

# **STORMWATER MANAGEMENT**

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## *THE NATURE OF STORMWATER RUNOFF*

Stormwater runoff is that part of the total precipitation that flows over the ground. Under natural conditions, during and following precipitation, stormwater within a watershed flows to lower elevations where it is either recharged to groundwater or drains as runoff to streams, ponds, bays, and other surface waters. The amount of runoff from an undeveloped watershed area depends upon:

- ?? storm characteristics
- ?? type and amount of vegetative cover
- ?? soils and soil permeability
- ?? slope characteristics
- ?? type and capacity of natural drainage systems

Storms are characterized by their:

- ?? duration (period of rainfall)
- ?? total precipitation
- ?? intensity
- ?? frequency
- ?? number of antecedent dry days

The number of antecedent dry days is one of the most important variables determining the amount of runoff and concentration of contaminants in stormwater due to its impact on the water storage capacity of soil and buildup of contaminants.

A portion of stormwater runoff also evaporates during overland flow and from surface waters. Recharge water (infiltration water) is that portion of stormwater that infiltrates the soil and moves downward to recharge the aquifers. A portion of the infiltration water is taken up by plants and lost to the atmosphere by evapotranspiration.

Due to the gradual percolation of much of the rainfall into the soil in relatively undisturbed watersheds, both the volume of runoff and rate of overland flow are reduced, thus maximizing aquifer replenishment in some areas and minimizing erosion. In developed watersheds, the amount of runoff also depends upon:

- ?? amount of impervious surface area
- ?? existing stormwater control measures
- ?? other factors

The presence of impervious surfaces and of stormwater drainage systems that conduct runoff

from the site may increase the volume, accelerate the flow, and in some cases, contribute to soil and streambank erosion. In areas where stormwater drainage systems have been installed, stormwater flows to stormwater management basins or other drainage structures for detention, extended detention, retention, or infiltration. In coastal areas, stormwater is sometimes discharged directly into surface water bodies or streams; in other cases, the overflow of drainage structures is directed into surface waters.

Stormwater as runoff or infiltration water is the vehicle by which pollutants move across land and through the soils to ground or surface waters.

Contaminants will accumulate or be disposed of on natural and urban land surfaces. Sources of contaminants include:

- ?? animal wastes
- ?? highway deicing materials
- ?? decay products of vegetation and animal matter
- ?? fertilizers
- ?? pesticides
- ?? airborne contaminants deposited by gravity, wind or rainfall
- ?? general urban refuse
- ?? by-products of industry and urban development
- ?? improper storage and disposal of toxic and hazardous material

The contaminants associated with and carried in stormwater runoff include the following major categories:

- ?? Metals
- ?? Organic Chemicals
  - ?? - Base Neutral Compounds
    - Acid Compounds
    - Volatiles
    - Pesticides
- ?? Organic Chemicals
  - Phosphates
  - Nitrates
  - Chlorides
- ?? Bacteria and Viruses
- ?? Oxygen Demanding Substances

Raindrops dislodge soil particles and contaminants from land surfaces. This material is then carried in solution or suspension and travels with the runoff. Suspended particles are deposited en route if/when the velocity of stormwater decreases. Contaminants carried in stormwater solution enter the soil through the larger pores at the soil surface and move downward and horizontally through the pore network. Water diffuses into the smaller pores by capillary or soil moisture tension. The rate of movement through the soils and surficial materials depends on the size, shape, continuity and arrangement of the pore network system. The most soluble

constituents such as nitrates and chlorides and many organic chemicals continue to move downward through the aquifer system or to the bays. Soils with a high clay, fine sand, or silt content or with the presence of interspersed clay lenses retard the rate of movement of water and some contaminants through the soil; contaminants may adsorb to soil particles. A portion of the nutrients and pollutants also may be used by plants and soil bacteria.

## **STORMWATER MANAGEMENT BASINS**

Two major types of stormwater systems exist in Westchester: nonstructural and structural.

### Nonstructural

Nonstructural systems attempt to deal with stormwater problems at their source. A variety of techniques are used to minimize stormwater runoff and erosion, maximize recharge and to maintain natural stormwater receiving areas. These include the use of:

- ?? ecological and land use planning
- ?? conservation easements
- ?? zoning ordinances (establishment of the amount of site development and coverage)
- ?? maintenance of natural vegetation
- ?? the use of swales, depressions and other grading and planting techniques

Vegetative controls provide contact between stormwater runoff and vegetated areas and accomplish pollutant removal by a combination of filtration, sedimentation and biological uptake that reduce pollutant concentrations, and/or by a reduction in runoff volume due to infiltration and evapotranspiration.

### Structural

Structural controls use built systems such as:

- ?? stormwater sewerage systems
- ?? detention basins
- ?? extended detention basins
- ?? retention basins
- ?? infiltration basins
- ?? sedimentation basins
- ?? dry wells
- ?? other systems

The treated water from these systems may be discharged into a stream or other surface waters.

Most of the runoff into stormwater management basins comes from impervious surfaces. Occasionally pervious surfaces are a source of runoff when the infiltration rate and water holding capacity are exceeded due to periods of high intensity rainfall. The so-called “first flush,” or first half-inch of runoff from land which has been made impervious, delivers a disproportionately

large load of pollutants during the early part of storms due to the rapid runoff of accumulated nutrients and pollutants. From 70 to 90 percent of the contaminants in stormwater can be removed by detaining the first flush of runoff.

Stormwater management basins can be classified into the following three categories:

- ?? Dry Basins - These are basins with the outlet located at the bottom. They are almost always dry, except for relatively short periods following larger storm events. The outlet size is restricted to limit the maximum flow rate. Dry ponds are often used for flood and erosion control and are not as effective as extended detention and retention basins for water quality purposes. They may, however, be retrofitted to achieve water quality control.
- ?? Extended Detention Basins - These basins employ an outlet structure that will cause stormwater runoff from most storms to pond in the basin. Following a storm, these basins drain in about 24 hours or more and will be dry at all other times. The outlet structures may be either perforated risers or subsurface drains. They provide a practical technique for retrofitting dry ponds to obtain water quality benefits, and can provide particulate (and the associated pollutant) removal efficiency nearly equivalent to that of wet ponds.
- ?? Wet Basins - These basins employ outlet structures designed to maintain a permanent pool of water, which is not released except by means of evaporation, infiltration, or attenuated release when runoff volume exceeds the present storage capacity of the permanent pool. They can provide high removal efficiencies for particulates, and have been observed to effectively reduce soluble nitrogen and phosphorus concentrations by means of biological activity.

## ***DESIGN OF STRUCTURAL STORMWATER MANAGEMENT BASINS***

Proper management of stormwater requires informed judgment in order to interpret data and evaluate empirical runoff projections. Knowledge of the quantitative and qualitative characteristics of rainfall and the watershed is needed to permit the prediction of rates of runoff. Since there is considerable variation in the frequency, intensity and duration of rainfall, the designer must rely upon data derived from observations over long periods of time. Rain gauges have been used for almost a century to measure the intensity, duration and amounts of rainfall from specific storms. Historical records can be used to identify future probabilities.

### ***Storm Characteristics***

Several general conclusions can be drawn concerning storms in Westchester:

- ?? Intense storms usually cover small areas and are of short duration; storms of lower intensity tend to cover larger areas and are of longer duration
- ?? Storms of high intensity and/or high total rainfall tend to have relatively lower frequencies of occurrence
- ?? Storms of high intensity often cause flooding and damage due to erosion and sedimentation

### Design of Closed Stormwater Drainage Systems

The most important consideration in designing stormwater control systems is to provide sufficient capacity to accommodate the peak rate of runoff. It is also necessary to determine the total amount of runoff for a given time period to insure adequate storage capacity of runoff. Stormwater drainage and stormwater systems are sometimes underdesigned due to high costs. The “rational method” is generally used as a first step for computing stormwater runoff for the design of closed stormwater drainage systems when the contributing area is less than 200 acres. This calculation method is based on selecting a design storm event that is characterized by its duration, average intensity and frequency of occurrence. This technique provides the average peak rate of runoff from a storm, but it does not provide a description of the actual storm. The formula for the Rational Method is  $Q = CiA$  where:

?? **Q** equals the amount of discharge (peak runoff rate) in cubic feet per second (SFS)

?? **C** equals the runoff coefficient(s) of the drainage area

?? **I** equals the intensity of rainfall inches per hour

?? **A** equals the area of the watershed (acres)

Also considered in the design of stormwater management basins is the basin volume needed to store the required number of inches of rainfall. For instance, the volume of rainfall from a 5-inch storm for a 100-acre watershed area would be determined as follows:

$$\begin{aligned} & \frac{5''}{12''/\text{ft}} \quad \times \quad 100 \text{ acres} \\ & \quad \times \quad 43,560 \text{ ft.}^2/\text{acre} \\ & \quad \times \quad \text{the runoff coefficient (0.30)} \\ & = 554,500 \text{ ft.}^3 \end{aligned}$$

The storage area of the basin is then calculated.

Soil and surficial permeability rates are used to determine the capacity of stormwater management basins. The USDA-Natural Resources Conservation Service has classified soils into hydrologic soil groups ranging from hydrologic soil group A, which has a low runoff potential and a high infiltration rate, to soil group D, which has a very low infiltration rate. Soil storage capacity is dependent upon other soil characteristics in addition to the infiltration rate. For instance, a fine sandy loam may have the highest storage capacity but will have a lower percentage of large pores than a sand or loamy sand. A fine sandy loam has a high storage capacity because of soil moisture tension. It should be noted that once the recharge basin is in operation, the permeability rates may decrease due to sediment clogging of the soil pores or they may increase due to the establishment of vegetation and associated increased soil porosity. Test drilling should be performed at each proposed recharge basin site to determine whether there is a clay lens beneath the site.

### Runoff Coefficients

Runoff coefficients refers to the percentage of ratio of runoff to the total amount of rainfall that will reach a stormwater management basin. A watershed that is completely forested and located

on gentle slopes will have minimum runoff following a storm of relatively high intensity and duration due to the high retention capacity and low runoff coefficients associated with natural groundcover. A watershed that is primarily developed with extensive impervious surface areas has limited storage capacity and high runoff coefficients. The amount of runoff is a function of the amount of rainfall, amount of evaporation and plant evapotranspiration (seasonally variable), soil permeability, slope, and possibly texture of the surface area. Runoff from impervious surfaces usually varies from 80 percent to more than 90 percent. Therefore, the runoff coefficient as a ratio is 0.80 or 0.90 accordingly. The runoff ratios from pervious surfaces usually vary from 0.10 (natural vegetation) to 0.60 (compacted bare soils) or higher. The runoff ratio for a lawn or golf course is approximately 0.20 to 0.35. The coefficients used to calculate runoff from pervious surfaces may be low in some cases, particularly during a storm that occurs when the ground is frozen. If snow is present, runoff is further increased due to snow melt.

### Key Problems

In the past, stormwater runoff systems were designed to get stormwater off the site and into stormwater drainage systems or onto roadways as fast as possible, sometimes at the expense of neighbors and downstream communities. Although a portion of the inland runoff was directed toward stormwater management systems, most of the stormwater and associated contaminants from areas adjacent to coastal waters were discharged untreated through drainage system outfalls and from roadways into surface waters and wetlands with impervious and modified pervious surfaces. Individual sites were developed without providing land for the recharge or treatment of stormwater and erosion control measures. Over time, this resulted in increased volumes and rates of runoff. Accelerated erosion and sedimentation were associated with the higher rates of runoff. An increase in runoff (and sedimentation) created the need for more extensive drainage systems to prevent the accumulation of water in streets and flood-prone areas. Since stormwater runoff is a transport vehicle for contaminants deposited on impermeable or relatively impermeable surfaces, it is often an important contributor to surface water degradation. To compound the problem, many coastal and inland wetlands were filled and developed, further reducing the storage area for stormwater, sediments and contaminants associated with the sediments. These conditions resulted in the following major effects:

- ?? increased local expenditures for the installation and maintenance of stormwater drainage systems and roadway maintenance
- ?? increased outlays for channel maintenance
- ?? increased flooding of roads and of lowland areas resulting in hazardous driving conditions, dangerous flash floods and property damage
- ?? loss of viable wetlands due to sedimentation
- ?? increased concentrations of contaminants in groundwater
- ?? the closing of a large portion of the area's shellfishing grounds due to high coliform concentrations introduced by stormwater
- ?? changes in the values of aquatic and estuarine water quality parameters with possible adverse affects on aquatic and marine species

### Health Related Problems

Stormwater runoff and stream base flow are important sources of pollutant loadings to Westchester streams, ponds and bays. Two categories of runoff to estuarine waters have been observed: upland runoff entering the freshwater portions of streams and conveyed thereby to the Sound, and overland runoff that enters the Sound (or the tidal portions of the streams) usually by direct overland flow or storm drainage systems. Impervious surfaces constitute the major source of stormwater runoff to streams and bays, but some runoff from pervious surfaces also occurs.

Stormwater runoff has been associated with high concentrations of bacteria in estuarine water and the closing of shellfishing areas due to high indicator bacteria counts. A study on Long Island involved monitoring bacterial counts following storms in freshwater storm events. It was calculated that stormwater runoff accounted for at least 93 percent of the total and fecal coliform discharge. Sedimentation rather than bacteriological die-off appears to be the mechanism for the attenuation of bacteria in stormwater runoff from ponds before discharge into marine water.

Nitrogen and phosphorus from fertilizers and other sources enter fresh and marine waters by stormwater runoff, stream flow and groundwater flow. Elevated nitrogen levels can result in a phytoplankton bloom and rooted aquatic growth (e.g., eelgrass), since nitrogen is a limiting growth factor in estuarine waters.

### Impacts On Fresh Surface Waters

Biological monitoring has been used to measure the impact of stormwater upon aquatic communities. Increased pollution in urban ponds and streams has resulted in marked changes in the type and number of species present. High concentrations of phosphorus from fertilizers applied to landscaped areas and phosphorus from other sources in the immediate watershed area can result in algal blooms and other eutrophic conditions.

The depletion of oxygen as measured by high biological oxygen demand (BOD) values in receiving waters is one of the most important impacts on freshwater systems. When high BOD loadings are discharged to surface waters, the resultant depressed oxygen levels eliminate those species that cannot survive at low oxygen levels. Aquatic life changes over time as high oxygen demanding species are replaced by those that can tolerate lower dissolved oxygen (DO) levels. This is an especially important problem in lakes and ponds. A pond that once had species indicative of good water quality such as mayflies, stoneflies and caddisflies may now have large numbers of worms such as Tubifex and Limnodrilus udekamianus. Other types of worms may be present that have special types of blood or breathing mechanisms that allow them to adapt to waters with low DO levels.

Grease and oil products are sometimes disposed of on the land, into storm sewers, or directly into surface waters. If sufficient concentrations of these products are found in the water column or accumulate on aquatic plants, they can harm or kill aquatic biota. High concentrations of salts from highway deicing practices also may impact aquatic vegetation and aquatic ecosystems.

### Basin Bank Stabilization

One of the most important features to include in basin designs and bank stabilization is to establish a vegetative buffer around stormwater management basins. The establishment of a vegetative buffer, utilizing a diversity of native plant species, is the most practical and cost-efficient alternative to protect and prevent degradation of detention ponds. Vegetative buffers should be established at or near the shoreline and continue landward for a desired distance ranging in size from 20 to 30 feet for most urban basins to 100 feet or more depending on the management objectives. Aquatic plant species also may be established in shallow water areas, or benches, along the shoreline. A vegetative buffer around the perimeter of a detention, extended detention or retention basin serves to:

- ?? reduce stormwater runoff from adjacent lawns, roads, and rooftops by encouraging infiltration
- ?? stabilize the banks and shoreline of the basin to prevent soil and bank erosion
- ?? filter nutrients and contaminants from runoff to prevent water quality degradation
- ?? provide shade for aquatic species and reduce the effects of thermal pollution
- ?? provide fish and wildlife habitat for feeding, breeding, avoiding predators, and shelter
- ?? maintain a diversity of native plant species, including grasses, herbs, shrubs and trees
- ?? discourage large nuisance flocks of Canada geese and gulls, who do not like habitat with taller grasses, shrubs or trees

#### Existing Management Practices: Local and State Controls

Stormwater runoff management in Westchester generally consists of local laws and ordinances, standards and guidelines for stormwater collection systems that are predominantly structural in nature. These standards and guidelines are based on the premise that watershed characteristics and various types of development will produce specific quantities of runoff. Collection systems are based on design standards and engineering practices that include the use of empirical formulas (such as the “rational method”), the construction and use of stormwater management systems according to a specified storage capacity (number of inches of rainfall), or the use of leaching systems, catch basins, dry wells or other structures deemed appropriate. The use of these standard structural systems has generally been successful. However, they have not always proved to be the best in respect to long-term environmental impacts, are implemented too infrequently, and are not the most cost beneficial in terms of maintenance costs.

A comprehensive approach to stormwater runoff management, in which performance standards and site development techniques are used to protect a site’s natural resources and downstream watershed, is becoming more widely accepted. Drainage designs are increasingly based on individual site characteristics and watershed management goals. This type of approach implements certain stormwater management objectives, such as preserving the integrity of natural drainage patterns to prevent flooding and damage to stream channels or other surface waters. It also requires adherence to standards that will insure the attainment of these objectives. The requirement that stormwater runoff from a developed site not exceed that generated under natural or undisturbed conditions is an example of such a standard. In this instance, developers are not required to install a specified type of drainage facility but are given the flexibility to choose the stormwater management system best suited to the needs of each development, subject to the requirements of a performance standard. The type of system that should be installed will

be determined by the system's effectiveness given the variations of:

- ?? slope
- ?? lot size
- ?? vegetation
- ?? water resources
- ?? soils
- ?? type of development under consideration

The State Environmental Review Act (SEQRA) review process can be used on a local level to incorporate environmental concerns, including stormwater management, into the planning and decision-making processes for development. According to SEQRA, each municipality can, under its own local law, provide a list of those critical environmental areas (CEAs), such as existing natural drainage systems, flood prone areas, wetlands and watercourses (and associated uplands), and/or steep slopes or areas prone to erosive forces where potentially hazardous or harmful environmental impacts may occur. Following CEA designation, the potential impact of any Type I or Unlisted Action on the environmental characteristics of the CEA is a relevant area of environmental concern and must be evaluated in the determination of significance of adverse environmental impact. This local law procedure can become a tool for the protection of the environment from the adverse impacts of inadequate or improperly designed stormwater controls.

## ***GENERAL RECOMMENDATIONS***

### *Regulations and Administration*

The following recommendations comprise preventive measures that can be used to minimize stormwater contamination of surface waters and groundwater resulting from site development and future land use activities as well as suggestions for reducing or eliminating existing impacts. For specific recommendations for municipalities in the WAC 5 study area, see Section 1 of this plan. Criteria are also provided for the selection and installation of appropriate stormwater control measures including both nonstructural and structural techniques. This section also describes a number of management practices, erosion and sediment control measures and the suitability of these measures for various types of site conditions.

### *Municipalities, County and State*

- ?? On publicly-owned lands adjacent to surface waters and wetlands, limit development and the establishment of impermeable paving.
- ?? Prohibit any new direct discharge of stormwater runoff into surface waters of freshwater or tidal wetlands.
- ?? Evaluate existing stormwater systems that currently discharge into surface waters to determine whether the systems can be modified to include additional control measures to minimize impacts on surface waters and adjacent areas:
  - Inventory direct discharges and assign remediation priority ratings based upon environmental impacts.

- Determine if there is sufficient land area to develop cost-effective energy dissipation areas and sediment basins as well as extended detention or retention basins to eliminate or reduce direct discharge and accompanying nutrient, pollutant and sediment loadings to surface waters and wetlands.
- ?? Local governments need to develop more complex design requirements for stormwater management basins and wetlands. The frequent practice of specifying a fixed treatment volume may not be sufficient to assure reliable pollutant removal. Local governments may wish to develop additional design criteria to improve pond and wetland performance. These might include requirements for sediment forebays, minimum length to width ratios, redundant treatment techniques, and greater structural complexity for wetlands.
- ?? Ensure adequate long-term maintenance of stormwater management basins through public acquisition, easements or permit/approval conditions. The retention and maintenance of these areas will facilitate the recharge and treatment of runoff, thus reducing the amount of stream flow following a storm and the subsequent associated high coliform loadings that would otherwise reach the bays. A reduction in coliform loadings to the Sound can be achieved through the use of basins to retain sediments thus allowing for the die-off of most coliform bacteria.
- ?? Do not mow or remove vegetation in or adjacent to stormwater management basins unless such removal is part of a prescribed maintenance program because plant growth generally enhances infiltration and nutrient/pollutant removal.
- ?? Incorporate the erosion and sediment control recommendations into municipal law (see separate municipal laws section).
- ?? Require adherence to the following performance standards for all new site development:
  - Protect and maintain the natural functions of the site by maintaining the absorptive, purifying and retentive functions that existed on the site before construction began.
  - Limit the post-construction volume and rate of runoff leaving the site to that calculated on the basis of natural or predevelopment conditions. The peak release rate of stormwater from all developments where retention is required should not exceed the peak stormwater runoff from the area in its undeveloped state for a storm of any intensity up to and including the 100-year frequency, and for rainfall of any duration. Calculations of the rate should be based upon an assumed runoff coefficient of 0.20, 0.25, and 0.35 for average slopes of 2 percent, 2 to 7 percent, and more than 7 percent, respectively.
  - Design the site stormwater system so that the runoff release rate from natural drainage channels will not exceed the natural carrying capacity of the channel.
  - Limit the release rate for stormwater systems serving new development. The volume and velocity of runoff discharged should not exceed the safe capacity of the existing drainage systems into which the discharge flows.
- ?? Require a stormwater management plan for any property when
  - a plat is to be recorded
  - land is to be subdivided
  - an existing drainage system may require alteration

### Site Planning Recommendations

Success in the reduction of stormwater related impacts and the costs of installing stormwater systems depends, in large measure, on proper site analysis and the selection and placement of development suited to the site.

?? Undertake a careful site analysis to identify any developmental constraints affecting the design of a stormwater control system that may be imposed by the location of existing on-site and off-site features.

The site analysis process should include the following steps:

- Prepare a key map locating the site within the watershed
- Prepare a watershed analysis map showing the site drainage system in relation to the watershed. Locate all natural drainage swales, depressions, steep slopes, high points, low points, flood prone areas, areas with depth to seasonal high water table less than six feet, areas of existing vegetation, sensitive wildlife habitats, and soil constraints. Stormwater impacts can be minimized by avoiding soil conditions with severe or moderate constraints
- a *slight constraint* indicates no limitations or a few that can be overcome with relatively little cost
- a *moderate constraint* indicates limitations that are more difficult and expensive to correct
- a *severe constraint* indicates the soil is very poor and will require replacement filling or modification if used (filling is not recommended)

?? Locate on-site areas suitable for the treatment of stormwater

?? Locate on-site areas suitable for development. Site building and paved areas only where the presence of the environmental conditions are favorable. The following soil and slope conditions may indicate soil suitability for development:

- nearly level or moderately sloped terrain (less than 15 percent gradient)
- moderately to rapidly drained soils (moderate to high permeability rate)
- a coarse or medium textured soil
- a seasonal high *water table* more than six feet below the surface
- other soil listed under *slight* constraints in the USDA-NRCS Soil Survey of Putnam and Westchester Counties (1994)

Use proper site design, including the following:

?? Minimize grade changes and site clearing

?? Retain native vegetation on steep slopes, in swales, on soils with a high content of silts, fine sands and clays, and in areas with a high water table or adjacent to surface waters

?? Avoid the use of paved surfaces such as parking lots and roadways where the presence of the following conditions indicate potential problems:

- severely sloped terrain
- floodplains
- existing swales
- depressions or lowlands
- soil constraints listed as *severe* or *moderate*

- ?? Incorporate the following general stormwater controls checklist into the site design as needed to meet the performance standards listed:
- Reduce the extent of impermeable surfaces insofar as possible
  - Use swales and shallow depressions to collect stormwater on-site, wherever possible
  - Preserve swales in their natural state; avoid disturbance of existing grades, vegetation (particularly ground cover) or soils and the alteration of surface hydrology
  - Provide temporary on-site areas to receive stormwater runoff flows that are generated by construction and other site development activities
  - Do not allow increased sediment resulting from the construction or operational phase of site development to leave the site or to be discharged into stream corridors or tidal or freshwater wetlands
  - Minimize the amount of soil area exposed to rainfall and the period of exposure. Cover or plant exposed soils as soon as possible
  - Do not allow the dumping or filling of excess soil or other materials generated from site development into swales and surface waters
  - Detain runoff on-site and direct stormwater from road surfaces to sediment basins before discharge to a sump wherever topography limits or precludes on-site detention or retention. At sites where vertical drainage is not feasible, all runoff from a 25-year frequency, 24-hour storm from unstabilized soil areas should be collected, desilted, and released into stable channels at an acceptable design velocity appropriate for channel characteristics

Once the site plan has been partially completed, undertake the following steps:

- ?? Calculate the amount of stormwater entering the site
- ?? Calculate the amount of natural runoff from the site
- ?? Calculate the additional amount of runoff due to the proposed installation of impermeable paving and other surfaces
- ?? Locate areas on-site for the storage and recharge of stormwater
- ?? Re-evaluate the site plan if the storage and recharge area capacity is not sufficient

#### Combine Development and Stormwater Controls

- ?? Use cluster development as a viable alternative to conventional subdivision layout to preserve environmentally sensitive qualities of wetlands, aquifer recharge areas, swales and woodlands
- ?? Reduce the length of roadways, thereby reducing the extent of cut and fill and stormwater runoff volumes and minimizing the possibility of erosion/sedimentation
- ?? Reduce the area of other impermeable surfaces such as walkways, patios and recreational facilities
- ?? Allocate open space for recreation and water quality protection

#### Natural Vegetation

- ?? Use natural vegetation as an important nonstructural alternative in the control of stormwater runoff and erosion/sedimentation. Natural vegetation includes woodland, free-standing trees, old fields, unmowed grasses, and wetlands. When left undisturbed, vegetation stabilizes steep

slopes, streambanks, and drainageways by:

- reducing stormwater velocity, allowing for absorption of water by soils to occur, thus recharging the aquifer below and allowing for greater filtration of nutrient-rich and contaminated water;
  - acting as a filter by trapping sediment particles
  - holding soil particles in place.
- ?? Identify site locations where existing vegetation will not be disturbed by grading, filling or removal; removal exposes valuable topsoil, making it highly susceptible to erosion/sedimentation
- ?? Stabilize exposed slopes during and after construction, by using temporary and/or permanent, structural or nonstructural stabilization measures. All areas not to be covered with an impervious surface should be temporarily stabilized immediately following disturbance. Permanent stabilization measures should be installed as soon as possible.

### Natural Depressions

- ?? Use natural depressions to collect runoff from the surrounding devilmnt and slow its velocity, allowing for recharge. Natural depressions consist of gently sloping land, vegetated with grasses, understory vegetation, and/or trees. Depressions also function as runoff holding areas, allowing sediment particles and debris to settle out before discharge to nearby surface waters. Except during storm events, depressions also may serve as recreational open space.

### Wetlands

- ?? Do not discharge untreated stormwater runoff directly into tidal or freshwater wetlands, and do not construct stormwater management basins in naturally-existing wetlands.

### Stormwater Detention

- ?? Use stormwater extended detention (temporary detainment of stormwater runoff, with gradual release to surface or groundwaters) to main the same volume and rate of site runoff after development as that which existed prior to the development. Extended detention basins are designed to drain completely 24 hours or more after a storm. An emergency spillway should be provided to allow release of runoff during storms that exceed the design capacity of the retention area. Except during storm event, detention areas also may serve as open space and should be as visually attractive as possible.
- ?? Maintenance of the control facility should be provided to insure sustained flow rates and visual attractiveness.

### Stormwater Retention Ponds

- ?? Stormwater retention should be used to permanently hold stormwater runoff on the site or for long-term detention to allow for the die-off of coliform bacteria. Retention basins can provide recreational and aesthetic benefits for development by supporting certain native plants and aquatic life. They also can provide a habitat for wildlife when the pond is planted with upland and aquatic vegetation. The retention pond should be sized to contain both the

normal dry weather water volume and expected runoff flows. It is recommended that the retention pond be designed to accommodate a 100-year, 24-hour storm. In areas where heavy sediment loads are anticipated, the aesthetic value of the permanent ponds and its surroundings will be severely reduced by deposited sediment and debris. Therefore, maintenance will be required or a more easily maintained sediment basin should be constructed immediately upstream from the basin.

### Drainage Channels

- ?? Naturally-vegetated swales or other types of drainage channels should be used to carry stormwater. Use grassed or vegetated waterways in areas where design velocities are low and soils have a low erosion potential. Stabilized vegetation also reduces the energy of flow, allowing for infiltration of runoff. Vegetative waterways are usually preferred over structurally-lined channels for reasons of aesthetic value.
- ?? Bare channels should be used only as a temporary measure for construction sites in areas where the slope is minimal, and the runoff velocity is low. Do not install bare drainage channels in areas with highly erodible soils. The permanent use of bare channels should be avoided.
- ?? Structurally-lined channels should be used only as necessary in drainage areas where the slope is high or runoff velocities and concentrations are erosive, particularly in areas of highly erodible soils that preclude the establishment of vegetative cover. The most common structural linings include stone riprap.
- ?? Shallow detention and recharge areas should be used upgradient of natural swales as required so that the existing volume and velocity of runoff into the swales is not exceeded. If this is not possible due to lack of land area or the presence of a high water table, etc., then vegetative and/or structural stabilization measures will be required to provide the swale with the capability to carry and/or recharge runoff without risk of erosion/sedimentation.
- ?? Protect the channel until a uniform vegetative cover has been obtained, eliminating the risk of erosion and/or sedimentation damage. Common channel stabilization methods include the use of seeding, mulches, and sod. Jute netting and other mulching techniques are frequently used to protect channels until vegetation is established.

### Diversion Control Measures

- ?? Use diversion control measures to direct stormwater away from an area where it could cause damage from flooding erosion and/or sedimentation. A surface drainageway is one type of a diversion control measure. It is a natural or constructed channel or waterway used to divert stormwater runoff. A berm is another type of diversion control measure. Surface drainageways and berms should be used to divert stormwater away from natural slopes where slopes or soils were exposed during construction and newly constructed fill slopes. Channels and waterways should have the capacity to provide a path for flow to move at non-erosive velocities to a stable outlet. Diversion control measures should not direct stormwater runoff to an adjacent property.

### Energy Dissipation

?? Use energy dissipation devices to slow the velocity of stormwater runoff to a non-erosive rate. This can be done by establishing a control area immediately adjacent to an outfall or other discharge point. Usually a pile of rocks, stones, gravel/crushed stone or boulders is used to reduce the velocity of the stormwater as it moves through the area. Energy dissipaters may also serve as sediment filters, trapping suspended particles and debris.

### Sediment Basins

- ?? Use sediment basins to protect surface waters from increased sediment loads by trapping the suspended solids before the runoff is released.
- ?? Remove accumulated sediment and debris periodically, so that the basin will function properly and its visual attractiveness will remain. Wherever possible, retain vegetation because the roots can increase soil permeability.

### Biofiltration Systems

?? Use a biofiltration system to detain runoff and reduce contaminant loadings. Biofiltration by a combination of physical and biological processes can minimize concentrations of coliform bacteria, heavy metals, and nutrients carried in stormwater runoff. A biofiltration system is essentially a man-made pond or wetland. The system includes an energy dissipater, located below the inlet pipe, to reduce water velocity and trap suspended solids (sediment and debris). The entire basin is lined with an impermeable vinyl sheet or clay layer to prevent leaching of trapped contaminants to groundwaters. The vinyl or clay is covered with clean sand and loam, and planted with indigenous aquatic plant species, such as *Typha angustifolia*, or cattails. All above-water areas are stabilized by plantings of rye grass, *Lolium multiflorum*, or Tall Fescue, *Festuca arundinacea*, or Red Fescue, *Festuca rubra*, to name a few. Removal of pollutants is accomplished as the runoff moves across the plants. After a detention time of several days, during which the contaminants are absorbed by the plants, significant reductions in contaminant levels occur. The treated runoff is then released to adjoining surface waters. The overflow chamber, located at the pond outlet (equipped with backflow and adjustable weir) controls the storage capacity. Maintenance involves the periodic cleaning of the surge tank and overflow chamber of floating debris and sediments, and biannual harvesting of aerial portions of aquatic plants.

### Permeable Paving

?? Use permeable or “porous” paving for patios, walkways and parking lots to reduce the volume of stormwater runoff by increasing infiltration to the ground below, thus allowing for recharge of the aquifer. Permeable paving may be used in areas where permeability of the soil is sufficient to allow rapid drainage and where a seasonally high water table is not anticipated.

<b>A comparative assessment of the effectiveness of current urban best management practices</b>							
<b>URBAN BMP OPTIONS*</b>	<b>RELIABILITY FOR POLLUTANT REMOVAL</b>	<b>LONGEVITY*</b>	<b>APPLICABLE TO MOST DEVELOPMENTS</b>	<b>WILDLIFE HABITAT POTENTIAL</b>	<b>ENVIRONMENTAL CONCERNS</b>	<b>COMPARATIVE COST</b>	<b>SPECIAL CONSIDERATIONS</b>
<b>STORMWATER WETLANDS</b>	Moderate to high, depending on design	20+ years	Applicable to most sites if land is available	High	Stream warming; natural wetland alteration	Marginally higher than wet ponds	Recommended with design improvements and the use of micropools and wetlands
<b>EXTENDED DETENTION PONDS</b>	Moderate, but not always reliable	20+ years, but frequent clogging and short detention common	Widely applicable, but requires at least 10 acres of drainage area	Moderate	Possible stream warming and habitat destruction	Lowest cost alternative to size range	Recommended with design improvements and the use of micropools and wetlands
<b>WET PONDS</b>	Moderate to high	20+ years	Widely applicable, but requires drainage area of greater than 2 acres	Moderate to high	Possible stream warming, trophic shifts, habitat	Moderate to high compared to conventional	Recommended, with careful site evaluation
<b>MULTIPLE POND SYSTEMS</b>	Moderate to high; redundancy increases reliability	20+ years	Widely applicable	Moderate to high	Selection of appropriate pond option minimized overall environmental impact	Most expensive pond option	Recommended
<b>INFILTRATION TRENCHES</b>	Presumed moderate	50% failure rate within five years	Highly restricted (soils, groundwater, slope, area, sediment input)	Low	Slight risk of groundwater contamination	Cost-effective on smaller sites; rehab costs can be considerable	Recommended with pretreatment and geotechnical evaluation
<b>INFILTRATION BASINS</b>	Presumed moderate if working	60-100% failure within 5 years	Highly restricted (see infiltration trench)	Low to moderate	Slight risk of groundwater contamination	Construction cost moderate, but rehab cost high	Not widely recommended until longevity is improved
<b>POROUS PAVEMENT</b>	High (if working)	75% failure within 5 years	Extremely restricted (traffic, soils, groundwater, slope, area, sediment input)	Low	Possible groundwater contamination	Cost-effective compared to conventional asphalt when working properly	Recommended in highly restricted applications with careful construction and effective maintenance
<b>SAND FILTERS</b>	Moderate to high	20+ years	Applicable for smaller developments	Low	Minor	Comparatively high construction costs and frequent maintenance	Recommended, with local demonstration
<b>GRASSED SWALES</b>	Low to moderate, but unreliable	20+ years	Low density development and roads	Low	Minor	Low compared to curb and gutter	Recommended, with checkdams as one element of a BMP system
<b>FILTER STRIPS</b>	Unreliable in urban settings	Unknown, but may be limited	Restricted to low-density areas	Moderate if forested	Minor	Low	Recommended as one element of a BMP system
<b>WATER QUALITY INLETS</b>	Presumed low	20+ years	Small, highly impervious catchments (<2 acres)	Low	Resuspension of hydrocarbon loadings; disposal of hydrocarbon and toxic residuals	High, compared to trenches and sand filters	Not currently recommended as a primary BMP option

\* Based on current designs and prevailing maintenance practices. Source: Metropolitan Washington Council of Governments 1992.