BMP FINDER:
Best Management Practices to Address Nonpoint Source Pollution: Definitions and Categorization by Sources and Pollutants Addressed

HOW TO USE THIS DOCUMENT

The primary purpose of this document is to supplement the Best Management Practices section of the Texas Nonpoint Source Pollution Assessment Report and Management Program by providing further information about the BMPs addressed there. This document provides detailed descriptions and implementation considerations for the various alternate BMP names and categories, as well as references to still more detailed technical guidance and specification documents addressing these BMPs. Because there is a lack of standardized terms for NPS BMPs, this document provides extensive cross-references to help the reader identify BMPs of interest by any of their various names and to compare related practices.

This document is addressed most directly to the agencies and organizations in Texas working to minimize and control nonpoint source pollution of our surface and ground water resources. It provides guidance and references intended to be most helpful for the design and implementation of NPS projects in Texas to meet the goals and objectives of the Management Program and to comply with applicable rules and guidance.

The first section of this document is an alphabetical list of BMPs with definitions, primary uses, and important considerations regarding their implementation. It provides the cross-referencing among variant names for various BMPs and among closely related BMPs as well as specific use guidelines and links to more detailed guidance documents.

The second is a table organized into sections representing the major sources for nonpoint source pollution, such as construction. Within these sections, each line item represents a preferred BMP for addressing a specific need such as surface stabilization, to prevent or control NPS pollution from this source. The column on the left identifies the specific need addressed, and the middle column names the preferred BMP. The column on the right identifies the pollutants or other impacts which the listed BMP controls with moderate to high effectiveness when properly implemented. Pollutants and impacts in **boldface** are those which the BMP has controls with high effectiveness, as verified by well-documented research. For most BMPs, effectiveness research and/or standardization of practices is still lacking.

Disclaimer: The following list and table are not intended to provide a comprehensive list of approved or authorized BMPs for Texas. It represents most of the BMPs actively being implemented through NPS programs in Texas.

NOTE: This document borrows heavily from the information provided in the WATER SHEDSS web page (http://h2osparc.wq.ncsu.edu/info/bmps.html). This is a decision support system for nonpoint source pollution control developed by North Carolina State University under a grant from the U.S. Environmental Protection Agency. The identification of pollutants controlled with high effectiveness by specific BMPs (indicated in boldface) is derived from this resource.

BMP DEFINITIONS AND IMPLEMENTATION CONSIDERATIONS

Aeration, Mechanical - injection of air into surface water to increase dissolved oxygen.

Animal Waste Collection - Animal wastes can be controlled through ordinances requiring collection and removal of the waste from curb-sides, yards, parks, roadways and other areas where the waste can be washed directly into receiving waters. The ordinances should include guidance on proper disposal of animal wastes. Spreading of animal waste on fields by industries can be addressed in such ordinances. *See also Waterfowl Management, Wildlife Management.*

Aquaculture Systems - *see On-Site Floating Aquatic Plant (Aquaculture) Systems*

Barrier - *see also Sediment Barrier*

Barrier Wall, Vertical - Together with a cover system, this is used to isolate and contain contaminants under the ground**.**

Basin - *see Sediment Basin; see Retention Pond*

Berm - *see Filter Berm*

Bio-Filter - *see Grassed Channel or Swale and Filter Strip, Vegetated*

Bio-Retention Area - *see Rain Garden*

Blankets and Matting[1] - Sheets or rolls of porous erosion control material, installed and anchored at the soil surface in channels and swales and on diversion dikes, steep slopes, and stream and tidal banks. Specifications and performance data on manufactured erosion control blanket products can be found in TxDOT's Field Performance Testing of Selected Erosion Control Products (see references at the end of this document). "Compost blankets" and other applications of loose material as a surface blanket for erosion control are addressed under *Mulch*. *See also Mattress.*

Boat Liquid Waste and Fuel Handling - Storage areas with adequate containment features, such as *curbs, berms, walls, or dikes*, should be established for liquid material. Separate containers for the disposal of waste oil, gasoline, antifreeze, and diesel, kerosene, and mineral spirits should be available and clearly labeled. Patrons should be provided with proper disposal information. Containers should be stored on an *impervious surface* and properly covered against weather. A permitted handler should remove such wastes. Fueling equipment should be equipped with automatic shut-off nozzles to reduce spillage during fueling operations. Inboard engine-boaters should be encouraged to use oil-absorbing materials in bilge areas, and to dispose of and replace them appropriately. Proper liquid waste and fuel handling minimizes loadings of oil and grease, hydrocarbons, and toxic chemicals into the water resource.

Boat Operation Controls - Boat operation can resuspend bottom sediment, reintroducing metals, nutrients, organic matter, and toxic substances into the water column. It can increase turbidity, affecting photosynthetic activity of algae and submerged aquatic vegetation, which provides important habitat and plays an important role in maintaining water quality by assimilating nutrients and stabilizing the substrate. Boat operation can also directly damage or destroy bottom habitat. To minimize such impacts from boat operation, motorized vessels should be *excluded* from areas that contain important shallow-water habitat, and *no-wake zones* should be established to decrease erosional energy and turbidity. Conscientious boat operation is most valuable in minimizing water quality impacts when used as part of a system of BMPs which involves environmentally guided siting, design, and construction of marinas, and includes measures which *minimize pollutant inputs* to near-shore waters, such as providing *boat sewage disposal facilities*, *solid and liquid waste disposal facilities*, *dry boat maintenance and repair facilities*, *fish-cleaning facilities*, *public information*, and *restricting in-the-water boat work* at marinas.

Boat Sewage Pumpout facility -

- **Dedicated slip-side system** - Continuous wastewater collection at the slip. Recommended where live-aboard vessels are situated. This involves fixed force main piping, pumping, and sewage disposal means on the part of the marina. Language should be included in slip leasing agreements mandating the use of pumpout facilities and specifying penalties for failure to comply.
- **Fixed-point system** - One or more centrally located sewage pumpout stations, generally situated at the end of a pier and often on a fueling pier for convenience. Pumps or a vacuum system with flexible hose attachment draws wastewater from a docked boat's pumpout fitting and moves it to an onshore holding tank, a public sewer system, a private treatment facility, or another approved disposal facility. For boats with small, removable toilets, a similarly connected dump station should be provided.
- **Portable system** - Portable facility that draws sewage from a docked boat's pumpout fitting via vacuum or pump setup and hose attachment into a storage tank. The full tank is discharged into the marina's disposal facilities. These are thought by many to be the most economical and logistically feasible means of ensuring proper disposal of boat sewage. An emerging portable technology is the radio-dispatched pumpout boat, which goes to vessels in response to radioed requests, eliminating the inconvenience of lines, docking, and maneuvering vessels in high-traffic areas

Boat Solid Waste Generation and Disposal - Marinas should ensure that solid waste from boat operation, maintenance, and repair is properly disposed of. Sufficient area should be designated, above the high water line, for boat repair and maintenance, and such work should not be allowed outside of designated areas. These areas should be cleaned regularly. In-the-water hull scraping or any process for removing paint from the boat hull that occurs underwater should be prohibited. Where feasible, boats should be removed from the water to perform cleaning. Boats cleaned in the water should be washed by hand. Detergents and cleaning compounds used should be phosphate-free and biodegradable. Use of detergents containing ammonia, sodium hypochlorite, chlorinated solvents, petroleum distillates, or lye should be discouraged. Abrasive blasting should be allowed only in booths or under tarp enclosures. Proper waste disposal facilities should be provided, including recycling facilities where possible. Designated *fish-cleaning areas* should be established, along with waste receptacles, explicit rules and educational information, and regular waste disposal. Fish-cleaning should be prohibited if marinas are not equipped to handle fish waste. Proper solid waste generation and disposal minimizes loadings of metals, biocides, other toxic chemicals, petroleum hydrocarbons, organic matter, and nutrients into the water resource. Conscientious solid waste handling is most valuable in minimizing water quality impacts when used as part of a system of BMPs which involves environmentally guided siting, design, and construction of marinas, and responsible boat handling and *boat operation controls* to minimize reintroduction of deposited pollutants

Branch Pack - A form of soil bioengineering which uses alternating tiers of live branch cuttings and compacted backfill to repair small localized slumps and holes in slopes. Cuttings are buried upright, angled roughly perpendicular to the slope face, and should penetrate the fill to undisturbed soil. Cuttings are alternated with wooden stakes sunk vertically several feet into undisturbed soil base and spaced every one to one and one-half feet up the backfill zone. Branch packing minimizes sediment loading and associated nutrient enrichment impacts downstream by shoring up eroded areas of streambanks and providing for their long-term stabilization. It is best used as part of a system which includes a component to deter undercutting at the bed/bank interface, such as *riprap* or *gabions*, and a means of reducing the erosive potential of incoming flows at their source, such as *livestock exclusion to* eliminate overgrazing and soil compaction by cattle in agricultural settings or providing *retention ponds* for impervious surfaces in urban settings.

Brush Berm [1] - *See Sediment Barrier, Brush [1]*

Brush Control -

Brush Layering - A form of soil bioengineering which uses live branch cuttings laid flat into small benches excavated in the slope face perpendicular to the slope contour. Cuttings taken from well-suited species, typically willow species or cottonwood, and properly installed, secured by live stakes angled into the slope face at intervals, will root and stabilize slopes. The goal is for natural recruitment to follow once slopes are secured. This stabilization method, one of the best available for stabilizing and revegetating stream banks and slopes, has the advantage of causing relatively little site disturbance. This technique differs from *live fascines* in the perpendicular orientation of rows as opposed to parallel fascine orientation. This up-and-down placement is intended to reinforce slopes in terms of mass stability, to protect against mass shearing and slumping. Brush layering reduces erosion of streambanks, fill slopes, and other exposed slopes, minimizing sediment loading and associated nutrient enrichment impacts down-gradient. When applied to stream banks, it is best used as part of a BMP system which includes a component to deter undercutting at the bed/bank interface, such as *riprap* or *gabions*; a means of buffering the construction from erosive flows, such as *tree revetments* (which can actually accrue sediments); and a means of reducing the erosive potential of incoming flows at their source, such as routing runoff in *grass swales*, using *detention ponds*, and providing discharge spreader *swales*. When applied to exposed hill-slopes, brush layering is best used as part of a BMP system which includes some means of temporarily securing remaining exposed soil from direct raindrop impact erosion, such as *mulch*, and measures to minimize upgradient runoff inflows.

Buffer, Vegetated - *equivalent to Filter Strip, Vegetated*

Certification - Requirement that certain activities be performed only by persons who have received training and approval from a regulatory authority.

Check Dam - *See also Filter Berm - Rock*[1] . A small dam constructed across a drainageway to reduce channel erosion by restricting flow velocity. Check dams should not be used in live streams. They can serve as emergency or temporary measures in small eroding channels that will be filled or permanently stabilized at a later date. They can also serve as permanent measures that will sediment in over time in gullies, which is a more common usage in range and agricultural settings. In permanent usage, when the impounded area is silted in, a relatively level surface or delta is formed over which the water flows at a noneroding gradient. The water then cascades over the dam through a spillway onto a hardened apron. By constructing a series of check dams along the gully, a stream channel of comparatively steep slope or gradient is replaced by a stair-stepped channel consisting of a succession of gently slopes with "cushioned" cascades in between. For temporary usage, consider the alternatives of protecting the channel bottom with materials such as riprap, geotextile, biodegradable, or other matting, or other linings in combination with vegetation before selecting check dams. Dams can be nonporous, such as those constructed from concrete, sheet steel, or wet masonry, or they can be porous, using available materials such as straw bales, rock, brush, mulch, wire netting, boards, and posts. Porous dams release part of the flow through the structure, decreasing the head of flow over the spillway and the dynamic and hydrostatic forces against the dam. Nonporous dams are durable, permanent, and more expensive while porous dams are simpler, more economical to construct, and temporary.

Chute, Paved - *see Flume (Chute), Paved*

Cleanup, Chemical - *see Barrier Wall, Vertical; Excavation; Geomembranes; Grouting; Hydrodynamic Control; In-Situ Treatment of Contaminants (Biological and Chemical); Interceptor Systems; Pumping; Slurry Walls; Soil Venting; Surface Drainage; Surface Seals*

Composite Revetment - *see Revetment, Composite*

Composting - The controlled biological decomposition of organic materials into a stable and safe product usable as a soil amendment, mulch, or for similar purposes. Home composting of yard trimmings and rakings helps minimize the entry of these yard materials into storm drains, where they contribute to organic matter, nutrient, and lawn chemical pollution of surface waters. Local governments can start programs for area-wide composting using yard trimmings picked up at the curb. The compost can be sold to local gardeners and lawn maintenance services, used in storm water BMPs, and used for local government landscaping purposes. *See also Landscaping* *and Lawn Maintenance Controls*

Comprehensive Nutrient Management Plan -

Constructed Wetlands[1] - *see Wetlands, Constructed*

Construction Access, Temporary - gravel or riprap area or pad located at points where vehicles enter and leave a construction site, this BMP provides a buffer area where vehicles can drop their mud and sediment to avoid transporting it onto public roads, to control erosion from surface runoff, and to help control dust.

Cribs - Timber boxes built outward from the river bank and filled with sand and gravel. The boxes can be stacked along the bank and fastened together as building blocks in the construction of hardened stream-bank protections. Cribs are preferred where stone is not available or timber is cheap, and are typically used on smaller streams. Their effectiveness is improved when vegetation is incorporated. *See also Gabions.*

Curb Elimination - The elimination of curbs along roadways and parking lots. Without curbs, runoff can be spread over large vegetated areas where runoff velocities can be reduced and pollutants can settle out and be taken up by plants or soils. Sections of existing curb can be removed and curb outlets can be installed at regular intervals or in appropriate areas to allow the storm water to flow onto well-vegetated areas. To avoid erosion, flooding and trash accumulation, the areas to install curb outlets should be carefully chosen and *street cleaning programs* should be modified to maintain these areas.

Dam - *see Check Dam; Filter Berm*

Debris Removal - Storm water control and conveyance structures require frequent debris removal to maintain proper function. Litter and yard wastes can clog inlets, catch basins, and outlets, lead to overflows, erosion and unintended flooding, and make these devices ineffective in storm water pollutant removal. Grates on inlets and outlets must prevent entry by children but should be easily cleaned by maintenance crews. Municipal facilities maintenance programs and commercial, and industrial storm water permittees should be required to regularly clean inlets, catch basins, clean-out access points, and outlets. *Forebays*, small settling basins just above a detention basin or other pond, can be installed where feasible. They are easily cleaned and separate much of the sediment, associated pollutants, and trash and floatables from the main pond. Paving portions of the *forebay* allows easy access for maintenance equipment. Hard bottoms can also be made permeable through the use of turf blocks or flexible revetment. *See also Street Sweeping Operations.*

Deflectors - Hardened structures anchored in the streambank and protruding into the current with an upstream face that is angled downstream at approximately 45 degrees from the flow. A downstream brace is set at approximately 90 degrees from the upstream deflector and is also anchored in the bank. Gravel/rock fill is placed in the interior of this wing structure. Deflectors are often used in series on alternating banks at separation distances of 5 to 7 channel widths to provide a natural sinuosity of flow, with the final placement involving a pair on opposing banks to reorient the flow down the channel center. The primary use of deflectors is for *habitat* enhancement in shallow, lower gradient streams lacking pools and riffles, but they can also serve to improve water quality by slowing flows, allowing for sediment deposition, and increasing channel sinuosity and hydraulic residence time. Single deflectors also cause the formation of scour pools, shelter pools, and riffles, while double wings lead to the formation of deep scour pools.

Detention Basins or Ponds - *See Retention Pond*

Dike - *see Diversion Dike; see also Check Dam; see also Filter Berm*

Diversion - A structure, also known as an *interceptor,* that channels up-slope runoff away from erosion source areas, diverts sediment-laden runoff to appropriate traps or stable outlets, or captures runoff before it leaves the site, diverting it to locations where it can be treated, used, or released without erosion or flood damage. Diversions include graded surfaces to redirect sheet-flow, *diversion dikes or berms* which force sheet-flow around a protected area, and storm water conveyances (*swales, channels, gutters, drains, sewers*) which intercept, collect and redirect runoff. Temporary diversions include excavation of a channel along with placement of the spoil in a dike on the downgradient side of the channel, and placement of gravel in a ridge below an excavated swale. Permanent diversions are used to divide a site into specific drainage areas, should be sized to capture and carry a specific magnitude of design storm, and should be constructed of more permanent materials. A *water bar* is a specific kind of runoff diversion that is constructed diagonally at intervals across a linear sloping surface such as a road or right-of-way that is subject to erosion. Water bars are meant to interrupt the accumulation of erosive volumes of water through their periodic placement down the slope, and divert the resulting segments of flow into adjacent undisturbed areas for dissipation. Where a diversion returns water to downslope sheet flow rather than to a channel, the use of a *level spreader* outlet is advisable.

Diversion Dike[1] - A barrier created by the placement of an earthen embankment to reroute the flow of runoff to an erosion control device or away from an open, easily erodible area. Diversion dikes should direct flow to a stabilized outlet, such as a *rock berm, sandbag berm, or stone outlet structure*.

Drop Inlet Protection - *see Inlet Protection*

Easements - legal interest held in property owned by another. As a BMP, such interests are used to place restrictions on disturbance of sensitive areas such as riparian zones. *See also Exclusion of Disturbances.*

Education -

Elimination of Garbage Disposals - Eliminating the use of kitchen sink garbage disposals can significantly reduce the loading of suspended solids, nutrients, and BOD to septic systems, as well as decreasing the buildup of solids in septic tanks, thus reducing pumping frequency. Eliminating garbage disposal use is most effective when used as part of a BMP system which involves other source reduction practices such as phosphate bans and use of low-volume plumbing fixtures, as well as mitigative BMPs such as upgrading and maintenance.

Embedded Flow Obstructions - Structures which protrude into the stream flow-path from anchor spots on the bank and impede and slow flow velocity, causing sediment deposition in the process and protecting stream banks. ***Fences***: Board or wire fences embedded in the banks can be used on small streams to reduce flow and induce sediment deposition. Fences are placed in series protruding into the channel or parallel to the current along the bank. They provide protection for the upper portion of the bank and do not address undercutting. ***Jacks and Posts***: Jacks are sets of typically three concrete, steel, or sometimes wood beams crisscrossed and bound together at their midpoints to form angular structures. These structures are set in a line along the foot of the bank, forming a "field" which breaks flows, causing turbulence, reducing velocities, and causing sediment deposition. They are often strengthened by wires strung between the beams, which also catch debris and further slow flows. The open construction of the jacks allows for vegetation to establish in the deposited sediments. Posts function similarly, but are single posts driven into the streambed in some kind of grid pattern along the foot of the bank, similarly forming a field. ***Pile Dikes***: Similar to rock spur dikes, but using timber pilings lashed together and driven into the streambed from the bank outward. They are permeable, allowing for flow between piles. Eroded banks can be rebuilt with the sediment that collects behind them. They are better suited for sandy-bottomed streams than coarse, steep rivers where rock dikes are more appropriate. ***Spur Dikes and Hard Points***: Rock piles extending from shore into the stream, usually used in series, with the first at the greatest downstream angle and the latter ones more perpendicular to the bank. Spur dikes extend further into the stream and deflect flows well away from the bank. Hard points extend only a short distance and slow velocities along the banks.

Erosion Control Compost, Blanket, or Mulch [1] - *see Mulch - Erosion Control Compost.*

Excavation - Removal of soil from a contaminated site for treatment or disposal. Excavation is often costly because of the labor and disposal costs.

Exclusion of Disturbances - Restriction of disturbances to protected areas for erosion and sediment control, stream bank and streambed protection. This commonly involves fencing and other access controls or policies to exclude livestock, off-road vehicles, construction traffic, addition of fill material, and other disturbances from sensitive areas such as riparian zones. *See also Boat Operation Controls; No-Wake Zone; Livestock Exclusion.*

Exposure Reduction - Limiting the exposure of potential pollutants to rainfall or runoff. Perhaps the best example is the now-required use of covered storage facilities for road salt. Other ideas for exposure reduction are: MOVE OR REMOVE. Industries, municipalities and homeowners can eliminate much pollution by reducing or eliminating exposure by simply moving materials indoors or removing materials, products, devices and outdoor manufacturing activities that contribute to storm water pollution when exposed to the weather. Particularly, use or removal of rarely used materials that are stored outdoors can be simple and effective. INVENTORY. An inventory of the items on commercial and industrial sites that are exposed to rain may provide useful information and a starting point for exposure-reduction activities. Examples are raw material stockpiles, stored finished products, and machinery or engines which leak fuel and oil. COVERING. The partial or total physical enclosure of stockpiled or stored material, loading/unloading areas, or processing operations. Drainage from a covering is captured and directed around potential contamination areas. This measure is useful for mitigating pollutants such as metals, oils and greases, and toxic and hazardous chemicals. Covering is most effective as part of a system of BMPs which also addresses interception of runoff prior to contact with potential sources of contamination, as well as BMPs which address treatment of contaminated discharge from such sources. EXPOSURE MINIMIZATION. Implementing "Just-In-Time" (JIT) management of materials and finished products to minimize the amount of materials in the stockyard and at the loading dock. JIT management uses very precise scheduling and intensive management to keep the amount of raw or finished products to a minimum, reducing waste, storage costs and clutter. MAINTENANCE. Site cleaning to reduce the amount of pollutants available to enter storm water. Recycling of empty drums and removal of hazardous substances and wastes as soon as possible. Grading and seeding of old stockpile areas and bare areas to reduce erosion and improve appearance. Preventive maintenance to reduce leaks, breakdowns, spills and accidents. Replacement of worn seals, fittings and other parts before they leak or break. Maintenance of all pollution control devices in good working order. Air pollution control devices can reduce the amount of toxic substances and particulates, which can get washed into storm water runoff. GOOD HOUSEKEEPING. Cleaning and trash pick up of grounds, parking lot and road sweeping, and disposal of old, unused equipment. TRAINING, PREVENTION PROGRAMS. Spill prevention and response programs and training to prepare commercial and industrial employees to prevent and respond to spills.

Extended Detention Basin [1] - Basin that temporarily stores a portion of storm water runoff following a storm event. It is used to remove particulate pollutants and to reduce maximum runoff rates associated with development to their pre-development levels. *See also Retention Basin*

Fences - *See Embedded Flow Obstructions; see also Sediment Barrier - Silt Fence*

Filter - *See also Grassed Channel or Swale; Infiltration Device; Inlet Protection; On-Site System Peat Filter; On-Site System Sand Filter; Sand Filter System; Sediment Barrier*

Filter Berm or Dike - *see Sediment Barrier - Filter Berm or Dike*

Filter Dike, Triangular [1] **-** Dike to intercept and detain sediment, constructed with welded wire mesh folded into a triangular cross-section and wrapped with geotextile fabric of the same composition as that used for silt fence. These dikes are intended for unprotected areas of less than one acre where there is no channel or other drainage way. This measure is effective on paved areas where installation of silt fence is not possible, or where vehicle access must be maintained, since they can be moved easily to allow vehicle traffic and then reinstalled.

Filter Sock (Mulch or Compost) [1] - A tube-shaped mesh fabric filled with compost, mulch, or a compost/mulch blend. This sediment control device, usually 8" to 18" in diameter, can serve the same purposes as filter berms or can be used for inlet protection or similar applications. The mesh fabric allows storm water to penetrate the compost/mulch material readily but holds the material in place to prevent erosion losses, and to facilitate the separation and removal of sediment deposited on the upslope side. It also allows the structure to be moved out of the way and then put back in place readily to let traffic through, and to help the structure hold its shape and remain intact if it is run over by trucks or equipment.

Filter Strip, Vegetated (VFS) [1] - *Also known as vegetated buffer strip.* An area of vegetation that filters solids from overland sheet flow between pollutant source areas and a receiving water or channel. VFSs can be natural or planted, should have relatively flat slopes, and should be vegetated with dense-culmed, herbaceous, erosion-resistant plant species, usually grass. The main factors influencing removal efficiency are the vegetation type and condition, soil infiltration rate, and flow depth and travel time, which are affected by size of contributing area, and slope and length of strip. Channelized flows decrease the effectiveness of VFSs. VFSs are often used as buffers bordering on construction areas or cultivated fields, or as outlet or pretreatment devices for other storm water control practices. Filter strips do not provide enough runoff storage or infiltration to significantly reduce peak discharges or the volume of storm runoff. For this reason, a filter strip should be viewed as only one component in a storm water management system. VFSs reduce pollutants such as sediment, organic matter, and many trace metals by the filtering action of the vegetation, infiltration of pollutant-carrying water, and sediment deposition. Although studies indicate highly varying effectiveness, trees in strips can be more effective than grass strips alone because of the trees' greater uptake and long-term retention of plant nutrients. Properly constructed forested and grassed filter strips can be expected to remove more than 60 percent of the sediment and perhaps as much as 40 percent of the plant nutrients in urban runoff. VFSs fail very easily if they are not maintained regularly. Filter strips function best when they are level in the direction of storm water flow toward the stream. This orientation makes for the finest sheet-flow through the strip, increasing infiltration and filtering of sediment and other solids. To prevent erosion channel formation, a *level spreader* should be situated along the top edge of the strip. Level spreaders are designed to disperse concentrated flows evenly over a larger area. One type of level spreader is a shallow trench filled with crushed stone. Maintenance includes periodic inspection, mowing, trimming, compost and/or fertilizer application, and repair of washed-out areas and bare spots. VFSs that are used for sediment removal may require periodic regrading and reseeding of their upslope edge because deposited sediment can kill grass and change the elevation of the edge, preventing uniform flow through the strip.

Filter System, Sand - A device used to treat storm water runoff from large buildings, access roads and parking lots. As the name implies, sand filters work by filtering storm water through beds of sand. Small sand filters are installed underground in trenches or pre-cast concrete boxes. Large sand filters are above-ground, self-contained sand beds. Both above-ground and underground versions use some form of pre-treatment to remove sediment, floating debris, and oil and grease from storm water before it flows onto the sand filter bed. There, sediment particles and pollutants adsorbed to the sediment particles are captured in the upper few inches of sand. The underground versions fit in very well in urban areas and on sites with restricted space. Depending on the design, the underground sand filters are practically invisible to casual observers. Maintenance of these sand filters is simple and done manually. Above-ground sand filters are often considered to be eyesores and are best used where they cannot be seen or where hedges or other visual barriers can be installed. Construction costs can be kept lower if lightweight equipment is used for maintenance, which reduces the structural reinforcing needed in the filter. Pollutant removal for sand filters varies depending on the site and climate. Overall removal for sediment and trace metals is better than removal of more soluble pollutants because the filter functions by simply straining small particles out of the storm water. Sand filters remove pollutants by settling out particles in the pretreatment devices and by straining out particles in the filter. Moderate to large parking lots should be the largest areas drained to underground sand filters. Underground sand filters should have pretreatment or settling chambers that hold 540 cubic feet of water for each acre of contributing drainage. For two-chambered sand filters, the volume of the filter chamber should equal the volume of the settling chamber and the sand filter bed should be 18 inches deep. The surface area of both the settling and filter chambers should have 360 square feet of area for each acre of drainage area. Above-ground sand filters may use *grassed filter strips, grassed swales or large basins* as pretreatment to prevent clogging of the sand filter. Sand filter beds should be 18 inches deep. Sand filters can provide effective reduction of the more common urban pollutants in storm water. Sand filters have demonstrated long lifetimes and consistent pollutant removal when properly maintained. Maintenance for sand filters is simple and inexpensive. Mosquito breeding is usually not a problem, even in underground settling chambers that hold pools of water for long periods. Oil and grease in the storm water typically forms a sheen on the water which prevents mosquito growth. Sand filters are more expensive to construct than infiltration trenches. No storm water detention is provided by sand filters. Maintenance for smaller, underground filters is usually and best done manually. Normal maintenance requirements include removal of the upper few inches of dirty sand and replacement with clean sand when the filter clogs, and periodic raking of the sand surface and disposal of accumulated trash. The pretreatment devices must be cleaned to remove sediment and debris. *See also On-Site System Sand Filters*.

Fish Cleaning Facilities and Controls - *see Boat Solid Waste Generation and Disposal*

Flume (Chute), Paved - A small concrete-lined channel to convey water down a relatively steep slope without causing erosion. Flumes serve as stable, permanent elements of a storm water system receiving drainage from above a relatively steep slope, typically conveyed by diversions, channels, or natural drainageways. Setting the flume well into the ground is important, particularly on fill slopes. Some means of energy dissipation should be provided at the outlet, and an inlet bypass route should be available for extreme flows.

Forebay - A separate upper section of a basin or pond separated from the main basin by a wall or dike and which receives the incoming storm water. It is used to help settle some of the storm water sediment and capture debris. *See Debris Removal***.**

Gabions - Traditionally, wire mesh boxes, baskets or cages filled with small rocks. They are wired together as building blocks in the construction of hardened stream-bank protections. Gabions now vary in size and shape and can be used in the form of walls, terraces, or blankets. Pole cuttings can be inserted through gabions with the aid of a metal rod, and should be extended into the subsoil. A slight downstream angle is recommended to avoid shearing under high flows. Gabions provide a means of long-term stream-bank stabilization and are best used as part of a system which includes a component to deter undercutting at the bed/foundation interface, such as *geotextile* or biodegradable fabric or rock *riprap*, and a means of reducing the erosive potential of incoming flows at their source, such as eliminating overgrazing and soil compaction by cattle in agricultural settings or providing detention ponds for impervious surfaces in urban settings**.** Gabions are a common substitute for riprap where smaller or non-angular stones are available. Gabions are useful for protecting steep banks where scouring or undercutting are problems. Their effectiveness is improved when vegetation is incorporated. *See also Cribs.*

Geomembranes - Installation of synthetic sheets in trenches dug around a chemically contaminated area restricts the spread of contamination. Geomembranes are relatively new, and there are concerns about the long-term efficiency and compatibility of the synthetic fibers with organic solvents

Grade Stabilization Structure - A structure designed to reduce channel grade in natural or constructed watercourses to prevent erosion of the channel from excessive grade or increased channel flows. This practice can prevent head-cutting or stabilize gully erosion. Grade stabilization structures may be vertical drop structures, concrete or riprap chutes, gabions, or pipe drop structures. Permanent ponds or lakes may be part of a grade stabilization system. Concrete chutes are often used as outlets for large water impoundments where flows exceed 100 cfs and the drop is greater than 10 ft. Where flows exceed 100 cfs but the drop is less than 10 ft., a vertical drop weir constructed of reinforced concrete or sheet piling with concrete aprons is generally recommended. Small flows allow the use of prefabricated metal drop spillways or pipe overfall structures. Designs can be complex and usually require detailed site investigations. Design of large structures (100 cfs) requires a qualified engineer. The National Engineering Handbook (Drop Spillways, Section 11, and Chute Spillways, Section 14) prepared by the USDA Natural Resources Conservation Service gives detailed information useful in the design of grade stabilization structures.

Grassed Channel or Swale[1] - *Also called grassy swale.* An earthen channel or swale vegetated with grass, which is dry except following storms and serves to convey specified concentrated storm water runoff volumes, without resulting in erosion, to disposal locations. They require shallow slopes and soils that drain well. Typical uses include roadside swales, highway medians, outlets for road culverts or runoff diversions, construction storm water routing, and drainage of low areas. Channels should conform to the natural drainage patterns. Channels are not meant to collect sediment, as it will reduce their conveyance capacity. Lining with riprap, geotextile or other material is required if design flows are to exceed 2 feet per second. Channel vegetation should be allowed to establish before flows are introduced. Because swales have a limited capacity to convey runoff from large or intense storms, they often lead into concrete lined channels or other stable storm water control structures. Swales may provide some reduction in storm water pollution through infiltration of runoff water into the soil, filtering of sediment or other solid particles, and slowing the velocity and peak flow rates of runoff. These processes can be enhanced by adding small (4-10 inches high) dams across the swale bottom, thereby increasing detention time. The pollutant-removing effectiveness of swales has been assessed as moderate to negligible depending on many factors, including the quantity of flow, the slope of the swale, the density and height of the grass, and the permeability of the underlying soil. Taller grass will slow velocities more, but grass cut to a short length may take up more plant nutrients. Maintenance of vegetation includes periodic inspection, mowing, compost and/or fertilizer application, removal of clippings where nutrient removal is an objective, and repair of washed-out areas and bare spots.

Grouting - A low-permeability grout wall is created by injecting fluids under high pressure into the ground. around a chemically contaminated area. Grouting is especially successful in areas of fractured bedrock, where emplacement of other low-permeability barriers is not feasible. Grouting fluids are typically comprised of cement, bentonite, or specialty fluids such as silicate or lignochrome grout.

Hard Points - *See Embedded Flow Obstructions*

Hardened Channel - A channel with erosion-resistant linings of riprap, paving, or other structural material designed for the conveyance and safe disposal of excess water without erosion. Hardened channels replace grass-lined channels where conditions are unsuitable for the latter, such as steep slopes, prolonged flows, potential for traffic damage, erodible soils, or design velocity over 5 feet per second.

Hay Bale Barrier - *see Sediment Barrier - Hay or Straw Bale* [1]

Household Hazardous Waste (HHW) Collections - collection centers or periodic collection events which accept hazardous chemicals and materials from households under safe conditions for recycling or proper disposal. Some collections may accept only recyclable or reusable materials such as used motor oil, other automotive fluids, lead-acid batteries, and paints. In some areas affected by historical water pollution by partially banned or discontinued ("legacy") pollutants, it is helpful for HHW collections to document and report any of these legacy chemicals that are received. *See also Minimization of Pollutants.*

Hydrodynamic Control - The spread of a leaking or spilled contaminant may be controlled by creating a cone of depression (lowering the water table) with pumping wells around the affected area. The lack of ground water will restrict movement of the plume. Additionally, a combination of pumping wells and injection wells around the area can create a potentiometric low that will trap the contamination in place. Vapor movement may be controlled with a pressure differential system or a vapor extraction system.

Hydrology, Restoration of - *see Restoration of Wetlands Hydrology*

Infiltration Device - Structure to facilitate the entry of storm water into the soil to remove pollutants and to recharge or replenish the ground water. Infiltration devices, also called exfiltration devices, include *infiltration basins*, *infiltration trenches* and *dry wells*. Properly designed infiltration devices can closely reproduce the water balance that existed pre-development, providing ground water recharge, control of peak flows from storm water and protection of streambanks from erosion due to high flows. Infiltration devices can remove a significant amount of pollutants through adsorption onto soil particles, and biological and chemical conversion in the soil. Infiltration basins with long detention times and grass bottoms enhance pollutant removal by allowing more time for settling and because the vegetation increases settling and adsorption of sediment and adsorbed pollutants. It is critical that infiltration devices only be used where the soil is porous and can absorb the required quality of storm water, and only where they will not direct poorly filtered runoff into sensitive groundwater resources. Maintenance needs for infiltration devices are higher than other devices partly because of the need for frequent inspection. Nuisance problems can occur, especially with insect breeding, odors and soggy ground. Some infiltration basins filter the entire amount of captured storm water; others discharge to receiving waters on the surface and have lower removal effectiveness. Some infiltration devices (*infiltration trenches*, *dry wells*, and *catch basins*) can be constructed underground, under parking lots or roads, taking very little land from other uses. Locating smaller infiltration devices is fairly easy so that large downstream devices can be replaced with a number of small structures upstream and still achieve the same control of storm water. Infiltration devices require permeable soils and reasonably deep water tables. Smaller infiltration devices such as dry wells or basins can be located near buildings to capture the runoff from roofs and other impervious surfaces. Infiltration devices help replenish the ground water and reduce both storm water peak flows and volume. Pollutant removal can be very high for many pollutants. Because they take up little land area and are not highly visible, many underground infiltration devices can be located close to residential and commercial areas. However, infiltration techniques work only where the soils are permeable enough that the water can exit the storage basin and enter the soil. These devices have a high failure rate, especially where maintenance is infrequent. Infiltration devices must have sediment removed before the storm water enters the device to prevent clogging of the soil. The water table must be at least two feet under the bottom of the device. Maintenance requirements include regular inspections, cleaning of inlets, mowing and possible use of observation wells to maintain proper operation. Infiltration basins and sediment removal devices used to prevent clogging of other infiltration devices must have the sediment removed regularly. If an infiltration device becomes clogged, it may need to be completely rebuilt.

Inlet Protection (drop inlets and curb inlets)

- **Block and Gravel** - A temporary sediment control barrier formed around a storm drain inlet

by the use of standard concrete block and gravel, to filter sediment from storm water entering the inlet prior to stabilization of the contributing area soils, while allowing use of the inlet for storm water conveyance. The height of the barrier should allow overflow into the inlet and not let overflow bypass the inlet to unprotected lower areas. An alternative design eliminates the blocks and involves only a gravel doughnut around the inlet. This practice can be used in combination with other temporary inlet protection devices, such as excavation and fabric.
- **Compost Filter Sock** -
- **Excavated** - A temporary excavated area around a storm drain drop inlet or curb inlet designed to trap sediment prior to discharge into the inlet. This practice allows use of the permanent inlet early in the development prior to stabilization of the contributing area soils. Frequent maintenance is required. This practice can be used in combination with other temporary inlet protection devices, such as fabric and block and gravel.
- **Fabric** - A temporary fabric barrier placed around a drop inlet or curb inlet to help prevent sediment from entering storm drains during construction operations, while allowing use of the inlet for storm water conveyance. The height of the barrier should allow overflow into the drop inlet and not let overflow bypass the inlet to unprotected lower areas. This practice can be used in combination with other temporary inlet protection devices, such as excavation and block and gravel.
- **Sod** - A permanent grass sod sediment filter area around a storm drain drop inlet for use once the contributing area soils are stabilized. This application is well-suited for lawns adjacent to large buildings.

In-Situ Treatment of Contaminants -
- **Biological** - The addition of nutrients and oxygen encourages the microbial breakdown of complex organic molecules into simpler, more stable compounds such as carbon dioxide and water. Generally, existing populations of bacteria are encouraged to breakdown the contaminants, although some strains of bacteria have been genetically engineered to rapidly metabolize particular contaminants. The efficiency and predictability of this method remains uncertain.
- **Chemical** - The addition of appropriate chemicals or treatment agents through wells around the site can alter the composition or consistency of the contaminants. For example, alkalies or sulfides causes heavy metals to precipitate as insoluble compounds and oxygen causes the chemical alteration of cyanide to less hazardous chemicals. The reliability of this method in comparison to other methods remains uncertain.

Integrated Pest Management - *see Landscaping and Lawn Maintenance Controls.*

Interceptor Swale[1] - A swale used to prevent off-site runoff from entering a disturbed area, or prevent sediment-laden runoff from leaving a disturbed site. The outflow from an interceptor swale should be directed to a stabilized outlet or sediment trapping device. *See also Diversion*

Interceptor System - Drains, trenches, and lined trenches that are used to collect contaminants that lie slightly above the water table. The contaminated water must be treated before disposal.

Jacks - *See Embedded Flow Obstructions*

Landscaping and Lawn Maintenance Controls - Significant amounts of fertilizers and pesticides enter the water from lawn maintenance and landscaping activities. Professional services may overapply fertilizers and pesticides to better please customers, and homeowners may not know the proper amounts of fertilizer and pesticides to use. Both groups may apply lawn-care chemicals too near water bodies. Requirements can be established through landscaping ordinances for business and industry to use native, hardy perennial species which require less fertilizer and water than common landscape varieties. Professional landscaping services can be required to minimize fertilizer and pesticide use and restrict application to the growing season. *Integrated Pest Management*, a well-established system to minimize the amount and toxicity of pesticides released to the environment, is a recommended landscape and lawn maintenance BMP. Particular attention should be paid to certain areas of high-intensity landscaping, such as cemeteries and golf courses, which may contribute large amounts of excess fertilizer and pesticides to runoff. Homeowners should be informed about the proper use of lawn and garden chemicals.

Level Spreader - An *outlet* designed to convert concentrated runoff to sheet flow and disperse it uniformly across a slope without causing erosion. This structure is particularly well-suited for restoring natural sheet flows to exiting drainage that has been altered by development, especially for returning sheet flows to receiving ecosystems such as wetlands where dispersed flow may be important for maintain pre-existing hydrologic regimes. The outlet's receiving area must be uniformly sloped and not susceptible to erosion.
Particular care must be taken to construct the outlet lip completely level in a stable, undisturbed soil to avoid formation of an outlet channel and subsequent erosion. Erosion-resistant *matting* of some kind may be necessary across the outlet lip depending on expected flows. Alternative designs to minimize such channeling include hardened structures, stiff grass hedges, and segmenting discharge flows into a number of smaller, adjacent spreaders. The level spreader is often used as an outlet for runoff *diversions*.

Live Cribwall - A hollow, box-like interlocking arrangement of untreated log or timber members, this structure is filled with suitable backfill material and layers of live branch cuttings, which root inside the crib structure and extend into the slope. Alternating layers of fill and branch cuttings should be compacted to remove air pockets and withstand flow turbulence. Once the live cuttings root and become established, the subsequent vegetation gradually takes over the structural functions of the wood members. Cribs may need to be countersunk into banks. Backfilling of the streambed with rock or cobbles to anchor the cribwalls into the banks should then occur. Live cribwalls provide a means of long-term stream-bank stabilization and are best used as part of a system which includes a component to deter undercutting at the bed/bank interface, such as rock *riprap* or *gabions*, and a means of reducing the erosive potential of incoming flows at their source, such as eliminating overgrazing and soil compaction by cattle in agricultural settings or providing detention ponds for impervious surfaces in urban settings.

Live Fascines (Wattling Bundles) - A form of soil bioengineering which uses long bundles of live branch cuttings bound together in long rows and placed in shallow trenches following the contour on dry slopes, and at an angle on wet slopes. When cuttings are taken from well-suited species, typically willow species or cottonwood, and when properly installed, secured by live stakes angled into the slope face at intervals, they will root and quickly begin to stabilize slopes. The goal is for natural recruitment to follow once slopes are secured. This stabilization method has the advantage of causing relatively little site disturbance. Live fascines reduce erosion and shallow face sliding of streambanks and other exposed slopes, minimizing sediment loading and associated nutrient enrichment impacts down-gradient. They are best used as part of a BMP system which includes a component to deter undercutting at the bed/bank interface, such as *riprap* or *gabions*, a means of buffering the construction from erosive flows, such as tree revetments (which can actually accrue sediments), and a means of reducing the erosive potential of incoming flows at their source, such as eliminating overgrazing and soil compaction by cattle in agricultural settings or providing detention ponds for impervious surfaces in urban settings.

Live Staking - A form of soil bioengineering involving the planting of live cuttings from hydrophytic shrubs or trees along the stream bank. *Also known as woody cuttings, posts, poles, or stubs*. As cuttings develop they protect streambanks from erosion, minimizing sediment and associated nutrient impacts downstream. Established cuttings also moderate bank and water temperatures, facilitate colonization of other species, and provide forage. Planting of dormant cuttings during the winter, and scoring of bases followed by soaking in rooting hormone increase likelihood of success. Vegetation selected should be able to: withstand the degree of anticipated inundation, provide year-round protection, have the capacity to become well-established under sometimes adverse soil conditions, and have root, stem, and branch systems capable of resisting erosive flows. Locally available native species should be used. Other important factors include rapid initial growth, ability to reproduce, and resistance to disease and insects. Plantings set with butts at anticipated growing season water table elevation but not completely submerged year-round yield the best survival. All zones should be covered to ensure establishment in the most suitable one. *Livestock exclusion* must be provided to achieve any measure of success. Species commonly used are several willow species, sycamore, and cottonwood. Stakings provide long-term stream-bank stabilization with delayed initial onset and are best used as part of a system which includes immediate means of buffering banks from erosive flows, such as *tree revetments* (which can actually accrue sediments), a component to deter undercutting at the bed/bank interface, such as loose *riprap* or *gabions*, and a means of reducing the erosivity of incoming flows at their source, such as eliminating overgrazing and soil compaction by cattle in agricultural settings or providing detention ponds for impervious surfaces in urban settings.

Livestock Exclusion - The fencing-out of livestock from areas, especially riparian areas, streambanks, and streambeds to provide for recovery of beneficial water quality/habitat functions. This practice is most applicable to riparian areas that have been severely affected by uncontrolled grazing. It allows for re-establishment of vegetative cover, which can secure banks, lower stream velocities, trap suspended sediments, increase meander, promote bank aggradation, and decrease down-gradient erosion. All of these changes improve local and downstream water quality. Water quality can also be improved by lowering average temperatures through shading of banks and channels. These effects in turn cause attenuation of flood flows and increased recharge potential, which raises water tables, improves baseflow, and supports greater forage cover in uplands. This practice also eliminates direct pollutant loading from manure deposition in the stream. Where grazing is a significant factor, this alone is often sufficient to facilitate stream-bank recovery. *See also Exclusion.*

Low-Head Dam (Weir) - Essentially the same type of construction as the check dam, built from rocks, logs, or other material, but intended for use in lower order perennial streams for water quality improvement and habitat enhancement. Weirs are most successful in streams with discharge not exceeding 6 cubic meters per second. Benefits include formation of pool habitat, collection and holding of spawning gravels, promotion of gravel bar/riffle formation, trapping suspended sediments, reoxygenating water, allowing organic debris deposition, and promotion of invertebrate production.

Low-Volume Plumbing Fixtures - Installation of fixtures such as low-volume flush toilets, shower heads, and faucet aerators reduce the wastewater volume load to septic systems or other on-site wastewater systems.

Matting - *see Blankets and Matting*[1]

Mattress - A form of soil bioengineering which uses a blanket woven of live green cuttings and biodegradable fiber, geotextile, or wire, laid into a slight excavated depression in the bank, anchored with live or wooden stakes, and often punched through with live stakings. It is then covered with soil and watered repeatedly to fill voids with soil and to facilitate sprouting. Variations include a solid blanket of live branches held in place by an overlying staked wire mesh blanket and soil. Mattresses minimize sediment loading and associated nutrient enrichment impacts downstream by acting as a buffer, disrupting the force of incoming flows, creating turbulence, lowering water velocities, causing deposition of sediment, and protecting banks. They are best used as part of a system which includes a component to deter undercutting at the bed/bank interface, such as riprap or gabions, a means of long-term stream-bank stabilization, such as live stakings, and a means of reducing the erosive potential of incoming flows at their source, such as routing runoff in grass swales, using detention ponds, and providing discharge spreader swales. *See also Blanket.*

Minimization of Pollutants - Removing potential pollutants from the watershed, using alternative chemicals, using alternative practices, recycling or reducing the use of polluting chemicals and other materials. In addition to the management methods presented here, many innovative ideas can be used to reduce pollutants at specific sites. Industrial and commercial managers and residential dwellers are in the best position to devise alternative and innovative procedures and new techniques that avoid or reduce pollutants, and can be given guidance, incentives, and thought-provoking encouragement to do so. Good examples of pollutant minimization are: COLLECTION/RECYCLING. Community hazardous waste and waste oil recycling centers. These activities remove some of the most polluting substances from places where the substances can enter storm water runoff. SEPARATION. Connecting the drains from vehicle washing areas to the municipal sewer or sanitary sewer system to prevent discharge of the wash water into a nearby stream, if permitted by the local government. SUBSTITUTION. Using non-toxic or non-hazardous materials in place of hazardous materials, such as water-based degreasers and water-based inks to reduce the amount of solvents and chemicals that enter the environment.

Mulch[1] - A protective layer or "blanket" of wood chips, compost, other organic material, gravel, or synthetic material applied to the soil surface to minimize raindrop impact energy and runoff, foster establishment of vegetation, reduce evaporation, insulate the soil, and/or suppress weed growth. Also called blanket or erosion control blanket. Mulch provides immediate protection, and is also typically used as a matrix for spreading plant seed. Organic mulches have been found to be the most effective. In order to absorb moisture and rainfall impact energy effectively, mulch should have a good particle size distribution, with most of its volume typically consisting of particles too large to pass through a 3/8 inch screen but less than 1 inch in diameter, and a minimum of fines. *See also Filter Berms and Socks, Mulch*[1]

- **Erosion Control Compost**[1] - A layer of compost or compost/mulch blend used as a surface application for erosion control. Applications are typically 2 inches unless otherwise specified, and are sometimes stabilized with a drum roller. Erosion control compost is recommended for use on slopes of 3:1 or flatter. The compost material often contains a seed mix to facilitate establishment of a vegetative cover.

No-Wake Zone - An area in which a boat's speed must be reduced in order to reduce the size of the wake it produces, commonly to 5 mph or less. This reduces the erosive action of waves on the shoreline and the disturbance of shallow sediments, among other purposes.

Oil, Grease, and Grit Trap Devices - A number of devices are used to remove oil and grease from storm water. One type, commonly known as oil-water separators, are mechanical devices manufactured by various industrial equipment manufacturers. Oil-water separators are usually installed at industrial sites and are not discussed in detail here. Another type of oil and grease removal device is the oil and grease trap catch basin (or oil and grit separator). These catch basins are underground devices used to remove oils, grease, other floating substances and sediment from storm water before the pollutants enter the storm sewer system. They are usually placed to catch the oil and fuel that leak from automobiles and trucks in parking lots, service stations, and loading areas. A third type of device is a simple skimmer and control structure used at the outlet of a sediment basin (forebay), typically used prior to discharge into a larger detention device. A popular design for the oil and grease trap catch basin uses three chambers to pool the storm water, allow the particulates to settle, and remove the oil. As the water flows through the three chambers, oils and grease separate either to the surface or sediments and are skimmed off and held in the catch basin. The storm water then passes on to the storm sewer or into another storm water pollution control device. Because these devices are relatively small and inexpensive, they can be placed throughout a drainage system to capture coarse sediments, floating wastes, and accidental or illegal spills of hazardous wastes. Oil and grease trap catch basins can reduce maintenance of infiltration systems, detention basins and other storm water devices. Since these catch basins detain storm water for only short periods, they do not remove other pollutants as effectively as facilities that retain runoff for longer periods. However, these basins can be effectively used as a first stage of treatment to remove oil and sediment from storm water before it enters another, larger storm water pollution control device, such as a wet pond. The second design involves an open sedimentation basin with a skimmer plate extending below the ponding control elevation at the outlet. Storm water velocities are reduced in this sump, dropping out coarse sediment and separating oils and greases and floatables, which are retained in the basin by the skimmer as the storm water discharges to a larger detention device or off-site. These sediment sump/skimmers are often designed larger than the underground chambers, have longer detention times, and thus remove more of the sediments and oils and greases. Oil and grease trap catch basins can be installed in most areas. Drainage areas flowing into the catch basin must be no larger than two acres and the catch basin must be large enough to handle dry weather flows that enter the basin. These catch basins can be installed in almost any soil or terrain, which allows their use near or at the impervious surfaces contributing heavily to the storm water runoff. Little land area is taken up by catch basins as they require only enough area for proper maintenance. Oil and grease skimmer design is essentially that of a sedimentation basin with a conrol structure discharge that allows for mounting of a skimmer plate. The plate should extend sufficiently below the lowest discharge level to preclude siphoning of the water surface by the discharge. Advantages. Oil and grease trap catch basins are inexpensive and easily installed in most areas. Since these devices are underground, there should be few complaints concerning appearances. These catch basins can be used very effectively as part of a system of storm water controls to remove oily pollutants and coarse sediment before they enter another storm water control device. Also small catch basins can be distributed over a large drainage area, which may prove advantageous over constructing a single large structure downstream. Sediment basins with skimmers are simpler and more easily maintained than the chamber design, tend to be larger and more effective in their role, and allow for photodegradation of hydrocarbons in addition to settling. Disadvantages. Pollutant removal is low for contaminants other than oil, grease and coarse sediment for both types of systems. Both must have the accumulated sediment removed or cleaned out frequently to prevent sediment-bound pollutants from being stirred up and washed out in subsequent storms. Sediment removal removes the oil and grease because these pollutants eventually bind to the sediment. The chamber type is more difficult to maintain because of its enclosed, underground design, and typically is less efficient than the sediment basin because it tends to be smaller. Odors are sometimes a problem. Maintenance. Oil and grease trap catch basins require regular inspection and cleaning at least twice a year to remove sediment, accumulated oils and grease, floatables, and other pollutants. Sump/skimmers require periodic but less frequent sediment removal. Wastes removed from these systems should be tested to determine proper disposal methods. The wastes may be hazardous; therefore, maintenance costs should be budgeted to include disposal at a proper site.

On-Site Alternating Bed Wastewater System - Construction of a backup absorption field, with the ability to route tank water to either field. The backup field is used while the primary field is rested and allowed to recover through biological activity. Fields are alternated every 6 months. Improper function of on-site systems is usually associated with the soil absorption field. Alternating bed systems help address hydraulic overload, the most common reason for failure of the absorption field.

On-Site Denitrification System - Even properly functioning conventional septic systems are not effective at removing nitrogen. In areas where nitrogen is a problem pollutant, existing conventional systems should be retrofitted to provide for nitrogen removal through effective linking of aerobic and anaerobic transformation processes. Systems such as sand filters and constructed wetlands (see Wetlands, Constructed below) have been shown to remove over 50 percent of the total nitrogen from septic tank effluent (USEPA, 1993). Denitrification systems are most effective when used as part of a BMP system which involves source reduction through elimination of garbage disposals and use of low-volume plumbing fixtures.

On-Site Floating Aquatic Plant (Aquaculture) Systems - Constructed shallow (generally less than 3 feet deep) pond systems using floating aquatic plants in the treatment of industrial or domestic wastewater. Wastewater is treated principally by bacterial metabolism and physical sedimentation. The plants take up nutrients through their roots but perform little actual treatment themselves, serving instead as an excellent substrate for microbial biomass which provides significant treatment. The water hyacinth Eichornia crassipes has been studied extensively for use in these systems. The major advantages are their extensive root systems and rapid growth rate. Their major limiting feature is cold temperature sensitivity, confining its use to the southern states. Other species, such as pennywort (Hydrocotyle umbellata) and duckweed (Lemna spp., Spirodela spp., Wolffia spp.), have greater cold tolerances than hyacinths and have also been used in these systems. These systems can provide effective secondary wastewater treatment or nutrient removal, depending on organic loading rate. They have been used most often for either removing algae from oxidation pond effluents or for nutrient removal following secondary treatment. The predominant mechanism for nitrogen removal is nitrification-denitrification, while phosphorus is removed through plant uptake, microbial immobilization into detritus plant tissue, and retention by sediments. Nitrogen and phosphorus removal by the plants is achieved only with frequent harvesting. Periodic removal of accumulated sludge is required. Where anaerobically generated hydrogen sulfide odor and mosquito breeding are problematic, design modifications such as step-feeding of inflows, recycling of effluent, supplemental aeration, and frequent harvesting of plants are effective. Aquatic plant treatment systems are most effective as part of a BMP system in which they perform the role of secondary, advanced secondary, or tertiary wastewater treatment.

On-Site Mound (Fill) Wastewater System - Creation of an artificial drain field using sand or other material when the original soil is inadequate. Effluent flows from the existing septic tank to a pump tank, from which it is pressure-distributed uniformly up into perforated pipes embedded in the fill, which is mounded above the original soil. The mounded soil serves as the absorption field.

On-Site Pressure Distribution (Low Pressure Pipe) Wastewater System - Installation of a storage tank and pump after the septic tank to distribute the septic tank effluent more evenly. More even distribution results in better treatment than the conventional gravity distribution method for a retrofitted system or the same treatment within a shallower soil for a new system

On-Site System Chemical Additive Restrictions - Restrictions typically applied to septic and other on-site wastewater treatment systems to protect the biological treatment processes and to prevent chemical releases to the environment. Organic solvents are advertised for use as septic system cleaners and sometimes as substitutes for sludge pumping. However there is little evidence that such cleaners perform any of the advertised functions, and can instead exterminate useful microbes, resulting in increased discharge of pollutants. In addition, the chemicals themselves, halogenated and aromatic hydrocarbons, can easily contaminate receiving waters, and common cleaner constituents are listed with the US Environmental Protection Agency as priority pollutants. Restrictions on the use of these additives can preclude further exacerbation of poor system function. Additive restrictions are most effective when used as part of a BMP system which involves other source reduction practices such as phosphate bans and use of low-volume plumbing fixtures, as well as mitigative BMPs such as upgrading and maintenance.

On-Site System Peat Filters - An innovative new filter system involves the use of a fibrous peat media. Effluent is pumped under pressure to the top of a factory constructed peat bio-filter module set on the soil surface. The effluent filters through the peat media before entering the soil treatment bed. The addition of a peat bio-filter allows for a reduction in allowed soil depth to a restrictive layer.

On-Site System Sand Filters - Like mound systems, the sand filter takes effluent from an existing septic tank. In the intermittent sand filter, septic tank effluent is intermittently applied to the top of a sand bed, collected by underdrains at the bottom of the bed, and piped into a soil absorption field. In the recirculating sand filter, a portion of the sand filter effluent is recirculated to achieve more treatment, and the sand is replaced on a periodic basis.

Outlet Stabilization Structure - A structure designed to control erosion at the outlet of a channel or conduit by reducing flow velocity and dissipating flow energy. This should be used where the discharge velocity of a structure exceeds the tolerances of the receiving channel or area. Designs will vary based on discharge specifics and tailwater conditions. A *riprap-lined apron* is the most commonly used practice for this purpose because of its relatively low cost and ease of installation. *Riprap stilling basins* or *plunge pools* should be considered in lieu of aprons where over-falls exit at the ends of pipes or where high flows would require excessive apron length.

Paved Flume or Chute - *see Flume (Chute), Paved*

Phasing - *see Scheduling and Sequencing*

Phosphorus-Based Waste Management Plan -

Phosphorus Detergent Restrictions - Conventional septic systems are usually very effective at removing phosphorus. However, certain soil conditions combined with close proximity to sensitive surface waters can result in phosphorus pollutant loading. If such conditions are sufficiently prevalent within areas of concern, restrictions or bans on the use of detergents containing phosphate can be implemented. Eliminating phosphates from detergent can reduce phosphorus loads to septic systems by 40 to 50 percent.

Pile Dikes - *See Embedded Flow Obstructions*

Plugging Wells and Testholes -

Plunge Pool - A pool typically lined with riprap, designed to dissipate the energy of a stream of water discharging from a pipe or similar structure before it enters another channel or structure.

Porous Pavement - An alternative to conventional pavement intended to reduce imperviousness and consequently minimize surface runoff. Porous pavement follows one of two basic designs. First, it may be comprised of asphalt or concrete that lacks the finer sediment found in conventional cement. This formulation is usually laid over a thick base of granular material. Second, porous pavement may be formed with modular, interlocking open-cell cement blocks laid over a base of coarse gravel, with a geo-textile fabric underlying the gravel. Both designs typically include a reservoir of coarse aggregate stone beneath the pavement for storm water storage prior to exfiltration into surrounding soils. Use of porous pavement requires permeable soils with a deep water table. Traffic must be restricted to exclude heavy vehicles. Its use is not advisable in areas expecting high levels of sediment loading from off-site. The porous pavement itself functions less as a treatment BMP and more as a conveyance BMP to the other necessary component of the design, the underlying aggregate chamber, which functions as an infiltration device. As with other infiltration devices, treatment is provided by adsorption, filtration, and microbial decomposition in the sub-soil surrounding the aggregate chamber, as well as by particulate filtration within the chamber. Operating systems have been shown to have high removal rates for sediment, nutrients, organic matter, and trace metals. These rates are largely due to the reduction of mass loadings of these pollutants through transfer to groundwater. For this reason, this BMP should not be used where geological features would allow direct transmission of unfiltered runoff to groundwater resources. Porous pavement has a high failure rate due to clogging either from improper construction, accumulated sediment and oil, or resurfacing. Excessive sediment will cause the pavement to rapidly seal and become ineffective. The modular, interlocking, open-cell concrete block type tends to remain effective for considerably longer than asphalt or concrete porous pavement. Porous pavement must be maintained frequently to continue functioning. Quarterly *vacuum sweeping* and/or jet hosing is needed to maintain porosity. Positive attributes include the diversion of potentially large volumes of surface runoff to groundwater recharge, providing both water quality and quantity benefits. While more expensive than conventional pavement, it can also eliminate the need for more involved storm water drainage, conveyance, and treatment systems, offering a valuable option for spatially constrained urban sites. Porous pavement may be most beneficial in watersheds with high percentages of impervious surface and high volumes of runoff. Its use is typically recommended for lightly trafficked satellite parking areas and access roads. Increased infiltration at the source (parking lots, etc.) will reduce the both volume of runoff and the delivery of associated pollutants to water bodies. *See also Infiltration Device.*

Posts - *See Embedded Flow Obstructions*

Protected shallow-water habitat -

Pumping (Contaminant Removal) - Pumping wells to remove contaminated ground water. The contaminated water must be treated before disposal.

Pumpout Facility - *see Boat Sewage Pumpout Facility*

Rain Garden - Gardens to treat storm water runoff from parking lots, roadways, or driveways through temporary collection of the water before infiltration. Also known as bioretention. They are slightly depressed areas into which storm water runoff is channeled by pipes, curb openings, or gravity. They are usually designed to handle a one inch rain, or what is called the first flush of a rainfall. Any type of soil can conceivably be used with the exception of shrink-swell clays. Vegetation placed in the garden should be tolerant of wet periods but not "wetland" plants as the garden will not hold water for long periods of time. Rain gardens are still a relatively new BMP with ongoing research, therefore the efficiency with which it removes pollutants is not yet quantified. Plant nutrients (especially phosphorus) may be adsorbed to soil particles, or taken up by the vegetation in the garden. Sediment may be removed through sedimentation as the water is held temporarily. Metals may be adsorbed to soil particles or organic matter. Pathogens may be destroyed through microbial processes in the soil, or through exposure to sunlight and dryness. Place the rain garden in a low lying area if possible to receive the runoff, or a flat area that can be dug down 6 – 12 inches. Naturally wet areas, or areas with a high water table (< 2 feet from surface) are not good locations. The rain garden should be designed to be 3-8% the size of the drainage area, depending on the amount of impervious surface. After vegetation has been planted a layer of *mulch*, 3 to 4 inches should be applied. The upper 3 to 5 feet of soil in the garden should include enough clay size particles to allow good vegetative growth and promote adsorption. When building a rain garden in an area with clayey soils, drainage must be included with drainage pipes and a gravel layer, or excavation of the soil is another option. If draining a parking lot or road allow a drop of several inches to keep debris from blocking the inflow. If the drainage has a high sediment load consider a *grassy area or buffer* prior to entering the garden to remove some of the sediment. If using a pipe or a concentrated inflow, prevent soil erosion or scouring by placing rocks in the inflow path. An overflow is required for the garden to divert excess water (rainfall above the design capacity). For flat areas, leaving an "exit" through the back of the garden while being careful to prevent soil erosion should suffice. The installation of an overflow pipe is another option. The pipe is set to the desired height of maximum water retention, usually about 9 to 12 inches. Rain gardens are aesthetically pleasing. Costs are relatively low. Rain gardens do not handle large amounts of storm water runoff and do not treat several common pollutants such as nitrate-nitrogen or large amounts of sediment. They must be maintained, usually once or twice a year. Vegetation must be cared for especially in periods of drought. If underdrains are present, periodic inspections must be done to make sure they remain clear. The mulch layer must be monitored for decomposition. Wildlife and pets should be discouraged from using the area to prevent animal waste pathogens. For more information on rain gardens (bio-retention areas) see:

http://courses.ncsu.edu/classes-a/bae/cont_ed/bioretention/index.htm
http://www.ence.umd.edu/~apdavis/Bioret.htm

Rainwater Harvesting[1] - *(See Retention/Irrigation Systems)* Capture and storage of rainwater from roofs and other impervious surfaces for landscape, domestic, or other consumptive uses. This can mitigate or eliminate the increased runoff volume and velocity due to additions of impervious cover, reducing the required capacity for down-slope retention and sediment control BMPs.

Remediation, Biological and Chemical Degradation - *see In-Situ Treatment of Contaminants*

Repair & Maintenance Restrictions - *see Boat Solid Waste Generation and Disposal*

Restoration of Wetland Hydrology - The most important element of wetland function, and perhaps the most frequently altered, is hydrology (water flow patterns). A wetland's hydrologic regime can be altered in a few basic ways. One of those ways is ***draining***, or lowering the elevation at which the system is able to discharge. Probably the most common method of draining involves ditching the wetland's outfall. In many instances, this can also be one of the easiest impacts to remedy, requiring only a determination of the pre-disturbance surface overflow elevation or the closest level that competing interests will allow, followed by *blocking of the outfall* ditch, allowing other wetland functions to return as the pre-disturbance hydrologic regime reestablishes. In the case of the channelization of a stream or river which serves as the outfall for contiguous floodplain wetlands, the solution can be much more involved. Channelization of streams often has occurred to provide flood relief for development within the floodplain during high flow events. Restoration of such streams would require gaining control of or acquiring the affected floodplain areas or portions of them based on modelling results, followed by reestablishment of channel sinuosity with *in-stream blockages* and reestablishment of bed elevation with *grade control structures*. Other methods of draining wetlands amount to variations on the theme of ditching. Wetlands can be drained by ditches which disrupt a lens or impermeable horizon beneath the system for some distance. In such cases, restoration may require *filling* of the length of the intercepted unit with clay or other low permeability material. Adjacent ditching or nearby large-scale excavation can act to draw wetlands down more rapidly, shortening the hydroperiod's duration and decreasing its amplitude. Construction of a *hydraulic barrier wall* by trenching and filling with clay or other material may by effective in such cases, particularly if the wall is tied into some confining unit in the soil. Actions to minimize the drawdown source may also be necessary, such as relocation in the case of the adjacent ditch or cessation or minimization of dewatering activities in the case of a large-scale excavation. One other form of drainage occurs in agricultural settings and involves the direct under-draining of the wetland with drain tiles. *Plugging* of the drain tiles' outfall points can effectively stop their draw-down impacts, and the tiles are likely to sediment in over time. A second basic means of altering wetland hydrology is by ***diverting the inflows***, either surface or subsurface, to wetlands. In rural and agricultural settings, *interceptor ditches* skirting the periphery of wetlands are neutralized most effectively by *blocking* them at intervals along their path or completely *filling them*. If only a single well-placed ditch block is used, the upper elevations of the wetlands may not recover and the entire wetland may be denied important dry weather inflows which can affect the ability to reestablish the desired biotic communities. A wetland's contributing area may also

be diverted in an agricultural setting through the use of drain tiles under a field or a surface ditching network which routes the discharge to another, often lower point in the landscape. Once control of the land or landowner cooperation is obtained, ditches and drain tiles can be *plugged*. In urban areas, diversion of inflows is common and takes the form of impervious surfaces, which intercept rainfall and preclude its natural infiltration into the soils and movement into wetlands as subsurface flow. Restoration of such urban wetland systems can be complicated, and may require *pumping* of storm water or *redirection of flows*, which may only be achievable for small portions of contributing area or larger areas as land uses change. Storm water engineers should be consulted for advice on specific cases. The last basic means of altering wetland hydrology is ***draw-down***, essentially by drawing the water out from underneath a wetland. Local or regional draw-down of the surficial aquifer can occur as a result of industrial activity or mining involving either intentional or consequential draw-down of the water table, as a result of over-pumping by well-fields, or as a result of channelizing of regional surface water drainage networks for flood control and development purposes. Such regional draw-downs typically must be addressed by working with the draw-down source(s) to minimize the draw-down magnitude. In addition, if the draw-down is relatively localized and active for a relatively limited time period, some form of continuous *groundwater surcharge zone* can be established between the activity and the impacted system to offset the ongoing depletion. If the draw-down activity is relatively permanent and affects only one or a small number of wetlands, a more permanent barrier such as a clay or synthetic *groundwater barrier wall* can be installed. Such a barrier is more effective if it ties into an impermeable soil horizon. If not, it may be most effective to use a combination of BMPs such as minimization of the hydraulic head differential (decreasing the draw-down), construction of a barrier wall, and surcharging as necessary on the up-gradient side of the barrier.
Minimize Other Disturbances. While alteration of hydrology is probably the most common impact to wetlands and riparian areas, other disturbances can be equally damaging. Wetlands being considered for restoration should be assessed for the potential occurrence of and ability to ameliorate or remove other ongoing disturbances, outside of natural disturbance processes, in addition to hydrologic alterations. Those disturbances typically take the form of significantly accelerated loading of pollutants carried by inflows to the wetland. The most damaging of these may be accelerated sediment deposition and nutrient loading. If signs of unnatural sediment accumulation (deltas of bare sediment, buried litter, etc.) or nutrient loading (eg., shift in edge species composition to opportunistic varieties without signs of physical disturbance) are found within the system, the wetland's contributing area should be evaluated. The ability to either make changes to land use practices at the source(s) and/or to install BMPs to capture pollutants during transport should be considered. An appropriate goal of restoration may well be to rehabilitate a wetland so that it can provide better pollutant removal. The intent of investigating upgradient BMPs, then, is to provide for sufficient pre-treatment to ensure the integrity and continued ability of the wetland to perform its desired functions, as a "car" in the water quality improvement "train". Other disturbances include direct impacts from logging, filling, excavation, peat mining, farming and animal access practices, and enhanced fire frequency. These impacts are more discrete in nature, and the likelihood of future occurrences should be investigated and minimized.

Restoration of Wetland Native Plant Communities - Reestablishment of degraded or displaced native plant communities where wetland water flow patterns are being restored. Hydrology is the most important element not only of wetland function in general, but also of maintaining or establishing viable, diverse, native plant communities in wetlands. It is not advisable to attempt reestablishment of lost flora where compromised hydrology has not been reestablished. If hydrology can be fully reestablished to pre-disturbance form, then pre-disturbance plant communities will likely follow independently given sufficient time. The time needed, however, is highly variable and can appear, in practical terms, indefinite. Therefore, it is often desirable to set the successional process forward by constructing the core elements of the desired flora and performing maintenance to further ensure their establishment. Such restoration work is particularly valuable when forested wetlands were lost and a recalcitrant herbaceous community has secured the site in their place. In situations where pre-disturbance hydrology cannot be fully reestablished, appropriate native flora can be established based on the hydrologic regime expected for the system. Forested systems can provide greater sequestration of nutrients in above- and below-ground biomass for long-term storage than herbaceous and shrub systems, and can be harvested periodically for profit and to remove those nutrients from the system. Further, their greater below-ground biomass can be permanently buried in the litter compartment. In riparian systems particularly, nonleguminous hardwood trees are the most effective vegetation for nitrate removal from subsurface flows, having deeper root penetration than other vegetation. A mixture of trees, shrubs, and herbaceous cover may provide the fullest nitrate removal in riparian areas. Dense-culmed herbaceous cover is most effective for filtration of suspended solids. Frequent maintenance during the initial establishment period to remove undesirable vegetation and regular monitoring and maintenance throughout the establishment of the desired plant community is fundamental to any restoration plan.

Retention/Irrigation System[1] - Systems which capture runoff in a holding pond, then use the water for irrigation of appropriate landscape areas. As the term is used by TCEQ, such systems are designed to achieve 100% removal efficiency of NPS pollutants by assuring full retention of storm water and complete consumption of retained water through irrigation, without discharge or release storm water flow into a receiving stream. Includes rooftop *rainwater harvesting* where water storage is adequate.

Retention Pond, Dry - Ponds or basins that temporarily detain a portion of storm water runoff for a specified length of time, releasing it slowly to reduce flooding and remove a limited amount of pollutants through settling. Also called *dry detention basin or device or dry pond*. They dry out between rain events. Pollutants are removed by allowing particulates and solids to settle out of the water. Overall pollutant removal is low to moderate, but they are effective at reducing peak storm water discharges, controlling floods and preventing downstream channel scouring. A variation, the extended detention basin, drains more slowly to increase pollutant removal efficiency and may retain a permanent pool of water. Proper design and frequent maintenance to clear inlets and outlets and to keep vegetation mowed is necessary to assure timely emptying of the basin to maintain treatment capacity. Maintenance of dry detention basins is both essential and costly. Cleaning out sediment will be necessary in 10 to 20 years' time. Cleaning involves digging out the accumulated sediment, mud, sand and debris with construction backhoe or other earth-moving equipment. *See also Sediment Basin*

Retention Pond, Wet[1] - *See also Extended Detention Basin*[1] Also called *wet detention basins or wet basins or ponds*, these structures maintain a permanent pool of water in addition to temporarily detaining storm water. Wet ponds are one of the most effective and reliable devices for removing pollutants from storm water, particularly dissolved nutrients. The permanent pool of water enhances the removal of smany pollutants. These ponds fill with storm water and release most of it over a period of a few days, slowly returning to its normal depth of water. They remove pollutants by settling suspended particulates; biological uptake, or consumption of pollutants by plants, algae and bacteria in the water; and decomposition of some pollutants. Wet ponds have some capacity to remove dissolved plant nutrients to help prevent eutrophication, a capacity generally lacking in "dry" BMPs. Wet ponds can be used in most locations where there is enough space to locate the pond. The large volume of storage in the pond helps to reduce peak storm water discharges which, in turn, helps control downstream flooding and reduces scouring and erosion of streambanks. Construction costs for wet ponds can be somewhat high because the ponds must be large enough to hold the required volume of runoff and to contain the permanent pool of water. Maintenance costs also tend to be substantial. Wet ponds should be designed to displace the older storm water with the newer storm water, which ensures the proper amount of holding time. If the design is improper, short-circuiting can occur where the newer storm water flows directly to the outlet, bypassing the main part of the wet pond. Basic considerations for the installation of wet retention ponds are location, the inflow runoff volume, hydraulic residence time, permanent pool size and maintenance. Volumes of storm water runoff and normal discharge available for the permanent pool must be calculated by trained hydrologists before constructing a wet pond. Long, narrow ponds or wedge-shaped pondsare preferred shapes to minimize short-circuiting of storm flows. These shapes also will lessen the effects of wind, which can stir up sediment and sediment-bound pollutants. Pond shape, depth and surrounding fringe areas must be considered to maximize the effectiveness of the basin. Marsh plants around the pond help remove pollutants, provide habitat and hide debris. People tend find these ponds to be aesthetically pleasing. The outlet must be sized to provide adequate time for pollutant removal, yet discharge the storm water before the next storm occurs. One disadvantage of wet retention basins is that they may contribute to thermal pollution and cause downstream warming. This may preclude their use in areas where sensitive aquatic species live. Wet ponds are not well suited to very small developments because of their large size. Wet ponds may flood prime wildlife habitat; and there are sometimes problems with nuisance odors, algae blooms and rotting debris when the ponds are not properly maintained. Wetland plants may need to be harvested or removed periodically to prevent releasing plant nutrients into the water when the plants die. The pool of water presents an attractive play area to children; hence, there may be safety problems. Wet ponds require regular inspection, removal of sediment according to a regular schedule of maintenance, regular mowing, and regular cleaning and repair of inlets and outlets. Operators of wet ponds must control nuisance insects, weeds, odors, and algae; inspect and repair pond bottoms; and harvest deciduous vegetation prior to the onset of fall as necessary. Mosquitoes can be controlled in wet ponds with fish of the Gambusia family which eat the mosquito larvae. The Gambusia can survive the winters in most areas if the permanent pool is at least three feet deep. Another control method which does not use insecticides is monthly application of briquettes containing bacteria which cause a disease in mosquitoes. The application needs to be done only in the warmer months. The bacteria can be purchased at hardware and garden stores.

Revetment, Composite - Tiering of any number of materials up bank slopes, such as cement burlap bags, stone, gravel, wire mesh blanketing, *gabions*, biodegradable fabrics, geotextile fabrics, *tree revetments*, and *live staking* of hydrophytic vegetation, matched to the erosive potential of the vertical stream-bank zones, for the purpose of reducing stream-bank erosion and associated sediment and nutrient impacts downstream. Cement burlap bags are often readily available, and can be customized to different degrees of permanence by adjusting the cement content. Wire mesh blanketing anchored through stone is used for high energy or steeply sloped situations. A number of biodegradable fabrics, such as coir (coconut) fiber mats and rolls, can be staked out or wrapped around fill material on slopes and planted through with live stakings or rooted hydrophytes, providing stabilization and a rooting environment. A number of synthetic geotextile fabrics are also available for similar applications. *Live staking* can be done directly into exposed banks, between sand cement bags, or through stone, mesh blanket, fabrics, or *gabions*. A combination of treatments should be selected as a system to target different aspects of bank erosion. For example, stone *riprap* at the bed/bank interface protects against undercutting and is most effective in combination with immediate means of buffering banks from erosive flows, such as *tree revetments* (which can actually accrue sediments), a long-term streambank stabilization component such as *live stakings*, and a means of reducing the erosive potential of incoming flows at their source, such as eliminating overgrazing and soil compaction by cattle in agricultural settings or providing detention ponds for impervious surfaces in urban settings.

Revetment, Tree - A form of soil bioengineering which uses uprooted, live trees laid on their sides and secured to the bases of banks along eroded stream segments, tops pointed downstream and overlapped about 30 percent. Species used are those with abundant, dense branching to promote sediment trapping, and those which are decay-resistant. Eastern red cedar (Juniperus virginiana), for example, is generally preferred to hardwoods. The flexibility of live trees is recommended, limbless trunks should be removed, revetment ends should be anchored at stable points along the bank, and the anchoring system should be chosen according to the bank material to be stabilized and weight of the object to be anchored. Tree size is important. the diameter of the tree's crown should be about two-thirds the height of the eroding bank, and trees greater than twenty feet tall are most economical for the majority of applications. As an alternative design, tree root wad revetments are created from uprooted live hardwood trees. These are cut into segments, the bottom segment containing the root mass is placed into an excavated hole in the bank trunk-first and protruding perpendicular to stream flow, the hole is backfilled, and remaining segments are used as footer logs to protect the base. Tree revetments minimize sediment loading and associated nutrient enrichment impacts downstream by acting as a buffer, disrupting the force of incoming flows, creating turbulence, lowering water velocities, causing deposition of sediment, and protecting banks. They are best used as part of a system which includes a component to deter undercutting at the bed/bank interface, such as *riprap* or *gabions*, a means of long-term stream-bank stabilization, such as *live stakings*, and a means of reducing the erosive potential of incoming flows at their source, such as eliminating overgrazing and soil compaction by cattle in agricultural settings or providing detention ponds for impervious surfaces in urban settings.

Riprap - A layer of loose angular stone designed to protect and stabilize channels or other areas subject to erosion from concentrated flows, or to protect slopes subject to seepage or areas with poor soil structure. Riprap is used on slopes where vegetation cannot be established, channel slopes and bottoms, storm water structure inlets and outlets, slope drains, streambanks, and shorelines. It should be a well-graded mixture of stone sizes, and should be underlain by a filter blanket of gravel, sand and gravel, or synthetic material to prevent soil movement into or through the riprap. Stones should be of sufficient size to resist washing downstream. For streambank uses, larger rock should be placed at the bank bottom below base-flow elevation. Riprap is well-suited for the high-energy zone of the streambank that is often submerged or that incurs direct stream flows, and when used at the bed/bank interface is effective at deterring undercutting. It is most effective when used as part of a system which includes a means of reducing the erosive potential of incoming flows at their source, such as eliminating overgrazing and soil compaction by cattle in agricultural settings or providing *retention ponds* below impervious surfaces in urban settings.

Road Salt Application Control - In areas where salt is used, reduced application or alternative agents, consistent with the need for safety, will reduce pollution of area water bodies. Sand is an alternative that is less harmful to vegetation and aquatic life. Storage facilities can be constructed or modified to prevent salt exposure to rainfall.

Rock Berm [1] - *See Filter Berm or Dike - Rock*

Roughening - *see Surface Roughening*

Runoff Diversion - *see Diversion*

Sand Filter System - *see Filter System, Sand*

Scheduling and Sequencing - timing and ordering activities to minimize disturbance and maximize control of NPS pollution. The BMP system is typically installed in reverse order, starting with sediment capturing devices, followed by key runoff control measures and runoff conveyances, and finally involving major land clearing activities after the minimization and capture elements are in place.

Sediment Barrier - A permeable barrier designed to detain sheet flow of storm water runoff from disturbed soil along a slope, settling some suspended solids from the detained water above the structure while allowing slow passage of the water through a filtering material. All sediment barriers should be installed along the contour, perpendicular to runoff flow, with each end curving gently up-slope enough to capture and pool the design volume of runoff during a storm event. *See also Filter Berms*

- **Brush** - Temporary sediment barriers constructed of limbs, weeds, vines, root mat, soil, rock, and/or other cleared materials piled together to form a berm, and located across, or at the toe of, a slope susceptible to sheet and rill erosion. Brush material should make continuous ground contact to prevent free flow of runoff under the berm. This structure is not intended to interrupt concentrated flow of water in a drainage way. Also known as *Brush Berms*.

- **Silt Fence**[1] - A temporary sediment barrier consisting of geotextile filter fabric buried at the bottom, stretched, and supported by metal posts, designed to retain sediment from small disturbed areas by reducing the velocity of sheet flows. Because they can cause temporary ponding, sufficient storage area and overflow outlets may be necessary. The drainage area capacity of silt fence is typically about 100 square feet per lineal foot of fence. Silt fences should be installed along the contour, perpendicular to runoff flow, with each end curving gently up-slope enough to capture and pool the design volume of runoff. They should not be used on steep slopes or in channels or swales. Also called sediment fence.
- **Hay or Straw Bale**[1] - Straw or hay bales staked into the ground, designed to retain sediment from small disturbed areas by reducing the velocity of sheet flows. Because they can cause temporary ponding, sufficient storage area and overflow outlets may be necessary. Ends must be well-anchored and should curve up-slope. Hay bales are less effective than straw bales.
- **Filter Berm or Dike** - A sediment control structure similar to a dam or dike, which gradually filters storm water as it passes through rather than simply impounding it. All filtering berms, dikes, and similar sediment controls should be installed along the contour, perpendicular to runoff flow, with each end curving gently up-slope enough to capture and pool the design volume of runoff. *See also Sediment Barrier.*
  - **Compost and/or Mulch**[1] **-** Berm formed of loose compost and used to intercept and detain sediment-laden runoff from unprotected areas. They should remain in place until the disturbed area is stabilized, after which they may either be left in place or dispersed as a thin mulch layer. Compost berms that will be left in place should be seeded.
  - **Rock**[1] - A check dam constructed of rock or riprap and used in areas of concentrated flow**.** *See Check Dam.*
  - **Sand Bag**[1] **-** Berm constructed of sand bags, typically designed to allow excess runoff volume to flow over the top of the berm. Under TCEQ guidelines for Tier I projects, sand bag berms are to be used only during construction activities in streambeds when the contributing drainage area is between 5 and 10 acres and the slope is less than 15%, often in conjunction with *temporary stream crossings* for construction equipment.

Sediment Basin[1] - An earthen or rock embankment located to capture sediment from runoff and retain it on a construction site, for use where other on-site erosion control measures are not adequate to prevent off-site sedimentation. Sediment basins are more permanent in nature than sediment traps, and can be designed as permanent features of a development. Basins are most commonly used at the *outlets* of diversions, channels, slope drains, or other runoff conveyances that discharge sediment-laden water, and are recommended for drainage areas of less than 100 acres. Earthen basins should use barrel and riser discharge structures, while rock dams can be designed to discharge over the top of the embankment, where a crest should be constructed as the low point. Smaller gravel should line the inside face of the rock dam. A sediment basin can be created where a permanent pond BMP is planned. Guidelines for construction of the permanent pond should be followed, but revegetation, placement of underdrain piping, and installation of sand or other filter media should not be carried out until the site construction phase is complete. *See also Sediment Trap/Stone Outlet; See also Retention Pond*

Sediment Fence - *see Sediment Barrier - Silt Fence*

Sediment Trap/Stone Outlet[1] - A small, temporary ponding basin or impoundment formed by an embankment or excavation to capture sediment from runoff. Traps are most commonly used at the discharge *outlets* of diversions, channels, slope drains, or other runoff conveyances that discharge sediment-laden water from areas impacted by construction or similar disturbances. Sediment traps are recommended for drainage areas of less than 5 acres. It is important to consider provisions to protect the embankment from failure from runoff events that exceed the design capacity. Plan for non-erosive emergency bypass areas. Traps should be readily accessible for periodic maintenance. High length-to-width ratios minimize the potential for short-circuiting. The pond outlet should be a stone section designed as the low point.

Seeding

- **Permanent** - Establishment of perennial vegetative cover with seed to minimize runoff, erosion, and sediment yield on disturbed areas. Disturbed soils typically require roughening and amendment with a nutrient source. Seeding should be done together with *mulching*. Seed mixtures are typically most effective, and species vary with preferences, site conditions, climate, and season.
- **Temporary** - Planting rapid-growing annual grasses, small grains, or legumes to provide initial, temporary stabilization for erosion control on disturbed soils that will not be brought to final grade for more than approximately one month. Seeding is facilitated by nutrient addition and *surface roughening*. Broadcast seeds must be covered by raking or chain dragging, preferably after *mulching*; hydroseed mixtures are spread in a mulch matrix**.**

Septic System - Inspection and Maintenance - *See also On-Site Systems.* The high degree of septic system failure necessitates regular inspections. Homeowners can be provided with educational materials and can serve as monitors of their own systems. Local governments can also develop an inspection program. A lower-cost, if less certain, alternative is for local governments to mail out printed reminders to owners informing them on tax or utility statements that inspection and perhaps maintenance is due for their systems. At a minimum, requirements should be established for inspection during change of property ownership. Septic tanks require pumping to remove accumulating sludge approximately every 3 to 5 years. The frequency can vary depending on tank size, family size, and garbage disposal use. Failure to remove sludge periodically will result in reduced tank settling capacity and eventual overloading of the soil absorption system, which is more expensive to remedy. Maintenance can be required through contracts, operating permits, and local ordinances/utility management. Local governments can issue renewable operating permits that require users either to have a contract with an authorized inspection/maintenance professional or to demonstrate that inspection and maintenance procedures have been performed on a periodic basis. Permit fees can be assessed to cover the program costs. Inspection and maintenance are more effective when used as parts of a BMP system which involves source reduction through elimination of garbage disposals and use of low-volume plumbing fixtures.

Septic Systems - Upgrade or Replacement of Failing Systems - *See also On-Site Systems.* Areas that are sources of elevated levels of nutrients, bacteria, or organic matter in water resources should be considered for installation of sanitary sewers or special requirements for on-site waste disposal systems. Local programs requiring proper on-site sewage disposal system installation and maintenance may control pollutants from a problem area. Septic tanks will operate better and longer if they are regularly inspected and cleaned. Local governments should pay special attention to the operation of small community sewage disposal systems to ensure they are operated by qualified personnel and maintained properly. Common repairs include refitting the onsite system with new inflows and outlets, creating an alternative drainfield, or the use of other alternative technologies. Replacement of the entire system may be required where the original one was inadequate, improperly constructed or installed, or where the system does not respond to corrective measures. Local governments and other programs can facilitate remedial measures on an ongoing basis by providing technical assistance to owners, an approved roster of repair professionals, a complaint response system, and financial assistance to low income households for performing the necessary repairs A number of alternative technologies are available for upgrading or replacing a failing system. These include *mound or fill systems, sand filters, and pressure distribution systems*. Upgrading or replacement is more effective when used as part of a BMP system which involves source reduction through elimination of garbage disposals and use of low-volume plumbing fixtures.

Setback from Stream Bank - Restriction of development activities within a specified distance of a stream bank can prevent or minimize erosion and gully formation, thus minimizing sedimentation and associated nutrient enrichment downstream. This practice is distinct from, although potentially overlapping with, such BMPs as *riparian buffers, floodplain preservation, and wetland preservation*, as the areas involved are defined differently and as the primary goals of these other BMPs include other pollutant removal, preserving natural sediment and nutrient removal functions, and water quantity issues in addition to minimizing erosion. Setbacks can be based on anticipated channel migration widths or concentrated runoff diffusion requirements. Setbacks are most effective at reducing stream-bank erosion when used as part of a BMP system including requirements for structures to diffuse flows of storm water discharges from upgradient development, measures to directly repair eroded streambanks, such as *live stakes, fascines, cribwalls, gabions, and revetments*, and a means of reducing the erosivity of incoming flows at their source, such as eliminating overgrazing and soil compaction by cattle in agricultural settings or providing detention ponds for impervious surfaces in urban settings. *See also Exclusion and Buffer.*

Silt Fence[1] - *see Sediment Barrier - Silt Fence*

Slope Drain, Temporary - Flexible tubing or conduit extending temporarily from the top to the bottom of a cut or fill slope for the purpose of conveying concentrated runoff down the slope face without causing erosion. These are generally used in conjunction with *diversions* to convey runoff down a slope until permanent water disposal measures can be installed.

Slurry Walls - The placement of low-permeability barriers in trenches dug around a chemical spill that either contains the contamination itself or restricts water flow through the area by an up-gradient barrier, preventing movement of the contamination. Low permeability barriers often consist of a cement/bentonite slurry.

Sodding[1] - Permanent stabilization of exposed areas by laying a continuous cover of grass sod. Sod is useful for providing immediate cover in steep critical areas and in areas unsuitable for seed, such as flowways and around inlets. Sod must be rolled over after placement to ensure contact, and then watered. Sodded waterways and steep slopes may require netting and pegging or stapling. *See also Vegetation.*

Soil Venting - Removal of volatile organic compounds (VOCs) contaminating the unsaturated soil and subsoil zone by vacuum pumping air through a well. Air circulates rapidly across the spill, promoting volatilization and biodegradation. The VOCs should be removed from the airstream before being released to the atmosphere. Non-volatile compounds are not effectively removed by this method.

Solid Waste Collection Facilities - Provision of secure waste collection systems in locations where litter or dumping is likely to occur without convenient disposal opportunities such as marinas and parks.

Spur Dikes - *see Embedded Flow Obstructions*

Stone Outlet Sediment Trap [1] - *See Sediment Trap, Stone Outlet. Also known as Sediment Basin/Rock Dam*

Storm Drain Inlet Protection - *see Inlet Protection*

Straw Bale Barrier - *see Silt Fence/Straw Bale Barrier*

Stream Bank Setback - *See Setback from Stream Bank.*

Stream Bank and Streambed Stabilization - *Refers to a wide range of BMPs used to reduce erosion and sedimentation in watercourses. See the table in the next section for cross-references.*

Stream Bank Vegetation - Vegetation is probably the most commonly used tool for stream-bank protection, particularly in small tributaries. Vegetation has the advantage of being self-propagating and self-repairing. Emergent vegetation provides two levels of protection. First, the root system helps to hold the bank soil together and increase overall bank stability by forming an interweaving network. Second, the stalks, stems, branches, and foliage provide resistance to stream flow, absorbing flow energy rather than deflecting it as hardened structures do or allowing it to erode soil particles. Vegetative cover above the waterline protects the banks from rainfall, runoff, and trampling forces. Bank vegetation has also been shown to provide protection from frost heave and subsequent bank failure. Vegetation also provides water quality benefits by causing settling of particulates and sorbed pollutants, by providing a substrate for periphyton that removes nutrients directly from the water column, and by assimilating nutrients from the soil. Native species should be used, and their hydric affinities should be matched to the zones in which they are placed. Vegetation can be seeded above the waterline, typically spread in a matrix such as a hydromulch, or sprigged. Vegetative cover does not work on high-velocity streams. The range of successful applications can be expanded by using vegetation in conjunction with other BMPs, such as geogrid pavers, *riprap*, *geotextile* or biodegradable mats and rolls, as well as with the other "live" BMPs listed above.

Stream Crossing, Temporary - A bridge, ford, or temporary structure installed across a stream or water course for short-term use by construction vehicles or heavy equipment, intended to keep sediment out of the stream and avoid damage to the streambed. Stream crossings should be avoided if at all possible, since they are a direct source of water pollution, they can cause flooding, and they are expensive to construct. While bridges are the most expensive method, they are the most preferred, as they cause the least disturbance to streambeds, banks, and surrounding floodplain, they provide the least obstruction to flow, and have the least erosion potential. Culvert crossings are the most common form of crossing, but can cause the most damage to the stream environment, cause the most flow blockage, and therefore can result in the most erosion. Fords involve making cuts in the banks and placing stone over filter cloth in the stream. They are often used in steep areas subject to flash flooding where normal flow is shallow (<3 inches deep) or intermittent. Fords should only be used where crossings are infrequent and banks are low. Temporary crossings may overtop during peak storm events, unlike permanent crossings. Fill in the floodplain should be kept to a minimum to reduce erosion potential and avoid upstream flooding. Choose crossing sites where erosion potential is low. Try to locate temporary crossings where permanent crossings will occur. Where appropriate, install in-stream sediment traps immediately below stream crossings to reduce downstream sedimentation. Temporary stream crossings, and bridge designs in particular, should be undertaken by a qualified engineer.

Street Sweeping Operations - Mechanical collection of debris, silt, and dirt from paved outdoor surfaces including streets and parking lots. High-efficiency systems increase the elimination of pollutants on pavement exposed to runoff. Street cleaning can reduce pollutants in runoff if it is performed regularly. Another benefit of street cleaning is that pipes and outlets in detention structures and ponds are less likely to become clogged. New street sweeping machines pick up much finer materials than older models, a feature designed to help reduce the transport of sediment-bound pollutants. Disposal of street sweeping wastes may pose a problem because of possible high levels of lead, copper, zinc and other wastes from automobile traffic. Testing of street sweepings may be appropriate to determine appropriate disposal or reuse alternatives. Some municipalities and industries have found that street sweepings can be used as cover in sanitary landfills. Industries could be required to regularly sweep access roads, parking lots, truck aprons and loading dock areas. Homeowners should be educated not to use streets and curbs as disposal areas.

Surface Drainage - Alteration of the land surface to promote drainage of surface water and precipitation away from the contaminated area. Rapid removal of the water from the land surface will limit infiltration. Restriction of water flow through the area will slow the contaminant spread.

Surface Roughening - Roughening a bare, sloped soil surface with horizontal grooves or benches running across the slope (parallel to contour lines, perpendicular to runoff flow direction). Grooves can be large-scale, such as stair-step grading with small benches or terraces, or small-scale, such as grooving with disks, tillers, or other machinery, or with heavy tracked machinery which should be reserved for sandy, non-compressible soils. Roughening aids the establishment of vegetative cover, improves water infiltration, enhances seed germination, and decreases runoff velocity.

Surface Seals - Installation of an impermeable cover above a chemically contaminated area that prevents infiltration of surface water and precipitation. Restriction of water flow through the area will slow the contaminant spread. Surface seals are commonly composed of compacted clay, mixtures of natural soils, and stabilizers such as cement, bitumen or fly ash; bentonite layers; sprayed bituminous layers; synthetic membranes, waste materials such as furnace slag, incinerator residues, fly ash, and clinkers.

Swale - A shallow, gentle depression in the ground which serves as a drainage course. Swales are most commonly grass-lined except where runoff flow or inundation is particularly frequent or intense. In such cases, *rip-rap* or other rock lining may be used. They may serve as diversions or conveyances for storm water. *See Diversion and Grassed Channel or Swale.*

Temporary Slope Drain - *see Slope Drain, Temporary*

Temporary Stream Crossing - *see Stream Crossing, Temporary*

Temporary Vegetation - *see Vegetation, Temporary*

Topsoiling - Preserving and subsequently re-using the upper, biologically active layer of soil to enhance final site stabilization with vegetation. Topsoiling should not be conducted on steep slopes. Stockpiled soil should be contained with sediment barriers, and temporarily seeded for stability. Surfaces which will receive topsoil should be roughened just prior to spreading the soil to improve bonding. Spread topsoil should be lightly compacted to ensure good contact with the subsoil. Good topsoil can act as a mulch, promoting final vegetation establishment, increasing water infiltration, and anchoring more erosive subsoils.

Vegetated Filter Strip or Buffer Strip[1] - *see Filter Strip, Vegetated*

Vegetation - Vegetation can be used to reduce the velocity of storm water, which helps it the water infiltrate into the soil and settle out sediment, as well as to increase the soil's resistance to erosion, to take up nutrients, and to perform other functions. Where possible, preserving natural vegetation and sometimes seeding it to increase ground cover minimizes erosion potential. Temporary vegetation, in conjunction with *mulching* and/or other erosion control measures, is also effective to prevent erosion on stockpiles and disturbed areas still subject to further disturbance. *See Filter Strips, Vegetated; Grassed Swales; Infiltration Devices; Riparian Areas; Seeding; Sodding*; *Stream Bank Vegetation*.

Vegetation, Temporary[1] - *see also Seeding, Temporary*

Water Bar - *see Diversion*

Water Quality Management Plan -

Waterfowl Management - Protection of sensitive wetland areas from damage by waterfowl. Wading birds (herons, egrets, ibises, etc.) nest in colonies. Most colonies are located in trees and bushes over water (ponds, marshes, and swamps). Ammonia sources from wading birds originate from eggs, young, and wastes that fall into the water. Colonized swamps showed elevated levels of ammonia and organic nitrogen. The impact of the wading birds on the colonized swamp was so profound that ammonia content showed an increase of 2 to 10 times that of the un-colonized swamps nearby. In turn, more duckweed and larger algal mats developed in the colonized swamps, affecting water quality and other aquatic life. If such impacts are determined to be significant contributors to an ongoing water quality problem, and all other more significant contributors have been addressed, possible management practices to counter the impacts include the introduction of herbivorous fish species to control aquatic weeds and liming the waters to control pH, which falls as ammonia and is converted to nitrate. Other waterfowl activity can increase pollutant loading. In the flightless stage of the molt, the eclipse, swans and snow geese can be extremely destructive, particularly to agricultural crops and marshlands along the Atlantic Coast where they winter. They graze, pull up sprouts, "muddle" (trample) during wet weather, and leave droppings. This increases the sediment and ammonia in runoff. Where this is determined to be a significantly detrimental contribution to pollutant loading, and where all other more significant contributions have been addressed, birds should be discouraged before they become "imprinted" (regularly return to the area); successful methods of discouragement and control should be quick and persistent.

- Install moving objects like scarecrows, gas-filled balloons, or plastic flags. One flag (a large black plastic trash bag on a four foot post is very effective) per acre is recommended. The combined use of flags or balloons with gas exploders and/or racket bombs is even more effective.
- Dogs and passing vehicles also discourage waterfowl.
- Live trapping that requires a permit is impractical on a large scale and gives only temporary results.
- Capture of bird and bat droppings under bridges using fabric sheets slung under inhabited bridge areas.

Wattling Bundles - *see Live Fascines*

Weather Modification -

Wet Basin or Pond [1] - *see Retention Pond, Wet*

Wetlands, Constructed [1] - Engineered systems designed to perform the water purification functions of natural wetlands. Constructed wetlands consist of former upland environments that have been modified to create poorly drained soils and wetland plants and animal communities for the primary purpose of pollutant removal from runoff. Aquatic treatment systems have been divided into natural wetlands, constructed wetlands, and aquatic plant systems. Constructed wetlands are very effective in removing suspended solids, particulate BOD, pathogens, sediment-attached nutrients and metals, and oil and grease. Constructed wetlands can be expected to achieve or exceed the pollutant removal rates estimated for wet pond detention basins and dry detention ponds. Constructed wetland systems can provide ground water recharge, thus lessening the impact of impervious surfaces. This recharge can also provide a groundwater subsidy to the surficial aquifer, which can benefit local vegetation and decrease irrigation needs. The use of constructed wetlands for storm water treatment is still an emerging technology, so there are no widely accepted design criteria. However, certain general design considerations do exist. It is important first to drop storm water inflow velocities and provide opportunity for initial sediment deposition with facilities which can be periodically maintained and which avoid the likelihood of entraining deposited sediment in subsequent inflows. It is important to maximize the nominal hydraulic residence time and to maximize the distribution of inflows over the treatment area, avoiding designs which may allow for hydraulic short-circuiting. Emergent macrophytic vegetation plays a key role, intimately linked with that of the sediment biota, by providing attachment sites for periphyton, by physically filtering flows, as a major storage vector for carbon and nutrients, as an energy source for sediment microbial metabolism, and as a gas exchange vector between sediments and air. Thus, it is important to design for a substantial native emergent vegetative component. Anaerobic sediment conditions should be ensured to allow for long-term burial of organic matter and phosphorus. A controlled rate of discharge is the last major physical design feature. While an adjustable outfall may seem desirable for fine-tuning system performance, regulatory agencies often require a fixed design to preclude subsequent inappropriate modifications to this key feature. The outfall should be fitted with some form of skimmer or other means to retain oil and grease. Plants must be chosen to withstand the pollutant loading and the frequent fluctuation in water depth associated with the design treatment volume. It is advisable to consult a wetlands botanist to choose the proper vegetation. Use of constructed wetlands has expanded recently to the treatment of solid waste landfill leachate. Location of constructed wetlands in the landscape can be an important factor in their effectiveness. Retention as a function of nutrient loading my be less efficient in downstream wetlands than in smaller upstream wetlands, but downstream wetlands could retain more mass of nutrients. Creation of in-stream wetlands is a reasonable alternative only in lower-order streams – such wetlands are susceptible to reintroduction of accumulated pollutants in large flow events as well as being unpredictable in terms of stability. Constructed wetlands are most effective as part of a BMP system which includes minimization of initial runoff volumes through the positioning of pervious landscaping features, routing of runoff to maximize infiltration, use of *pervious pavement, grass swales, swale checks*, or other measures, pre-treatment of collected runoff to minimize sediment and associated pollutant loads, and off-line attenuation of larger storm event runoff to optimize wetland performance and minimize downstream erosion-related water quality impacts. Disadvantages. Constructed wetlands may contribute to thermal pollution and cause downstream warming. This may preclude their use in areas where sensitive aquatic species live. They are not a competitive option compared to other treatment methods where space is a major constraint. The ponded water may be a safety hazard to children. Maintenance. Constructed wetlands have an establishment period during which they require regular inspection to monitor hydrologic conditions and ensure vegetative establishment. Vegetation establishment monitoring and long-term operation and maintenance, including maintenance of structures, monitoring of vegetation, and periodic removal of accumulated sediments, must be provided for to ensure continued function. Frequent initial maintenance to remove opportunistic species is typically required to establish a diverse, hydrophytic regime. Operators of wetlands may need to control nuisance insects, odors, and algae.

Wetlands, Natural or Restored - In 1989, the Texas Legislature established a single statewide definition for wetlands: *Wetlands means an area (including a swamp, marsh, bog, prairie pothole, or similar area) having a predominance of hydric soils that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support and that under normal circumstances supports the growth and regeneration of hydrophytic vegetation*. The many water quality improvement functions and values of wetlands are now widely recognized. At the same time, concern has grown over the possible harmful effects of toxic pollutant accumulation and the potential for long-term degradation of wetlands from altered nutrient and hydraulic loading that can occur with the use of wetlands for water treatment. Because of these concerns, the use of natural wetlands as treatment systems is restricted by federal law. Most natural wetlands are considered "waters of the United States" and are entitled under the Clean Water Act to protection from degradation by NPS pollution. Wetlands must be part of an integrated landscape approach to NPS control, and cannot be expected to compensate for insufficient use of BMPs within the upgradient contributing area. Restored wetlands are subject to the same restrictions as unmodified natural wetlands. *See also Restoration of Wetlands Hydrology and Restoration of Wetlands Native Plant Communities*

Wildlife Management - **Beavers** - Beaver activity has been thought to negatively affect trout streams by increasing siltation and by raising temperatures via reducd flow rates and increased sunlight penetration. Over-populations of beavers can cause property damage, blocking or damaging water control devices in farm ponds and reservoirs, and allowing algae and mosquito increases. A major problem related not only to the beaver but also to other wild and domestic animals is their role in transporting the protozoan parasite *Giardia lamblia* via feces. Since normal concentrations of chlorine used in the treatment of water is not sufficient to kill *Giardia cysts*, filtering surface water is required. Control measures include installing fencing across stream bottoms in small, low order streams. Install fencing perpendicular to the stream flow and between 200 to 400 feet on each side of the stream. Install fencing along stream banks near row crops, pine tree plantations, or intensively managed plantings. Along or around water control structures, install fencing early and allow beavers to build their dam against the fence. Wrap the bottom 3 feet of appealing trees with hardware cloth. Install a drainage device in a beaver dam. The inflow end should extend far into the beaver pond as to discourage beavers from covering the pipe with debris. Least effective nonlethal methods include: chemosterilants, electric fences, scare techniques, scents, and live traps. Inhibit young, dispersing beavers during late spring and early summer by installing fencing across stream bottoms in small, low order streams.

Wildlife Management - Muskrats - Muskrats favor still or slow-moving bodies of water and occasionally streams where they burrow in the banks to make "dens". Environmental impact potential from muskrat activity includes bank erosion, property damage (man-made earthen dams and sometimes crops), and Giardia lamblia via feces. Control measures include

- Laying 6- to 12-inch layer of sand, pea gravel or rip rap on the inner surface of a dam, 2 to 3 feet above and below the water line.
- Add a concrete filled trench to an earthen dam, 3 feet below the water line and 1 foot above.
- Obstruct burrowing by laying 1- to 2-inch mesh along the bank, 1 foot above and 3 feet below the water line.
- Construct new farm pond with a berm.

TABLE: PREFERRED BEST MANAGEMENT PRACTICES BY SOURCES AND POLLUTANTS ADDRESSED

Glossary of pollutants/impacts:

HC	hydrocarbons, petroleum
N	nitrogen
O&G	oil & grease
BOD	biological oxygen demand (resulting in reduced level of dissolved oxygen)
P	phosphorus
TDS	total dissolved solids
TSS	total suspended solids, including sediment
VOC	volatile organic compounds

SOURCES/Needs	**PREFERRED BMPS**	**Causes & Pollutants Addressed**
AGRICULTURE		
All Facilities	Water Quality Management Plans	N, P, bacteria, BOD, toxics
All Facilities	Livestock Exclusion	N, P, bacteria, BOD, TSS
Animal Facilities	Animal Waste Management Training	N, P. Bacteria, BOD
Animal Facilities	Comprehensive Nutrient Management Plans	N, **P**, bacteria, BOD
Animal Facilities	Phosphorus-Based Waste Management Plans	N, **P**, bacteria, BOD
Animal Facilities	Composting	N, P, bacteria, BOD, TSS
BOATS & MARINAS		
Boat Operation	Boat Operation Controls	
Boat Operation	No-Wake Zones	TSS
Boat Operation	Protected Shallow Water Habitats	TSS, habitat destruction
Boat Liquid Waste and Fuel Handling	Proper Storage and Handling	O&G, HC, toxics
Sewage Disposal	No-Discharge Zone	N, P, BOD, bacteria
Sewage Disposal	Boater Education	N, P, BOD, bacteria

Sewage Disposal	Boat Sewage Pumpout Facilities	N, P, BOD, bacteria
Solid Waste Disposal	Boat Repair & Maintenance Restrictions	HC, metals
Solid Waste Disposal	Solid Waste Collection Facilities	N, P, BOD, bacteria, metals
Solid Waste Disposal	Fish Cleaning Facilities/Controls	N, P, BOD, bacteria
CONSTRUCTION		
Construction Planning	Construction Sequencing	TSS
Surface Stabilization	Mulching	TSS
Surface Stabilization	Preserving Natural Vegetation	TSS
Surface Stabilization	Recontouring	TSS
Surface Stabilization	Riprap	TSS
Surface Stabilization	Temporary Vegetation[1]	TSS
Surface Stabilization	Sodding	TSS
Surface Stabilization	Erosion Control Blanket	TSS
Surface Stabilization	Erosion Control Compost	TSS
Surface Stabilization	Surface Roughening	TSS
Surface Stabilization	Temporary Gravel Construction Access	TSS
Surface Stabilization	Topsoiling	TSS
Surface Stabilization	Interceptor Swale	TSS
Runoff Control	Runoff Diversion Dike	TSS
Runoff Conveyance	Grass-Lined Channel or Swale	TSS
Runoff Conveyance	Hardened Channel	TSS
Runoff Conveyance	Temporary Slope Drain	TSS
Runoff Conveyance	Paved Flume (Chute)	TSS
Outlet Protection	Level Spreader	TSS
Outlet Protection	Outlet Stabilization Structure	TSS

Sediment Traps & Barriers	Block and Gravel Drop Inlet Protection	TSS
Sediment Traps & Barriers	Excavated Drop Inlet Protection	TSS
Sediment Traps & Barriers	Fabric Drop Inlet Protection	TSS
Sediment Traps & Barriers	Sod Drop Inlet Protection	TSS
Sediment Traps & Barriers	Sediment Basin	TSS
Sediment Traps & Barriers	Rock Berm	TSS
Sediment Traps & Barriers	Check Dam	TSS
Sediment Traps & Barriers	Stone Outlet Sediment Trap	TSS
Sediment Traps & Barriers	Sand Filter System	TSS
Sediment Traps & Barriers	Sediment Fence/Straw Bale Barrier	TSS
Sediment Traps & Barriers	Triangular Filter Dike	TSS
Sediment Traps & Barriers	Filter Berm (rock, sandbag, compost, mulch, etc.)	TSS
Sediment Traps & Barriers	Filter Socks (mulch or compost)	TSS
Sediment Traps & Barriers	Brush Barrier	TSS
Sediment Traps & Barriers	Vegetated Buffer or Filter Strip	N, P, TSS
Sediment Traps & Barriers	Constructed Wetlands	N, P, TSS, metals

Sediment Traps & Barriers	Wet Basins	TSS
Sediment Traps & Barriers	Extended Detention Basin	TSS
Stream Protection	Streambank Stabilization	TSS
Stream Protection	Streambed Stabilization	TSS
Stream Protection	Temporary Stream Crossing	TSS
Construction Waste Management	Manage and Dispose of Construction Wastes	TSS, toxics
Construction Waste Management	Collect and Dispose of Toxic Sandblasting Grit	toxics
FORESTRY		
HABITAT DEGRADATION		
Wetlands & Riparian Areas	Restore Hydrology	TSS, habitat
Wetlands & Riparian Areas	Restrict Disturbance (e.g. adding of fill, farming, animal access, off-road vehicles)	TSS, habitat
Wetlands & Riparian Areas	Restore Native Plant Communities	habitat
Wetlands & Riparian Areas	Review/Certification of Hydrological Modifications	habitat
IN-STREAM REMEDIATION		
Dissolved Oxygen Restoration	Aeration	BOD
pH Adjustment	Chemical pH Treatment	pH
INDUSTRIAL SITES (See also Construction and Urban Storm Water)		

Industrial Prevention Measures	Debris Removal	
Industrial Prevention Measures	Vertical Barrier Wall and Cover System	VOC
Industrial Prevention Measures	Secondary Containment	
Industrial Prevention Measures	Runoff Diversion	
Industrial Control Measure	Floating Aquatic Plant (Aquaculture) Systems	
PETROLEUM PRODUCTION		
Petroleum Production	Education, Training, and Technical Assistance	HC, TDS
Petroleum Production	Well and Testhole Inspection	HC, TDS
Petroleum Production	Plugging Wells and Testholes	HC, TDS
ROADS (See also BMPs under Construction and under Urban Storm Water)		
Road and Highway Planning	Project Sequencing and Phasing	
Preventive Measures for Roads	Road Salt Application Control	TDS
ON-SITE WASTEWATER SYSTEMS		
Management	Chemical Additive Restrictions	
Management	Septic System Education	N, P, bacteria, BOD
Management	Elimination of Garbage Disposals	N, P, bacteria, BOD
Management	Inspection and Maintenance	N, P, bacteria, BOD
Management	Phosphorus Detergent Restrictions	P
Structural Controls	Denitrification Systems	N
Structural Controls	Floating Aquatic Plant (Aquaculture) Systems	N, P,
Structural Controls	Upgrade or Replacement of Failing Systems	N, P, bacteria, BOD

Structural Controls	Alternating Bed System	
Structural Controls	Mound (Fill) System	
Structural Controls	Pressure Distribution (Low Pressure Pipe) System	
Regulation	Sale Inspections	N, P, bacteria, BOD
Regulation	Inspection and Permitting of Installed Systems	N, P, bacteria, BOD
Regulation	Local Ordinances	N, P, bacteria, BOD
SPILL CONTAINMENT AND CONTAMINANT REMEDIATION		
Spill Prevention	Public Education	toxics
Spill Prevention	HHW and Empty Pesticide Container Collection	toxics
Spill Prevention	Storm Drain Stenciling	toxics
Spill Response	Environmental Hotline and Response	toxics
Spill Response	Spill Cleanup	toxics
Spill Response	RCRA Facilities Investigation & Remediation	toxics
STREAMBEDS AND STREAM BANKS		
Stream Bank Protection	No-Wake Zones	TSS, habitat
Stream Bank Protection	Livestock Exclusion	TSS, habitat, BOD
Stream Bank Protection	Stream Bank Setbacks	TSS, habitat
Stream Bank Protection	Blankets and Mattresses	TSS
Stream Bank Protection	Branch Packs	TSS
Stream Bank Protection	Composite Revetment	TSS
Stream Bank Armoring	Gabions	TSS
Stream Bank Protection	Live Fascines (Wattling Bundles)	TSS
Stream Bank Protection	Live Staking	TSS
Stream Bank Protection	Tree Revetment	TSS

Stream Bank Protection	Vegetative Cover	TSS
Stream Bank Protection	Live Cribwall	TSS
Stream Bed Protection	Check Dam	TSS
Stream Bed Protection	Deflectors	TSS
Stream Bed Protection	Grade Stabilization Structure	TSS
Stream Bed Protection	Low-Head Dam (Weir)	TSS
UNDERGROUND STORAGE TANKS		
UST Containment	Slurry Walls	HC
UST Containment	Grouting	HC
UST Containment	Geomembranes	HC
UST Containment	Surface Seals	HC
UST Containment	Surface Drainage	HC
UST Containment	Hydrodynamic Control	HC
UST Contaminant Removal	Pumping	HC
UST Contaminant Removal	Interceptor Systems	HC
UST Contaminant Removal	Soil Venting	HC
UST Contaminant Removal	Excavation	HC
UST In-Situ Treatment	In-Situ Treatment of Contamination - Biological	HC
UST In-Situ Treatment	In-Situ Treatment of Contamination - Chemical	HC
URBAN STORM WATER		
Urban Preventive Measures	Public Education	

Urban Preventive Measures	Household Hazardous Waste Collection - with Tracking of Legacy Pollutants	toxics
Urban Preventive Measures	Exposure Reduction	
Urban Preventive Measures	Composting	N, P, TSS, BOD
Urban Preventive Measures	Landscaping And Lawn Maintenance Controls	N, P, TSS, BOD, toxics
Urban Preventive Measures	Minimization Of Pollutants	
Urban Preventive Measures	Parking Lot And Street Cleaning Operations	N, P, TSS, BOD, HC
Urban Preventive Measures	Streambank Stabilization	TSS
Urban Preventive Measures	Buffers, Easements, Etc.	TSS
Urban Preventive Measures	Sanitary Waste Management	N, P, BOD, bacteria, metals
Urban Control Measures	Dry Detention Basins	**TSS**, metals, BOD, **bacteria**
Urban Control Measures	Infiltration Devices	**N, P, TSS, metals, BOD, O&G, bacteria**
Urban Control Measures	Oil, Grease, and Grit Trap Devices	**O&G**, TSS, HC, toxics
Urban Control Measures	Porous Pavement	N, P, TSS, BOD, metals
Urban Control Measures	Rainwater Collection	N, P, TSS
Urban Control Measures	Sand Filters	N, P, **TSS, metals**, BOD, **O&G**, bacteria
Urban Control Measures	Rain Gardens	N, P, TSS, BOD, metals, bacteria

Urban Control Measures	Filter Strips	TSS, metals, O&G
Urban Control Measures	Grassed Swales or Channels	TSS, metals, O&G
Urban Control Measures	Water Bars (Roadways)	TSS
Urban Control Measures	Wetlands, Constructed	**N**, P, **TSS, metals**, BOD, **O&G**, **bacteria**
Urban Control Measures	Wetlands, Natural and Restored	**N**, P, **TSS, metals**, BOD, **O&G, bacteria**
Urban Control Measures	Wet Retention Ponds	N, P, **TSS, metals**, BOD, **O&G, bacteria**
Urban Control Measures	Curb Elimination	N, P, TSS, metals, BOD, O&G, bacteria
Urban Control Measures	Animal Waste Collection	N, P, TSS, BOD, bacteria
Urban Control Measures	Cleanup and Debris Removal	TSS
WILDLIFE		
Wildlife	Waterfowl Management	N, P, BOD, bacteria
Wildlife	Wildlife Management	N, P, BOD, bacteria
OTHER		
Stream Flow Protection	Brush Control	habitat
Stream Flow Protection	Weather Modification	habitat
Stream Flow Protection	Discharge Release Management	habitat
Stream Flow Protection	Diversion Management	habitat

RESOURCES AND REFERENCES FOR NONPOINT SOURCE BMPS

[1] TCEQ Description of BMPs (for Clean Water Act Chapter 404 Tier I Projects) – description and guidance on implementation of selected erosion and sediment control BMPs:
http://www.tnrcc.state.tx.us/permitting/waterperm/wqstand/erosion.pdf
http://www.tnrcc.state.tx.us/permitting/waterperm/wqstand/401best.wpd
BMPs described with specifications in this document is identified with the superscript [1] .

Preventing Nonpoint Source Pollution: A Guide to Pollution Prevention for Small Businesses Galveston Bay National Estuary Program, 1993. http://gbep.tamug.tamu.edu/publicationsx.html

National Management Measures for the Control of Nonpoint Pollution from Agriculture. EPA-841-B-03-004. U.S. Environmental Protection Agency, July 2003.

WATER SHEDSS Decision Support System for Nonpoint Source Pollution Control
http://www.water.ncsu.edu/watershedss/
Catalogue of Nonpoint Source Management Measures (WaterSHEDSS BMP catalogue)
http://h2osparc.wq.ncsu.edu/info/bmps.html

National Menu of Best Management Practices for Phase II Storm Water Permits
http://cfpub.epa.gov/npdes/stormwater/menuofbmps/menu.cfm

Urban Storm Drainage Criteria Manual
http://www.udfcd.org/usdcm/usdcm_orders.htm

The 2003 TxDOT specifications for compost used in erosion and sediment control BMPs:
http://www.dot.state.tx.us/des/landscape/compost/specifications.htm
ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/2003spec/specs/161.pdf

Field Performance Testing of Selected Erosion Control Products: Final Performance Analysis Through the 2001 Evaluation Cycle, Texas Department of Transportation / Texas Transportation Institute Hydraulics and Erosion Control Laboratory
http://www.dot.state.tx.us/insdtdot/orgchart/cmd/erosion/contents.htm

How to Select, Install, and Inspect Construction Site Erosion and Sediment Control BMPs for NPDES Storm Water Permit Compliance (September 2001); International Erosion Control Association, developed under a grant from the U.S. Environmental Protection Agency.

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