Stormwater Management for the 1990's

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As America enters the last decade of the 20th century, local governments and their citizens prepare for changes in drainage design.

Historically, stormwater management has been limited to planning, designing and implementing storm drainage improvements. For the most part, planning and design have focused on protecting only the site being drained, with little consideration of the downstream effects of resulting increases in volume and peak flows.

But as America enters the last decade of the 20th century, local governments, having witnessed the downstream flooding damages that result from current drainage design practice, and citizens who want better water quality in their urban lakes and streams are ready for a change in the traditional practice of drainage design. This new comprehensive stormwater management approach controls both the quantity and quality of stormwater runoff, so the total system is protected from flooding and water-quality degradation.

Congress, in its 1987 reauthorization of the Clean Water Act (CWA), provided additional impetus for controlling the impacts of stormwater runoff. Under the 1987 CWA amendments, the U.S. Environmental Protection Agency (EPA) is required to institute a national pollutant discharge elimination system (NPDES) permitting program for urban storm drainage systems. By 1992, communities with populations of 100,000 or more likely will be required to obtain NPDES permits for stormwater management systems.

A practical approach that addresses drainage and water quality on a watershed-wide basis comprises seven key elements:

1. Policy decisions for acceptable levels of drainage service;
2. Implementation of best management practices (BMPs) for control of runoff quantity and quality;
3. A stormwater management ordinance defining drainage and water quality goals to guide the planning, design, construction and financing of stormwater management facilities;
4. Master planning efforts using mathematical models simulating quantity and quality of stormwater runoff to develop a capital improvement plan for flood control and water-quality protection;
5. Adequate operation and maintenance programs;
6. System monitoring and enforcement activities; and
7. A financing program providing sufficient funds to achieve the previous six elements.

In the drainage setting, level of service means the extent to which stormwater is allowed to pond on the surface during a storm of a designated return interval- a 10-year, 25-year, or 100-year storm. A typical five-level approach is:

- Level A (Superior)- maximum water level below the top of curbs and all traffic lanes open;
- Level B (Excellent)- partial yard flooding and standing water on the shoulder traffic lanes;
- Level C (Standard)- yards flooded, first floor of buildings dry, road flooded except for crown;
- Level D (Substandard)- first floor of buildings flooded, water level up to six inches over the crown of the road;
- Level E (Uncontrolled)- essentially no flood protection.

Different levels of service might be provided for different storms, such as Level A protection for the 10-year storm and Level D for a 100-year storm. Also, the level of service might be different in developed areas from that in new developrnents. In new developments, the drainage systems must meet the standards set by the community for stormwater management. Older areas, however, may not receive that level of protection either because they initially were designed for a lower level of service or because upstream development has increased runoff volumes and peak runoff flows passing through the downstream system, reducing the level of protection below the original design level.

Upgrading these systems to the same level of service as that in new developments can be prohibitively expensive in many cases. The community must decide on the level of service that will be provided in these areas based on approved funding levels for remedial drainage facilities.

The level-of-service approach applies only to stormwater quantity control, not to control of pollutants in urban runoff. First, the design storms for sizing water quality controls are not the same as those used for designing drainage facilities. Design storms for drainage systems are large, infrequent storms (10-, 25-, 50- or 100-year), while design storms for runoff quality control are small, frequent storms, generally with a return period of one to two months. The “first flush” from these frequent storm events carries the highest concentrations of pollutants.

Second, the cause-effect relationship of pollutants in urban runoff and the impairment of aquatic life in urban streams is difficult to quantify in terms that can be applied to design criteria for runoff control. Also, the pollutant removal efficiencies of the stormwater quality-control facilities are not established well enough to achieve a specified amount of pollutant reduction. Thus, stormwater management is addressed better by the use of BMPs.

An important step in developing a stormwater management program is the adoption of BMPs to reduce the discharge of pollutants in urban runoff as much as possible. BMPs- a term coined by the EPA during the nationwide Section 208 nonpoint source pollution studies conducted in the 1970’s- are structural or non-structural controls or a combination of both designed to reduce the amount of pollution in stormwater runoff.

Structural Controls

Structural controls collect and treat runoff pollution loads to reduce the amount of pollutants reaching the water bodies. Typical structural BMPs for cleansing urban runoff include infiltration devices, wet detention basins and extended dry detention basins. Locating and removing illegal sanitary sewer connections, overflow structures and industrial drains are also considered structural BMPs.

Infiltration trenches and basins capture runoff and allow it to infiltrate into the ground. The soil filters pollutants as the runoff passes through to the groundwater. Although they are the most effective structural stormwater quality control, infiltration devices can be used only where soil conditions allow the captured volume of water to seep into the ground before the next storm.

A wet detention basin consists of a permanent water pool, an overlying zone that can hold the design runoff volume temporarily so it can be related at the allowed peak discharge rate, and a vegetated shallow zone serving as a biological filter during discharge. Wet detention basins cleanse runoff by allowing suspended particles to settle and by removing dissolved pollutants through biological processes such as uptake by aquatic plants and metabolism by phytoplankton and microorganisms.

In addition to providing effective flood and water-quality protection, well-designed and maintained wet detention basins can enhance the surrounding community aesthetically.

An extended dry detention basin captures and holds stormwater runoff long enough to allow suspended pollutants to settle. Relatively long detention times (20 to 40 hours) are required to remove suspended pollutants. Unlike wet detention basins, extended dry basins do not remove dissolved pollutants.

Non- structural BMPs include practices such as street cleaning, fertilizer application control and zoning restrictions to limit population densities. These BMPs are developed to control pollution resulting from construction and to reduce pollutants from roadways, commercial, industrial and residential areas; flood management projects; landfills and other municipal waste facilities; areas associated with applications of pesticides, herbicides and fertilizers; and toxic spill discharges.

Zoning and land-use controls limit the amount of pollutants discharged into the water by restricting development within the watershed. An example of a non-structural approach is the requirement either of a minimum lot size for a single-family residential development or a clustered development of greater density balanced by designating a large portion of the site as natural open space.

Stormwater management strategies for urbanizing areas involve balancing structural controls, such as detention and infiltration basins, with non-structural controls, such as development density restrictions and buffer zones.

Local officials using appropriate engineering evaluation techniques need to consider the BMP options that meet their short and long-term objectives. These options will vary throughout the nation, but in general they must be proven to be technically effective and cost-effective, and they must have community support.

Once a municipality has chosen a policy regarding level of service for drainage and flood protection and has identified water-quality goals, a stormwater management ordinance should be established to guide the development and implementation of the stormwater management master plan.

The ordinance defines the level of service to be provided for drainage control and desired water-quality protection to be derived from the use of BMPs. For example, the municipality may require the peak runoff rates after development not exceed pre-development levels and may set permit requirements for new development and redevelopment. The ordinance also may specify the design criteria for the stormwater management facilities with reference to a technical manual of design details. The responsibilities of the municipality, the users (property owners) and developers are defined, and a legal framework is established for financing and operating the stormwater management system.

Master planning

The master planning process determines the most cost-effective system of stormwater management facilities to meet the runoff quantity and quality control requirements for current conditions and planned development. The keystone is a mathematical model simulating drainage problems under current conditions and assessing the effectiveness of stormwater management controls to mitigate current flooding and prevent flooding from future developments.

The master planning procedures are a facilities plan defining the location and size of new facilities and necessary improvements to existing ones; a capital improvements program for construction to address critical needs while ensuring drainage improvements or new facilities in one area do not cause problems in another; and a tool for evaluating future development impacts on existing and planned stormwater management facilities.

To be acceptable to the community, the master plan must include both immediate plans to solve critical problems and long-term improvements for a balanced stormwater management program. The community must support the program with adequate funds to capitalize, operate and maintain the needed facilities.

The master plan first examines stormwater management on a basin-wide scale without detailed analysis in the small catchment areas. Runoff hydrographs from these large subareas are generated and routed through the drainage system using computerized mathematical models such as the U.S. Army Corps of Engineers HEC-1 and HEC-2 models, the U.S. Soil Conservation Service TR20 and TR55 methodologies or the EPA SWMM model package.

An important consideration is the tradeoff between requiring detention facilities in the subareas or using larger regional facilities to control downstream flows. While regional facilities require more planning and are more difficult to capitalize, watershed studies in northern Virginia have shown the net cost to the community can be 1/2 to 1/3 the cost of small local detention facilities.

Added benefits of regional facilities are better hydraulic performance, more reliable control, easier access for maintenance and the opportunity to incorporate stormwater management facilities into multipurpose assets. Many areas across the United States have integrated detention facilities for flood control into recreational facilities such as baseball and soccer fields, playgrounds and parks.

Once the basin-wide facilities requirements have been developed, the detailed subarea planning can be done. Constraints to local facility planning are limits on volume and peak discharge rates at the lower end of the basin as determined in the basin-wide planning effort. Not all subareas need to be analyzed in detail, only those with known problems. Communities with enough money to solve all known drainage problems, not to mention the unknown ones, are rare.

Water-quality planning also must be discussed. Not enough accurate simulation models exist for runoff water quality; master planning for runoff quality control is a more qualitative science and must be worked into the master plan subjectively, using BMPs for runoff quality management.

Where the master planning effort includes recreational lakes or reservoirs that must be protected, some simple wasteload allocation analyses can be performed. The impacts of urban runoff can be estimated using a lake eutrophication model coupled to a spreadsheet model calculating seasonal or annual runoff pollutant loads based on land use. The required pollution control load reduction then is compared to typical removal efficiencies of the various BMPs. Studies of this nature have been performed for several reservoirs and lakes in Florida, North Carolina, and Virginia.

The capital improvements program outlines the necessary new facilities and improvements identified through the master planning process and determines the priority for construction based on public demands, protection of health and safety and the availability of funds. Typically, the capital improvements program will be a combination of short-term projects that produce immediate results for critical problems and long-term projects such as the construction of regional facilities. A public hearing may be appropriate in finalizing the capital improvements program so the community can be involved in determining the most important projects and the improvements it is willing or able to finance.

A limit to many stormwater management plans in the past is their inflexibility to changes in land use. A recent development in the last decade that has helped stormwater managers avoid this problem is the advent of microcomputer-based stormwater models that can use a database containing current land use files and drainage facilities. These models are a tool for the ongoing evaluation of future development impacts on stormwater management facilities.

Both Cincinnati and Daytona Beach, Fla., are developing these "living models" of their drainage facilities and land-use patterns. As new facilities are constructed or old ones improved, these changes are made to the database. When new developments are proposed or built and zoning changes suggested, city engineers can use the living model to assess the impacts of those changes on drainage system performance. The resulting information can be presented to city councils to assist them in making decisions that affect drainage. It also can assist site-plan reviewers in checking proposed development plans for downstream impacts and guide them in determining the required plan modifications or remedial downstream improvements to accommodate the upstream development.

An ongoing operation and maintenance program is critical to maximizing performance of stormwater management facilities. Although operation and maintenance accounts for about 30 percent of the operating budget of stormwater-management money, little of this money is spent on preventive maintenance. The vast majority is used for remedial maintenance - opening clogged inlets, replacing collapsed culverts and pipes and repairing caved-in drainage ditches.

As stormwater management systems for runoff quantity and quality become more sophisticated, the need for preventive maintenance will become greater. Detention facilities will require periodic sediment removal to maintain flood storage and permanent pool volume. Outlet works must be inspected regularly to remove debris and check for blockage.
Infiltration devices need periodic inspection to prevent clogging. All facilities should be maintained to be aesthetically pleasing so the community regards them as assets rather than liabilities. Such preventive maintenance can go a long way in reducing nuisance flooding during minor storms and minimizing flood damages and threats to human health and safety during extreme events.

With the exception of maintaining a few rain gauges and an occasional flow gauge on a waterway, most urban communities do little to build a base of simultaneous rainfall and runoff data. As a result, most master plans today are developed with uncalibrated models using hydrologic parameters based upon the modeler's experience with applications of drainage models in some other location where data are available. Stormwater engineers, therefore, tend to be conservative in their estimates of hydrologic parameters for models in areas without adequate calibration data. Many of these systems may have been oversized by 20 to 40 percent.

A significant savings in capital costs could be realized by using better calibrated models based on actual rainfall and runoff data from the specific area. But when funding is tight, monitoring often is cut from the budget.

This situation will change, particularly with respect to monitoring the quality of stormwater runoff. The EPA almost certainly will require some water-quality monitoring as part of the NPDES permit for stormwater systems. Moreover, communities will undertake a monitoring program to demonstrate the effectiveness of their stormwater management programs in reducing pollutants in urban runoff and to document the improvements in water quality.

Enforcement is another area traditionally under-funded, but it will become more important as water controls and refined hydrologic controls are built into the stormwater management system.. If they are not, detention ponds may fill prematurely with sediment, outlets may plug and the resulting system may perform more poorly than if no runoff controls existed at all.

Where maintenance of stormwater management facilities is the responsibility of a private entity, such as a homeowners' association, periodic inspection by the appropriate public agency is necessary to ensure these facilities are maintained and operated properly.

Implementing a comprehensive stormwater management program controlling water quality as well as flooding requires significant financial resources. The new federal stormwater management requirements come at a time when federal grants for water-pollution control projects have been replaced by the state revolving fund (SRF) loan program.

Although the SRF program makes loans available below market rate and extends eligibility to non-point source control projects, American cities and counties still must bear full financial responsibility for stormwater management programs.

Many communities that have relied upon traditional tax-based methods to fund drainage improvements now are looking for more equitable financing methods to fund these more ambitious stormwater programs. General fund programs or property taxes are inappropriate since they depend on property values and bear little correlation to stormwater runoff. Additionally, drainage improvements usually are a low priority for limited tax dollars.

Special districts (assessments) can provide segregation of program improvements on a basin-by-basin basis and correlate respective capital improvements to each one. These special assessments may provide necessary capital dollars but usually cannot fund the long-term operation and maintenance, renewal and replacement and monitoring needs of a comprehensive stormwater management program.

Many communities are implementing stormwater utilities that rely on user fees rather than traditional tax revenues. Like a water or wastewater utility, the stormwater utility is user-oriented, with costs allocated according to the services received. Charges are related to a given parcel's stormwater runoff in excess of that contributed in its natural, undeveloped, state. Thus, each parcel of land in a jurisdiction is assessed a fee based on its runoff characteristics.

The fee structure is based on an equivalent residential unit (ERU), which is the average impervious area for all dwelling units (single-family, multi-family; condominiums and mobile homes) in an area. The runoff potential for parcels in all other land-use categories then is assessed by the number of ERUs equal to the impervious area contained on each parcel. Typical monthly charges range from $2-$3 per ERU.

This equitable funding system can generate ongoing revenue from monthly user fees to cover planning, design and construction of facility improvements; operation and maintenance; monitoring and enforcement; and the administrative management requirements of a comprehensive stormwater management program.

Stormwater management in the last decade of the 20th century will have a new and more comprehensive focus. As engineers and local governments try to mitigate downstream flooding due to upstream development, stormwater quality controls will become more sophisticated, requiring that post-development runoff peaks do not exceed those of pre-development conditions. Consideration of pollution caused by urban runoff will require integrating stormwater runoff quality controls into storm drainage facilities.

Furthermore, the public will demand that stormwater management facilities be an aesthetically pleasing compliment to the urban landscape. Substantial funding will be required at a time when federal grants are unavailable and public tax rebellions are common.

This new stormwater management focus presents a challenge for municipalities. Communities can implement an effective stormwater management program that will provide immediate and long-term improvements to control the drainage and water-quality impacts of urban runoff. By implementing a stormwater utility, American cities and counties can be sure of an ongoing revenue source to fund the program and meet federal NPDES permit requirements.

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