Watershed Planning

A. The Importance of a Healthy Stream Ecosystem[1]

Today, it is generally recognized that clean water is essential for the health and functioning of an ecosystem, including that in which the human population is a part of. That is, the quality of water affects the health and well-being of plant and animal life, including people. Historically, the restoration and protection of water quality has grown in importance as our understanding of the complex processes involved in both the maintenance of healthy, functioning ecosystems and the mechanisms of degradation has improved.

1. Legislative Efforts to Protect Water Quality and Water Resources

a. Federal

The need for protecting our water resources is reflected in both federal, state, and local laws and regulations. At the national level, the Federal Water Pollution Control Act of 1948 (which regulates dumping and disposal into navigable waters), the Water Quality Act of 1965 (which created ambient water quality standards for interstate waters), and the Federal Clean Water Act (1972 and amended in 1987; this act deals with point and non-point source water pollution, wetlands, and protection of aquatic life) form the basis for efforts to protect water quality and water resources.

[1] An ecosystem is a complex of the plants and animals and the physical environment of an area and their interactions.

b. State

State and local laws and programs have been formulated to address issues of protecting regional and local water resources. The restoration of water quality and plant and animal communities in the regional resources of the Chesapeake Bay and its tributary waters, such as the Anacostia River, have been the focus of many state and local laws and programs. These regional waters provide significant economic and recreational resources.

Initiatives to protect and restore the Chesapeake Bay, the nation's largest and most productive estuary, began in the early 1980's. As a result of extensive data documenting the decline of the Bay's health, the Chesapeake Bay Agreement of 1983 was formulated. This agreement is a commitment by the states of Pennsylvania, Maryland, and Virginia, the District of Columbia, and the U.S. Environmental Protection Agency to restore and protect the Bay through correcting existing pollution problems and avoiding new ones that affect the Bay. This regional commitment to clean up the Bay is an important framework on which other regional, state, and local water resource legislation and programs rest.

c. Local

(1) Anacostia Restoration

Locally, the Anacostia River has also been the focus of extensive restoration and protection efforts. In the 1970's, the Anacostia River was designated a scenic river under the Maryland Scenic and Wild Rivers Act (Md. DNR, undated). In 1984, the first Anacostia Watershed Restoration Agreement was signed by the State of Maryland and the District of Columbia. It outlined the initial steps to restore the Anacostia. In 1987, Prince George's and Montgomery Counties were added in a new partnership created by the second Anacostia Watershed Restoration Agreement. This second agreement formalized a cooperative partnership and resulted in significant progress. The agreement called for the formation of an Anacostia Watershed Restoration Committee (AWRC) to develop a restoration plan and coordinate the efforts of the various local, state, and federal agencies to ensure the plan's rapid implementation. The restoration plan, entitled *A Commitment to Restore Our Home River: A Six-Point Action Plan to Restore the Anacostia River* (Anacostia Restoration Team, November 1991), was adopted by the four jurisdictions involved in the agreement in 1991; the action plan provides specific goals and detailed strategies for restoring the river by the turn of the 21st century.

More recently, in 1994, the Anacostia River was listed as a threatened river by the American Rivers, a national conservation organization dedicated to protecting and improving American rivers. The designation is an upgrade over its 1993 status of endangered and reflects the extensive efforts of many jurisdictions to restore the river system. In addition, the Clinton Administration has designated the Anacostia River a priority ecosystem and the U.S. Environmental Protection Agency has a established a Five-Point Action Plan to restore the watershed.

(2) Paint Branch

As a tributary of the Anacostia River, Paint Branch is subjected to the same regional and local efforts for protection and restoration as the other parts of the River under the Anacostia River watershed restoration plan. Because of the high quality conditions of its headwater streams and the presence of a naturalized, self-sustaining, brown trout fishery, Paint Branch within Montgomery County has been afforded additional protection through a number of State and County actions.

In 1974, Paint Branch and all of its tributaries upstream of the Capital Beltway were classified by the Maryland Department of Natural Resources Water Resources Administration as Use III Waters.[2] Paint Branch was the first stream system in Montgomery County to be identified as Use III. In 1980, Maryland DNR designated the Paint Branch watershed upstream of Fairland Road as a "Special Native Trout Management Area." This designation was the first of its kind in Maryland and was intentionally designed to give the streams special status and maximum protection afforded by state regulations.

The *1981 Eastern Montgomery County Master Plan* singles out the brown trout fishery in Paint Branch as a feature so valuable as a water quality indicator and unique as a natural resource for the County that special measures are required to preserve it. These special measures include rezoning to achieve a low ultimate impervious land cover and associated lower land disturbance and forest cover loss, larger park acquisition, and recommendations to incorporate extraordinary best management practices in land development projects.

The policy established in the *1981 Eastern Montgomery County Master Plan* of protecting a high quality feature of a part of the upper Anacostia River system, such as Paint Branch, is in keeping with the County's commitment to protect the Anacostia River by helping avoid degradation and possibly improving conditions in downstream sections.

In addition to the recommendations of the 1981 master plan, the County provides protection to the streams of Paint Branch under a variety of laws, regulations, and guidelines which apply to all County streams. The Planning Board applies stream buffer guidelines (Montgomery County Planning Department, 1993) for new development in the County. County requirements for stormwater management and sediment and erosion control are designed to reduce the impacts of land-disturbance activities and land development on streams and other water bodies. Under the County Forest Conservation Law, forest stands that are associated with streams are given the highest priority for protection, in recognition of the importance of forest cover in the health and function of stream systems. In addition, the County has on-going capital improvement programs to identify and improve streams that have been degraded by existing land uses.

[2] Use III waters are also identified as "Natural Trout Waters." This designation indicates that the stream system possesses the overall high quality conditions and other natural features that are able to support natural trout populations, including propagation and their associated food organisms. "Propagation" is the continuance of a species by generation of successive reproduction in the natural environment as opposed to the maintenance of the species by artificial culture and stocking.

More recently, Montgomery County has established a process to apply more rigorous water quality protection measures for new development in specific areas of the County. Effective on March 3, 1995, the County Council can designate certain areas as Special Protection Areas. Such areas are defined as containing existing water resources or other environmental features directly relating to those water resources that are of high quality or unusually sensitive, and where proposed land uses would threaten the quality or preservation of the resources in the absence of special water quality protection measures.

On July 11, 1995, the County Council designated the Upper Paint Branch as a special protection area. As part of this designation, the Council established that new development would be subject to combined application of the SPA legislation and performance criteria set forth in the *1981 Eastern County Master Plan.*

2. Characteristics of a Healthy Stream Ecosystem

A stream system includes not only the stream channel itself, but is also defined by the freshwater wetlands, floodplains, near-stream area, seeps, and springs that are linked to the stream. A healthy stream has high water quality and supports a diverse plant and animal life. It has a fairly even and regular flow of water which is derived mostly from groundwater.[3] (This groundwater-derived flow of water in a stream is known as baseflow). Some of this groundwater enters the stream by way of wetlands, springs, and seeps.

Ideally, the stream carries relatively low sand, silt, and sediment loads. There should be relatively low occurrences of in-stream channel erosion. The stream channel and banks are relatively stable, although some stream bank undercutting does occur as a part of the dynamic nature of stream flows. Undercut stream banks, if not excessive, are part of a stream's natural morphology and are frequently used by fish for cover.

The stream is usually made of segments with different water flow characteristics. There should be shallow, fast-moving runs, areas with fast moving water with cobbles and rocks known as riffles, and deep, slow-moving pools. Riffles provide habitat for a variety of aquatic insect larvae and other macroinvertebrates.[4] (Macroinvertebrates are an important source of food for fish.) These riffle areas also allow oxygen to be mixed into the water, which contributes to a high level of stream productivity. Pools are used by fish for cover and protection and may provide cooler water temperatures in the warmer months.

In the Piedmont region,[5] in which almost all of Montgomery County lies, the water in a healthy stream is clear, cool (below 68°F. in the summer), and odorless. A large part of the cool water may originate from groundwater sources. Cool or cold water is important in a Piedmont stream because many stream-dwelling organisms that are intolerant to pollution are also sensitive to temperature fluctuations, especially temperature increases.

Another important component of a healthy stream system is the near-stream, or riparian, vegetation cover, especially forest. Near-stream vegetation provides stability to stream banks, reduces and filters surface stormwater runoff, and aids in maintaining recharge areas for groundwater. Forest cover along and near the stream is necessary to provide shade to the stream channel to aid in water temperature moderation. In addition, for small streams, which includes most of the streams in Montgomery County, leaf litter and woody

[3] Groundwater in the Piedmont region is derived from precipitation that infiltrates through the regolith. Regolith is a mantle of unconsolidated material beneath the ground surface that is created by rocks that have weathered in place over geologic time. This layer of regolith can be as thick as 200 feet in the Piedmont region and is made up of saprolite, soils, and alluvium. Saprolite is clay-rich residual material derived from weathering of bedrock.

Movement of water from precipitation moves downward through the regolith until it reaches the water table, which is the area of regolith and fractured bedrock that is saturated with water. Once water reaches the water table, it flows laterally to a point of discharge, which may include: seeps along steep slopes, bank and channel seepage into streams and ponds, seeps where bedrock is near the surface or where impermeable soils exist, and springs where fractures or geologic structures intersect the land surface or stream bank. Depending on the hydrology of the area, wetlands may or may not exist in these discharge areas. (Hau, 1995)

[4] Macroinvertebrates are animals without a spinal column and can be seen without the use of a microscope. Examples include insects, mollusks, worms and crayfish.

[5] The Piedmont region in Maryland is a physiographic area which is characterized by undulating topography with low knobs and ridges and numerous stream valleys. Almost the entirety of Montgomery County lies within the Piedmont region. The eastern edge of the Piedmont area in Montgomery County can be roughly marked by US 29. The remaining County land lying approximately between US 29 and the eastern County line is known as the fall line, which is a transitional area between the Piedmont and the Coastal Plain physiographic areas. Streams within the fall line are typically fast-flowing and are associated with steep-sided and narrow gorges.

debris supply the chemical energy for the stream ecosystem. Various aquatic insect larvae and crustaceans[6] feed on leaf material. These organisms are, in turn, fed upon by predatory organisms, including other macroinvertebrates (e.g., stoneflies, some caddisflies, and hellgrammites) and fish. Without an abundant and constant supply of leaf material and woody debris, the stream ecosystem changes in the mix and diversity of organisms found in the stream.

The biological communities found in a healthy stream are abundant and diverse. There is a diverse population of microbes (fungi and bacteria), aquatic insect larvae, crustaceans, and fish which make up these communities. Many of the species found in a healthy Maryland Piedmont stream can live only in cold, relatively silt-free, clean streams with steady baseflow and some variation in stream channel structure to provide habitat for different stages and functions of the species' life cycles; that is, these species can usually live and reproduce in stream systems where there are no wide fluctuations in chemical and physical conditions from those defined for a healthy stream.

B. Factors that Contribute to the Degradation of a Stream System

The cover and uses of the land that drains to a stream greatly influences the quality and health of that stream. Uses that involve extensive land disturbance, the elimination of vegetative cover, especially forest cover, and the replacement of pervious surfaces with impervious surfaces result in the degradation of the receiving stream system.

1. Change in Land Use

When a piece of land is cleared of trees, graded, and developed, several features of the land change. The natural surface water runoff storage capacity is lost by removing the protective canopy of trees, grading of natural depressions, and removal of spongy topsoil and leaf litter. With the compaction of soil and placement of impervious materials on the land (e.g., buildings, roads, sidewalks, driveways, parking lots), the natural feature of the land that enables rainfall to percolate into the soil is lost. Essentially all of the water from rainfall and other precipitation events become surface runoff that travels directly to receiving streams.

If the development of land covers a significant portion of a watershed, the receiving stream system will be adversely affected. Clearing and grading of land can generate sediment that enter the stream even with sediment and erosion control measures in place. Loss of forest cover within and around the stream valley increases the potential for unstable and eroding soils, exposes the stream to sunlight and raises water temperatures in the summer months, and eliminates the main energy source for the stream system. With the loss of forest material as an energy source, the stream system must rely on other sources, such as sunlight and algae, and the aquatic organisms that depend on leaf litter and woody material disappear.

2. Impervious Surfaces

The placement of extensive impervious surfaces in the watershed eliminates recharge areas for groundwater that feeds stream baseflow. Since impervious surfaces cover up the natural recharge areas for groundwater, more water from precipitation events (e.g., rainfall and snowfall) enters the stream as surface stormwater runoff and less as groundwater-derived baseflow. Stream baseflow becomes irregular and can be very small or eliminated during dry weather periods. Decreased baseflow reduces the ability of small streams to dilute and "neutralize" the effects of pollutants.

During warm weather (e.g., summer), extensive impervious surfaces can elevate the temperature of stormwater that travels over these surfaces prior to entering the stream, even with the use of stormwater management controls; this is because impervious surfaces absorb and reflect heat, and water travelling over these surfaces will pick up this heat. Warm stormwater runoff can adversely increase the temperatures of the receiving stream waters.

3. Stormwater Runoff

Stormwater runoff entering the streams may also be erosive and carry adverse levels of pollu-

[6] Crustaceans are a scientifically-defined group of animals with specific characteristics, including an exoskeleton (i.e., an external supportive covering), a segmented body, and the absence of a spinal column. Examples of crustaceans include lobsters, shrimp, crabs and crayfish.

tants and trash, even with stormwater management controls in place. The runoff from a developed area tends to enter a stream as a point source rather than as dispersed flow that is filtered through vegetative cover.

Increased land development and urbanization in a watershed usually results in increased pollutant-generating activities, such as motor vehicle uses (which generate oils and greases, metals, salts, sand, etc.), care and maintenance of lawns and other landscaped areas (which generate pesticides, fertilizers, etc.), use and disposal of various material (which generates trash), and care of pets (which generates animal waste). The higher pollutant loads often lead to lower water quality in the receiving streams; many times, this lower quality is in violation of state water quality standards that are designed to protect the streams. Some of these pollutants can also cause lower dissolved oxygen levels in the receiving streams, which can be detrimental to many aquatic species.

4. Sediment Loads

To adjust to increases in stormflows due to increased impervious surfaces in the watershed, a stream will widen its channel, creating higher sediment loads and severely disturbing the stream bank area through undercutting, treefall, and slumping. Much of the sediment forms sandbars and silt deposits in the channel. These bars and deposits are constantly shifting and adds to the streambank erosion process by deflecting stream flows into erodible bank areas.

Increased sediment loads can reduce a stream channel's capacity to carry water; this causes lateral channel erosion to make up for this "lost" volume. In addition, increased sediment load in the stream can severely degrade or eliminate the natural runs, riffles, and pools that are present in healthy streams. This change in the stream morphology greatly reduces the diversity and availability of habitat for aquatic organisms.

The sediment may also be deposited within the small spaces between cobbles and gravels in riffle areas. This is known as embedding. Embedding greatly limits the quality and availability of spawning areas for fish, especially trout. It also reduces the circulation of water, organic matter, and oxygen to the filter-feeding aquatic insect larvae that live among and under the riffle areas.

C. Effects of Urbanization on Species Diversity and Composition of the Stream Community

The significant changes in the stream's morphology, hydrology, and water quality that occur when land development increases in a watershed degrades the health and viability of the biological community in the stream. The number and variety of species found in the stream community typically drops when the physical and chemical features of the stream degrade. Species that need steady, cold, clean, relatively silt-free stream flow often cannot go through parts or all of their life cycles in degraded streams; these species, which have relatively narrow ranges of tolerances of stream conditions, may be greatly reduced in numbers or disappear altogether in a degraded stream.

Species that have narrow tolerances for degraded stream conditions are often used as indicators, or "markers," for the overall good health of a stream. Examples of these indicator species include certain aquatic insect larvae such as stoneflies (Plecoptera order[7]) and certain species of mayflies (Ephemeroptera order) and caddis flies (Trichoptera order). Fish have also been used as indicators of long-term (i.e., several years) stream health because they are relatively long-lived and mobile. In Maryland Piedmont streams, trout are often used as indicators of a healthy stream.

D. Assessing Urbanization Impacts on a Stream System

1. Stream Monitoring

The health of a stream system can be documented in various ways. The ideal way is to methodically and consistently quantify the physical, chemical, and biological conditions within the streams over time. Such a monitoring program

[7] This and other scientific names referenced in this study are part of a standardized scientific classification system for plants and animals. This classification system categorizes plants and animals into a hierarchy of groups. The major types of taxonomic categories are as follows, listed in order of decreasing inclusiveness (e.g., a phylum includes a wider range of organisms than a species): kingdom, phylum, class, order, suborder, family, subfamily, genus, species.

would be able to document the water chemistry; physical features of the stream channel's shape, size, and stream bottom characteristics; and the size, composition, and diversity of the entire biological community in the stream. If the stream system degrades, the ideal monitoring program would be able to document the declining changes within the streams' physical, chemical, and biological conditions. In addition, the ideal monitoring program would also be able to track specific changes to the land uses in the watershed and pinpoint the causes of degradation to the streams.

In reality, stream systems within Montgomery County rarely have been or can be monitored in a truly comprehensive manner. This is because monitoring resources are always limited, compared to the numerous streams that should be monitored because of their potential for declining quality. Often, only certain components of the stream system are monitored, such as limited water chemistry parameters or certain groups of organisms (e.g., fish or aquatic macroinvertebrates). And the monitoring program usually is set up so that only a very limited number of widely-spaced monitoring stations can be put in place, with very limited time periods available for collecting data. Because of limited resources, monitoring programs usually include methods to identify the presence or absence of species or groups of species that have small tolerance ranges for "unhealthy" stream conditions (i.e., indicator species); these methods enable the health of a stream to be documented fairly accurately without having to implement an extensive monitoring program. However, such monitoring programs usually do not include methods to track or identify the specific causes of degradation of the streams.

If stream monitoring resources are limited, one way of assessing the health or changing conditions of a stream system and the factors that affect its health is to examine all available data on the streams' conditions, in conjunction with characterizing the watershed's impervious cover.

2. Level of Watershed Imperviousness

Impervious cover in a watershed can be viewed as an easily quantified, planning-level (i.e., general) measure of human impact on the aquatic resources in the watershed, including the stream system. The proportion of a watershed covered in impervious surfaces can indicate the degree to which stream and wetlands baseflows, water temperatures, water quality, and stream morphology are adversely altered. It can also signify the susceptibility of the watershed to unstable and erodible soil conditions, and loss of vegetative cover (e.g., due to grading and construction activities).

In general, the greater the proportion of a watershed covered in impervious surfaces, the lower the quality and health of the stream system found in the watershed. The absolute imperviousness levels tolerated by different stream systems vary. This is because many variables affect how well a stream is buffered from the negative effects of urbanization. These variables include the characteristics of the soils, geology, and topography in the watershed; the size and configuration of the stream; the extent, location, and type of vegetation cover in the watershed; the importance of baseflow in the stream's overall flow patterns; the amount and type of stormwater management serving existing development and the extent and location of urban land uses with respect to the stream.

A study of 27 small watersheds in the Maryland Piedmont region found a direct relationship between stream quality and watershed imperviousness (Klein, 1979). The study concluded that generally, stream quality impairment is observed when watershed imperviousness reaches between 12 and 15 percent. Severe degradation occurs when watershed imperviousness is at about 30 percent. For more sensitive stream systems, such as those supporting naturally-reproducing trout populations, the study recommends that watershed imperviousness should not exceed 10 percent to maintain the quality and integrity of these streams. It should be noted that most of the development in the watersheds that were studied did not have stormwater management controls to help offset adverse impacts.

Since the Klein study, other studies have been conducted to determine the relationship of stream quality and watershed imperviousness and urbanization. These studies cover a variety of physiographic areas in the United States and one area in Canada; their findings and conclusions are clearly summarized in a research article on impervious cover (Schueler, 1994).

Although these studies cover a wide range of stream systems (for example, ranging from the Jones and Clark study [1987], which looked at several streams draining to the Potomac River in northern Virginia, to streams in the state of

Washington [Booth and Reinelt, 1993]), they lead to the same general conclusion: few, if any, streams with moderate to high levels of watershed imperviousness (25 percent or more) can support diverse, healthy insect communities. With respect to a stream's ability to support pollution-sensitive fish such as trout and salmon, the Schueler article found that the general upper limits of trout or salmon streams are in the range of 10 to 15 percent watershed imperviousness.

The Interstate Commission on the Potomac River Basin (ICPRB) has noted that in general, stream quality is impaired when urbanization (developed areas) reaches 10 percent of a watershed. Normally, a stream is "severely impaired" when at least 25 percent of the area it drains is impervious. (ICPRB, 1992).

A Metropolitan Washington Council of Governments (MWCOG) study of water temperature impacts of urbanization and stormwater management (SWM) facilities on small headwater streams in the Eastern Montgomery County area revealed that summer stream temperatures increase linearly with increasing watershed imperviousness. The study showed that watershed imperviousness has a negative effect on stream temperatures under both baseflow and stormflow conditions, regardless of whether SWM controls are present or absent in the watershed. Stream temperature regime changes occur when watershed imperviousness exceeds about 12 percent. The results of the study strongly suggest that coldwater organisms, such as trout, will most likely be lost when watershed imperviousness exceeds 12 percent to 15 percent (Galli, 1990).

The Anacostia Watershed Restoration Committee's (AWRC) Upper Paint Branch Work Group recognized the lack of specific watershed imperviousness "thresholds" to establish limits in which stream degradation will definitely occur. The work group references a range of upper limits for watershed imperviousness (between 10 and 15 percent) beyond which coldwater stream systems in Maryland become severely degraded or are destroyed (AWRC, 1994).

In addition to the *amount* of impervious cover, the location of the impervious surfaces in the watershed is important in determining the degree with which such land cover will adversely impact the stream system. For example, paved surfaces located adjacent to or within a stream buffer, as defined by the Montgomery County Planning Board's environmental guidelines (M-NCPPC, 1993), will have a greater adverse affect on the stream than the same paved areas located 200 feet uphill of the stream buffer. As another example, paved surfaces located in the extreme headwaters of a stream system will create greater adverse impacts on the system than paved surfaces located further down in the watershed; this is because smaller streams have less flow and channel resiliency to counter the effects of impervious cover than larger streams.

E. Techniques for Reducing Urbanization Impacts on Streams

1. Land Use Controls

The control or management of land uses placed in a watershed is generally considered the most effective tool in influencing the health of a stream system. Management of land uses that maximizes retention of vegetation cover, especially forest, and minimizes disturbance and modification of soils and topography is the most effective method to protect the high quality conditions of a stream system. Preservation of a watershed's vegetation cover is especially important in that part of a watershed that drains to small streams (i.e., commonly defined as first to third order streams) because of the limited ability of these streams to withstand and counter adverse impacts. Retention of vegetation cover, especially forest, is also crucial in the area surrounding a stream channel.

The tools to manage land cover and uses in a watershed include zoning, overlay zoning, performance criteria for land development, and the use of legally-protected conservation areas in and around sensitive natural features. If urbanization or suburbanization is to take place in a watershed, and the preservation of the stream system is a goal, land use tools that greatly limit the overall impervious cover should be implemented in those areas of the watershed that drain to small streams. Ideally, urban and suburban uses that result in high impervious cover should be located in areas that drain to larger streams and rivers (fourth order streams or larger), although the overall watershed imperviousness should still be relatively small. In addition, areas immediately in and around streams should be placed in protected conservation areas throughout the watershed.

2. Best Management Practices

When a land use will result in significant clearing of vegetation, disturbance of soils, modification of the natural topography, and/or creation of impervious surfaces, stormwater management and sediment and erosion control measures are usually required by State and County laws to be put in place. Such measures are termed best management practices (BMP) and are designed to reduce the adverse impacts of land disturbance and land development on aquatic resources. A best management practice is a method or measure considered to be the most effective and practicable means available to prevent or reduce the amount of pollutants or other detrimental water resource impacts generated from non-point sources.[8]

BMPs include many types of measures. They can range from engineered structures such as stormwater management ponds or sediment traps to vegetated buffer areas that are preserved or enhanced on either side of a stream to design and layout features of a development project that are sensitive to protecting water resources.

BMPs vary in their effectiveness in protecting water resources. Although the performance of engineered BMP's have improved over the years due to better design, their effectiveness is generally limited by the following factors: inherent limitations of engineering designs to completely replicate natural conditions and features, limitations of performance efficiencies of the control measures, poor construction of these measures, and/or poor maintenance of these measures after they are put in place and are operational.

In a research article on impervious cover, Schueler (1994) notes that many types of water quality pollutants generated from urban land uses can be lowered by the use of a variety of stormwater management practices. However, he also points out that "even when effective practices are widely applied, we eventually cross a threshold of imperviousness, beyond which we cannot maintain pre-development water quality" (Schueler, 1994).

A study of sediment control measures in Maryland showed that the sediment traps and basins used at the time of the study were not very effective (Schueler and Lugbill, 1990). The study found that only a 46 percent sediment removal rate could be considered to be a representative estimate of the effectiveness of existing sediment control designs in Maryland. No sediment control measures were found to be 100 percent effective over the entire length of time they were in operation. In addition, it was found that small-sized sediments (i.e., extremely fine clays and colloids) may be very difficult, if at all possible, to trap within the control measures. It should be noted that the Maryland and Montgomery County sediment and erosion control design standards have been revised to increase sediment-trapping efficiencies, because of the results of the study; it is not known how much improvement has occurred on land development sites with these changes in design standards. Even with improved designs, however, the success of sediment control measures are highly dependent on proper construction, inspection, and maintenance of these measures on the site.

Some characteristics of healthy stream systems that are typically diminished or eliminated by extensive land development in the watershed may not be fully mitigated by engineered measures. Reduced stream baseflow due to impervious surfaces covering groundwater recharge areas may not be fully brought back to pre-development flow patterns with current engineered best management practices. Several types of stormwater management facilities can generate warm water discharges, including those that previously were thought to be thermally neutral (e.g., infiltration-dry ponds) (Galli, 1990).

Some engineered best management practices are effective at mitigating some of the impacts resulting from urbanization, but may exacerbate or create other adverse conditions. A well-known example of this is the SWM retention facility (i.e., wet pond). This type of facility can be effective at trapping many water quality pollutants, but it introduces warm water discharges into the stream, which can only be partially mitigated.

[8] Non-point source pollution is pollution that originates from diffuse sources and not from discernible, confined, or discrete sources. For example, fertilizers or pesticides on a lawn that are carried in surface water runoff to a stream are non-point source pollutants. In contrast, nitrogen and phosphorus compounds discharged into a stream from a wastewater treatment plan are point source pollutants.