WET WEATHER FLOWS IN NEWLY URBANIZING AREAS: INITIAL THOUGHTS ON DESIGNS FOR THE FUTURE

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Abstract. Newly urbanizing areas have a unique opportunity to contribute significantly to the solution of urban wet weather flow problems. Adopting and implementing management techniques at the time of development may be more efficient than retrofitting existing areas. However, in order for significant progress to occur, these techniques and the methods used to design them must be practical, cost-effective, and acceptable to the public. This paper examines some of the issues related to wet weather flow management in newly urbanizing areas and some of the on-going activities to develop a guidance manual.

INTRODUCTION

Precipitation falling over an urban watershed passes through an extremely complex hydrologic and hydraulic system (Nix, 1994). As it moves through this system it concentrates into larger and larger flow streams and picks up a suite of pollutants in the process. An urbanized area is, by definition, an area of concentrated human activity. With this activity comes an increase in runoff volumes and flow rates due to the covering of much of the surface with impervious materials (concrete, asphalt, etc.). In addition, an urban area can only be maintained by a large influx of a great variety of materials. Subsequently, there is a high concentration and diversity of waste materials. Some of this waste is transported from the urban area to receiving waters by wet weather flows. This transport process is very efficient since urban areas generally have elaborate drainage systems to quickly remove runoff. Essentially, an urban area produces larger, more diverse waste discharges and no longer has the physical, biological, and chemical "buffers" it had in its natural state.

The engineering community's view of urban wet weather flows has changed and evolved over the years. In earlier times, the concern was for flood control and removing runoff as expeditiously as possible. In more recent times, the cross purposes of efficiently removing runoff from streets and parking lots and yet not overwhelming receiving waters led to more comprehensive management techniques. Presently, engineers and planners are faced not only with the control and management of runoff quantity but the maintenance of water quality as well.

Urban wet weather quantity problems remain a high priority in most localities. However, interest in urban wet weather quality has swelled as a result of the 1987 Water Quality Act. This act, which amended the 1972 Clean Water Act, outlines a permitting system to regulate stormwater discharges from medium and large municipal storm sewer systems, current holders of NPDES (National Pollutant Discharge Elimination System) permits, and a host of industrial activities. The USEPA published regulations in November, 1990 to flesh out the permitting system (Federal Register, 40CFR, 1990). The result is that a good portion of urban wet weather discharges in the United States will be handled, from a regulatory perspective, as "point" sources of pollution.

We are in the initial stages of a USEPA-funded project to develop a guidance manual for wet weather flow management in newly urbanizing areas. This paper summarizes some of our initial thoughts and work on the topic.

URBAN WET WEATHER QUANTITY PROBLEMS

Precipitation falling on an urban watershed will strike either a pervious or impervious surface. On pervious surfaces most of the rainfall infiltrates to the subsurface while a small part remains as surface runoff. A portion of the infiltrated water may take a relatively slow subterranean path to a surface stream. On impervious surfaces nearly all rainfall becomes surface runoff. Surface runoff from both surfaces finds its way to channels and streams. Urban drainage systems speed this process along.

Urban watersheds are, of course, characterized by impervious surfaces and efficient drainage systems. The increased volumes and flow rates of runoff produced under these conditions have a number of harmful impacts, including the following (Nix, 1994):

- **Flooding**. Developed areas and their drainage systems are usually very good at discharging runoff -- so much so that they transfer the problem to downstream locations that may not be as hydraulically efficient. The result is localized flooding. On the other hand, older or inadequately designed drainage systems can themselves be overwhelmed by runoff from increased urbanization. The result is flooding at the "headwater" of the drainage system.
- **Stream Erosion**. The increased runoff accompanying urban development increases the bed load or sediment-carrying capacity of a stream. This diminishes the integrity of the stream bed and stream banks. In addition, the sediment load

carried by a stream can accumulate at downstream points where the flow characteristics (e.g., velocity) are such that the bed load capacity is reduced.

- **Habitat Destruction**. A stream ecosystem is a delicate balance between all of its biological and chemical components. It is also in a precarious equilibrium with the physical environment. Increased runoff to a stream changes this balance and can threaten the established ecosystem. Increased thermal loads normally associated with urban runoff can also disrupt sensitive ecosystems.

URBAN WET WEATHER QUALITY PROBLEMS

As rainfall moves through the atmosphere it washes out air pollutants and carries them to the Earth's surface. Rain drops striking the surface will dislodge some particles (mostly soil on pervious surfaces; a wide variety of dust and debris on impervious surfaces) and dissolve other materials. Surface runoff carries the particles dislodged by the initial precipitation impact, other particles dislodged by the movement of the runoff itself, and a number of dissolved materials to drainage systems and watercourses. In some cases, the infiltrated water will threaten aquifers with a variety of pollutants.

Pollutant Sources. The pollutants carried from the watershed surface come from a number of sources such as: transportation, industrial activities, decaying vegetation, soil erosion, animals, fertilizer/pesticide application, deicing agents, dryfall, and general litter. Pollutants may also be contributed by the watershed's natural and manmade drainage systems. In natural channels, erosion can produce a significant amount of pollution, as can the resuspension of settled materials in manmade channels and sewers.

Other sources of urban wet weather pollution are plentiful and may include: leaking sanitary sewers, direct connections of sanitary sewers to storm sewers, poorly operating septic tanks, illegal disposal to storm sewer systems, accidental spills, leaking underground storage tanks, leachate from landfills, or leakage from hazardous waste sites.

The range and variety of sources of wet weather pollution is extensive and somewhat overwhelming. This has no doubt led to the rather haphazard measures taken in the United States to manage wet weather flows. Newly urbanizing areas may have, however, a better opportunity to "do it right" than existing urban areas.

WET WEATHER FLOW MANAGEMENT IN NEWLY URBANIZING AREAS

The fragmented approach to wet weather flow management in the United States is probably a result of at least three factors. First, individual property rights are among the most cherished of American values. Many wet weather flow management techniques infringe on those rights. Second, the American governmental system is a cauldron of levels and competing interests. It is not unusual for several governmental entities to be involved in wet weather management for a given area. Third, we understand little about wet weather flows, the pollutants they carry, and the impact of those flows and pollutants. And what we do know has not been well communicated to mainstream America. Americans have traditionally viewed wet weather flow as "clean" water. Should it surprise anyone that when a more dramatic environmental problem comes along wet weather flow takes a back seat? Is it any wonder that so little has been done or that it is so difficult to stir up interest, much less initiate action?

These factors will not change significantly in the foreseeable future. Wet weather flow management will probably not occur by large coordinated efforts backed by significant public concern and funds. While it is true that there have been some interesting successes, most of these have occurred in "upscale areas" with disposable public income and/or the political clout to attract state and federal funds. Artificial situations. Artificial results.

So how is the problem, when we decide exactly what it is, going to be solved? Much of the urban growth in America is relatively uncontrolled and much of it occurs in areas far more interested in economic growth than environmental quality. Existing urban areas will, for the most part, not lead the effort. "Retrofitting" for comprehensive wet weather flow control is an expensive luxury that few urban areas can afford. However, one extraordinary opportunity exists. The incorporation of control measures in newly urbanizing areas is probably fairly painless, especially if the marginal costs above and beyond the normal drainage functions are low. Many American cities have grown 50% or more over the last 25 plus years. The inescapable truth is that if measures had been incorporated in these areas as they were constructed, the nation's wet weather problem would have already been reduced at a cost that would almost certainly be less than an "equivalent" amount of retrofitting. Starting now to incorporate control measures in expanding urban areas will help to avoid continuing this truism 25 years from now.

While wet weather flows are the focus of this study, it is foolish to separate them from dry weather flows. Both have impacts on the same receiving waters. The most effective design methodology will view the water resources of an urban area in an integrated fashion.

WET WEATHER MANAGEMENT OBJECTIVES

Wet weather management involves the prevention, transport, and treatment of excess runoff flows and pollutant loads. Prevention is often the technique of first choice since the control of flashy, dynamic flows and loads is expensive and difficult. Upland controls, "best" management practices, and good "housekeeping" prevent pollutants from being carried along with storm flows or entering the drainage system. Preventative measures such as detention basin, infiltration basins, and porous surfaces can all be used to replace the natural storage lost through development. Runoff flows and pollutant loads not captured by upland controls enter a drainage or transport system. Here there are opportunities for controls as well, with in-line storage or other hydraulic measures leading the list. Treatment of "end-of-the-pipe" flows can be accomplished by a variety of storage-treatment systems, perhaps integrated with dry weather treatment facilities.

Regardless of the actual technology used, the objective of wet weather management is to control runoff flows and pollutant loads in a cost-effective manner. Ideally, wet weather controls are implemented in concert with an overall urban wastewater management scheme. However, as mentioned above comprehensive, large-scale efforts are difficult to achieve. We are not proposing that such efforts be abandoned. We are proposing that the engineering profession lead the way to good sense, practical management measures much as it has done in other ways to protect the public welfare and that the effort be focused on the typical development enterprise.

CHARACTERISTICS OF A GOOD DESIGN METHODOLOGY

The literature is replete with design methodologies and planning strategies for wet weather flow management. Few have gained wide practice. Some of this is due to the lack of pressure to solve the problem. Equally at fault is the fact that most are not geared toward the practicing engineer. We feel that a good design methodology will have the following characteristics:

- focused on micro-development (tens of acres),
- robust and flexible,
- cognizant of the expense of data collection and management,
- reproducible and consistent,
- uses the power of the computer found on nearly every engineer's desk,
- uses widely accepted models to simulate the wet weather flow system,
- uses levels of spatial and temporal discretization appropriate to the task,
- accounts for uncertainty in the real and modeled systems,
- has a common-sense feel,
- has a rationale easily conveyed to lay persons,
- relatively inexpensive to implement, and
- produces results that are economically, politically, and socially acceptable in the average urban setting.

A successful methodology will lead the effort to manage wet weather flows and pollutant loads from newly urbanizing areas. In other words, good engineering practice will become the codified approach. This is our basic objective.

REVIEW OF CURRENT AND PAST WET WEATHER FLOW MANAGEMENT PRACTICES

In order to benefit from the insights of the past, we have undertaken a review of current wet weather flow management practices and how they have evolved over time. Over the years many ideas have been proposed, some tried and others not, that may be applicable under current conditions. Ultimately, the goal of this initial work is to chart the progress or regress (depending on your point of view) in the development of design and management strategies and to apply the lessons learned (and perhaps lost) to the development of a "new" design methodology.

Journals dating from 1860 to the present were searched for articles pertaining to stormwater design and management. In addition, books, reports, conference proceedings, and other forms of print were searched. Items related to wet weather flow were recorded into ProCite® (Personal Bibliographic Software, Inc., 1995), a bibliographic software package, for future reference. As references were accumulated a simultaneous critical review was conducted for each reference to determine its applicability. The critical review involved considering the title of the piece of work, possibly reading the abstract or perusing the article, and occasionally reading the entire page.

The literature review initially focused on journals. There are currently over 900 journal papers from nearly 50 different journals referenced in the ProCite database. However, the journal sources have by no means been exhausted. We are continuing our search through these sources and anticipate that this list will grow substantially.

The next part of the review considered the "gray" literature including government documents, conference proceedings unpublished documents, and private and public reports. Government documents were searched for reports related to stormwater management. Federal agencies with major contributions to the field include: the US Environmental Protection Agency (USEPA), the US Geological Survey (USGS), and the Federal Highway Administration (FHWA). This is not to say that other agencies did not contribute significantly, only that to this point the majority of the reports and documents recorded have been published by these agencies. Local and state agency reports were also documented in the database.

Conference proceedings were another area targeted for published material pertaining to wet weather flow. Proceedings are not always easily attained, even if one knows the location and date of the conference. Proceedings have been procured through libraries, interlibrary loan, authors, and sponsoring organizations and agencies. This is considered to be an important vein of knowledge that has not been well organized in the past. This facet of the search will require a great deal more attention.

The database also contains over 220 EPA documents and over 65 USGS reports. These two government agencies are the largest single contributors, with the remaining 120 plus reports being distributed among many state, local, academic, and private entities.

Other references include theses and dissertations, books, private reports, unpublished documents, and other sources discovered while searching through the more conventional sources. As of January 31, 1997 over 2,000 references have been entered into the ProCite database, along with keywords for each. Some references are also accompanied by an abstract or notes describing the content of the work. This will facilitate future use of the database for literature searches.

SUMMARY

We have begun the process of developing a guidance manual for managing wet weather flows in newly urbanizing areas. Addressing the problem in newly urbanizing areas is probably the most efficient way to contribute to the overall solution of wet weather flow problems. Our intent is to produce a manual with practical value for the engineering community and solid technical guidance for regulators.

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