Impacts

Sediment from erosion is the pollutant most frequently associated with construction activities. However, other pollutants of concern include nutrients, metals, pesticides, oil and grease, fuels, other toxic chemicals, and miscellaneous wastes. These pollutants originate from a variety of activities including paving operations, demolition, materials storage, equipment fueling, and other daily activities necessary for project construction or site (commercial or industrial) management. By taking an activities inventory, the contractor/operator can identify potential pollutant sources and then select appropriate BMPs to address these sources. Appropriate BMPs are usually specific to the construction activity or site (commercial or industrial) management activity.

1.3.3.1 Nutrients

Phosphorous and nitrogen from fertilizers, pesticides, construction chemicals, and solid waste are often generated by site activities. These nutrients can result in excessive or accelerated growth of vegetation or algae resulting in impaired use of water in lakes and other sources of water supply through taste and odor problems. Excess algae can also deplete dissolved oxygen levels resulting in fish kills. Collectively, the problems associated with excessive levels of nutrients in a receiving water are referred to as *eutrophication* impacts.

1.3.3.2 Oxygen Demanding Substances

Lower dissolved oxygen (DO) levels are often the cause of fish kills in streams and reservoirs. The degree of DO depletion is measured by the biochemical oxygen demand (BOD) test that expresses the amount of easily oxidized organic matter present in water. The chemical oxygen demand (COD) test measures all the oxidizable matter present in urban runoff. BOD is caused by the decomposition of organic matter in stormwater that depletes DO. Other non-organic materials in the water can intensify DO depletion.

1.3.3.3 Metals

Many artificial surfaces (e.g., galvanized metal, paint, or preserved wood) contain metals that can enter stormwater as the surfaces corrode, flake, dissolve, decay, or leach. However, significant portions of metals in urban runoff are from cars and trucks. Over half the trace metal load carried in stormwater is associated with sediments to which these eroded metals attach. Heavy metals are of concern because they are toxic to aquatic organisms, can be bioaccumulative, and have the potential to contaminate drinking water supplies.

1.3.3.4 Pesticides

Herbicides, insecticides and rodenticides (collectively termed *pesticides*), are commonly used on construction sites, lawns, parks, golf courses, etc. Unnecessary, excessive, or improper application of these pesticides may result in direct water contamination, indirect water pollution by aerosol drift, or erosion of treated soil and subsequent transport into surface waters.

1.3.3.5 Oil, Grease and Fuels

These products are widely used and can be spilled/leaked/dumped on the ground where they can wash into waterways. Sources include leakage during normal vehicle use, hydraulic line failure, spills during fueling, and inappropriate disposal of drained fluids. These products can cause harm to plant and animal life.

1.3.3.6 Other Toxic Chemicals

Often synthetic organic compounds (adhesives, cleaners, sealants, solvents, etc.) are widely applied and may be improperly stored and disposed. Accidental spills and leakage or deliberate dumping of these chemicals onto the ground or into storm drains causes environmental harm in receiving waters.

1.3.3.7 Miscellaneous Wastes

Miscellaneous wastes include wash water from concrete mixers, paints and painting equipment cleaning activities, solid organic wastes resulting from trees and shrubs removed during land clearing, wood and paper materials derived from packaging of building products, food containers, such as paper, aluminum, and metal cans, industrial or heavy commercial process wash/cooling water, vehicle washing, other commercial or industrial wastes and sanitary wastes. The discharge of these wastes can lead to unsightly and polluted receiving waters.

1.4 Post Construction Management for Stormwater Quality

Temporary BMPs are intended to address construction activities while permanent BMPs address long-term stormwater management objectives / requirements.

Temporary BMPs may include a variety of “good housekeeping” measures and short-term EPSC activities. An appropriate professional such as the construction site operator and/or licensed professional civil engineer should apply temporary BMPs. A licensed professional engineer must design some of the more complicated or sensitive BMPs. The temporary management practices should be designed and submitted to the plan review engineer with the community in which the development is being built. The contractor is responsible for properly constructing, implementing and maintaining the temporary practices and seeking guidance when the measures do not appear to be meeting the stormwater management objectives (namely that sediment and other pollutants do not leave the construction site).

Permanent BMPs may include swales, sediment or detention ponds, and a variety of other features. These permanent management practices are selected by licensed professional civil engineers, incorporated into the plans and specifications for the project, and long-term maintenance responsibilities are identified. The contractor is responsible for properly constructing the permanent controls.

Permanent BMPs are the final improvements to and configuration of the project. They are designed to control long-term stormwater pollution. Permanent BMPs are normally selected in the planning phase in conjunction with the approval of the tentative map designed during the design phase of a project and completed to the satisfaction of the community in which it is being built. Occasionally, unforeseen natural or manmade factors may require revisions to or additions of permanent BMPs during the construction phase.

During construction, the contractor must ensure that the post-construction BMPs are installed properly and that any maintenance that may be necessary during construction is performed. After the project is complete it will then be the responsibility of the private or public owner (or other entity formally identified) to provide for long term operation and maintenance.

1.5 BMP Selection Process

1.5.1 Define BMP Objectives

Each construction project is unique. Therefore, an understanding of the pollution risks of the construction activity is essential for selecting and implementing BMPs. Defining these risks requires review of the characteristics of the site and the nature of the construction, information which should be assembled for the construction plans. Once these pollution risks are defined, BMP objectives are developed, and BMPs selected. The BMP objectives for construction projects are as follows:

1. Practice Good Housekeeping: Perform activities in a manner which keeps potential pollutants from either draining or being transported off-site by managing pollutant sources and modifying construction activities.

2. Contain Waste: Dispose of all construction waste in designated areas, and keep stormwater from flowing on to or off of these areas.

3. Minimize Disturbed Areas: Only clear land which will be actively under construction in the near term (e.g., within the next 3-4 months), minimize new land disturbance during the rainy season, and do not clear or disturb sensitive areas (e.g., steep slopes, buffers and natural watercourses) and other areas where site improvements will not be constructed.

4. Stabilize Disturbed Areas: Provide temporary stabilization of disturbed soils whenever active construction is not occurring on a portion of the site. Provide permanent stabilization during finish grade and landscape the site.

5. Protect Slopes and Channels: Outside of approved grading plan area, avoid disturbing steep or unstable slopes. Safely convey runoff from the top of the slope, and stabilize disturbed slopes as quickly as possible. Avoid disturbing natural channels. Stabilize temporary and permanent channel crossings as quickly as possible, and ensure that increases in runoff velocity caused by the project do not erode the channel.

6. Control Site Perimeter: Upstream runoff should be diverted around or safely conveyed through the construction project. Such diversions must not cause downstream property damage. Runoff from the project site should be free of excessive sediment and other constituents.

7. Control Internal Erosion: Detain sediment laden waters from disturbed, active areas within the site to minimize the risk that sediment will have the opportunity to leave the site.

Site characteristics and contractor activities affect both the potential for erosion and contamination by other constituents used on the construction site. Before defining BMP objectives, you should carefully consider:

1. Site conditions that affect erosion and sedimentation including:

    a. Soil type, including underlying soil strata that are likely to be exposed to stormwater.
    b. Natural terrain and slope.
    c. Final slopes and grades.
    d. Location of concentrated flows, storm drains, and streams.
    e. Existing vegetation and ground cover.

2. Climatic factors, which include:

    a. Seasonal rainfall patterns.
    b. Appropriate design storm
        i. quantity of rainfall
        ii. intensity of rainfall
        iii. duration of rainfall

3. Type of construction activity.
4. Construction schedules, construction sequencing and phasing of construction.
5. Size of construction project and area to be graded.
6. Location of the construction activity relative to adjacent uses and public improvements.
7. Cost-effectiveness considerations.
8. Types of construction materials and potential pollutants present or that will be brought on-site.
9. Floodplain, Floodway, and buffer requirements.

1.5.2 Identify BMP Categories

Once the BMP objectives are defined, it is necessary to identify the category of BMPs that is best suited to meet each objective.

To determine where to place categories of BMPs, a map of the project site can be prepared with sufficient topographic detail to show existing and proposed drainage patterns and existing and proposed permanent stormwater control structures. The project site map should identify the following:

1. Locations where stormwater enters and exits the site. Include both sheet and channel flow for the existing and final grading contours.

2. Identify locations subject to high rates of erosion such as steep slopes and unlined channels. Long, steep slopes over 100 feet in length are considered as areas of moderate to high erosion potential.

3. Categorize slopes as:

   a. Low Erosion Potential (0 to 5 percent slope)
   b. Moderate Erosion Potential (5 to 10 percent slope)
   c. High Erosion Potential (slope greater than 10 percent)

4. Identify wetlands, springs, sinkholes, floodplains, floodways, sensitive areas or buffers which must not be disturbed, as well as other areas where site improvements will not be constructed. Establish clearing limits around these areas to prevent disturbance by the construction activity.

5. Identify the boundaries of tributary areas for each outfall location. Then calculate the approximate area of each tributary area.

6. Define areas where various contractor activities have a likely risk of causing a runoff or pollutant discharge.

With this site map in hand, categories of BMPs can be selected and located. It is more cost-effective to prevent erosion/pollution than to remove sediment/pollutants, and erosion prevention is achieved most cost-effectively by planning before construction begins and phasing construction activities.

BMPs that can achieve more than one BMP objective should be taken into account when selecting BMPs to achieve maximum cost-effectiveness. For instance, it is not always necessary to install extensive sediment trapping controls during construction. In fact, sediment trapping should be used only as a short-term measure for active construction areas, and replaced by permanent stabilization measures as soon as possible. However, it should be noted that perimeter/outfall control in the form of permanent detention ponds should be built first and used as temporary sediment control by placing a filter on the outlet. After construction is complete and tributary area is stabilized, the permanent outlet configuration can be reestablished.

1.5.3 Selecting BMPs for Construction Site Management (Sections SPD, EPP, SMP)

Certain contractor activities may cause pollution if not properly managed. Not all of the BMPs will apply to every construction site. However, all of the suggested BMPs should be considered, and those which are appropriate for the project at hand should be selected. Considerations for selecting BMPs for contractor activities include the following:

1. Is it expected to rain? BMPs may be different on rainy days vs. dry days, winter vs. summer, etc. For instance, a material storage area may be covered with a tarp during the rainy season, but not in the summer. However, it should be noted that plans should be made for some amount of rain even if it is not expected to generate a flooding event.

2. How much material is used? Less intensive BMP implementation may be necessary if a "small" amount of pollutant containing material is used (however, remember that different materials pollute in different amounts).

3. How much water is used? The more water used and wastewater generated, the more likely that pollutants transported by this water will reach the stormwater system or be transported off-site. Washing out one concrete truck on a flat area of the site may be sufficient (as long as the concrete is safely removed later), but a pit should be constructed if a number of trucks will be washed out at the same site.

4. What are the site conditions? BMPs selected will differ depending on whether the activity is conducted on a slope or flat ground, near a stormwater structure or watercourse, etc. Anticipating problems and conducting activities away from certain sensitive areas will reduce the cost and inconvenience of performing BMPs.

5. What about accidents? Pre-establishing a BMP for each conceivable pollutant discharge may be very costly and significantly disrupt construction. As a rule of thumb, establish controls for common (daily or weekly) activities and be prepared to respond quickly to accidents. Define the difference, not everything can be called an accident and maybe classified as negligent disregard of proper practices.

Therefore, keep in mind that the BMPs for contractor activities are suggested practices which may or may not apply in every case. Construction personnel should be instructed to develop additional or alternative BMPs which are more cost-effective for a particular project. The best BMP is a construction work force aware of the pollution potential of their activities and committed to a clean worksite.

Effective EPSC management first minimizes erosion by keeping the soil protected (e.g. minimize disturbed areas) as long as possible (EP) and second, directs runoff from disturbed areas to locations where suspended soil materials can be removed prior to discharge from the site (SC).

The use of source control BMPs to control erosion before its starts is the preferred method of long-term sediment control. However, on active construction areas, there may not be sufficient time for EP BMPs to become established to the point at which they are fully effective before the onset of erosive events. In these situations, SC BMPs can provide a more immediate level of protection by removing suspended sediment from flows before being transported. However, the best protection on active construction sites is generally obtained through simultaneous application of both EP BMPs and SC BMPs. This combination of controls is effective because it prevents most erosion before it starts and has the ability to capture sediments that become suspended before the transporting flows leave the construction site.

BMPs for erosion and sediment control are selected to meet the BMP objectives based on specific site conditions, construction activities, and cost-effectiveness. Different BMPs may be needed at different times during construction since construction activities are constantly changing site conditions.

The following general items are provided to aid in preparing the project plans and choosing appropriate erosion and sediment control BMPs.

Minimize Disturbed Areas

The first step for selecting BMPs is to compare the project layout and schedule with on-site management measures that, where appropriate, can limit the exposure of the project site to erosion and sedimentation. Scheduling and planning considerations are the least expensive way to limit the need for EPSC controls. Consider the following BMPs:

1. Do not disturb any portion of the site unless an improvement is to be constructed there.

2. The staging and timing of construction can minimize the size of exposed areas and the length of time the areas are exposed and subject to erosion.

3. The staging of grading operations should limit the amount of areas exposed to erosion at any one time. Only the areas that are actively involved in cut and fill operations or are otherwise being graded should be exposed. Exposed areas should be stabilized as soon as grading is complete in that area.

4. Retain existing vegetation and ground cover where feasible, especially along watercourses and along the downstream perimeter of the site.

5. Do not clear any portion of the site until active construction begins.

6. Construct outfall detention or perimeter sedimentation control (with filter weirs/berms and temporary sedimentation control barriers first).

7. Quickly complete construction on each portion of the site.

8. Install landscaping and other improvements that permanently stabilize each part of the site immediately after the land has been graded to its final contour.

9. Minimize the amount of denuded areas and any new grading activities during the wet months of December through May.

10. Construct permanent stormwater control facilities (e.g., detention basins) early in the project and use for sediment trapping, slope stabilization, velocity reduction, etc. during the construction period.

Stabilize Disturbed Areas

The purpose of site stabilization BMPs is to prevent erosion by covering disturbed soil. This covering may be vegetative, chemical, or physical. Any exposed soil is subject to erosion—either by rainfall striking the ground, runoff flowing over the soil, wind blowing across the soil, and vehicles driving on the soil. Thus all exposed soils should be stabilized except where active construction is in progress. Locations on a construction site which are particularly subject to erosion and should be stabilized as soon as possible include:

1. Slopes
2. Highly erosive soils
3. Construction entrances
4. Stream channels
5. Soil stockpiles

1.5.3.1 Site Perimeter

1. Disturbed areas or slopes that drain toward adjacent properties, storm drain inlets or receiving waters, should be protected with temporary linear barriers (continuous berms, silt fences, sand bags, etc.) to reduce or prevent sediment discharge while construction in the area is active. In addition, the contractor should be prepared to stabilize those soils with EP measures prior to the onset of rain.

2. When grading has been completed, the areas should be protected with EP controls such as mulching, seeding, planting, or emulsifiers. The combination of EP measures and SC measures should remain in place until the area is permanently stabilized.

3. Significant offsite flows (especially concentrated flows) that drain onto disturbed areas or slopes should be controlled through use of continuous berms, earth dikes, drainage swales, and lined ditches that will allow for controlled passage or containment of flows.

4. Concentrated flows that are discharged off of the site should be controlled through outlet protection and velocity dissipation devices in order to prevent erosion of downstream areas.

5. Perimeter controls should be placed everywhere runoff enters or leaves the site. They are usually installed just before clearing, grubbing and rough grading begin. Perimeter controls for all but the smallest projects will become overloaded by both runoff and sediment. Additional controls within the interior of the construction site should supplement perimeter controls once rough grading is complete.

1.5.3.2 Internal Swales and Ditches

1. More often, flows are directed toward internal swales, curbs, and ditches. Until the permanent facilities are constructed, temporary stormwater facilities will be subjected to erosion from concentrated flows.

2. These facilities should be stabilized through temporary check dams, geotextile mats, and under extreme erosive conditions by lining with concrete.

3. Long or steep slopes should be terraced at regular intervals (per local requirements). Terraces will slow down the runoff and provide a place for small amounts of sediment to settle out.

4. Slope benches may be constructed with either ditches along them or back-sloped at a gentle angle toward the hill. These benches and ditches intercept runoff before it can reach an erosive velocity and divert it to a stable outlet.

5. Overland flow velocities can be reduced by creating a rough surface for runoff to cross (e.g. tall grass).

1.5.3.3 Internal Erosion

Once all other erosion and sediment control BMPs have been exhausted, excessive sediment should be removed from the stormwater both within and along the perimeter of the project site. The appropriate controls work on the same principle: the velocity of sediment-laden runoff is slowed by temporary barriers or traps which pond the stormwater to allow sediments to settle out. Appropriate strategies for implementing sedimentation controls include:

1. Direct sediment-laden stormwater to temporary sediment traps.

2. Locate sediment basins and traps at low points below disturbed areas.

3. Protect all existing or newly-installed storm drainage structures from sediment clogging by providing inlet protection for area drains and curb inlets.

4. Construct temporary sediment traps or ponds at the stormwater outfall(s) for the site.

5. Excavate permanent stormwater detention ponds early in the project, use them as sedimentation ponds during construction, remove accumulated sediment, and landscape the ponds when the upstream drainage area is stabilized.

6. Temporary sediment barriers such as:
   a. Continuous Berms
   b. Silt Fences
   c. Straw Bale Barriers
   d. Sand Bag Barriers
   e. Brush or Rock Filter

   These barriers should only be used in areas where sheet flow runoff occurs. They are less effective or ineffective if the runoff is concentrated into rill or gully flow.

1.5.3.4 Stormwater Inlets and Outfalls

1. Stormwater inlets, including drop inlets, and pipe inlets, should be protected from sediment intrusion if the area draining to the inlet has been disturbed.

2. Stormwater inlet protection can utilize sand bags, sediment traps, or other similar devices.

3. Internal outfalls must also be protected to reduce scour from high velocity flows leaving pipes or other drainage facilities.

1.5.4 BMPs for Good House Keeping

Most permanent BMPs will be proposed by the developer early in the planning stage of a project. For most projects, there will be no single BMP which addresses all the long-term stormwater quality problems. Instead, a multi-level strategy will be worked out with the community in which the development is being built, which incorporates source controls, a series of on-site treatment controls, and community-wide treatment controls.

In most cases permanent BMPs can be implemented most effectively when they can be integrated into other aspects of the project design. This requires that conceptual planning consider stormwater controls rather than as an afterthought to site design. The following should be considered early in the design process.

1. Is a detention/retention facility required for flood control? Often, facilities are required to maintain peak runoff at predevelopment levels to reduce downstream conveyance system damage and other costs associated with flooding. Most permanent BMPs can be incorporated into flood control detention/retention facilities with modest design refinements and limited increases in land area and cost.

2. Planned open space which will be relatively flat (e.g., final grade slopes less than 5 percent) may be merged with stormwater quality/quantity facilities. Such integrated, multi-use areas may achieve several objectives at a modest cost.

3. Infiltration BMPs may serve as groundwater recharge facilities, detention/retention areas may be created in landscaped areas of the project, and vegetated swales/filters may be used as roadside/median or parking lot median vegetated areas.

1.5.5 BMPs for Post Construction

After construction, water quality can be impacted by increased sedimentation and/or pollutant loading. This section will describe BMPs that will fulfill permit requirements to implement and enforce a program to address storm water runoff from new development and redevelopment projects that drain into existing storm drainage systems and streams. Typical development and redevelopment projects include municipal and commercial operations connecting and discharging storm water into local systems.

IV. Additional Resources

This Stormwater Management Manual of Best Management Practices was created using information from many sources. To find out more information regarding Stormwater BMP's, please feel free to visit the websites of the agencies and other resources provided below.

Indiana Department of Environmental Management	http://www.in.gov/idem/
Indiana Department of Natural Resources	http://www.in.gov/dnr/
Indiana Department of Transportation	http://www.in.gov/dot/
Environmental Protection Agency	http://www.epa.gov/
Environmental Protection Agency - Region 5	http://www.epa.gov/region5/
American Water Works Association	http://www.awwa.org/
Water Environment Federation	http://www.wef.org/
Kentucky Division of Water	http://www.water.ky.gov/
Gwinnett County (GA) Stormwater Management	http://www.co.gwinnett.ga.us/
Metropolitan Council of Minnesota	http://www.metrocouncil.org/
Pennsylvania Association of Conservation Districts	http://www.pacd.org/