

## STORMWATER BMPs AND TECHNOLOGY IN 1993

Ben Urbonas, P.E.  
Chief Master Planning Program,  
Urban Drainage & Flood Control District

### ABSTRACT

The use of separate stormwater Best Management Practices (BMPs) has become common practice throughout the world. Much of this technology is emerging and it is often used without full understanding of its limitations and without recognizing the effectiveness of various BMPs under field conditions. This paper discusses a number of structural and non structural BMPs. The assessments presented here are based on extensive literature review, field observation and discussions with stormwater professionals in many parts of United States about their experiences in how well these BMPs performed.

### INTRODUCTION

Current literature describes a variety of techniques to reduce pollutants found in *separate urban stormwater runoff* (i.e., not *combined sewer systems*). Many of these same practices can also be applied for areas served by combined sewer systems to reduce the frequency of overflows and to enhance its quality. These techniques depend on facilities that provide passive treatment and on "good housekeeping" measures. As a group they have been labeled as *best management practices*, or BMPs. After considerable literature review, Roesner *et al.* (1989) concluded the following about structural BMPs:

"Among all these devices the most promising and best understood are detention and extended detention basins and ponds. Less reliable in terms of predicting performance, but showing promise, are sand filter beds, wetlands, infiltration basins, and percolation basins. All of the latter appear to be in their infancy and lack the necessary long-term field testing that would provide data for the development of sound design practices."

Information that has been published since 1989 has expanded our understanding of BMPs and their performance.

### OBJECTIVES IN BMP USE FOR STORMWATER QUALITY MANAGEMENT

The following five basic objectives, summarized conceptually in Figure 1, have evolved to improve urban stormwater quality:

- Prevention. Prevention of pollutant deposition on urban landscape.
- Source Control. Preventing pollutants from coming into contact with precipitation & runoff.
- Source disposal and treatment. Reduction of volume and rate of surface runoff at, or near, its source.
- Follow-up treatment. Interception of runoff downstream of all source and on-site controls using structural BMPs to provide follow-up treatment.

## NON-STRUCTURAL BEST MANAGEMENT PRACTICES

Non-structural BMPs include a variety of institutional and educational practices. Some of these non-structural practices deal with the land development and redevelopment process. Others focus on educating the public to modify its behaviour that contributes to pollutant deposition on urban landscape; while still others search out and disconnect illicit wastewater connections, control accidental spills, and enforce clear violations of ordinances designed to prevent the deposition of pollutants on the urban landscape. Non-structural BMPs include:

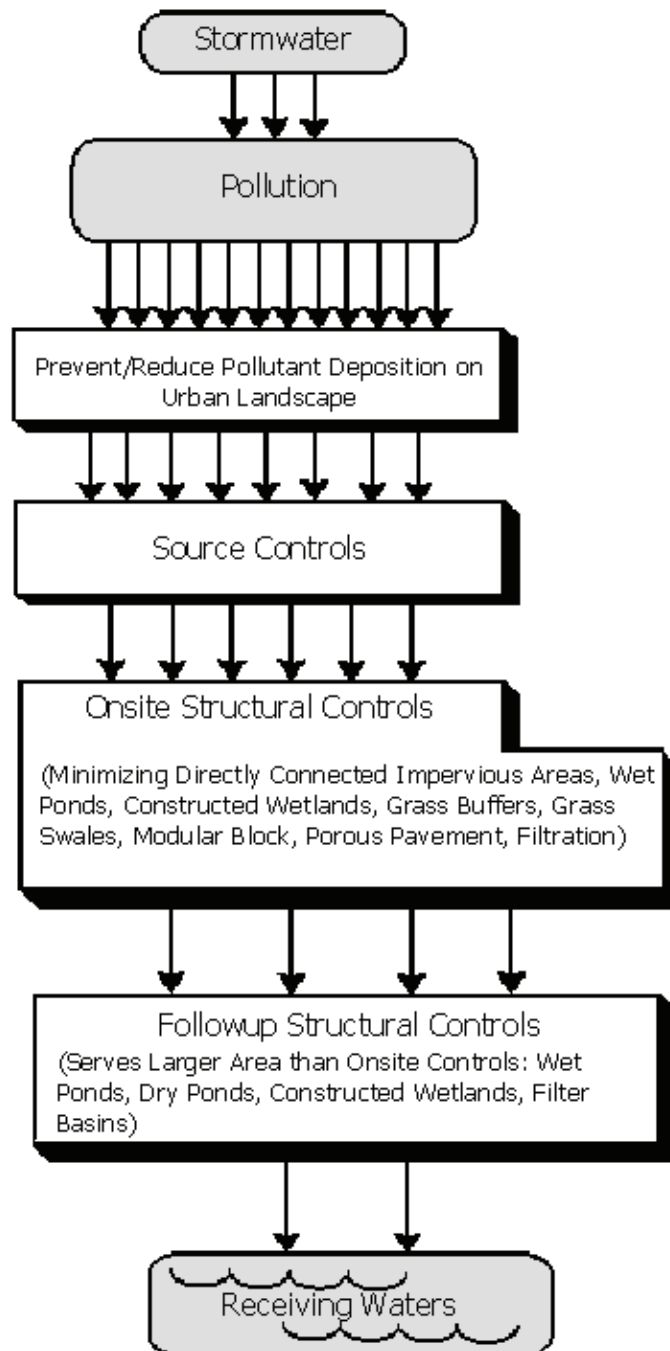


Figure 1. BMPs in Series to Maximize Water Quality. (After UDFCD, 1992)

- Adoption and implementation of building and site development codes to encourage or require the installation of structural BMPs.
- Adoption and implementation of site disturbance control programs.
- Encouraging the use of *minimized directly connected impervious area* in new development, including: the use of landscaped areas, grass buffers, and roadside swales instead of curb, gutter and storm sewer.
- Public education on proper use and disposal of household chemicals, paints, solvents, motor oils, pesticides, herbicides, fertilizers, antifreeze, etc.
- Street sweeping, leaf pickup and efficient street deicing programs.
- Detection and elimination of illicit discharges of wastewater lines to separate storm sewers.
- Enforcement of the operation and maintenance requirements of privately owned stormwater management facilities, including structural BMPs and non-structural programs on-site.

## STRUCTURAL BEST MANAGEMENT PRACTICES

Stormwater runoff quality enhancement begins with the avoidance and prevention of pollutant deposition onto the urban landscape (Urbonas and Stahre, 1993). Structural BMPs act only as a backup to the "good housekeeping measures" being practiced within any community. Among others, structural BMPs include:

- Minimized directly connected impervious area. This practice is especially useful in developing and redeveloping urban areas. It relies on non-traditional layout of urban streets, parking lots and buildings to slow down the disposal of stormwater runoff. Figure 2 compares traditional drainage practices with those minimizing directly connected impervious areas.
- Infiltration Practices. These practices include the use of *swales*, *grass buffer strips*, *porous pavement*, *percolation trenches*, and *infiltration basins*. Water that is infiltrated becomes a part of groundwater flows. As a result, care must be taken when using infiltration near well fields, and this practice is not recommended for use in sites that have gasoline stations, chemical storage areas and other chemically contaminated urban land uses.
  - *Grass Swales*. The slower the flow in a grass swale, the more pollutants will be removed from stormwater through sedimentation; the ultimate being a swale that acts as a linear detention basin.
  - *Grass buffer strips*. To be effective for the removal of heavier sediment particles, grass buffer strips need to have healthy turf-forming grasses. In arid and semi-arid climate they need to be irrigated.
  - *Porous Pavement*. Porous pavement has been in used in United States and Europe since mid-1970s. It is constructed either of monolithically poured porous asphalt or concrete, or out of modular concrete paver block.
  - *Percolation Trenches*. Rock filled percolation trenches temporarily store stormwater and permit its percolation into the ground. Percolation trenches typically serve small impervious tributary areas, namely, two hectares or less.
  - *Infiltration Basins*. Infiltration basins temporarily store stormwater on their surfaces where it eventually infiltrates into the ground. Infiltration basins also serve small sites of two to four hectares of tributary paved surface.
- Filter Basins and Filter Inlets. Use of sand filter basins were first reported by Wanielista *et al.* (1981) and Veenhuis *et al.* (1988). Upstream of, or above the filter media itself, detention storage is needed to even out the flow rates going through the filter. As an alternative to a filter basin, an ingenious sand filter inlet has been suggested by Shaver (1992).

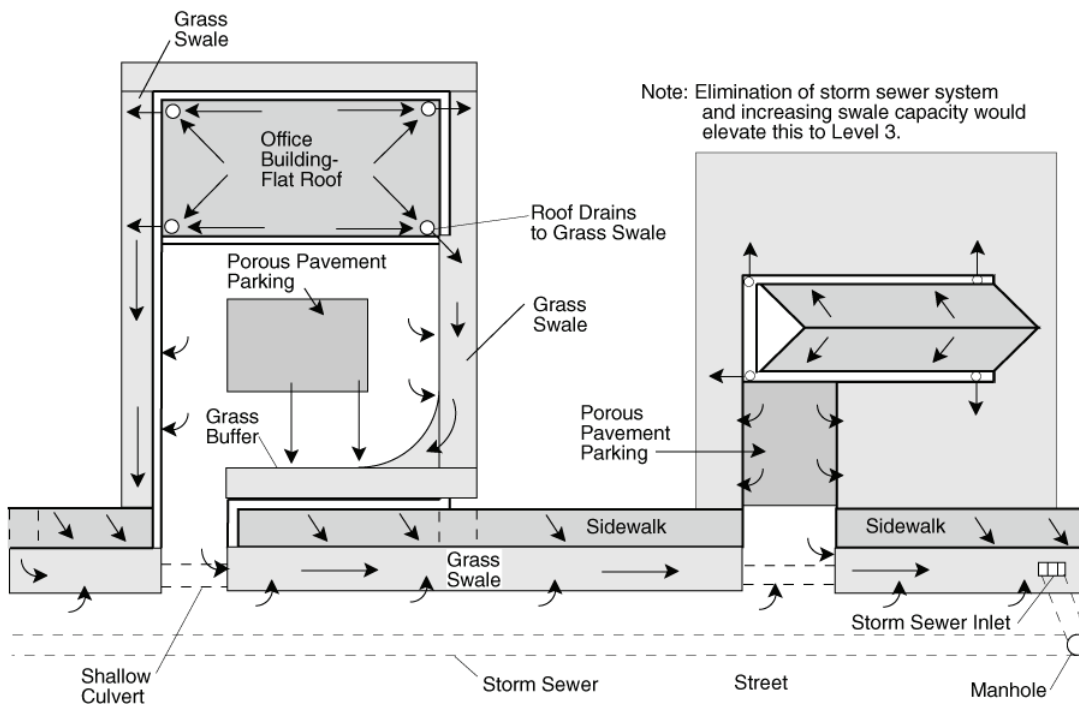
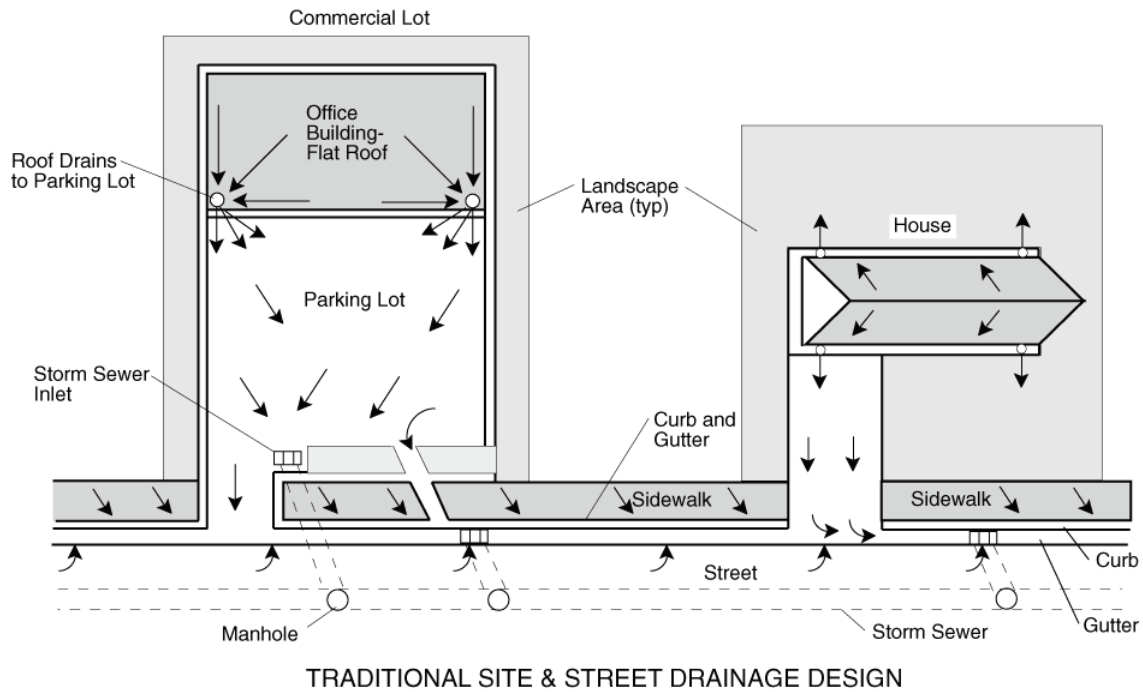


Figure 2. Comparing traditional and minimized directly connected impervious area drainage. (After UDFCD, 1992)

- Water Quality Inlets. Water quality inlets, namely, multi-chambered underground sediment and oil separation vaults have been in use for a number of years in the United States, primarily serving very small tributary areas.
- Extended Detention Basins (Dry). Dry detention basins are the most common type of detention facilities throughout the world. According to Grizzard *et al.* (1986), if these basin

are to serve as water quality enhancing BMPs they need hold stormwater runoff for relatively long periods of time, with emptying time for the 80th to 90th percentile runoff event volume needing to be approximately 24 to 40 hours, thus the term *extended detention basins*. Sedimentation is the main treatment process in these basins.

- Retention Ponds. Retention ponds have a permanent pool with a surcharge detention volume above this pool. Processes that are suspected to be at work in a *retention pond* are sedimentation, flocculation, agglomeration, ion exchange, adsorption, biological uptake and remobilization, solution, and physical resuspension of particulates. In the main body of the pond, pollutants are removed by settling and nutrients are removed by phytoplankton growth in the water column. Marsh plants around the perimeter of the pond help to remove nutrients and to trap small sediment.
- Wetlands. Currently, the use of *wetlands* as a stormwater quality enhancing is an emerging technology. They can be used as source controls or as follow-up treatment devices. Wetland basins, in essence, are another form of detention.

## **AN ASSESSMENT OF BMP EFFECTIVENESS**

### **Non-Structural BMPs.**

Public Education and Citizen Involvement Programs. To be effective, it is necessary to actually modify how the majority of individual use and disposes fertilizers, pesticides, herbicides, crankcase oil, antifreeze, etc. To what degree and in what numbers changes in behavior can be achieved have yet to be answered. The more aggressive the public education process, the more effective it may be. Programs that also facilitate the disposal of unwanted household products, such as used oil and unwanted household toxicant disposal centres, are likely to increase public participation.

Street Sweeping, Leaf Pickup and Deicing Programs. Prior to 1983 U. S. EPA demonstrated through field tests that street sweeping has little effect on improving the quality of stormwater runoff. It is possible, however, that strategically scheduled sweepings in the fall and in winter months can reduce the load of leaf litter and street deicing products reaching receiving waters. Street sweeping at this time appears to be most effective at picking up litter and is used for aesthetic purposes.

Local Government Rules and Regulations. Well drafted ordinances, rules, regulations and criteria and their enforcement can provide the basis for an effective stormwater management program especially in providing structural BMPs and erosion and sediment control for new land development and redevelopment. Installing structural controls as land develops or redevelops is less expensive than retrofitting structural BMPs later.

Elimination of Illicit Discharges. Untreated wastewater discharged through illicit connections is a public health concern, which justifies efforts to find and eliminate illicit wastewater connections. Illegal dumping, however, because to its covert nature, is almost impossible to control.

### **Structural BMPs.**

Minimize Directly Connected Impervious Area. This can be a most effective stormwater best management practice for use in developing and redeveloping areas. It is not possible to provide a simple estimate of the reduction in pollutant loads, this practice, however, reduces peak flow rate of stormwater runoff, its volume and in the load of pollutants that it carries. Under ideal site conditions, surface runoff from storms with less than 13 to 25 mm of rainfall can be virtually eliminated.

Grass Swales. Removal rates exceeding 80 percent of suspended solids by grass swales were suggested by Whalen and Callum (1988). This may be possible when soils have high infiltration rates and the swales have flow velocities less than 0.15 m/s. More typically, pollutant removals are not that high. Grass swales can be effective when land slopes are less than 0.03 m/m.

Grass Buffer Strips. Grass buffer strips can remove larger particulates, provided the flow is kept very shallow and slow. Under ideal conditions, removals of 5 to 25 percent of suspended solids have been suggested. Buffer strips are an important part in a series of practices that act in combination with each other, such as infiltration, percolation, wetlands and detention.

Porous Pavement. Field evidence indicates that modular pavement block porous pavement is the only form of porous pavement that can be recommended for use at this time. This type of pavement has been in use since the mid-1970's (Day *et al.*, 1981; Smith, 1984; Pratt, 1990) with very few reported problems. On the other hand, Schueler *et al.* (1991) and others have reported that monolithic porous pavement surfaces tends to seal within one or two years after their installation. Estimates of pollutant removals for modular porous pavement range from range from zero to 95 percent, depending on the pollutant and on the site conditions.

Percolation Trenches. Groundwater mounding can develop under a trench and it can surface within the trench. Schueler *et al.* (1991) report that about 50 percent of percolation trenches constructed in the eastern United States have exhibited failure. When properly operating, percolation trenches can remove up to 99 percent of particulates.

Infiltration Basins. The buildup of a groundwater mound under an infiltration basin and the sealing of its infiltrating surfaces are the two major causes of failure. Schueler *et al.* (1991) report that as much as 90 percent of infiltration basins installed in Maryland, U.S.A. over the last 15 years have failed. Properly operating basins can remove anywhere from zero to as high as 70 to 99 percent of the pollutants found in stormwater, depending on the constituent and site conditions.

Sand Filter Basins and Filter Inlets. Filters can be very effective BMPs where land area is at a premium, but they need regular maintenance to keep working. Sand filters can be oversized, however, to reduce their maintenance frequency. Average removal efficiencies reported by Veenhuis (1989) for a sand filter in Austin, Texas were between 60 and 80 percent for suspended solids, biochemical oxygen demand, total phosphorus, total organic carbon, chemical oxygen demand and dissolved zinc; while concentrations of dissolved solids in the effluent were 13 percent higher than in the influent. Average concentrations of total nitrite plus nitrate (NO<sub>2</sub> + NO<sub>3</sub>) were 110 percent higher in the effluent than in the inflow. Sand filter inlets suggested by Shaver (1992), while effective, are expensive to construct and, as a result, are most likely for use where land costs are very high. Filter basins, on the other hand, are only marginally more expensive to build than detention basins.

Water Quality Inlets. Episodal evidence over a number of years indicates poor performance by water quality inlets (i.e., sand and oil and grease traps). Recent field studies by Schueler *et al.* (1991) confirmed this. These devices are very expensive and appear to offer very little water quality enhancement in return.

Extended Detention Basins. Performance of extended detention basins is documented by field and laboratory data. Removal rates range from 10 to 90 percent, depending on the constituent and geometry of the installation. For similarly sized extended detention basins, removal rates for total suspended solids, lead and other less soluble constituents are only marginally less than observed for retention ponds and wetlands.

Retention Ponds. Hartigan (1989) stated that retention ponds can remove 40%-60% of phosphorus and 30%-40% of total nitrogen. Other studies show lesser annual removal rates. Schueler (1992), based on studies in Washington, D.C. area, reports that permanent pools can act as heat sinks resulting in warm water releases, and retention ponds may not be appropriate for use if they discharge to streams that support trout.

Wetland Basins. Wetlands do not appear to remove pollutants any better than detention basins or retention ponds. The claim that they are more effective in the removal of nutrients from stormwater has not yet been substantiated by field data. To remove nutrients, regular harvesting and "mucking out" will probably be required; however, even with regular harvesting nutrient removal rates have not been shown to improve significantly. This technology suffers from lack of prolonged field studies needed to answer how wetlands respond to stormwater loadings over an extended number of years.

TABLE 1. BMP Percent Pollutant Removal Ranges. (Colorado S.W.T.F., 1990)

Type of Practice	TSS	Total P	Total N	Zinc	Lead	BOD	Bacteria
Porous Pavement	85-95	65	75-85	98	80	80	n/a
Infiltration Basin	0-99	0-75	0-70	0-99	0-99	0-90	75-98
Percolation Trench	99	65-75	60-70	95-99	n/a	90	98
Retention Pond	91	0-79	0-80	0-71	9-95	0-69	n/a
Extended Detention	50-70	10-20	10-20	30-60	75-90	-----	50-90
Wetland Basin	40-94	(-4)-90	21	(-29)-82	27-94	18	n/a
Sand Filter Basin	60-80	60-80	(-110)-0	10-80	60-80	60-80	n/a

## SUMMARY

Table 1 summarizes the removal efficiencies of several structural best management practices currently in use in United States. All of them, when properly designed for local soil, groundwater, climate and site geology, will remove pollutants from stormwater. All practices, however, could benefit from well conceived, prolonged (i.e., at least five years) field studies.

## REFERENCES

- Colorado S.W.T.F. (1990), *BMP Practices Assessment for the Development of Colorado's Stormwater Management Program*, Final Report to Colorado Water Quality Control Division, Denver CO.
- EPA (1983), *Results of the Nationwide Urban Runoff Program, Final Report*, U.S. Env. Protect. Ag'cy, NTIS Access No. PB84-18552, Washington D.C..
- Grizzard, T.J., Randall, C.W., Weand, B.L. and Ellis, K.L. (1986), "Effectiveness of Extended Detention Ponds," *Urban Runoff Quality - Impact and Quality Enhancement Technology*, Urbonas, B.R. and Roesner, L.A., Editors, Am. Soc. of Civil Engineers, New York, NY.
- Hartigan, J.P. (1989), "Basis for Design of Wet Detention Basin BMPs," *Design of Urban Runoff Quality Controls*, Am. Soc. of Civil Engr., New York NY, p. 122-144.
- Pratt, C.J. (1990), "Permeable Pavement for Stormwater Quality Enhancement," *Urban Stormwater Quality Enhancement*, American Society of Civil Engineers, New York, NY, p. 131-155.
- Roesner, L.A., Urbonas, B.R. and Sonnen, M.B. (1989), Editors, Design of Urban Runoff Quality Controls, Am. Soc. of Civil Engr., New York NY.
- Schueler, T.R., P.A. Cumble and M.A. Heraty, *Current Assessment of Urban Best Management Practices; Techniques for Reducing Non-point Source Pollution in the Coastal Zones*, (Review Draft). Metropolitan Washington Council of Governments, Washington, D.C., Dec., 1991.
- Schueler, T.R. and Galli, J. (1992), "The Environmental Impact of Stormwater Ponds," *Affects of Urban Runoff on Receiving Systems*, Am. Soc. of Civil Engineers, New York, NY.
- Shaver, E. (1992), "Sand Filter Design for Water Quality Treatment," *Affects of Urban Runoff on Receiving Systems*, Am. Soc. of Civil Engineers, New York, NY.
- Smith, D.R. (1984), "Evaluation of Concrete Grid Pavements in United States," *Proceedings Second Conference on Concrete Block Paving*, Delft, Australia.
- UDFCD, *Urban Storm Drainage Criteria Manual: Volume 3 - Best Management Practices*, Urban Drainage and Flood Control District, Denver CO.
- Urbonas, B, and Stahre, P. (1992), *STORMWATER - Best Management Practices and Detention*, Prentice Hall, Englewood Cliffs, NJ, 1993.
- Veenhuis, J., Parish, J., Jennings, M. (1989), "Monitoring and Design of Stormwater Control Basins," *Design of Urban Runoff Quality Controls*, Am. Soc. of Civil Engr., New York NY, p. 224-238.