Watershed '96

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Integrated Watershed Approach For Improving Water Quality In The Mill Creek, Cleveland, Ohio

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Project Goals

The Mill Creek project was undertaken with the deliberate intent to integrate facilities planning, aimed at the control of combined and sanitary sewer overflows, with the longer-term goal of developing a comprehensive watershed plan to restore the water quality of this urban stream. In addition, the project recognizes the goals of providing improved management of sewerage and drainage services for the residents of this watershed. In particular, the District has adopted the goal that the project should be integrated with the efforts of local communities to address a variety of flooding issues.

Project Overview

There are several major elements of the project which represent the District's vision of a truly integrated approach to watershed management:

- Source inventory and characterization to aid in developing effective control strategies.
- Comprehensive inventory and understanding of the sewer system.
- Comprehensive assessment of the factors affecting Mill Creek water quality (focus of this paper).
- Integration of broad community goals into facility planning process.
- Public information and feedback process to incorporate community goals into watershed planning.

- Creation of an ongoing process to advocate for sound management of Mill Creek as an important community resource.

Watershed Description

Mill Creek is a tributary of the Cuyahoga River which discharges to Lake Erie in the Cleveland area. Figure 1 shows the Mill Creek along with the 11 cities included in the watershed.

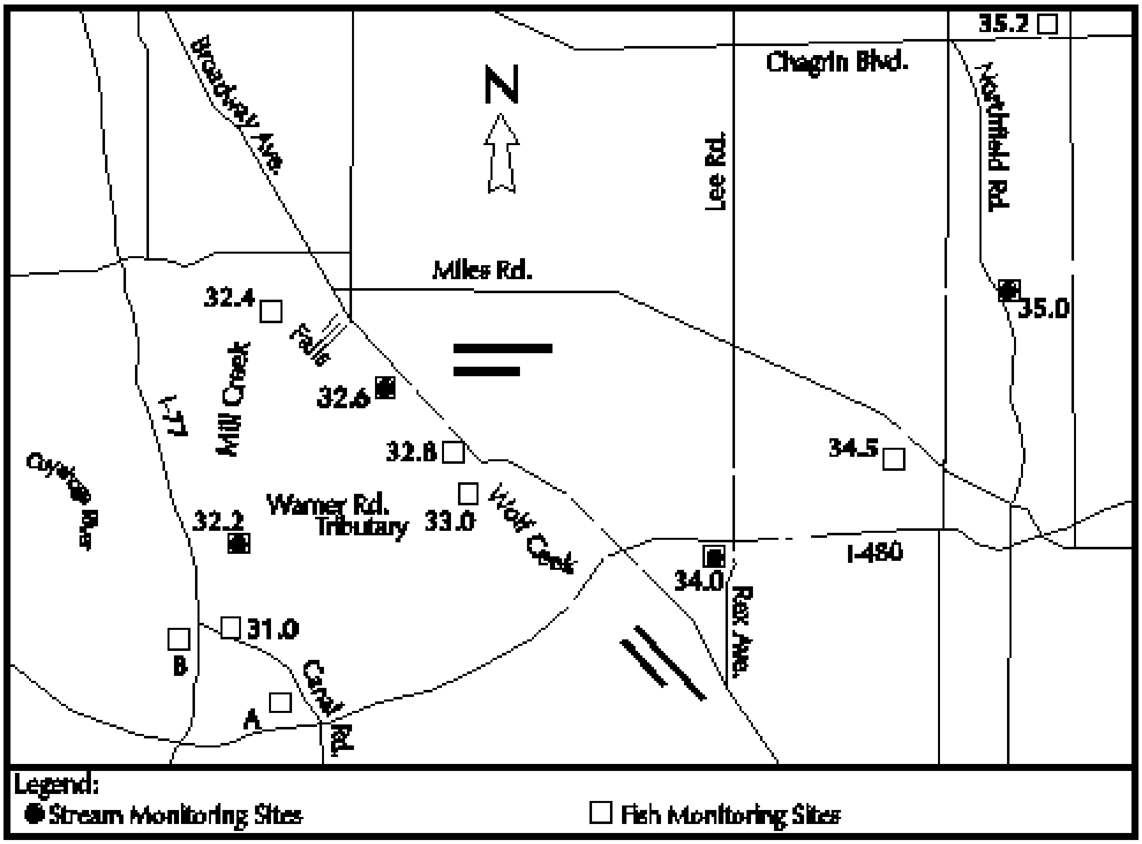

Figure 1. Monitoring sites.

Mill Creek has a drainage area of 23.4 square miles with a length of 12.2 miles. The average stream gradient is 53.5 feet/mile. A unique feature of the water course is the 60-foot falls that effectively divide the upper and lower portions of the stream and provide a virtually absolute barrier to fish migration.

Land use in the watershed is primarily urban, zoned for single and multiple family dwellings. A small portion, located mostly along main streets, is zoned for business and office space or industry. Open space is limited to small parks, cemeteries, golf courses and a race track.

A total of 175 outfalls discharge to Mill Creek and its tributaries. The outfalls may be broadly classified as combined sewer, storm and mixed. While Mill Creek receives inputs of leachates from old adjacent landfills, it has no permitted dry weather sources.

Water Quality Monitoring

The data collected from the Water Quality Monitoring Program was used to assist in evaluating current conditions within Mill Creek. The data was used to aid stream and source modeling and other water resources assessment activities, such as source-receiver interactions and control facilities benefits.

Figure 1 presents the four stream monitoring sites selected to provide complete coverage of stream water quality from the headwaters through to the mouth of Mill Creek. All ten sites shown in Figure 1 were monitored for fish, macroinvertebrates and sediment.

Stream Monitoring

Chemical and Physical Data

Figure 2 shows a typical real-time dry weather data set, conductivity, pH and temperature at station 32.2. Excessive cycling and high stream temperatures, exceeding 30øC at times, were observed at this site. It is thought that this condition reflects the loss of tree canopy which would moderate response to daytime temperature increases.

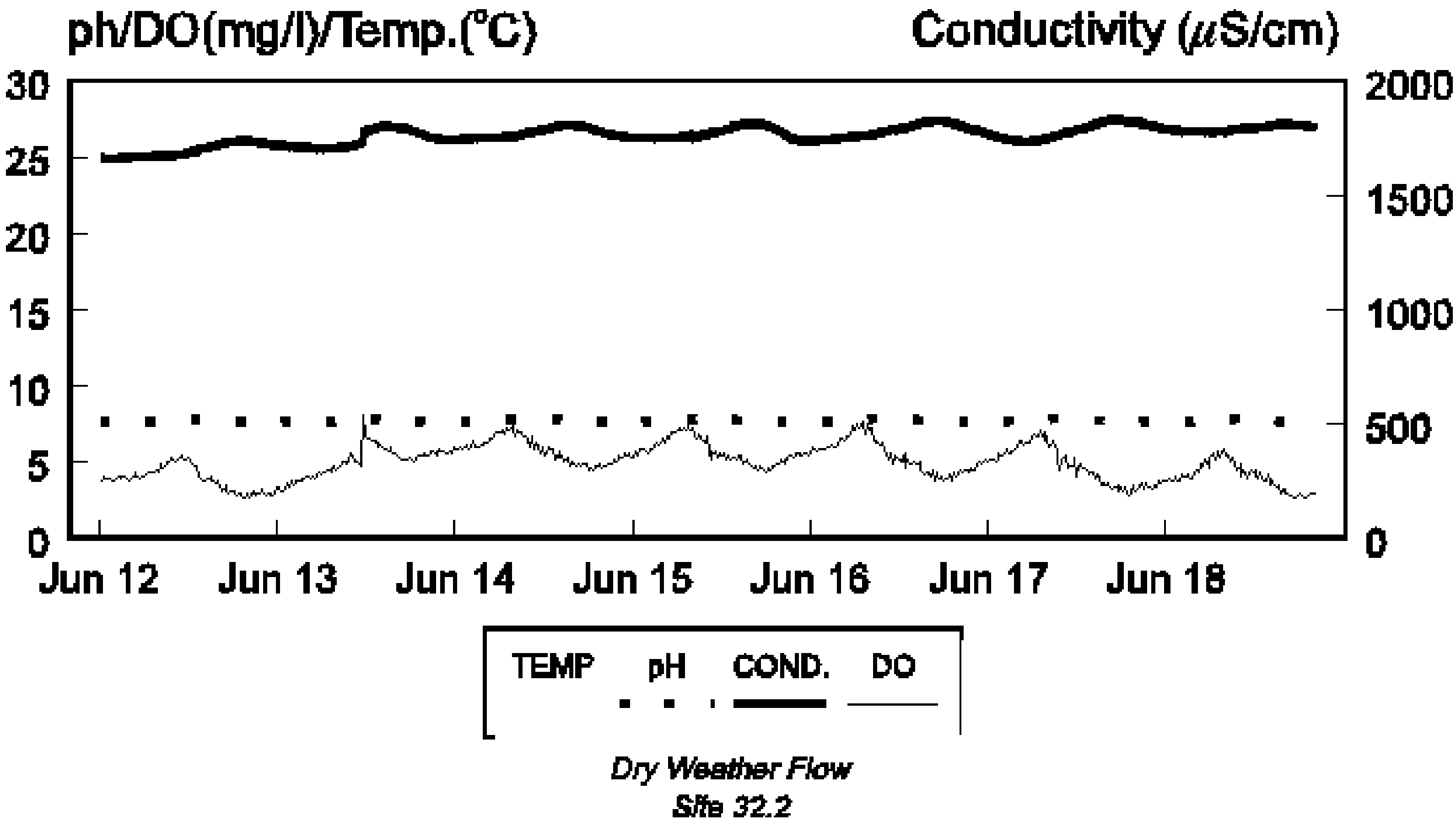

Figure 2. Large temperature variations in Mill Creek occur during dry weather flows at Site 32.2.

Bacteria densities were also measured at four locations in Mill Creek. Figure 3 shows Fecal Coliform and E. Coli pollutographs for the most upstream and downstream stations for the storm event of May 24, 1995. Significantly higher bacteria densities observed near the mouth of the Mill Creek reflect the cumulative impact of a variety of pollution sources including stormwater and downstream CSOs.

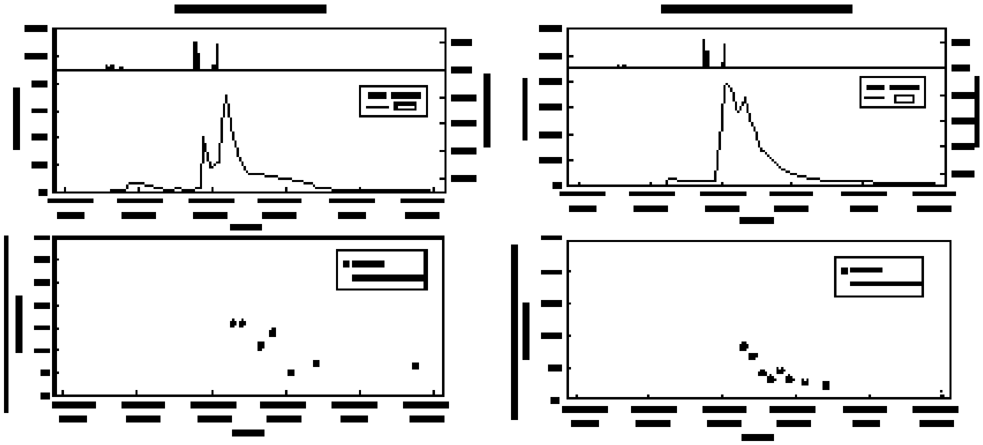

Figure 3. Bacteria concentration in Mill Creek varied with creek flow during the storm event of May 24, 1995.

The dramatic increase in creek flows creating high velocities and bed scour are suspected to contribute to non-attainment of fish and biological activity as measured by biological indexes.

Heavy metals concentrations measured in Mill Creek did not exceed water quality standards except for a couple of instances. Copper and zinc exceeded water quality standards on three occasions during three wet weather events. This is common for stormwater runoff in developed areas.

Biological Data

An extensive biological monitoring program was a major component of the Mill Creek stream assessment. Biological monitoring encompassed fish and macroinvertebrate collection, detailed stream and riparian zone habitat evaluation and toxicity studies during storm and low flow periods. Biological monitoring provided a direct measure of stream ecosystem integrity as well as important data about non-water-quality factors such as habitat conditions which limit the success of aquatic communities.

Early findings from the fish collection program indicated low species diversity and total number of fish at the 13 stream biomonitoring sites, as shown in Figures 4 and 5. The most downstream Station No. 31 showed the influence of the Cuyahoga River on species diversity. In other areas, Mill Creek fish communities generally declined in a downstream direction. No fish were collected at Site 33, Site 34.5, or at the most upstream location, Site 35.2.

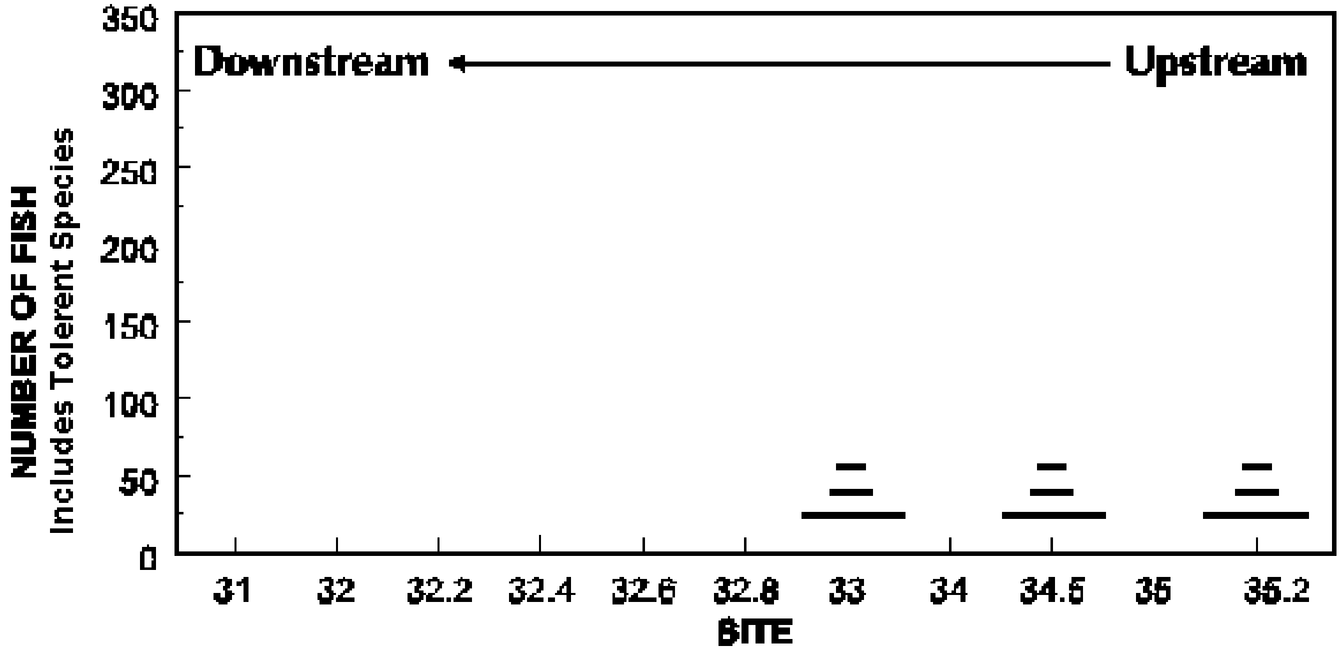

Figure 4. Relatively few fish were counted in Mill Creek during June and July, 1995.

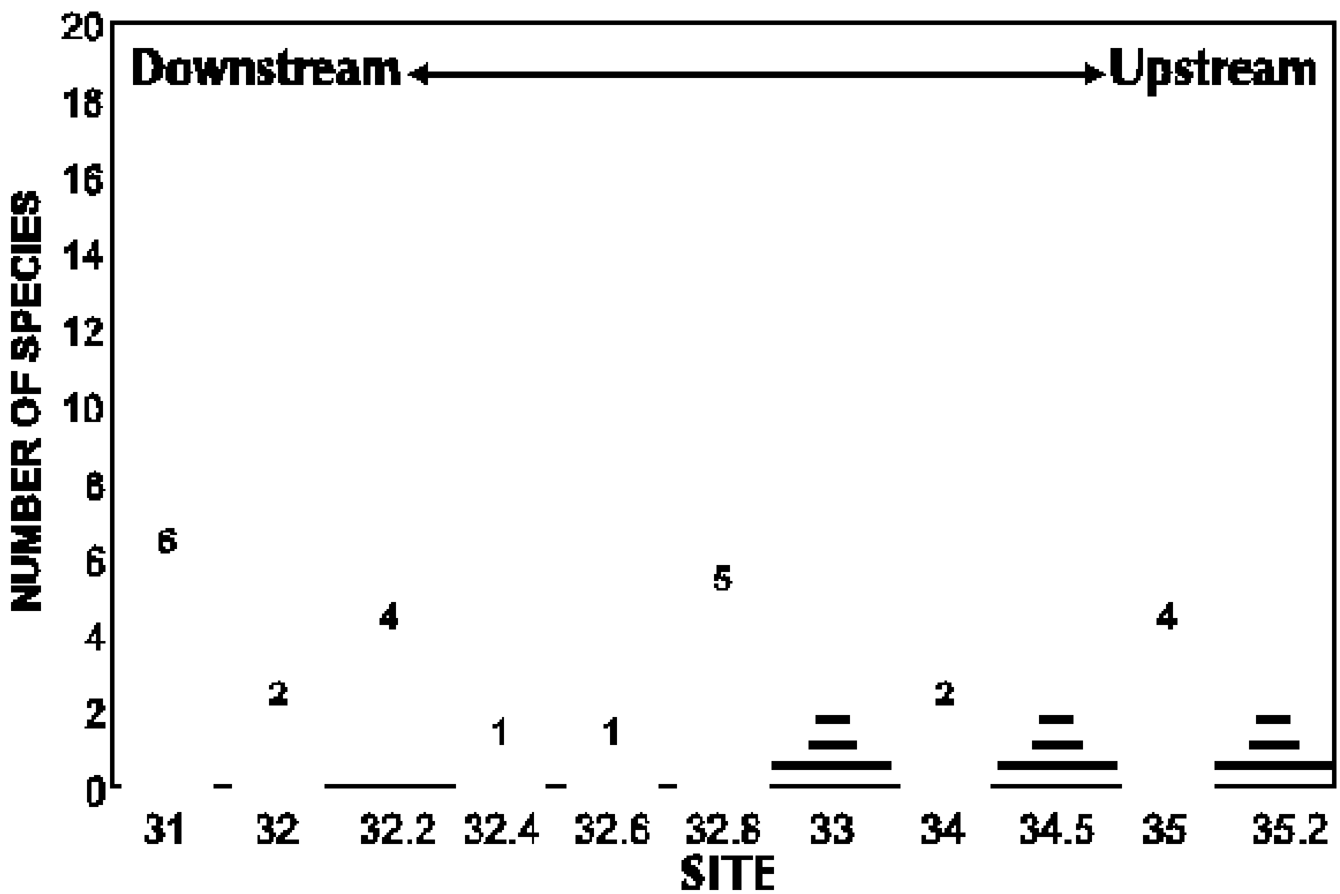

Figure 5. Low fish diversity was measured in Mill Creek during June and July, 1995.

Emerging Issues

Chemical data have shown limited indication of toxicity or low dissolved oxygen levels in Mill Creek to date. However, biological sampling has shown low fish quantities and diversity. It appears, therefore, that stream characteristics affecting the aquatic life in Mill Creek may be one or more of the following:

- Sediment deposition
- Scour
- Pool size at low flow
- Temperature variations
- Range of flow variations

Community Goals And Public Information Program

As part of the facilities planning effort for this watershed, the District developed a public information program to understand and respond to community goals. In addition to public information activities including newsletters, public meetings, neighborhood meetings, and meetings with interested parties, the District has established two committees to provide consultation with the District during facilities planning.

The Policy Advisory Group includes mayors, council members and other policy makers. This group will meet three times at different stages of planning. The Watershed Protection Committee (WPC) is composed of a variety of stakeholders who will participate in five workshops planned by the District. These workshop will solicit input to facilities planning and will also seek to impart information on the factors which limit the uses of Mill Creek. The critical feature of the WPC is the anticipation that this group will reconstitute itself as an ongoing community effort that will advocate for new community actions in areas such as stormwater management and habitat protection.

Conclusion

A major concern for the District is represented by the scenario that after investing substantial sums for control of CSOs and potential sanitary sewer overflows, Mill Creek shows only a marginal response in the direction of attainment of water quality goals.

It is suspected that the real limiting factors are a complex mix which include a dramatically altered hydrologic cycle for the stream and the loss of critical habitat features which we are not capable of adequately quantifying. In turn we are concerned that given irreversible changes in this urban watershed, current water quality standards may not represent a realistic goal. Despite this concern we are hopeful that substantial progress in restoration of stream quality is possible.

While new facilities to control wet weather discharges will play a significant role in this restoration we believe substantial progress also depends on a new sense of stewardship for Mill Creek at the individual and community level. We are hopeful that the ongoing work of the Watershed Protection Committee will be able to make a substantial contribution both in the restoration of Mill Creek and the attainment of related community goals.

Watershed Planning in a Developed Urban Area

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Arlington County is an urbanized area of 26 square miles across the Potomac River from Washington, DC. It was largely developed between 1930 and 1950 when it was the fastest growing county in the United States and is now essentially fully built up, with 60 percent of its land in single-family residential housing. In the last three decades, portions of Arlington have been undergoing redevelopment to higher density office and commercial uses.

County staff are working on a master plan for storm water management which takes a watershed approach to problems such as flooding, runoff pollution, and stream degradation. During plan preparation, we have identified some issues in watershed planning for a small, fully developed jurisdiction which make it different from those for less urbanized areas. Some issues are technical, such as the definition of watersheds and the appropriate scale for planning and computer modeling. More weighty questions involve the legal, regulatory, and equity issues associated with treating citizens differently based on the watershed in which they live.

The Nature of Urban Watersheds

By the strict definition, a watershed is the area of land contributing runoff to an outlet point. Selection of the outlet point determines the boundaries of the watershed. In this respect all watersheds are the same, whether urban, rural, humid, or arid. The purpose of this conference, however, is to take a broader view of watersheds. In the context of watershed management, a watershed is an area contributing to the streamflow, water quality, and ecological health of downstream areas. This definition creates a distinction between urbanized watersheds and those in their natural state.

The primary distinction is the elimination or reduction of natural streams. In the case of Arlington and most older cities, development took place when the only storm water issue was accommodating the amount of flow. Drainage problems were identified by occurrences of flooding or erosion, and the solution was to build a storm sewer or culvert to put the flow underground. As a result, older urban drainage systems consist of a large interconnected system of man-made storm sewers and channels with a few reaches of highly stressed natural streams, many of which have been straightened or otherwise modified. Flows from these drainage networks empty into a receiving water (e.g., the Potomac River, the Great Lakes, the Chesapeake Bay) which is distinct from the system by being large with respect to the network.

Urban watersheds also function differently; for example, stream health is not an issue where there is no stream. Changes in the chemistry of runoff from urban areas are well documented. These include more pollutants, more toxic pollutants, and higher bacterial contamination.

The small size of many urban jurisdictions brings a smaller scale of watershed planning. Arlington's master plan effort focuses on tributaries and sub-tributaries to streams which have a watershed area ranging from about 100 acres to 1,000 acres. More detailed networks are appropriate for drainage and catchment studies related to storm water projects or development impact analysis.

Watershed Size and Scale

Many of the watersheds in a small jurisdiction would not be separately delineated when looking at a larger area. Several of Arlington's tributary streams are considered part of a larger "direct Potomac" drainage area in statewide watershed plans.

Watersheds are frequently defined based on the location and size of perennial streams. In urban areas which are completely storm sewered, this procedure is not possible. Arlington used several evaluation criteria to combine networks of tributaries, channels, and storm sewers into watersheds. The most important were the original drainage pattern and channel/pipe size. Using a map of the storm sewer and stream network, major drainage conduits were identified. This system corresponded roughly to pipes of 72 inches diameter and larger, or culverts greater than 30 square feet in cross-section. Watersheds delineated for these branches matched reasonably well with the original stream watersheds identified from historic USGS maps.

For the master plan effort, each of these watersheds is being be subdivided for further study. The scale to be used depends on the type of planning, analysis, or design to be done. In Arlington's experience, nonpoint source pollution modeling can be conducted on a fairly coarse scale. The catchments average about 50 acres, and pipes smaller than 60 inches diameter are not modeled. The larger pipes and streams are joined into equivalent pipes averaging about 1,000 feet long.

For computerized hydraulic and hydrologic models of the major drainage system, the same pipe networks are used, but without creating equivalents. Lengths and slopes are those found in the field. Because the pipes are shorter, about twice as many catchments are modeled; essentially one for each tributary of 30 inches and larger. These catchments average about 25 acres.

The most detailed modeling uses catchments averaging about 5 acres in size for all pipes 30 inches and larger. A study showed that this was a reasonable threshold, giving the same results for the larger system as a model of the whole pipe network with a fraction of the effort. The study also showed there were no capacity problems in the smaller pipes that would be hidden if they were left out of the model.

Storm Water Management Issues

The impacts of storm water runoff in a small developed area focus on a few issues. As always, one is the adequacy of the drainage system for the quantity of runoff. The amount of storm water flow is clearly a function of watershed characteristics such as land cover, slope, and soils. Regardless of the size of the contributing area, upstream watershed and drainage characteristics govern the amount of flow and timing of peaks. Similarly, downstream channel and storm sewer capacity dictate whether the flows can be handled. Thus the use of watershed boundaries is a necessity for design of drainage improvements.

There are situations where it may be appropriate to require different design criteria for storm water systems in different watersheds. One example in Arlington is Four Mile Run. Since 1976, developers in this watershed have had to provide detention for the 100-year storm to preserve capacity in a flood control channel financed by the Corps of Engineers.

Runoff pollution is a second issue. In Arlington, it affects the water quality of both the small tributaries and the Chesapeake Bay. As with the quantity of flow, the quality is a function of the watershed characteristics. However, in urban areas, runoff quality doesn't differ significantly by watershed. This is because the single most overriding characteristic of the watershed in estimating runoff quality is whether it is developed or not. The Nationwide Urban Runoff Program study (U.S. EPA, 1983) could find no statistically significant difference in runoff quality between types of urban land use. The only land use difference that could be used to predict the amount of runoff pollution was between open/non-urban land and urban land.

This finding lends itself to a decision on boundaries for runoff quality planning. If the entire jurisdiction is developed, runoff quality for all watersheds is essentially the same. Runoff quality controls can therefore be applied equally across the jurisdiction without the need to distinguish among watersheds.

A third issue is the effect of urban runoff on tributaries and receiving waters. The condition of small urban streams and their habitat is tied closely to the level of development of their watersheds, particularly the degree of imperviousness. Channel degradation, sedimentation, lower base flows, and higher temperatures all impair stream habitat; all are functions of changes in hydrology caused by urbanization.

As with runoff quality, however, conditions of urban streams vary less than expected. Schueler (1994) documents impacts at 10 percent to 15 percent imperviousness, a level exceeded in every tributary watershed in Arlington. Above this level, channels become unstable and begin to erode, habitat quality becomes poor, and stream biodiversity drops.

For streams in open, undeveloped watersheds where imperviousness is less than 15 percent, stricter controls on development and stronger efforts at stream protection could be required. Otherwise, the same level of stream restoration efforts and runoff controls are appropriate everywhere in a completely developed jurisdiction, and need not be focused on particular tributaries.

Legal and Regulatory Issues

A watershed approach to storm water planning means that a local government could write its ordinances to apply to only one part of its jurisdiction or apply its regulations differently in different areas. Is this legal?

For new development, there is a long history of land use controls regulating activities in only part of a jurisdiction. Some examples follow.

- Zoning laws are one of the major limits on the activities of landowners, based simply on the location of the property.

- In Virginia, the Chesapeake Bay Preservation legislation governs what kinds of new development are permissible near tributaries to the Bay. The regulations also govern redevelopment, including improvements to single-family residences.

- The Four Mile Run 100-year detention requirement is an example of regulating development by watershed. Arlington's storm water ordinance applies more stringent standards to this watershed than to the remainder of the County.

For a fully developed urban area, the legality of placing restrictions on existing development and residents' activities based on the watershed of residence is a more difficult question. It appears to be acceptable if based on zoning law. A local government can regulate how landowners may use their property depending on its zoning classification. Other non-zoning legal methods may be possible, such as special taxing districts or sewer districts.

Equity Issues

When a jurisdiction treats its citizens differently based on residence in a particular watershed, equity can be an issue. As examples:

- Should residents in a watershed where stream restoration is underway pay more in taxes than those in a watershed with no streams?

- Should developers in watersheds with streams be required to manage storm water differently than developers in fully storm sewered watersheds?

The current consensus is that storm drainage, like transportation and other public improvements, is a community benefit for which the community contributes equally. Similarly, clean water, parks, and open space have been treated as community benefits. Using this reasoning, the costs of stream restoration or flood control should be shared throughout the community and not just by the residents of the watershed.

However, it is also considered fair to ask developers and redevelopers of properties to do more in watersheds where the needs are more critical, especially where the changes to properties would otherwise exacerbate problems. It has not been considered fair to ask existing residents in the same watershed to contribute more than other residents in the jurisdiction. One benefit of this approach is political. Costs are not seen by existing taxpayers; property values may even rise because the additional storm water management cost may lead to higher priced houses.

The disadvantage is that it leaves the burden of watershed management on new arrivals. In a developed area, watershed improvements financed by redevelopment alone are likely to be minimal compared with the problems faced. Serious efforts toward watershed and stream improvements will likely require regional storm water detention facilities and preventive control of pollution sources. These activities cannot be financed or built by new development. Since the benefits will be shared by all, the burdens should be shared as well.

This reasoning also applies to developed watersheds that cross jurisdictional boundaries. Residents of all the watershed jurisdictions share responsibility for the problems and will share the benefits. It is not inequitable to apportion the costs of improvement programs to all the residents in the jurisdictions spanned by the watershed.

Conclusion

Urbanized watersheds function differently than natural watersheds. However, watershed characteristics still govern capacity problems from peak flows, and to some extent impacts on the receiving waters. Thus the watershed approach is appropriate for planning and analysis of storm sewer and stream flows, but is less important for runoff quality controls.

There appear to be no legal barriers to regulating either new development or existing activities by watershed. Whether it is equitable is a philosophical and political issue. Because storm water problems in developed areas have been caused by the land use and activities of existing residents, it is fair that they contribute to costs of improvements.

Within a single jurisdiction, apportioning costs of watershed restoration to just the residents of the watershed is less equitable. It goes against the long-standing principle that storm drainage is a public service which benefits upstream and downstream residents both, and it ignores the fact that people living outside the watershed will also benefit from the restoration.

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Sustainable Watershed Management at the Rapidly Growing Urban Fringe

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Introduction

From one major metropolitan area to another, land development is proliferating. Even in so-called "no growth" regions, development_large lot residential subdivisions and expansive office parks_is sprawling outward at surprisingly rapid rates, consuming ever increasing amounts of undeveloped areas at the urban fringe. In the Philadelphia metropolitan area, which has experienced over 350 years worth of development, total developed acreage increased by nearly 20 percent during the '80s decade, even though total population remained virtually constant. From a water resources perspective_both water quality and water quantity, this dynamic has alarming consequences. Water resources are affected as water supply systems, wastewater treatment systems and stormwater management systems are constructed. New impervious surfaces translate into significantly reduced ground water infiltration and aquifer recharge. Reduced recharge, by definition, results in lowering the water table with a corresponding reduction in stream base flow_the life of the stream for most of the year. As base flow decreases during dry periods, crucial first-order tributaries literally dry up, with drastic ecological consequences. Existing wells, especially older shallow wells and springs, are jeopardized. In addition, future ground water use at other, yet undeveloped, parcels is threatened, adversely affecting their value.

At the other flow extreme, the impervious surfaces which reduce infiltration mean increased stormwater discharges. Even with careful design, the use of detention basins for stormwater management, which only control the peak rates of stormwater discharge site-by-site, increase the total volume of stormwater discharged. As detention basins multiply throughout a watershed, these delayed releases may also accumulate, with destructive downstream impacts. Flooding may actually worsen. With these increased runoff volumes, stream bank and channel erosion is aggravated, and basic stream morphology is adversely altered. A mix of water pollutants, scoured from the urbanizing landscape with stormwater, is also an important concern. This is especially true in high quality watersheds. This water quality impact includes wet weather discharges or "mass loads" of nonpoint source pollution from these new impervious areas, containing hydrocarbons, metals, other toxics, BOD/COD, and a host of other pollutants. Stormwater pollution also is generated from large areas of created and chemically maintained landscapes, such as lawns and gardens, generating nutrients, sediment, COD, pesticides and herbicides. During dry weather, nonpoint source water quality impacts include malfunctioning on-site septic systems and other small but significant wastewater flows.

Water supply in these metropolitan fringe zones typically is ground water-based, pumped from the aquifers with corresponding reductions in stream base flow. Water use can be considerable for different land uses and activities and often increases during the warmer weather months when stream flow is already at its lowest point. Land-based wastewater treatment systems lessen these water loss impacts on aquifers and stream flow, although a significant portion of water used is lost by evapotranspiration with some systems. If conventional wastewater treatment plants with centralized collection and conveyance systems are constructed, water is completely "lost" to the immediate watershed area. Furthermore, water quality impacts of wastewater effluent discharges downstream can be extremely harmful. In addition to these direct water quality impacts, development typically translates into removal or partial removal of riparian vegetation which serves multiple critical functions for overall stream quality. Stream temperature regimes are adversely affected as the result of reduction in stream shading. All of these pollution impacts combine to adversely affect the stream system and its biota in a variety of ways.

Sustainable Watershed Management

The fundamental resource management objective proposed here is to measure the tolerance limits of the natural system and balance the human use of these land and water resources so that we live within the carrying capacity of these natural systems. This concept takes the form of a program we call Sustainable Watershed Management The following management objectives have been established based on this concept, with modeling methodologies developed to achieve these objectives:

- Maintain stream base flow, and in particular during drought periods (Q7-10).
- Maintain ground water levels in order to protect existing/future wells.
- Assure that stream flooding is not increased.
- Prevent ground water contamination, particularly from nitrate.

- Minimize additional point and nonpoint source pollutant inputs into surface waters.

To quantify the critical links between land development and water resources, we have developed a series of "models" for application on a watershed basis. In this program the different impacts on the hydrologic cycle are described by different but overlapping models, such as the Low Flow Maintenance Model, the Dry Year Nitrate Impact Model, the Cumulative Flooding Model and the Impervious / Pervious Runoff Impact Model. The Model Program includes a variety of both technical and institutional objectives and related work tasks:

- Bringing together the various agencies and institutions which must cooperate and coordinate efforts to achieve water resource protection. The precedent-setting alliances already in existence will be expanded to forge stronger and more effective joint watershed-wide efforts. Data developed by other agencies has been integrated in computer compatible format (technical resource sharing). Financial contributions also are being sought from municipalities to reinforce participation and commitment.

- Development of a Geographic Information System (GIS) of spatial data, including natural resources, existing and future land use, and political and hydrologic boundaries for the Watersheds. This GIS has been designed for subsequent application in other Chester County watersheds and elsewhere in Pennsylvania. The GIS will be structured to serve existing agency needs, such as at the Chester County Planning Commission, and to exploit all existing data development, such as at the US Geological Survey, Chester County Health Department and elsewhere.

- Documentation of generic water resource impacts resulting from new land development. The Low Flow Maintenance Model, based on the concept of maintaining balance within the hydrologic cycle, has been developed to evaluate potential impacts of land use changes on stream baseflow and other water table-driven functions such as well development, especially during dry periods. The Dry Year Nitrate Impact Model has been developed to assess groundwater quality impacts resulting from new land development. The Pervious/Impervious Runoff Impact Model focuses on nonpoint source surface water quality impacts. This array of models results in a total methodology which can be used more broadly in other watersheds throughout Chester County and other counties.

- Delineating the Baseline Future of the Watersheds, defined by the existing municipal plans and zoning ordinances, as an evaluation of the existing patterns of land management.

- Applying the above impact analysis to the Baseline Future for watershed municipalities, and recommending alternatives.

- Evaluating the existing management system that governs land development/water resources and identifying management gaps linked to water resource impacts. Of special importance will be analysis of legal capabilities for expanded municipal action, grounded in the Pennsylvania Municipalities Planning Code.

- Developing a Model Program, including both a detailing of what technically needs to be done differently (technical issues) as well as how to go about doing it (institutional issues). This Model Program will include alternative scenarios, selection of which ultimately must be done by municipalities. The resulting Model Program will include a Sustainable Watershed Plan for the French and Pickering Creeks, to be translated into municipality-specific comprehensive plans, zoning ordinances, subdivision regulations, Act 537 and other planning during the next implementation phase of the program.

Stream Low Flow Maintenance

As an example of how we link water resources and land use, we will summarize one of the developed models, which we call the Low Flow Maintenance Model (LFMM). The structure of this Model emphasize the dynamic nature of the hydrologic cycle_the continuous movement of water from one phase to another. To focus on one particular element of this very dynamic hydrologic cycle can be conceptually dangerous. For example, we often identify "ground water" or "stormwater" as distinct management areas. In terms of ground water, such an isolated and narrow perspective has given rise to viewing_and therefore managing_ground water as something of a static reservoir, available for utilization/exploitation without impact. This concept fails to take into account the delicate balance of the groundwater system and the fact that every subtraction from ground water inputs (i.e., reduced infiltration, well pumping, etc.) translates into a reduction of ground water output (i.e., stream base flow). Although a highly variable time lag separates a typical subtraction, the impact ultimately cycles through the stream base flow.

The water table can act as the barometer of the entire system, and when the water table drops below stream bed elevation due to reduced aquifer inputs, the stream goes dry.

Streams in southeastern Pennsylvania (and many other parts of the country) are maintained by continuous base flow discharge for about 330 days a year (White & Sloto, 1990). Declines in base flow impact the aquatic community in a variety of ways, including reduced habitat, benthic stress, temperature changes, and a host of other effects. For pollutant discharges which are continuous in nature, reduced base flow translates into lesser pollutant dilution and effectively increased in-stream pollutant concentrations. Although maintaining base flow is vital, making sure that the stream does not go dry completely during drought periods is absolutely essential, especially in vulnerable headwaters or first order streams, where essential biochemical processes break down detritus material for food chain processing.

One statistic available to define the critical base flow condition is the Q7-10, the lowest 7-consecutive-day average flow with a probability of occurring no more than once in 10 years. In the French Creek system, the Q7-10 value has been calculated (Helm, 1995) as a flow of 0.32 m2/s (11.26 ft3/s), or 1795 l/d/Ha (192 gal/d/ac) contribution, assuming that all watershed acres contribute equally. Owners of undeveloped watershed properties have some expectation and legal right to utilize their "fair share" of this ground water in the future. Thus a keystone of sustainability is the equitable allocation of water resource development rights across both developed and undeveloped properties throughout a watershed. However, the concepts of "fair share" and "equitable allocation" become extremely challenging to define, both technically and legally. If we consider the base flow as a resource which can be further depleted by some fraction of the total, two extreme positions are possible.

At one extreme, we could propose to use all of the base flow (100%) to serve future needs, effectively drying up the stream during future drought periods; on the other hand, we could prevent any further reduction (0%) in low base flow, effectively stopping any further consumptive activity within the watershed. In this LFMM model, we select an additional consumptive limit of 10%. That is, each watershed hectare (acre) must continue to yield 90 percent of the Q7-10 value of 1795 l/d/Ha (192 gal/d/ac), and can experience a minimal impact or loss of up to 10 percent of the Q7-10 value, or 179.5 l/d/Ha (19.2 gal/d/ac). We call this value the Low Flow Margin Factor, because it constitutes the upper limit, or threshold of ground water recharge depletion allowable, as new development occurs. It is important to keep in mind that this low flow objective is to be established as a regulatory limit.

Development Uses and Densities

Given the need for a strategy to manage land development so that low base flow is maintained, we consider the ways in which development-related aquifer depletion occurs: aquifer withdrawals for water supply, the wastewater treatment approach utilized, and the stormwater management techniques used. All of these depletion sources resulting from new land development must be combined and integrated within the limits of the Low Flow Margin Factor calculation, the total of which must not exceed 19.2 gal/d/ac, if a near balance in aquifer recharge and stream base flow is to be achieved. Unfortunately, our best efforts in minimizing water depletion objectives are never totally successful, and some water loss impact does occur, even in systems that we think of as 100% recycled, such as individual wells with on-site septic systems.

Analyzing the existing and potential future hydrologic balance in each of the estimated 140 sub-basins comprising the two watersheds requires the formulation of what is referred to as the Water Balance Model (WBM). The WBM accounts for the movement of incident rainfall in terms of seasonal variability and event probability, as well as the evaporative and transpirational losses as a function of temperature and vegetative land cover. The dynamics of groundwater movement through the soil and the groundwater reservoir are analyzed to determine the net effect of infiltrated rainfall and wastewater effluent balanced against well withdrawals and groundwater discharge to stream base flow. The model considers temporal variability of yearly rainfall in terms of average, wet or dry periods, and spatial variability of groundwater availability and recharge by geologic structure and land cover/soil type.

The WBM is applied to each area based on the assumption that the developable land within the watersheds is used according to the applicable Zoning which comprises the 18 municipalities. The WBM is not a "water budget" in the conventional sense, with resources allocated to various uses, but is meant to define a bookkeeping process by which the dynamics of water movement, through the soil and into the groundwater reservoir with gradual discharge as base flow, can be managed. In this manner, the resource can be "sustained" with a balance between the dynamics of the natural drainage system and the consumptive demands of human use.

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Note: This information is provided for reference purposes only. Although the information provided here was accurate and current when first created, it is now outdated.

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Integrating Water Quality into Urban Stormwater Management: A Watershed Approach in Fort Collins, Colorado

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Stormwater Utility, City of Fort Collins, CO

Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

There is increasing interest in managing the quality of urban runoff. For example, current federal regulations require cities over 100,000 in population to obtain permits for storm drainage systems as point sources discharges under the National Pollutant Discharge Elimination Program (NPDES)(Clean Water Act sec. 402(p)). Watershed management is also receiving renewed attention as an appropriate method for water quality management (The Colorado Water Quality Forum 1991, EPA 1994, Horner, Skupien, Livingston, and Shaver 1994, Water Quality 2000 1992). At the same time, flood control agencies nationwide are seeking methods for providing a balance between protection of human life and property and concern for the environment. For example, including the quality of the environment as a goal "concurrent with reducing human vulnerability to flood damage" (Galloway, et. al. 1994) has been proposed for flood control actions conducted by the US Army Corps of Engineers on the Mississippi River.

The primary purpose of this paper is to outline the City of Fort Collins Stormwater Utility's urban watershed management approach that integrates the efforts to control the quality of runoff along with its quantity.

Watershed Concepts

In order to tie management actions to the geographic characteristics of the watershed, three primary components are conceptualized: land surfaces, tributaries, and receiving waters. These three primary components form a spatial basis for management efforts within the urban watershed. Each component is altered during urbanization causing environmental degradation. Although impacts are site specific, similar types of stresses are described in many urban settings. For example, fundamental changes in the rainfall-runoff processes occur due to the construction of streets, buildings, and storm sewer systems. Increases in peak flow rates impact downstream properties with increased flooding. Altered chemical composition of water flowing from the urban landscape can cause toxic conditions in water bodies downstream. Chemical, physical and biological alterations combine to create a variety of water quality impacts (Osborne and Herricks 1988, Jones 1988).

A Watershed Approach_Planning to Implementation

For integrated urban drainage management to be successful, methods are needed to identify stressors to local environments; prioritize their importance; determine their cause(s); and plan responses which are likely to be effective. The complexity of controlling the water quantity and quality impacts to humans and the environment, makes the determination of proper control measures difficult. A watershed planning and management framework is an essential beginning.

Watershed planning should proceed in a tiered approach of goals, objectives, and actions (The Colorado Water Quality Forum 1991). Figure 1 shows a planning process hierarchy proposed by Sheeran (1976). The practitioner should remember that outreach to those with an interest in watershed planning is key to the process in order to gain full acceptance of the "ends."

Identifying the Mission

Identification of the mission is the first step in this process. The Fort Collins Stormwater Utility was established in 1979 to "consolidate all drainage related activities into a single program" (Engemon and Krempel 1983). The Utility's statutory mission is the ". . . control of flood and surface waters" so that ". . . waters may be properly drained and controlled, pollution may be reduced and the environment enhanced . . ." (City of Fort Collins Code Sec. 26-492). Protection of people and property from flooding along with reducing pollutants and environmental enhancement is the broadly stated mission.

Setting Goals And Objectives

Setting goals is an important part of the water resource planning process (Grigg 1985). To develop local watershed goals for both water quantity and water quality for Fort Collins, federal, state and local policies were reviewed.

The overall national water quality goal, described in the 1972 Clean Water Act, is "to restore and maintain the physical, chemical, and biological integrity of the nations waters." A Colorado water resources task force defined ecological integrity as

"An ecosystem where interconnected elements of physical habitat, and the surficial processes that maintain them, are capable of supporting and maintaining the full range of biota adapted for the region....their inherent potential is realized without management support or intervention...."

The City's Comprehensive Plan Goals and Objectives (1991) calls for: the joint use of drainage facilities, such as open channels and detention ponds, for open space purposes; consideration of long range ecological effects and costs when addressing short-term and long term economic problems; design, and location of new development to be compatible with environmental considerations; and maintenance of adequate public access to the city's lakes, rivers and streams. In addition, protection from the 100 year recurrence interval flood can be considered a primary goal for quantity management (City of Fort Collins, 1988).

It is evident that federal and state water quality goals recognize the need for comprehensive approaches to water quality management and that local policy makers value ecosystems associated with water bodies as public amenities. This led to the City Council adopting a watershed goal statement, to "promote clean water" in local water bodies in order to "support a variety of wildlife." The intent was to avoid the use of jargon, define management boundaries (the urban water environment), and be supportive of ecosystem management by including wildlife variety in the goal statement.

Next, objectives were formulated subsequent to these goals. Following a natural systems approach, objectives to meet these goals were based upon the three components of the watershed: land surfaces, tributary systems, and the receiving waters. Since contaminants in urban runoff are tied to deposition of contaminants on land surfaces, pollution prevention, avoiding deposition of anthropogenic sources of contamination on land surfaces, was adopted as a watershed objective. The urban tributary system is composed of streets, curb and gutter, storm sewers, channels and detention ponds. It is used to convey water away from urban areas and to modify peak flow rates. In natural systems water quality is modified by the tributary system. So, a second watershed objective is water quality treatment within this tributary system to mitigate the effects of urbanization. Receiving waters include the creeks, reservoirs, and wetlands recognized as part of the City's natural areas system. These areas are stormwater conveyances as well as important habitats and must serve both functions. The primary water quality management objective for receiving waters is the protection and restoration of aquatic, wetland and riparian habitat components.

In summary, preventing the introduction of pollutants within the watershed, treating for pollutants which we are not able to prevent, and preserving and restoring habitats comprise the objectives layer in our planning process.

Implementation_Strategies And Activities

Strategies link objectives to definable tasks, termed activities, in this management structure. Since a watershed approach for water quality must be implemented in conjunction with existing water management the strategies serve to integrate the watershed objectives into the current operation of the Stormwater Utility. The three strategies are: (1) to use the master planning process to protect and restore habitat; (2) use the stormwater design criteria and development review process to insure water treatment in the engineered tributary system; and (3) to utilize regulatory and education programs to prevent pollution on the land surfaces. Some examples of Best Management Practices (BMP's) for each strategy follow.

Pollution Prevention_Education And Regulation

Many of the contaminants described in urban drainage are by-products of typical urban life. Site development, lawn maintenance, and use of the automobile have direct and indirect effects on water quality. The decision to deposit contaminants on a watershed is made, by an individual or industry, by balancing values. These values may be economic or personal, conscious or unconscious. The use of education and regulation will increase conscious decisions to reduce activities which cause pollution. Pollution prevention activities selected by any jurisdiction should evaluate local needs, identify programs currently in place within the watershed and seek to support existing programs.

The City of Fort Collins and Larimer County Colorado have implemented pollution prevention activities including, household hazardous waste collection, integrated Pest Management for maintaining public lands, and spill prevention plans for appropriate locations. Public education activities include the Children's Water Festival which provides a day of interdisciplinary education about water for the fourth grade classes within the local school district. The City's Natural Resources Department trains volunteers about specific values of city-owned natural areas with its master naturalist program. Activities specific to the Stormwater Utility include stormwater inlet stenciling, brochures about water quality and watershed impacts, and a citizen monitoring/educational program for elementary schools.

Water Quality Treatment_Design Criteria And Construction Standards

Stormwater treatment BMP's should be designed to remove pollutants expected from particular land uses and integrated into individual property drainage and landscape plans. The City's Stormwater Design Criteria and Construction Standards specify acceptable drainage methods to be used for individual developed properties. The Standards are enforced by a development review staff at the design stage and construction inspectors in the field to insure conformance throughout the development process. The Design Criteria manual contains sections on drainage policy, documentation required with submittals, hydrology standards, and requirements for the design of streets, storm sewers, culverts, channels, detention storage and sediment control during construction. The addition of treatment BMP's for new and re-developing sites is currently underway.

Habitat Protection And Rehabilitation_Basin Master Planning

Master planning of drainage systems for the protection of habitat components normally associated with drainage ways is perhaps the most important and least understood component of the watershed approach presented here. While aquatic, wetland and riparian lands are integral to chemical, physical and biological integrity, requirements for their protection in stormwater design are typically lacking. The strategy of using basin master planning for habitat protection addresses this deficiency. It places the habitat protection objective within the technical context of drainage management where it has the most significance.

In Fort Collins stormwater basin master plans guide the major stormwater system improvements as the city grows. Master Plans model watersheds to determine flow rates, delineate flood plains and urban flooding zones, evaluate channel sizes, and flood detention needs. Master plans proceed in the following order: gather data; identify problems; develop alternative solutions; select a preferred alternative; and estimate final costs. Adoption of a Master Plan sets the general configuration of the drainage system in the watershed. Construction of facilities implements the master plan. In order to integrate habitat concerns we must evaluate environmental and flood control problems simultaneously. Opportunities for their mitigation must proceed together in the master planning process. Integrating habitat protection and restoration requires specific activities of habitat assessment and mitigation planning as part of the overall process.

The first activity is defining the boundaries of habitats to be protected, mitigated or restored. The next activity is to gather data on these areas and identify problems. To gather habitat data and identify problems the city proposes to develop and use Rapid Bioassessment Protocols for Streams and Rivers (USEPA 1989). Rapid Bioassessment Protocols were developed to characterize the existence and severity of impacts; identify the sources and causes of impacts; evaluate the effectiveness of control actions; support use attainability studies; and characterize regional biotic components. In the case of drainage master planning, initial channel characterization will provide a rating (excellent, good, fair, poor) of the stream aquatic and riparian habitats associated with receiving waters. Problems can be identified as fair or poor quality habitat in need of rehabilitation.

In developing and evaluating alternatives, solutions to problems identified for both flood control and habitat will be used to evaluate conceptual designs. This way habitat can be modeled along with the hydraulic analysis of the drainage system and appropriate improvement alternatives can be formulated. Alternatives can then be evaluated based upon both economic and environmental costs and benefits. A preferred alternative can be selected through public process with those likely to be asked to fund the implementation of construction and /or restoration activities.

The final planning hierarchy for the watershed approach is shown in figure 2. In this case a watershed planning approach to stormwater quality has successfully linked the spatial characteristics of watersheds to specific objectives associated with their role in the precipitation-runoff process. Finally, these objective were linked by specific strategies to functions typically performed by public works entities and the engineers, hydrologists, ecologists and landscape architects working on urban drainage system design. Activities to protect the water environment are underway throughout our urban watersheds.

Forming a Partnership to Preserve Resources_The Virginia Beach Agricultural Reserve Program

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On May 9, 1995, the City Council of Virginia Beach, Virginia adopted a landmark growth management and farmland preservation program in the Commonwealth. The Virginia Beach Agricultural Reserve Program (ARP) establishes a voluntary, market-based program where the city may purchase conservation easements from farmland owners. By approving the Agricultural Lands Preservation Ordinance, the Virginia Beach City Council committed to funding ARP for 25 years at approximately $3.5 million annually. In addition to a dedicated property tax increase, funds will come from a new cellular telephone tax, and payment in lieu of taxes by the Back Bay National Wildlife Refuge.

During 1995, as we examined the consequences of continued suburban sprawl on the American quality of life, only two new farmland preservation programs were adopted in the United States. Both of these programs were brought about through the efforts of grass-roots citizen groups. Each is funded with a dedicated local property tax increase_startling at a time when the mantra heard throughout the halls of Congress is lower taxes, lower taxes. How did the citizens of Virginia Beach come to the conclusion that farmland preservation was needed, and how did they convince their fellow taxpayers that this was the time to commit to it? It was done by building a strong partnership of traditional foes that brought a voluntary, market-based solution to a variety of community challenges. ARP will help to stabilize the tax base and future tax rates; prevent continued sprawl from degrading important resources; and protect a land base to assure a continued agricultural industry.

Background

Virginia Beach was the fastest growing large city in the United States for the two decades of the 1970's and 1980's. From the time the city was incorporated in 1963 by combining a small, oceanfront resort with agricultural Princess Anne County, its population grew to more than 420,000 making it the largest city in Virginia. The source of this growth was the establishment of a large military presence in the region. This created a large home building industry supported by the related suppliers, realtors, and bankers.

Farmland became a commodity for developers and began to lose its identity as an industrial resource. Virginia Beach found itself with one powerful industry group growing by consuming the resources of another. Over half the farmland in Virginia Beach has been converted in the last three decades and only 32,000 acres of crop land are farmed in the city today. That remaining land has the highest per acre yield for corn and soybeans in the Commonwealth, even though it was relegated to subsistence farming in earlier centuries.

Biodiversity and Natural Resources

This cropland is not the only significant natural resource in Virginia Beach. Sitting at the mouth of the Chesapeake Bay, there are more than 37 miles of oceanfront and interior shoreline; 7,000 acres of land are preserved in two unique natural state parks; two national wildlife refuges, totaling 7,700 acres, are within the North American Flyway along the Atlantic shore; the city encompasses 1,100 acres of tidal marsh, 11,600 acres of swamp, and 17,600 acres of freshwater wetlands.

These other natural resources are threatened by continuing sprawl, as well. The southern Virginia Beach agricultural area surrounds wetland and forest resources which have been identified as some of the most diverse ecosystems east of the Blue Ridge Mountains and recognized as a priority area of the Atlantic Coast Joint Venture of the North American Waterfowl Management Plan; it is the headwaters area of the Albemarle-Pamlico-Currituck Estuary and the Roanoke-Tar-Neuse-Cape Fear River Ecosystem of the National Wetlands Priority Conservation Plan. It is also one of the Nature Conservancy's areas of focus in Virginia identified through Natural Heritage inventories as exemplary ecosystems and critical habitat for at least 46 rare and endangered species.

Local Land Use Planning

In 1979, an urban service boundary was established by implicit policy of the City Council, and later, by explicit policy with the adoption of a Green Line in 1986, more than a decade and a half into the growth boom. Political pressure and deep pocketed developers continued to breach the line with subdivisions and utilities. A costly litigation from a down-zoning action made the Council wary of denying rezoning and conditional use permit requests in the rural agricultural area. Even as a water shortage restricts new hookups, large lot sprawl continues in the rural area served by septic systems and wells. Clearly, a new strategy was needed for rural preservation.

ad hoc Southern Watersheds Committee

Environmental and agricultural interests have been no closer in Virginia Beach than the rest of the country over the past years. Virginia Beach may be the only locality in the country with its own definition of wetlands that excludes an entire range of hydric agricultural soils. It is also an area supporting a number of endangered plant and animal species. Some, like the state-endangered Canebrake Rattlesnake or the federally-listed Dismal Swamp Shrew, are creatures few find sympathy for. The coalition that formed to preserve farms and wetlands was not immediately a cohesive and comfortable group.

The ad hoc Southern Watersheds Committee, as it called itself, started meeting in response to a proposed change in the Comprehensive Plan for the Southern Rural Area of Virginia Beach. Although the changes were represented as a way to preserve rural character, deter the need for major urban infrastructure, protect environmental resources, provide reasonable development opportunities, and provide the opportunity for continued agriculture they were merely a new standard for the continuing conversion of agricultural lands to houses, and provided no means to promote the continuation of agriculture as a healthy industry.

Going into these discussions, the farming community was wary of commitments which would not be kept; it feared increased regulation; and it felt it had been made a scapegoat for many unrelated environmental problems. The environmental community was also wary of promises which would not be kept; it held concepts about agricultural pollution which were general rather than specific to local industry; it had little hard knowledge about the business of farming; and it had watched three decades of growth consume its wetland and forest resources.

This group was diverse in character and had come together by chance and interest rather than having been recruited or appointed. The membership consisted mainly of farm and conservation interests, but these individuals also brought expertise and experience as a former Chairman of the Chamber of Commerce, a former Chairman of the Planning Commission, the Chairman of the Agricultural Advisory Commission, a director of the Council of Civic Organizations, a former Chairman of the Princess Anne Historical Society, the president of a local environmental group, representatives from a local Audubon Society chapter and Sierra Club group, board members of the Farm Bureau, specialty and grain farmers, a forest land owner, a specialty produce business owner, the Director of Agriculture, a rural City Councilperson, Director of Protection of the Virginia Chapter of The Nature Conservancy, and the Manager of Back Bay National Wildlife Refuge.

Funding

The group coordinator was partially funded through an EPA Near Coastal Waters Grant; the rest of the time was donated. This funding allowed someone to devote their focussed attention to this effort, something that was vital to its success. Later administrative funding came from a

Cooperative Agreement with the U.S. Fish and Wildlife Service and from the Virginia Coastal Resources Management Program for a public opinion poll. Continuing funding is being provided by the Virginia Environmental Endowment. This funding is critical at the grassroots level. Even the most ardent volunteer cannot donate enough time and effort to coordinate this lengthy process.

The Process of Setting Goals

Ground rules were established after the first two meetings: there would be no debate over wetlands definitions or values, and the discussions must stay focussed on the process and project. These simple rules avoided the reopening of old wounds. The meeting structure was informal with a coordinator, or moderator, who kept the discussions directed and set the general meeting agenda, but there was no attempt to identify a leader or hierarchy; everyone and all opinions were equal. This did not avoid many heated discussions at the beginning, but in the long run, it promoted a great deal of respect within the group.

The Committee set a common goal for their process and anticipated proposal: To promote and enhance agriculture as an important local industry which is part of a diverse local economy. This goal was agreed upon after some very frank discussions about differing agendas, intentions, and perceptions.

The conservation interests freely admitted their concern about potential degradation of the wetland resources within the rural area. The abundant diversity of these systems is an indication of their health and of the minimal pollutant contribution of surrounding areas. This led to a consensus agreement that: agriculture is, and has been, a compatible use to these wetlands; the potential threats of nonpoint source pollution, alteration of hydrology, destructive land use practices, fire suppression, and invasive exotic species comes from continued sprawl, not continued agriculture.

The farm and forestry interests worried that entering into an agreement to preclude residential or commercial development that protected wetlands would also lead to future restrictions of their farming or forestry practices, and they would be trapped in an industry where they could not make a profit. Given the flat topography of our coastal plain, the high water table which creates a denitrification process, and the coastal microclimate which allows for greater production with less input, a consensus grew that any program proposed should not require additional restrictions of performance criteria for farming. It was felt that the successful implementation of a program would actually preclude the need for future environmental regulation. Once the Committee was comfortable in their consensus positions, farmland programs from around the country were investigated for local applicability. The ARP is a combination of elements of several successful state and local programs with ranking criteria developed specifically for southern Virginia Beach.

Community Context

Virginia Beach's rapid growth of earlier decades brought the level of residential development well beyond the identified goal for a balanced and sustainable tax base of 70 percent residential and 30 percent industrial/commercial. The agricultural southern watershed area has a very shallow water table making it unsuitable for significant industrial development. Virginia Beach's other major industry is tourism. To be assured that it will remain a destination into the future, Virginia Beach must retain the characteristics that make it attractive. The rural area with its significant natural resource features is an appealing companion to the oceanfront beaches for family vacationers.

By enacting the ARP and preserving the agricultural industry sector, Virginia Beach's infrastructure resources can remain concentrated in the densely developed parts of the city and redevelopment in those areas will be the focus of future growth. There is a reserve of over 20,000 existing residential lots within developed and zoned areas of the city.

Virginia Beach also faces the challenge of converting from a typical suburban development pattern as the city's housing stock ages and needs replacement. While Virginia Beach lacks a typical city core, it has the opportunity to develop business, commercial, and recreational corridors while redeveloping obsolete sectors of the city.

Community Outreach

A candid evaluation was done of the potential support and opposition from stakeholders in the community to a proposed purchase of development rights program. From that research, an outreach program was instituted to educate the community about the proposal's benefits to Virginia Beach as a community. Presentations and meetings went on for over a year with any interested person or group; their concerns were heard and incorporated into the final proposal.

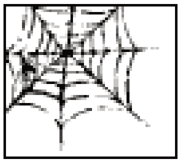
Careful attention was paid to the financing and economic impacts of the proposed program. Because ARP does have positive benefits to Virginia Beach in preserving a profitable industry which demands little in services and infrastructure, the Director of Management and Budget not only endorsed the program, but helped to design the dedicated funding sources. In public presentations, there was a simple comparison made between the annual cost of ARP ($3.5 million) and the annual cost of a new high school ($4.5 million) with the concluding point that ARP is a finite program while operating costs for facilities goes on forever. The annual cost to the typical homeowner in Virginia Beach is $20; that is less than a membership at the recreation center and not enough to take a family of 4 to the movies on Friday night. The total cost of the program is less than half the cost of infrastructure it will preclude.

As we built community support for ARP, we asked people to call their councilpersons and to send postcards stating that they supported ARP and understood that it meant a property tax increase. We did not want the policymakers unclear that the voters knew they would have to pay for the program.

Conclusion

The ARP is aimed at the southern watersheds area of the city identified in the Comprehensive Plan and by local residents for future and continuing agriculture and rural uses. The ARP is designed to bridge the gap between the short-term economic pressures on the farmland owner and the long-term benefits of farmland preservation. It gives another choice to a farmland owner, one that did not exist_the sale of development rights in return for working capital that can be reinvested in the farm. Preservation of productive farmland will reduce future tax increases to pay for the deficit of more and more suburban sprawl and infrastructure to serve it. It will keep the family farm a part of our living heritage and can promote the development of small businesses serving agriculture, tourism, and recreation. It will protect Back Bay and the North Landing River systems, resources we value for their beauty and richness. The ARP is a sound investment in Virginia Beach's future.

In Virginia Beach, a self-appointed group of citizens was able to bring the first farmland preservation and growth management program into existence in Virginia in 1995 because they set aside the rhetoric and disputes to work toward a common-sense solution to a community challenge. Their program is fair, it will save future community costs, it promotes the growth of a local industry group, the environment will benefit from it with no additional regulation, and it enhances the quality of life in their community.



Nanticoke Watershed Alliance: A Case Study in Forming a Grassroots Watershed Organization

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The River

The Nanticoke River begins its journey in southern Delaware, flowing southwest to the Chesapeake Bay through the Lower Eastern Shore of Maryland. One of the Chesapeake's healthiest rivers, the Nanticoke supports almost a third of Maryland's tidal wetlands and includes extensive freshwater wetlands in both states. This 370,000 acre watershed provides exceptional habitat of national significance for threatened plants, animals, and natural communities.

Bald eagles, ospreys, and great blue herons are common in the skies above the Nanticoke, while the waters below thrive with a profusion of fish and shellfish: American shad, striped bass, largemouth bass, white and yellow perch, crabs, oysters, and clams. Flocks of migrating waterfowl_black ducks, canvasbacks, mallards, and teals_use the Nanticoke as a resting point and wintering area. Otters, owls, and muskrats also call the Nanticoke their home. There are more than 120 rare species such as the bald eagle, black rail, seaside alder, Delmarva fox squirrel, and spreading pogonia orchid.

The Nanticoke is endowed with outstanding abundance and diversity of wildlife, undisturbed land, and rural characteristics. The river and its major tributaries--are free of dams and support excellent fisheries.

The Nanticoke is a wonderful river for recreation, education, nature study, and simple solitude. It has a rich history of Native Americans, tall ships, steamboats, slaverunning, piracy, and the underground railroad. There are properties within the watershed on the National Register of Historic Places. Some of the northernmost stands of bald cypress trees on the Atlantic Coast are found within this watershed. These characteristics should be preserved. However, development pressure is growing.

Early Action

In response to that pressure, citizen groups formed to take action. In Maryland a citizens group called Friends of the Nanticoke sprang to life in a classic manner: in response to a crisis concerning development. Simultaneously, upriver in Delaware, another citizens group coalesced in anticipation of similar crises. Each group's goals and work were and still are typical of river conservation groups.

In 1992, at the request of the Nanticoke Watershed Preservation Committee (NWPC) and the Delaware Department of Natural Resources and Environmental Control, the National Park Service's River, Trail and Conservation Assistance Program began to provide planning assistance for the conservation of the Nanticoke River and its watershed. A memorandum of understanding, signed by the states of Maryland and Delaware, NWPC, the Friends of the Nanticoke, and the Wicomico Environmental Trust expanded the project into a bi-state planning effort that promotes the river and the watershed as a treasured resource.

This bi-state group, now known as the Nanticoke Watershed Alliance, is made up of representatives from a host of different interests including Chesapeake Forest Products, Glatfelter Pulp Wood, Delmarva Power and Light, Survival Products, MD Department of Natural Resources, MD State Office of Planning, DE Department of Natural Resources and Environmental Control, Chesapeake Bay Foundation, Lower Shore Land Trust, the Nature Conservancy, the National Park Service, the three original citizens groups, and many local residents, some of whom are watermen and farmers. The Alliance is growing rapidly, the atmosphere is positive and productive, and partnerships are at the core of the Alliance's work.

The Nanticoke Watershed Alliance is currently conducting several projects involving partnerships: a shad restoration project in conjunction with Chesapeake Bay Foundation and Delmarva Power and Light; a water quality monitoring program with Salisbury State University; and a canoe trail with the Nature Conservancy, Chesapeake Forest Products, and the Chesapeake Bay Foundation. Partnership projects that have taken place in the recent past include the building of osprey platforms, running a float trip, surveying attitudes, a canoe race, various cleanups, and publishing a directory of all organizations having any kind of project related to the Nanticoke River. We are working toward implementing a bi-state boating traffic study.

Early Trouble

A positive and productive atmosphere was hardly the case in the early days of the Nanticoke Watershed Alliance. Inherently disparate river interests were polarized on almost all issues. The timber companies and farmers were at odds with the environmental groups and everyone was at odds with the state natural resource departments. Getting these groups to the bargaining table was not an easy task. Everyone knew that an Alliance should be formed, but no one knew what the mission of such a group should be or how to capitalize on the common thread among such diverse constituents.

The story of how the Alliance finally formed and partnerships developed is an important case study in early watershed planning. There are many lessons to be learned from the experience of the Nanticoke Watershed Alliance.

As with most if not all consortiums, particularly those that reach across state lines, fear and suspicion predominated for a long time. Forward progress of any real significance was not possible until that fear and suspicion could be addressed and shown to be unnecessary, a two-fold task. Fear gripped many players as they stepped into untested waters. Suspicion had already long been in the hearts and minds of citizens due to copious government land regulations. Everyone assumed government officials had a hidden agenda. (It turns out they do, but those agendas aren't necessarily always threatening.)

The overall answer to laying these fears aside was patience and the wisdom that comes with time. But more specifically, certain key tactics helped: 1) obtaining information to answer questions, 2) the willingness to say "I don't know" when we didn't, 3) tapping the source of passion within each participant that brought them to the table in the first place, which was in many cases more personal than professional, and 4) undertaking small projects that forced people to work together and share a success, thereby beginning down the road of trust.

The Turning Point

The big quagmire for us was the issue of Federal Wild and Scenic River Status. Only two or three people out of twenty five thought it was a good idea, but that was enough to scare the pants off a few others, which resulted in a year-long, hot debate, through which no other topic could pass. Those were the most frustrating days of our evolution. Looking back now, it's amazing to realize that despite flaring tempers, we never actually lost anyone because of that debate. Losing someone in a controversy usually means giving them over to negative public relations.

The key tactics mentioned earlier eventually won everyone over to the realization that while federal status may someday be appropriate and even helpful to the river, the timing was all wrong. The entire watershed would have been divided over this issue and there would have been a blood bath. It was hardly worthwhile. Besides, there was no guarantee the river would qualify, and the process was long and difficult. Time would be better spent taking on more and smaller projects.

Settling this issue was the turning point for the Nanticoke Watershed Alliance. With the table cleared and players frustrated by inactivity, we threw ourselves into writing our articles of incorporation, by-laws, and applying for 501(c)(3) status, and conducting some cleanups and getting some publications on line. Now we were getting somewhere.

Easily the most surprising and also the most effective partnership to be made within the Nanticoke Watershed Alliance was the one between the "green" groups and the local timber industry. Members of the "green" groups originally saw the timber industry as destructive to the watershed. The timber industry saw the "greenies" as radical extremists. "Green" groups now see that far worse prospects lie in store for the watershed than thousands of acres of trees, which will remain as such. The timber folks eventually came to see that not all environmentalists are foaming at the mouth. We share a passion for quiet woods and for wildlife which creates ample opportunity for us to work together.

Another gap to bridge was the one between everyone else and the government agencies. Some government agency representatives were extremely enthusiastic to help, while others were extremely hesitant. Some of them accused the citizens groups of having a closed door policy and the citizens groups weren't sure they really wanted to work with government. Only when the doors were removed from their hinges did everyone settle down to the work that needed to be done. Perhaps the "green" groups had the most to learn from this whole experience.

Our work is far from done: we have yet to bring the local Indian tribe into our fold and our vision for the river will not be complete without them, fundraising has not yet become a strong focus of the board, we have no strategic plan, and we do not yet have the ear of our local politicians. But our commitment is very strong and our potential is unlimited. Our teamwork has been recognized by EPA, the Alliance for the Chesapeake Bay, and River Network. And now that we are united in our endeavors, our energy is indomitable.

Lessons Learned

- No two groups or set of experiences are alike. Yet if one ignores the lessons to be learned from others on that basis, one is destined to repeat their mistakes.

- Accept that a crisis is sometimes necessary to facilitate growth within the organization.

- No one can be left out of the circle. If people are excluded, they will eventually thwart the work of the group, so bring them in early.

- Build trust by getting busy doing the agreeable projects first and controversial ones later.

- Keep participants in one corner of the ring and the problem in the opposite corner.

- Other consortiums like ours exist, but they are few and far between. Where they do exist they are powerful, respected, effective, and efficient organizations. Partnerships are the wave of the future. In a time of budget cutbacks and federal government shutdowns, shared resources, which include people, money, and time, are not only necessary, they make good sense.

Watershed Partners Participate in Comprehensive Municipal Infrastructure Planning: A Case Study

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Lower Colorado River Authority, Austin, TX

The City of Smithville is a forward looking community with a population of over just four thousand, yet it retains its early sense of comfortable seclusion, resting high on the banks of the Colorado River. Centuries old oak trees line its streets. But this small conservative Texas community is aggressive in sustainable economic development which is compatible with environmental leadership strategies. Capital projects completed over the past three years include a school complex, a regional hospital, two parks with major recreational and camping facilities, little league fields, savings and loan institution, supermarket/gas station complex, and several restaurants. In addition, projects on the drawing boards or under construction include a medical office complex, minimum security correctional facility, wildlife museum and civic center, motels, expansion of the regional airport, and other commercial businesses such as gas stations, fast food restaurants, and retail establishments.

Smithville is approximately 30 miles from the new Austin-Bergstrom International Airport. This major airport is located on the southeast (Smithville) side of Austin on the major highway to Houston. The unique rural and pristine nature of Smithville naturally attracts new residents. Coupled with the fact that this beautiful Texas rural community has been found by "the investors" has caused development to head that way. The City of Smithville is prepared for this but the new activity will be on their terms. The town fathers, led by Mayor Vernon Richards, the retired Southwestern Bell Vice President for Marketing, are very progressive about protecting their segment of the Colorado Watershed-environmentally, culturally, historically, and financially. The city has won many awards in these areas including several from the Governor, Keep Texas Beautiful, Clean Texas 2000, Texas Natural Resources Conservation Commission (TNRCC), and the Texas Municipal League. The City Council does not consider increased taxes as an option to support this development but rather pursues an aggressive grant program and increases their resources through partnerships with other organizations.

Since the City sits on the banks of the Colorado River, one such strategy has been to form a major partnership with the Lower Colorado River Authority (LCRA) to ensure the protection and constructive use of the area's natural resources. The LCRA is a Texas conservation and reclamation district committed to the well-being and safety of the over 1.2 million citizens it serves. The LCRA provides reliable, low cost electricity to 33 cities and 11 electric cooperatives in all or part of 58 Texas counties. The City of Smithville is one of those electric customers. Because the Colorado is a major source of drinking water, a top priority for the LCRA is the protection and constructive use of the river and its tributaries. In addition, there are six dams on the Colorado which provide flood control and hydroelectricity. The river also supplies the water necessary for the operation of LCRA power plants, the Southwest Texas Nuclear Project, more than 135 municipalities, water districts and private water systems, and is the source of irrigation for rice growers in Matagorda, Colorado and Wharton Counties. A comprehensive watershed management approach is the sermon that the LCRA delivers to all its communities. The City of Smithville is a working model of how LCRA can partner with a community to implement that strategy in order to influence managing the river, its tributaries and surrounding watershed.

The Texas Clean Rivers Act of 1991 mandated that river authorities and other designated entities assess the water quality within each river basin. Section 319 (b)(2) (B) of the federal Clean Water Act and the TNRCC State Management Plan require identification of programs for technical assistance, education, training, technology transfer, and demonstration projects. The purpose of these programs is to achieve implementation of best management practices (BMPs) and measurable documentation of improved water quality. Each river has been divided into segments based on an identified set of characteristics and each segment has been evaluated relative to its level of water quality. The TNRCC made the determination that 319 grant funds will be based on the seriousness of the water quality problems in a particular segment. Smithville lies at the upper end of Segment 1402 of the Colorado River. According to the Texas Water Commission 1992 document entitled "The State of Texas Water Quality," 11th Edition, Segment 1402 is affected by inorganic nitrogen, phosphorous and fecal coliform.

This classification qualified the city as eligible to apply for 319 funds to address their nonpoint source pollution (NPS) issues. As additional new construction occurred, NPS and erosion problems on the banks of feeder creeks increased due to lack of proper controls and planning. Mayor Richards and the City Council recognized this problem and worked with the LCRA to submit a 319 grant proposal to the Environmental Protection Agency (EPA) through the TNRCC. This effort was successful and a three-year grant was awarded for a total project cost greater than $300,000 with the federal share being capped at $170,000. In order to facilitate the comprehensive watershed approach, the LCRA has taken the lead in working with the City of Smithville to be a demonstration project for small cities. The overall purpose of the project is to implement a municipal NPS control and abatement program including managing potential water quality impacts due to storm water runoff. In the particular case of Smithville, the occurrence of NPS and its subsequent impact on the water quality of the Colorado River and its feeder creeks is a direct result of poor drainage throughout the city. With the advent of more construction, the amount of impervious cover is increasing which reduces the storage and infiltrative capacity of the land. This increases the proportion of surface runoff to rainfall dramatically-resulting in the degradation of downstream waterways due to increased flows and velocities eroding the natural geomorphology of the stream. In addition, this rapid form of runoff and loss of infiltration depletes the base flow conditions of a stream which further affects the benefits of the riparian corridor.

The most critical commercial drainage area to be studied is defined by a ten square block area in the northwest quadrant of the city. Located in this ten-block area is a new supermarket with a large paved parking lot and gas pump facilities, a barbeque restaurant, service station, car wash, recycling drop off center, and meat slaughtering facility. One boundary of this area is Gazeley Creek which drains directly into the Colorado River. Under current conditions, the existing NPS runoff discharges out of a storm drain into a channel located in Gazeley Creek which is highly degraded from urbanization and continues to erode due to lack of any erosion deterrents. The negative impact on water quality is neither contained nor filtered in any way, at this time. In developing the initial project plan, the LCRA proposed to determine the current surface runoff to a rainfall ratio for the predominantly commercial area and establish baseline conditions. The next step would be to modify and reduce the runoff to a rainfall ratio to more closely resemble undeveloped conditions through two means. First, storm water attenuation devices will be constructed within the contributing watershed area which will consist of infiltration and storage practices such as trenches, shallow berms, or Gambian type structures to promote groundwater recharge. Second, an end of pipe best management practice (BMP) would be constructed. This BMP will function similar to an extended detention type basin with groundwater recharge enhancement facilities. Currently eroded channel banks will be rehabilitated predominantly through bio-revetment. Behind the channel banks, infiltration chambers will be installed. These infiltration chambers will be recharged as the pond fills. Once the pond drains, the infiltration chambers should provide both groundwater recharge and increase the period of base flow in the stream.

The main project objectives are: (1) Implementation of the BMP; (2) Verification of its effectiveness; (3) Production of a video demonstrating the capability of small cities to implement NPS control programs and other water quality protection efforts; and (4) Preparation of a plan for implementation of further BMP's throughout problem areas in the city. High-level project tasks include: (1) Construction of the BMP reducing pollutant loading for a ten-block commercial area in Smithville; (2) Monitoring upstream and downstream of the BMP to document water quality benefits; (3) Conceptualize, shoot and produce a video addressing NPS pollution strategies in a small, growing rural community; and (4) Preparation of a detailed master drainage plan which demonstrates the economic feasibility of incorporating water quality protection into rehabilitation and reconstruction of a currently inadequate city drainage system. The primary measure of success for this demonstration project will be the actual reduction of surface runoff achieved for varying rainfall intensities. Sediment transport and nutrient loading data will also be gathered to further assess the benefits of BMP implementation. Results will be quantifiably measured through (1) Water quality data collected from pre, interim and post water sampling; (2) The level of compliance with EPA, TNRCC, and LCRA water quality standards; (3) Implementation and verification of Best Management Practices that reduce nonpoint source discharges; (4) Consideration f a Master Drainage Plan for Smithville for future implementation by the Smithville City Council; and (5) Completion and distribution of the project video tape.

Well, all this sounds very good! But, in the grant process, as you all know, things take awhile-no matter how well intended our friends in Dallas and Washington are. The problem we encountered was, that in the two-year application and approval process, Mother Nature dramatically increased the erosion problem at the ten block commercial site which, in turn, increased construction costs for the BMP beyond the approved grant budget Small cities like Smithville often don't have the resources to adequately maintain their infrastructure systems such as drainage, street maintenance, etc. to begin with much less face major capital expenditures for NPS erosion structures. It was not possible to increase the amount of the grant and even LCRA didn't have additional resources to throw at the problem so inquiring minds went to work to develop "the creative solution." Basically, it boiled down to adding more partners in order to capture more resources. One place that we went was Texas A&M University. Texas A&M is one of the largest universities in the nation serving over 40,000 students and employing over 2,200 faculty members. It ranks in the top ten in enrollment of National Merit Scholars, has students from over one thousand nations, and is located in College Station-approximately two hours from the City of Smithville. The University has a national reputation in the field of engineering and the A&M University System houses four major engineering components: The College of Engineering, The Engineering Extension Service, The Engineering Experiment Stations, and The Texas Transportation Institute. The LCRA and the City of Smithville met with A&M Officials to determine if there was a possibility of utilizing some or all these resources to assist with this project.

Professors Robert Lytton and Walter Moore of the College of Civil Engineering had been championing the idea of giving engineering students some real life engineering experience before leaving the college environment and entering the work force. The local professional consulting engineering firms support this project because they realize that this type of practical training will provide better prepared engineers to enter the profession. Through his efforts and those of the Deputy Vice Chancellor of Engineering, Ray Flumerfelt, Texas A&M became an active partner in the City of Smithville project. In early September 1995 (Fall Semester), approximately sixty upper division and graduate students, visited Smithville to evaluate specific NPS problems that involve street and commercial area drainage besides bank erosion at the designated BMP construction site (Gazeley Creek). Classes were held on the site and conducted by the Mayor, City Manager, city public works personnel, LCRA engineers, and TNRCC project staff.

The students, as part of their class assignment, formed "consulting firms" to work on the city's most pressing drainage problems. As part of their projects, each student "firm" designed structural devices such as filtering ponds, Gambian falls, and underground retention facilities to mitigate or prevent the NPS pollution associated with the rain runoff of city streets and commercial development. The student "firms" presented their proposals, as part of their final examination, to the Mayor, City Manager, Project Manager and Project Engineer at the end of the semester. The proposals were judged on the efficiency and effectiveness of the solution design, budget considerations and aesthetic enhancement of the site. The winning project designs were awarded $100 and will be integrated into the real life project solution by the project team including the City's professional consulting engineers for final engineering design, before construction.

Another partnership has been formed to facilitate a reduction in certain labor costs. The Mayor has entered an agreement with the County Sheriff to utilize minimum security trustees on a daily work program. These individuals will do the manual labor required to clear brush from the Gazeley Creek site and along the drainage channel into the Colorado. They will assist in the construction phase of the BMP installation including the placement of the monitoring equipment. In addition, as part of this project, another group of students worked on computer geographic information systems programs and equipment to create and/or accurately update city maps for streets, utility lines, and topographical features. Contour maps at the appropriate intervals (1'), master drainage plans, or storm water strategies are currently nonexistent for both the designated commercial area and the city as a whole. Besides being used as base information for the NPS project, this information will be necessary for future use in utility and street planning and other capital improvement projects such as expansion of the regional airport. The FAA grant of over $2.0 million for that expansion requires an erosion and NPS plan. Two summer school engineering surveying classes will focus on this section of the city to incorporate the appropriate mapping data into the master drainage plan.

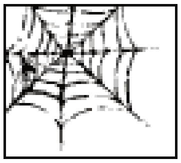
The success of the Fall Semester has lead to increased activity for the next several semesters. Present plans are for the civil engineering class to continue to study the drainage problems in the city, draft the master drainage plan, and prepare draft ordinances to implement the plan. Also, the students will be required to provide cost estimates for their proposals and present the final product to the Smithville City Council. The additional resource of this student work will enable the city to consider well-developed alternative solutions to some of their long term drainage and pollution problems at a very low front end cost.

The City of Smithville has also committed to build a new water/wastewater plant as they are currently approaching capacity with their existing facility. The hydrology engineering class will be working with the City Manager to develop the specifications for the Request for Proposal-not only for the design and construction of that plant but for the operations and maintenance phases as well. The geotechnical engineering class will be working with the LCRA transmission company to relocate 15 miles of transmission lines and towers to facilitate the extension of the airport runway as part of the expansion of the regional airport. That class will be specifically involved in the soils analysis, testing and design of the footings for the transmission tower. They will be supervised by licensed LCRA engineers and will be involved in certain day to day aspects of that project. This project is being funded by the Texas Department of Aviation through federal funding received from the FAA.

The School of Landscape Architecture is working with the College of Engineering in the "Make it Pretty" phase of all the projects. They have dedicated several masters' students who will do their final design projects on the aesthetics or visual design of the various engineering applications utilized to solve the Smithville problems. Also there is a 15,000 square foot historical building which is in the process of being restored for a Wildlife Museum and Civic Center. The basic historic documentation and concept design is being done by a master's level student from Architecture. This project is being funded by the Texas Department of Transportation ($400,000) through dedicated intermodal transportation funds, LCRA community assistance grants and a $5.0 million mounted wildlife collection from a private individual donor.

Professional expertise from all the partners plus participation by engineering students and faculty from Texas A&M engineering components will facilitate completion of a significant component of a master comprehensive infrastructure plan for the City of Smithville. Other ongoing programs which are utilizing similar partnership arrangements are a recycling drop off program which markets their recyclable commodities through a recycling marketing cooperative, comprehensive intermodal transportation study, site selection and construction of a regional correctional facility, expansion of local recycling programs to include cooperative marketing component, restoration of original historic buildings, identify and remediation of environmental hazards, energy conservation measures for existing and new housing, a master environmental plan for City expansion, and development of existing and new river access recreational facilities. Major agencies involved include Texas Natural Resource Conservation Commission, Texas General Land Office, Texas Department of Commerce, Texas Commission of the Arts, Texas Department of Transportation, Federal Aeronautics Administration, Texas Water Development Board, Texas Parks and Wildlife Department, Texas Department of Corrections, The Central Texas Recycling Association, Keep Texas Beautiful, Private Businesses, Environmental Organizations, Texas Office of State Federal Relations, Office of the Governor, and other state, federal and locally elected officials.

NOTE: A major benefit of this approach which can't be quantified is the personal and professional relationships that have developed across disciplinary and generational boundaries. To put it another way, when the A&M students are playing hookie, they can be found in the Mayor's backyard-fishing on the banks of the Colorado River.



Meeting the Goals of an Urban Subwatershed Study_A Case Study

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The City of Scarborough, located in Southern Ontario, recently undertook a study of the Morningside Tributary subwatershed. The impetus for the study came from the pressure to develop the area and the fact that the tributary itself had just been proclaimed a part of a new urban park. The Rouge Park is billed as Canada's largest urban park and there were concerns about the impact of development in this subwatershed on the park.

A tributary of the Rouge River, Morningside Tributary drains 22 km2. The subwatershed is one-half fully urbanized with residential, commercial and industrial land uses. The remaining fifty percent includes golf courses, agricultural and open space. The subwatershed represents the last large area within Scarborough's limits not yet fully urbanized. In 1980, a diversion structure was constructed, diverting all major flows for about fifty percent of the Morningside Tributary subwatershed to the Rouge River. Only baseflows up to 0.50 cubic metres per second are designed to continue downstream of the diversion. The diversion structure was constructed to reduce flooding potential downstream, thereby allowing full development of the downstream area.

With the cooperation of City Council, the various jurisdictional agencies, special interest groups and the development industry, five goals for the study were identified.

1. Ecosystem Protection and Enhancement
   "provide a strategy whereby the economy depends not only on the continued and sustainable urban development, but also on the protection and enhancement of the ecosystem and its habitat."
2. Greenlands System
   "protect, restore, develop and enhance the historic, cultural, recreational and visual amenities of the subwatershed."
3. Floodplain Management
   "minimize the threat to life and destruction of property and natural resources from flooding and preserve or reestablish the natural floodplain hydrologic functions where possible."
4. Pollution Prevention
   "prevent pollution before it happens; minimize the adverse impacts of pollution by managing it at source."
5. Land Use Planning and Integration
   "link the strategy and recommendations of this study to official municipal plans to guide and authorize development within the subwatershed."

Ecosystem Protection and Enhancement

The subwatershed lies within the Carolinian life zone, known for its distinct wildlife and vegetative species. With more than fifty percent of the subwatershed fully urbanized, a need was recognized to preserve and enhance where possible the important environmental features of the subwatershed.

Development in the past had little regard for ecosystem protection. Ecosystem features such as watercourses, forest cover and riparian habitat were treated as secondary to the development of an urban system. In portions of the subwatershed, low base flow, degraded habitat and channelized sections of the creek are all the result of a planning process that historically dealt with the environment after land uses and development rights were established. This consequence of this approach is a degraded, fragmented ecosystem.

The approach used in this study was to put the ecosystem first to determine the parameters necessary to protect the existing environmental features of the subwatershed and to provide a framework for improving and enhancing the entire ecosystem of the subwatershed. The study focussed on providing vegetated linkages within the subwatershed and also adjacent watersheds. An important outcome of the study was the conservation of a substantial corridor for the watercourse following biodiversity principles. The corridor width was based on many factors including meander belt width, floodplain management, and appropriate buffering.

The study also identified that restoration work to increase the vegetative cover in the subwatershed from the present level of fifteen percent to a minimum of twenty five percent is required to allow for a sustainable subwatershed. Vegetated, connecting links to the Rouge River system will be incorporated. Since fifty percent of the subwatershed still remains in a relatively undeveloped state, there is greater potential for the implementation of these recommendations and thus greater potential for the return to a more balanced, natural ecosystem.

The Morningside Tributary study is the first step in rethinking the role of land use planning in the context of the ecosystem approach. While not a panacea for all planning issues, the study has offered the City an alternative and more comprehensive method for handling development issues.

Greenlands System

One of the goals of the subwatershed study was to "protect, restore, develop and enhance the historic, cultural, recreational and visual amenities of the subwatershed." The subwatershed study planned to carefully assess the provision of municipal services for development of the area in an ecologically sound manner. It was expected that this would lead to preservation of lands in the stream corridor as a greenland area, where no development would be permitted. This evaluation had not been done in such a comprehensive manner prior to this.

It was thought that a greenlands system would encompass all of the lands required to protect the long-term health of the subwatershed and to provide ecological linkages to adjacent watersheds. There was a gap between desire to protect these greenlands and the authority to carry out this wish.

The undeveloped lands in the central reaches of Morningside Creek had been designated for development as an industrial area since the 1970's. Although the lands were predesignated in the City's Official Plan, the owners of the area had operated a golf course on a portion and the remainder was in agricultural use or vacant. New owners applied for development approval for a new concept which included housing and commercial development on a portion; industrial development was proposed on the remainder. The new proponent agreed to actively participate in the subwatershed study and agreed, in principal, that a greenlands area would be desirable.

The Rouge Park Management Plan and the Morningside Tributary subwatershed plan identified the need to protect the stream corridor. Earlier planning decisions, however, had designated only a much narrower corridor for protection. What tools were available to broaden this narrow band to the wider area hoped for in the Park Management Plan and implied by the greenlands goal?

Historically in the City of Scarborough, stream and valley corridors have been protected from development by public acquisition. Severe flooding in the early 1950's resulted in public acquisition of large areas of the Rouge River and Highland Creek for flood protection. The Metropolitan Toronto and Region Conservation Authority gradually identified flood prone areas and, through regulation, prohibited development. Gradually, municipalities also negotiated and received developer concurrence to deed the land below the valley crest.

In the case of Morningside Tributary, the stream corridor is made up of a very wide but shallow flood plain. In the upper reaches of this Tributary, the remains of forested areas extend out from the valley. As a result of the subwatershed study, the land being considered as greenlands, and concurrently park, constitutes forty five hectares. The subwatershed study had direct impact on increasing the open space allotment to allow for ecological factors.

For many years, the Ontario Planning Act has required a dedication of parkland consisting of two percent for industrial and five percent for residential development. This levy is supplied either in land or cash. Within the Morningside Tributary subwatershed, this will allow acquisition of a small portion of the greenlands and Rouge Park. In principle, if the valley land or stream corridor is a proportion of the developer's lands, the applicant will often design the Plan of Subdivision to allow dedication of up to ten metres from the stable top-of-bank, even if the lands are in excess of the parkland levy.

Development charges, a fee for developing land, has had the option of being used to acquire valley and stream corridors. The legislation is now changing so it can only be used for hard services such as stormwater ponds. As a result, this is no longer an option to help acquire greenlands.

Stewardship, private owners caring for their lands, has been identified as a potential route to protect greenlands. This may be a workable solution for cases where the private landowners do not wish to build on their lands. It may well be workable for existing golf courses as well. It is not a particularly viable option for the landowner who wishes to build on their lands. There is currently no tax advantage for stewardship which is being explored.

Tax deductions may be another option to acquire greenland areas. However, in Ontario, it is not yet possible, although discussion at the Provincial level is currently taking.

The bottom line to protecting greenlands, especially if the lands to be protected are extensive, is economics. Developers have been willing to deed substantial amounts of greenland if the overall economics allow for this. As a result, some money has been set aside in a special capital budget fund designed to acquire priority watercourses. The subwatershed Studies have generated data which helps establish priority lands to be acquired.

Floodplain Management

Prior to the subwatershed study, much of the urban development occurred on the basis of stormwater management studies. These were generally prepared for the specific development. These previous studies recommended efficient conveyance systems via the construction of storm sewers and channelization of the creek. Diversion and storage facilities were constructed to mitigate potential downstream impacts from developing upstream areas. A large diversion structure was partially constructed in 1980 to allow for development of the area. The diversion structure was designed to divert all of the major flows for fifty percent of the subwatershed to the Rouge River, with base flows only continuing downstream of the diversion.

Through the course of the subwatershed study it was recognized that the hydrologic cycle had been negatively modified by the construction of these works. Stream base flow could not support the cold water fishery that once existed. Since the diversion scheme was only partially completed, a risk of flooding and property damage still existed under regulatory conditions.

Through the use of computer simulation techniques and drawing on the expertise of the multidisciplinary team, a better understanding of the hydrologic cycle was developed. A stream corridor analysis was undertaken, which will guide the limit of future development within the subwatershed. Based on this analysis, the stream corridor will maintain the natural meander belt width and low flow channel, complete with appropriate buffers. This width varies, but is generally in the range of 60 metres.

Based on the analysis performed in the subwatershed study, the stream corridor will convey the regulatory storm events upstream of the diversion structure. The diversion structure will be modified to provide for the establishment of base flow conditions which will allow re-introduction of a cool water fisheries. The structure will allow storms up to a twenty year design event to be conveyed safely downstream in the natural channel. Stream flows reaching the diversion structure and exceeding this value will be diverted towards the Rouge River through a stormwater management facility. This flow target was established based on fisheries habitat and to protect against downstream flooding.

The stream corridor will envelop all significant adjacent vegetation. Ten metre wide buffers will provide an element of protection to the significant vegetation. This will provide for better terrestrial habitat and for biodiversity.

Pollution Prevention

As the subwatershed continues to allow urban development, the water quality of the creek must be safeguarded. Urban stormwater discharge can contain high concentrations of suspended solids, chemical oxygen demand, phosphorus, pathogens, pesticides, de-icing salts and numerous other substances. There is also the possibility of accidental and illegal discharges into storm sewers.

The first phase in the development of a suitable water quality management plan was to select a long list of alternative techniques for restoring and enhancing the watercourse system. The philosophy of approach adopted toward the implementation of stormwater management practices had a bearing on the preparation and evaluation of the list of alternatives. The approach adopted in this study assumes that:

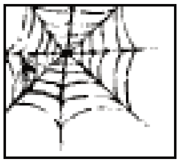
- stormwater runoff is a resource and should be utilized where possible for non-potable functions, where zero impact on baseflow can be demonstrated;
- since prevention is more efficient and cost effective at controlling stormwater quality, site level controls should be maximized where possible; and,

- fewer but larger centralized controls with multipurpose (quantity, quality, erosion recreation, and aesthetics), usage are preferable to numerous small uni-purpose facilities.

The preferred, ultimate water quality management plan consists of a centralized control strategy with source and pre-treatment control in new developments. Retrofitting of existing developments has been incorporated into the plan where cost effective.

Land Use Planning and Integration

The lengthy environmental studies which were undertaken in Phases I and II of the Morningside Sub-Watershed Study, have provided more detailed information about the environmental concerns in the subwatershed. This information has been shared with municipal staff, the developers and environmental interest groups. Phase III of the subwatershed study has set out how the municipal planning process can make the most of this information. Most importantly, City policies and procedures are being modified to incorporate this most unique approach to planning within the City of Scarborough's boundaries.



Watershed Management in the Headwaters of Nations' Rivers: The Mississippi and the Volga

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Howard Mooers, Associate Professor
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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

Why? There are countless books about two rivers. At the first glance it seems like one could add nothing new to the well known facts. Mighty Mississippi_Father of Waters. Mother Volga. Two national rivers for centuries inspired poets. Decades ago they became objects for large scale engineering remodeling and countless research projects. And yet surprising gaps strike one's mind if somebody turns to the consideration of accumulated knowledge about two rivers.

"Volga flows into the Caspian Sea", Russians say to mock somebody repeating facts familiar to a first grader. On a visit to the newly open gorgeous Tennessee fresh water aquarium I admired excellent collection which was exhibited with the great love to aquatic nature and imagination. Species from all great world rivers were exhibited under illuminated maps. I could not believe my eyes when looked at the Volga map: the river did not flow to the Caspian sea! The downstream stretch was bent and turned towards the Black sea. I explained the error to the attendant. The map makers were mislead by the canal connecting the Volga with the Don. Russians possess comparable amount of knowledge about the Mississippi. General sources of information on its hydrology are as fresh as Tom Sawyer's and Huck Finn's water rafting adventures from Mark Twain's novels.

While implementing in 1930-1950s canal, reservoir and dam construction plans designated to boost centrally planned economy, Russian hydrologists and engineers paid little attention to the practices of their colleagues at the Mississippi. Similarly, river management and gradual development of resource conservation strategies in the later basin were based solely on own experiences. Both approaches could be described in many cases as "try and error methods". There were obvious and strong reasons for mutual ignorance. Countries were political rivals for too long, and the current of events around two national rivers followed the politically designated streamline. For decades independently developed river basin management strategies were applied to each river. While navigation locks and levees were chosen as basic control structures for the Mississippi, the Volga experienced drastic flow regulation by hydropower dams, which turned this river into the almost continuous chain of shallow lakes.

Historic parallels. Historic parallels are astonishing. As old as the human race is the history of human impacts on the hydrologic regime and water quality of great rivers. National symbolic character of both rivers, however, does not originate in a too remote past. Consolidation of the entire basins under national authority is a relative historic novelty. Only in 1550s, six centuries later than the beginning of the Russian statehood, Czar Ivan the Terrible was able to concur Tatar cities Kazan and Astrakhan, which guarded the midstream Volga and its mouth. The USA became the owner of the Mississippi from its source to its mouth only in XIX century, after the purchase of Louisiana from France in 1803. Since that both rivers were put on the national service to unite and connect scattered settlements and to advance national frontiers. The Volga tributaries conveyed Russians to the Ural mountains and then to Siberia, the Mississippi's ones carried pioneers to the gates to the West.

The commercial exploitation of rivers boosted economic development on its watersheds. Stages of capitalism repeatedly played its turns around two rivers in late XIX - early XX centuries. Prosperous lumber industry in the headwaters floated countless timber rafts downstream. When forest resources declined by predatory clear cuts and fires, upstream shipments of grain and other agricultural products dominated among navigation cargos for a while. Steamboats and machine revolution were the yeast for urbanization. Large and small cities started to dump its raw sewage and industrial wastes into the rivers. Navigation required safe passages_so locks, dams and canalized streams were created. Growing industries demanded cheap electricity_and the challenge to harness the rivers for hydropower generation materialized. Flood protection needs directed levee construction, as agriculture did drainage works. Eventually, the rivers and their watersheds experienced major alterations that affected flow regimes, land features and the underlying structure of the original ecosystems.

The hydropower era was marked for two rivers by amazing analogies as well as by exploring alternative ways. By 1913 the Mississippi already had the largest in the world 1.4 km long hydropower dam at Keokuk, Iowa. The project was implemented under the guidance of the famous engineer Hugh L. Cooper. Later Cooper was serving to the Russian government as a consulting engineer for the Dnieperstroy hydroelectric project. He became the first foreign recipient of the Order of the Red Star when the completed dam over the Dnieper river was dedicated in 1932 (Scarpino, 1985). The Dnieper dam, the first of this class in the Soviet Union, became the prototype for the further construction of a cascade of hydroelectric power dams over the Volga. In 1940-1970s the Volga was converted into a continual chain of shallow water lakes - reservoirs.

Other giant hydropower projects did not succeed at the Mississippi after the Keokuk dam. Costly and harmful to the environment when built at plain rivers, these projects did not become very popular in the USA where more beneficial mountainous sites were available. However, in 1913 the motif of glorifying the erection of the huge dam and the man's victory over nature sounded loudly at Keokuk. "Utilizing the water power wasting at our doors," "The will of Man hath won" were the headlines of the local newspapers. Stanzas from poems reverberated with optimism and the adjectives like colossal, mammoth, enormous, spectacular, greatest and boldest were filling the articles, describing the Mississippi dam (Scarpino, 1985). This original motif was reiterated and amplified at the Volga banks few decades after. From today the Keokuk dam could be fairly viewed as one of the seeds for historic, personal, economic and emotional links between two rivers.

The Mississippi came through its development periods at the higher speed, probably, distinctive for the dynamic nature of the whole American economy. Most of the man-induced changes were compressed here into a few short decades since 1890s till mid 1950s. Environmental movement and regulations, developed since 1960s prevented many of new hydraulic structures from being erected, wetlands from being drained and reduced pollution.

The Volga confronted human impacts which were more extended in time and scale, profound in effects, than on the Mississippi. The magnitude of events was drastic. In 1930-1940 Stalin's prisoner camps provided abundant labor for erection of many dams across the Volga, locks and canal network, linking the river with several sea ports. More than 300 reservoirs were constructed in the basin, 8 in the main stream, which flooded 40,000 sq. km of productive flood plain. Water exchange slowed down 10 times and pollution reached the hazardous level. Fish catch in the Volga-Caspian basin decreased from 614,900 ton in 1930 to 76,500 in 1988 (Zubareva, 1994). The hydraulic structure construction boom ended in mid-1980s after the notorious public fight against the water transfer project Northern rivers_the Caspian sea. It was the first victory of the public opinion over the centrally planned system, the first one in the dramatic chain of events, which eventually lead to the collapse of the Soviet Union. However, that victory of environmental movement turned to be fruitless at the time. Environmentalists were not capable to achieve considerable positive results under general economic, political and legal disarray of the last decade.

What is similar? River management strategies in both basins are undergoing radical transformations. Goals and objectives for water resources use, means and principles of control are changing. This is just the right time to look and study what could be similar or different, and what could present mutual interest from the experience of human interactions with two great rivers. It is especially interesting because river management concepts in the both river basins accepted the theory of the river unity with its watershed. Any undesirable condition of the river, whether it is flood, pollution or river channel sedimentation, is linked to and could be controlled by watershed management.

With this kind of refocusing the apparent similarities of many hydrologic features in two upstream basins become of more significance. Maximum peak flow in both upper basins originates from snow melt. The Mississippi and the Volga upstream basins are situated on gently rolling plains in mixed forest zones. Northern portions extend into coniferous forests, and southern ones into hardwood forest zones, where, respectively, 50-60% and less than 30% of forested land remains. Steppe and prairie occupy the south edges of both upper basins. The annual precipitation is 500-600 mm with similar seasonal distribution in both areas. The Quaternary sediments are of glacial till and moraine, glacial outwash, lacustrine and alluvial origin. Wetlands are typical. They occupy more than 25% of area at less disturbed watersheds, and have hydric soils with various degree of gley process development and/or peat accumulation (Bhowmik et al, 1995; Sergeev, 1984). The land forms in the Upper Mississippi and the Upper Volga were created by the glaciation. In the first basin the recent Wisconsin glaciation was spread over the northern portion, and Illinois glacier land forms are found further south. In the Upper Volga the recent glacier (Valday) occupied the smaller north western margin of the basin, while Moscow glacier forms dominate the rest of the territory.

High gradients of climate and associated runoff changes are typical for the Mississippi headwaters. Annual runoff in Minnesota decreases from 430 to 50 mm from the north east to the south west over 360 km distance (1.05 mm/km). In the Upper Volga more uniform hydrology conditions exist. Runoff changes from 300 to 100 mm over 600 km towards south west (0.33 mm/km). The hydrology of watersheds in middle parts of the basins is quite similar (figure 1).

Turning point and goals. By the end of the XX century the river basin management policies seem to arrive to a turning point both at the Mississippi and the Volga. This is the time for formulating new policies, which need to be free from former extremes_both from selfish ripping off economic merits for the sake of one generation, and from lifting unrealistic environmental prohibitions, calling for the restoration of untouchable wilderness. This balanced management approach is known as a "sustainable development".

However, for now sustainability exists more like a theory, than as a practical accomplishment. Balancing conflicting needs is not an easy task. Local experience and general wisdom are not always sufficient for making right choices, either in the Mississippi and in the Volga basins. That is there, where so many natural similarities and unresolved environmental problems exist. That is why the comparative analysis of two river basins with differing magnitudes of human impacts could become especially beneficial. And that is now, when the learning of environmental history lessons in detail becomes more possible than ever. The prerequisites to this study are the following: 1. The periods of extensive engineering development for both river channels are left behind. Driven by floods at the Mississippi, alarming pollution and shallow reservoir ecosystems degradation at the Volga, the focus of attention in both countries gradually is being shifted to upstream watersheds management. 2. The Soviet Union collapsed and many previous restriction for the information exchange have been removed. 3. Geographical Information Systems become available to serve for spatial data analysis and for linking diverse watershed impacts to downstream endpoints.

How to perform a comparative study? The Natural Resources Research Institute, University of Minnesota, Duluth, initiated a project with the goal to demonstrate how GIS could facilitate watershed management. The project, funded by IREX (International Research and Exchange Board), is titled "GIS as an integrating tool for multidisciplinary environmental efforts in the headwaters of nations' rivers: the Mississippi and the Volga". This is the international study, conducted in cooperation with Russian colleagues, who spent lifetime for water resources research of the Volga basin. Wide gaps exist in Russia among advanced theoretic perceptions of scientists and the practice of land and water resources use in river basins. The purposes of the project is to convey to the related agencies in Russia the experience of GIS applications in integrated studies and management of watersheds, accumulated in the USA, and to establish the exchange of research results, beneficial for scientific studies of global environmental problems. Collaborative links were established at the Moscow State University, Russian Academy of Science, research stations in Moscow, Novgorod, Tver and Kostroma regions, State Institute of Applied Ecology, National Park "Losiny Ostrov." Field studies of wetland impacts on watershed hydrology under variety of natural and human impacts were conducted at the following watersheds: river Polomet' and lake Valday (Novgorod Region); river Velesa, tributary to the Zapadnaya Dvina at the vicinity of Sosvyatskoye (Zapadnaya Dvina district, Tver Region); river Unzha, tributary to the Volga (Manturovo and Makariev districts, Kostroma region); river Istra, tributary to the Moscow river at Kholcsheviki (Istra district, Moscow Region); river Yauza, tributary to the Moscow river (city of Moscow and Mytischi district of Moscow Region). The discussions with Russian colleagues revealed the growing interest to the variety of issues of GIS applications to water resources management. Though this technique is still not so easily available to many researchers and decision makers in Russia, the noticeable advance in its development was made in the last two years. Original GIS software were created and applied at the Moscow State University, State Institute of Applied Ecology, Geocentre Moscow and Geosoft Istlink. Researchers of this institutions are working on linking process based hydrological and environmental models with GIS.

The results of the project are available on WWW (http://gp1.nrri.umn.edu/russia.html).

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Modeling Soil Erosion and Sediment Transport on Watersheds with the Help of Quasi Three-dimensional Runoff Model

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The main objective of this study was the development a distributed physically-based soil erosion model and the including its in the hydrological modelling system of Water Problems Institute of Russian Academy of Sciences (Kuchment, 1983). The developed soil erosion model allows to simulate the temporal and spatial variations in erosion by raindrop impact and overland flow, sediment transport and deposition.

Structure of the Model

Quasi Three Dimensional Model of Rainfall Runoff Formation

A physically based model of rainfall runoff formation is based on using differential equations which describe the processes of overland, groundwater, subsurface, channel flow as well as vertical moisture transfer in soil. The catchment is represented in the horizontal plane by rectanqular grid squares. The main channel and the tributaries of different orders are represented by the boundaries of grid squares.

The model describes the following processes:

1. vertical moisture transport in the unsaturated zone (the one-dimensional Richard's equation is used; the calculations is carried out for each grid square of hillslope);

2. groundwater flow and the interaction of surface and groundwater on the hillslope and in the river channel (the two-dimensional Boussinesq equations are used);

3. overland flow (the two dimensional kinematic wave equations are applied);

4. unsteady flow in the river network (the one-dimensional kinematic wave equations are used).

The organization of the interaction between components of the hydrological modelling system allows to take feedback into account. Coupling of the calculations of the vertical moisture transport with the overland and groundwater flow is accomplished by means of a special procedure. More detailed description of the hydrologic block of the quasi three dimensional model can be seen in (Demidov, 1989; Kuchment et al., 1991).

Modeling Soil Erosion and Sediment Transport in the River Basin

A soil erosion and sediment transport model was developed as a separate block of the hydrological modelling system. The soil erosion model describes the temporal and spatial variations of the soil erosion and the sediment transport in the river basins during flood events (erosion by raindrop impact and overland flow, sediment transportation and deposition).

The erosion rate by raindrop impact, $D_r\,(kg\ m^{-2} s^{-1})$, is expressed by the following equation

$$D_r = K_r K_s i F_r R^{\beta}, \qquad (1)$$

where K_r is the soil erodibility factor for erosion by raindrop impact; K_s is the fraction of bare soil; i is the ground surface slope $(m\ m^{-1})$; R is the rainfall intensity $(cm\ s^{-1})$; β is an exponent; F_r is the factor reflecting influence of the water depth on erosion by raindrop impact that is expressed as (Park,1982)

$$F_r = \begin{cases} \exp(1 - h\bar{D}^{-1}) & \text{if } h > \bar{D} \\ 1 & \text{if } h \le \bar{D} \end{cases} \qquad (2)$$

where h is the flow depth (m); $\bar{D}$ is the median diameter of raindrops that is determined from $\bar{D} = 0.0193\ R^{0.182}$ (Laws, Parsons, 1943).

The erosion rate by overland flow impact, $D_e\ (kg\ m^{-2}s^{-1})$, is calculated as (Ariathurai, Arulanandan, 1978)

$$D_e = \begin{cases} K\left[\frac{\tau}{\tau_c} - 1\right] & \text{if } \tau > \tau_c \\ 0 & \text{if } \tau \leq \tau_c \end{cases} \qquad (3)$$

where K_e is the overland flow soil erodibility coefficient; is the shear stress $(kg\ m^{-1}s^{-2})$; τ_c is the critical shear stress, which is taken to be equal

$$\tau_c = pgi(ni^{-0.5}V_p)^{1.5} \qquad (4)$$

where is the water density $(kg\ m^{-3})$; g is the acceleration of gravity (ms^{-2}) ; n is the Manning roughness coefficient $s\ m^{-1/3}$; V_p is the pickup velocity (ms^{-1}) that is determined by the equation (Shamov, 1954) $V_p = 1.14(g\ a\ d)^{0.5}$, where $a = (P_T\ P^{-1} - 1)$, P_T is the sediment density $(kg\ m^{-3})$; ; d is the grain diameter (m).

The sediment transport capacity, $G_T\ (kg\ m^{-1}\ s^{-1})$, is calculated by means of the Engelund-Hansen's equation

$$G_T = 0.04\ \frac{V.V^{2}P_T}{\psi a g} \qquad [5]$$

where V is the flow velocity (ms^{-1}); V* is the shear velocity (ms^{-1}); ψ is the criterion which is equal $\psi = a\ d\ h^{-1}i^{-1}$.

The sediment transport by the overland flow is described by two-dimensional sediment continuity equation

$$\frac{\partial}{\partial t}(hC) + \frac{\partial}{\partial x} G_x + \frac{\partial}{\partial y} G_y = E \qquad [6]$$

$$E = -(1 - \varepsilon) P_T \frac{\partial z}{\partial t}$$

where C is the sediment concentration $(kg\ m^{-3})$; G_x, G_y are the sediment transport rate in the x and y -direction respectively $(kg\ m^{-2} s^{-1})$; ε is the soil surface porosity; z is the soil surface elevation (m); E is the erosion or deposition rate on surface slope $(kg\ m^{-2} s^{-1})$. Sediment routing in channels is described by the one-dimensional sediment continuity equation. Numerical integration of these equations are carried out an implicit finite difference scheme.

Model Application

To test the soil erosion block in the hydrological modelling system the observation data of the water regime and the sediment flow for the Studeniy River basin located in area of Transcarpatian water balance station were used. The watershed area is 25.4 km2, the average height of the watershed is 793 m above sea level, the average width is 3.2 km, the channel length is 8.0 km and the average channel slope is 31.2%0. The surface cover is represented by sandy clay loams; the soils are moderately podzolized brown soils. The lengths of the reaches of the channel network, the slopes of the river bed and the catchment surface were determined from a topographic map.

The lenghts of the reaches of the channel network, the slopes of the river bed and the catchment surface were determined from a topographic map. The horisontal permeability coefficient was determined by matching the values of the observed base flow with these calculated and was taken equal to 0.6 m day-1. In the calculations of the vertical moisture transfer in the unsaturated zone, the saturated hydraulic conductivity coefficient was taken equal to the horisontal permeability coefficient. The equiblirium moisture profiles calculated for a different thickness of the unsaturated zone were used as the initial moisture profiles.

The results of the calculations of maximum discharges and total runoff for floods show a sufficiently well agreement with observed values. The error in the calculations of maximum discharges constitutes in the average 17%. At the same time, the difference between observed and calculated total runoff for each flood does not exceed 14%.

The estimation of the soil erosion model parameters have been obtained from literature data and calibration. The calibration was carried out by comparing the calculated sediment hydrographs with observed data for the flood of 12-13 May 1970. On results of the calibration the raindrop soil erodibility coefficient, K_r , was taken equal 50 and the overland flow soil erodibility coefficient, K_e , equal 0.1 10-3. The calculations of soil erosion during other four floods carried out without changing the calibration value of K_r and K_e. The calculations on the model were carried out with a half hour time step. The calculation results of suspended sediment discharges on the whole sufficiently well fit to observed data.

The calculation results showed that the groundwater table in the near-channel areas before the start of the flood significantly influences on the total volume of sediment runoff from the watershed in comparison with flood runoff. For example, a rise of the groundwater table by 0.2m for the flood of 27-28 June 1974 caused increasing flood runoff volume on 20% and at the same time the total sediment runoff in this conditions increased on 70% (Table 1). The groundwater table in the near-channel areas before the beginning of the flood especially greatly caused on the calculation results for the flood of 24-25 June 1974. Because of increasing the groundwater table the rainfall runoff of this flood increased about two times and sediment runoff about twelve times (Table 1).

Table 1. Effect of the groundwater table in the near-channel areas on the total volume rainfall and sediment runoff.

Date of flood	Groundwater table, m	Volume of runoff, mm	Volume of sediment runoff, T
12-13 May, 1970	0.3	22.7	1410
	0.5	17.8	677
16-17 July, 1970	0.4	18.9	608
	0.6	12.4	101
24-25 June, 1974	0.5	18.9	892
	0.7	8.8	72
27-28 June, 1974	0.3	26.7	2910
	0.5	i22.3	1720

22-23 July, 1974	**0.3**	**16.9**	**679**
	0.5	**11.7**	**186**

The spatial variation of the net erosion or net deposition in the catchment for the flood of 24-25 June 1974 is shown in Figure 1. From the figure it can be seen that large erosion is on steep and excessive moistening grid squares where overland flow can be formed. Deposition of suspended sediment is usually on flat grid squares due to decreasing a sediment transport capacity.

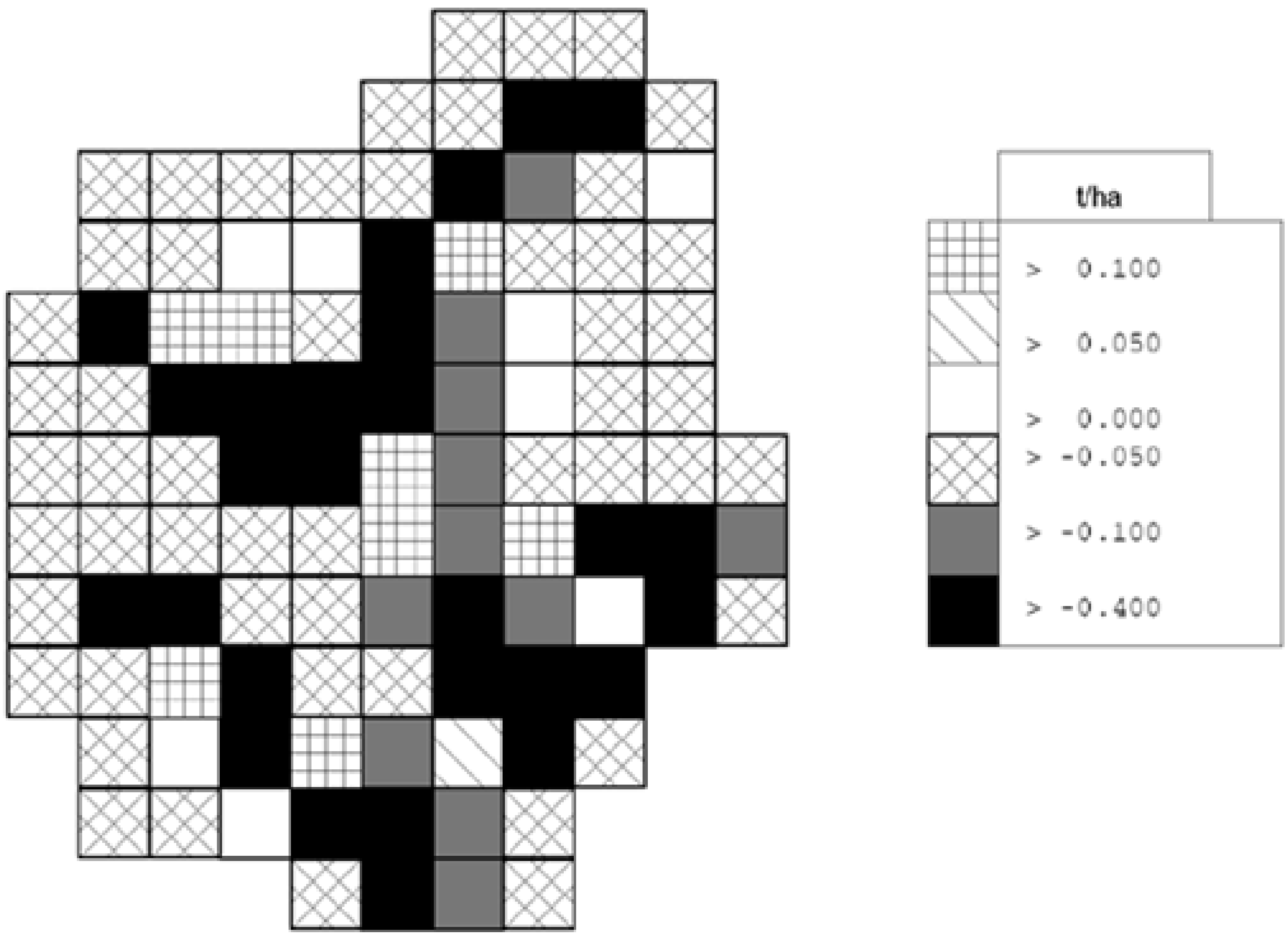

Figure 1. Spatial distribution of the net erosion/deposition on the Studeniy Watershed for the flood of July 22-23, 1974.

Conclusion

A physically-based model describing soil erosion and sediment transport processes was coupled with hydrological modelling system (quasi three-dimensional physically-based model of rainfall runoff formation). The erosion rate is taken to be the sum of the erosion rates caused by raindrop impact and overland flow that are determined by rainfall intensity, hydrologic and hydraulic variables and soil characteristics. The hillslope sediment transport model is based on two-dimensional sediment continuity equation, the sediment transport in the river network is described by a one-dimensional equation of mass conservation.

In modelling the sediment transport was taken into account that the sediment discharges may be limited by the sediment transport capacity which is expressed by Engelund-Hansen's equation. The developed soil erosion model describes both the temporal and spatial variations of soil erosion and sediment yield in a catchment.

The model was tested for the Studeniy River basin. Results of the calculations of water and sediment discharges from the model were in agreement with observed data. The calculation results also showed that the groundwater table in the near-channel areas before the start of the flood significantly influences on the soil erosion process rate and the total volume of sediment runoff from the watershed.

The physically-based model allow to determine on the genetic basis the role of hydrometeorological factors and surface watershed characteristics on development of soil erosion processes, to quantify the effects of changed land use and conservation practices on sediment yield.

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Consensus Building in Watershed Management Initiatives: Lessons from the National Estuary Program

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The U.S. Environmental Protection Agency is charged with administering the National Estuary Program (NEP), section 320 of the Clean Water Act. There are currently 28 National Estuary Programs around the country. The NEP employs consensus building processes to develop Comprehensive Conservation and Management Plans (CCMPs) to protect and enhance water quality and living resources in estuaries of national significance. Estuary study areas are often defined by watersheds.

Consensus building is an effective tool for facilitating partnerships among all levels of government, the private sector, and the public. This type of decision-making often leads to acceptance of and support for difficult decisions and actions, particularly when all stakeholders are involved in the process of identifying issues and setting priorities. Consensus aids in developing community based stewardship of natural resources.

This panel, moderated by Suzanne Orenstein, Vice President of RESOLVE, Inc., will describe the use of consensus building in different phases of the NEP process. Richard Volk, Director of the Corpus Christi National Estuary Program will discuss consensus building in the visioning process; Helen Drummond, Water Quality and Sediment Quality Team Leader of the Galveston Bay National Estuary Program will illustrate how they applied consensus based approaches to move from scientific characterization of the estuary to plan and action item development; and Lee Doggett from the Casco Bay Estuary Project will explain their community and consensus based process in strategically prioritizing actions.

The Visioning Process and Its Role in Consensus-Building

Richard Volk, Program Director
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Abstract

The Corpus Christi Bay National Estuary Program (CCBNEP) is an ecosystem scale regional planning effort that is stakeholder driven and that involves consensus decision-making. During the Program's four-year planning phase, more than 100,000 volunteer hours will be invested, mostly in large group meetings. In an effective meeting, the group must be of one mind; focused on the same problem in the same way at the same time. Such focus is particularly challenging for regional planners, since the task of regional planning often means different things to different people. In its early stages therefore, the Program's Management Conference recognized the value in creating a Program Vision Statement to help set the parameters for the regional planning effort_both in approach (and thus content), and on the time scale to be used for goal setting. A CCBNEP Vision Statement and Operating Principles were developed by more than 110 participants during a two-day workshop in February 1995. An innovative computer-based balloting program was utilized to obtain large group input on the 'key themes' to be included in the vision statement. Guidelines for what a vision statement should and should not be were discussed. After its successful development, the vision statement and operating principles were ratified by the Program's Management Committee and have become the basis for discussion by the more than 325 individuals representing 165 stakeholder groups involved in the development of potential management actions for the study area.

Moving From Characterization To Plan Development

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Galveston Bay is the largest estuary in Texas and the second most productive in the United States. It covers over 600 square miles and its average depth is about 10 feet. The Bay is surrounded by 203 square miles of estuarine marsh, 14 square miles of forested wetlands and 61 square miles of fresh water ponds and lakes.

The Galveston Bay system is adjacent to one of the largest urban areas in the United States. Nearly 50% of the nation's petrochemical production and 30% of the nation's petroleum industry is located around these bays, comprising the world's largest petrochemical complex. The Port of Houston is the third largest port in the United States and sixth largest in the world-more than 140 million tons of cargo pass through this port each year. Approximately 60% of the wastewater discharged in Texas flows into the Galveston Bay System, and 45% of all wastewater treatment plants on the U.S. Gulf Coast are in the Galveston Bay region. More than 7 million people, half the Texas population, use the Galveston Bay System as a final destination for wastewater.

Galveston Bay's lower watershed is home to some 3.5 million people, with a government structure that includes five counties, some 15 agencies with bay resource jurisdictions, and an incredible 500 or more water, utility, and drainage districts. This patchwork mosaic of jurisdictions gives new meaning to the term "fragmented".

The problems which currently plague many coastal ecosystems fundamentally differ from those of the past. In the past, major improvements in water quality were possible with relatively simple (if expensive) end-of-the-pipe regulation. Some gains are still to be made in traditional water quality approaches. However, the traditional management approaches do not apply to problems like pervasive habitat loss, diffuse sources of non-point contamination, or freshwater inflow alteration. These are ecosystem problems, not limited to individual natural resources, nor circumscribed by political boundaries. These problems are complex and interrelated, involving the bay itself, its tributaries to some distance upstream, and the watersheds where humans carry on their daily activities.

How The Galveston Bay Plan Was Created

The Galveston Bay National Estuary Program was created to comprehensively address problems resulting from human pollution, development, and overuse of estuarine resources. Work was undertaken by an appointed consortium of state and federal agencies, industry, and citizen members - the GBNEP Management Conference, in three phases:

Phase One: Agreement on bay problems. A Priority Problems List was established by consensus of the Management Conference. This list provided guidance for the next step.

Phase Two: Scientific characterization of the problems. Over a four-year period, numerous scientific studies were carried out to determine the status, trends, and probable causes of the problems. This effort culminated in publication of a book entitled: The State of the Bay: A Characterization of the Galveston Bay Ecosystem. This step resulted in substantial re-definition of the bay's problems, providing a strong factual foundation for management planning.

Phase Three: Development of solutions. The Galveston Bay Plan links a set of specific initiatives to the identified problems in Galveston Bay. These solutions were developed over three years by sixteen task forces established by the Management Committee of the GBNEP.

The approach taken by the Management Conference to develop The Galveston Bay Plan was one of consensus-building among all Galveston Bay user groups, government agencies, and the public. This approach was based on a philosophy that the best governance for Galveston Bay can only be established by strong and direct involvement of the people who live and work in the Galveston Bay region. No environmental program in the history of the state has involved citizens and stakeholders more actively in environmental problem-solving.

The Role of the Public

Strong involvement by the public was indispensable to the development of The Galveston Bay Plan. When the GBNEP began in 1989, a Citizen's Advisory Steering Committee (CASC) was established. Appointments to this committee included a variety of stakeholder interests: industry, shipping, recreational boating, commercial and recreational fishing, development, agriculture, and environmental groups. The committee was instrumental in assuring that citizen/stakeholder perspectives were at the forefront of planning. The CASC undertook several projects that were aimed at fostering public awareness and involvement with the GBNEP and the development of The Galveston Bay Plan.

Numerous public meetings were also held to obtain citizen input on the developing Galveston Bay Plan. A total of 35 meetings were conducted between April, 1989, and June, 1994. The public was made aware of the availability of summary documents and encouraged to attend the public meetings through a variety of mechanisms: news releases to area media; paid display and legal notice advertising; articles and notices in environmental group and civic association newsletters; postcards mailed to all BayLine subscribers; and speeches by staff and volunteers to targeted groups and organizations. One-page news advisories, or reminders of the meetings, were faxed to radio stations and newspapers in the locale of the meetings one to two days in advance of each meeting.

The developing Plan was also reviewed by numerous "focus groups" through an active outreach program sponsored by the GBNEP. These focus groups included industry, environmental groups, local governments, and others. Fifty-six focus group meetings were held between June 1993, and May 1994. The direct involvement of the general public and Galveston Bay stakeholders helped shape The Plan that was unanimously approved by the GBNEP Policy Committee for submission to EPA Adminstrator Browner.

The Role of the Scientist

The Scientific/Technical Advisory Committee, established in 1989, provided scientific and technical guidance to the Management Conference by identifying estuarine problems and by overseeing studies to establish the trends and probable causes necessary for management action.

Because the world views of scientists and resource managers clearly differ, some sort of agreed-upon guidance was necessary for these diverging views to be reconciled. Certain conceptual boundaries were applied to the program' s scientific activity in order to provide information of optimal use in management planning. These guidelines were:

- Projects must address the right questions, requiring that managers have a role in identifying and ranking project topics;
- Projects must be undertaken in the context of a perturbed ecosystem, requiring that projects focus on impact dynamics rather than traditional ecology alone;
- Projects must provide data at a scale of resolution applicable to management, requiring generalized geographic ordering of projects and sampling within projects;
- Results must be available to managers in an accessible, useful format, requiring that data be converted to synoptic information; and
- Ongoing work must fulfill a sensory feedback function to managers, requiring a monitoring program with a direct link to management objectives.

To address this last issue, a Priority Problems List was agreed upon as a focal point for consensus about where to begin the scientific process. Generally, issues were advanced in this process if they had system-wide impact, impaired designated uses, or (more practically) if they could be quickly or cheaply fixed. For Galveston Bay, the preliminary Priority Problems List was drafted by scientists based upon joint expert opinion. The list was then adopted by consensus of the Management Committee.

Over a course of about 4 years, the program then carried out several dozen scientific projects. Seventeen issues emerged from the bay characterization process as worthy of management attention. In rank order of importance for bay management, the top six problems were:

- Vital Galveston Bay habitats like wetlands have been lost or reduced in value by a range of human activities, threatening the bay's future sustained productivity.
- Contaminated runoff from non-point sources degrades the water and sediments of bay tributaries and some near-shore areas.
- Raw or partially treated sewage and industrial waste enters Galveston Bay due to design and operational problems, especially during rainfall runoff.
- Future demands for freshwater and alterations to circulation may seriously affect productivity and overall ecosystem health.
- Certain toxic substances have contaminated water and sediment, and may have a negative effect on aquatic life in contaminated areas.
- Certain species of marine organisms and birds have shown a declining population trend.

Each study which contributed to these findings was published in the program's technical monograph series. These volumes were made available to all who requested copies and distributed to some 50 area libraries. Two State of the Bay Symposia were convened, and proceedings published, in 1991 and 1993. Finally, the scientific work was compiled in a single book entitled The State of the Bay: A Characterization of the Galveston Bay Ecosystem.

The Galveston Bay Plan

Based on characterization study findings goals were established to address each problem identified in the priority list. These goals were then the basis

Table 1. Goal Priorities in *The Galveston Bay Plan.*

for more specific objectives and actions, which are the heart of The Plan. Table 1 describes the relative importance of The Plan's goals. The table subdivides the goals into three major bay management categories: Water and Sediment Quality Improvement, Habitat/Living Resources Conservation, and Balanced Human Uses. Goals in each of these categories are classified by their priority level- that is their relative importance in comprehensive planning to solve the problems. Within each priority level in the table individual goals are also listed in order of priority. Ultimately, 82 management actions were established, each of which were assigned a priority rank of "High," "Medium," or "Low" based on deliberation by the Management Conference, including the sixteen task forces. In assigning these ranks, the Management Conference considered both the costs and probable outcomes of the actions, and made judgments about which were most significant in

Priority Level	**Water/Sediment Quality Improvement**	**Habitat/Living Resource Conservation**	**Balanced Human Uses**
Very High	Reduce NPD pollutant loads Reduce toxicity and contaminant concentrations in water and sediments. Eliminate wet weather sewage bypasses/overflows	Increase the quantity and improve the quality of wetlands for fish and wildlife. Eliminate or mitigate the conversion of wetlands to other uses caused by human activities	Ensure beneficial freshwater inflows necessary for a salinity, nutrient , and sediment loading regime adequate to maintain productivity of econmonically important and ecologically characteristic species in Galveston Bay.
High	Eliminate pollution problems from poorly operated wastewater treatment plants Restore and/or compensate for environmental damage (injury) resulting from discharges of oil or the release of hazardous substances. Eliminate illegal connections to storm sewers, which result in introduciton of untreated wastes directly to bay tributaries	Acquire existing wetland habitats and provide ecomonic incentives for conservation Reverse the declining population trend for affected species of marine organisms and birds, and maintain the populations of other economic and ecologically important species.	Reduce the potential health risk resulting from consumption of seafood contaminated with toxic substances. Reduce negative environmental consequences to the bay (i.e. human-induced erosion) form shoreline development

relation to the bay's documented problems. The assigned rankings will provide a guideline for expenditure of funds during implementation of The Plan. In all, several hundred meetings were convened as The Galveston Bay Plan evolved through six complete revisions.

The cohesiveness of the comprehensive planning effort is reflected in the unprecedented level and breadth of endorsements that The Galveston Bay Plan has received. Support for The Galveston Bay Plan ranges from The Texas Chemical Council and Greater Houston Partnership to the Galveston Bay Foundation (a non-profit conservation organization) and The League of Women Voters. Examples of the numerous statements of support from diverse organizations appear on several pages in the front of The Galveston Bay Plan itself. Prior to The Galveston Bay Plan, no natural resource management program in Texas had ever received such a broad basis of support for implementation of comprehensive ecosystem management.

	Increase dissolved oxygen in problem areas.		
Moderate	Reduce agricultrual NPS pollutant loads Reduce industrial NPS pollutant loads. Reduce marina water quality degradation associated with sewage. Reduce marina/dockside NPS loads	Selectively moderate erosional impacts to the bay and associated shorelines Increase porductivity of oyster reefs in West Bay. Restore deteriorated colonial bird nesting islands to usefulness and create new islands for birds where nesting habitat is inadequate.	Reduce oyster reef harvest closures. Ensure that alterations to circulation do not negatively affect productivity and overall ecosystem health.
Low	Reduce construction NPS pollutant loads. Reduce the impact from spills on the natural environment. Eliminate illegal dumping. Eliminate waterborne debris	Eradicate or reduce the populations of exotic/opportunistic species which threaten desirable native species, habitats, and ecological relationships. Prevent the introduction of additional exotic species.	Reduce risk of water-borne illness resulting from contact recreation. Increase environmentally compatible public access to bay resources.

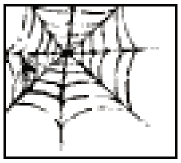
Based on this broad agency, industry, and environmental consensus, The Galveston Bay Plan was endorsed by the Governor of Texas in December, 1994, and simultaneously submitted for approval by EPA Administrator Browner. The Plan was given federal approval in April 1995 and has become the first crossjurisdictional ecosystem management document of its kind to be implemented in Texas.

Implementation of the Galveston Bay Plan

The Texas Natural Resource Conservation Commission (TNRCC) and the Texas General Land Office (GLO) are jointly administering implementation of The Galveston Bay Plan. A Galvetson Bay Estuary Program (GBEP) Director and a staff of 9 TNRCC employees oversee implementation. The composition of the staff reflects The Plan's initiatives, with expertise in wetlands and estuarine habitats, coastal resource conservation, non-point source pollution issues, water quality and public education. Work of the staff also include support actions such as regional monitoring initiatives, research, and fostering continued public participation in establishing management policy. The duties of the GBEP staff include the following:

- Acquire, manage and disperse funds to implement The Plan.
- Review federal, state and local projects in an open process for consistency with The Plan.
- Provide for coordination with the Texas Coastal Management Program (CMP) and the Coastal Coordination Council (CCC).
- Provide for coordination and communication among state and federal resource agencies for the many cross-jurisdictional issues.
- Monitor implementation of specific actions by The Plan's partners.
- Identify and communicate bay improvements to agencies, stakeholders, and the public, and redirect The Galveston Bay Plan where improvements lag.
- Conduct public outreach and education to increase public awareness of Galveston Bay, and to advocate conservation of the estuary.
- Evaluate the impacts of proposed actions on cultural resources and areas of historical significance.

Diverse concerns for habitat and wildlife, competing resource uses, water quality, and human health cannot be adequately addressed without the involvement of multiple natural resource agencies and bay stakeholders. To achieve success, problems of a regional nature-those affecting the entire ecosystem-will require regionally coordinated actions. Because of the comprehensive nature of The Plan, the creation of a Galveston Bay Council (GBC) to advise the GBEP is an important part of implementation. The GBC consist of representatives of federal, state and local natural resource agencies, the research community, local governments, citizens groups including representatives from low-income and minority communities, and other Galveston Bay stakeholders. The GBC will help the GBEP provide a continuing focus on Galveston Bay issues and coordination among the implementing organizations. The GBC will have a strong advisory role; not merely perfunctory.



Note: This information is provided for reference purposes only. Although the information provided here was accurate and current when first created, it is now outdated.

Priority Setting for the Casco Bay Estuary Project

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The Casco Bay Plan focuses on five priority issues. There was a need to limit the number of issues included as part of the five year estuary project because of time and financial constraints. These may not be the only issues the Casco Bay Estuary Project addresses but they are the issues it will address first. Once implementation is underway, the Project may identify and address other issues. This paper focuses on the process of issue prioritization for the Casco Bay Estuary Project.

Background

Casco Bay was accepted into the National Estuary Program in April, 1990. That summer the organizational structure was developed and committees were formed. These committees included a Management Committee, a Citizens Advisory Committee, a Local Government Committee and a Technical Advisory Committee. The Management Committee of the Casco Bay Estuary Project represents a diverse group including state and federal agencies, industry, citizen groups, local government officials, and scientific and education institutions. However, Management Committee members realized that public participation was vital to the success of the Project and the development of the Casco Bay Plan.

Public Input

In the fall of the first year, the first public forum was held. The forum had three goals:

- educate participants about issues facing Casco Bay;
- allow participants to hear what other citizens think the important issues are; and
- develop a list of priority issues.

Over 120 people attended the forum. The day began with talks by experts on issues affecting the Bay. Participants then broke into small groups to brainstorm about the issues. The issues were sorted into three categories:

- problems that should be addressed;
- actions that need to be taken; and
- questions that need answering.

This process yielded over 75 different items. After reviewing the lists from all groups, each small group reconvened to discuss which of these 75 issues were most important. The day ended with an informal "vote," with each participant voting for the two issues they felt were most important. The issues most widely viewed as important were:

Problems:

- Toxic waste, such as PCBs and oil pollution
- Balancing economic development with environmental protection
- Lack of enforcement
- Nutrients
- Bacteria
- Combined sewer overflows (CSOs)

Actions:

- Educate the public
- Include the Kennebec River in project

- Develop baseline data
- Step up enforcement

Questions:

- What is the extent of contamination by heavy metals and PCBs?
- What are the flows and currents in the Bay?
- What is the nutrient carrying capacity of the Bay?
- Who has existing data?

Many of the issues raised at the forum were addressed in the projects in the project's first year workplan including measuring contaminant levels in sediments of Casco Bay and modeling the currents and flushing rates in Bay.

Follow-up Public Input

The Management Committee identified three broad priorities for the first year of the project. These were:

- A need for more information so that specific issues and problems can be prioritized. This includes gathering and analyzing existing information and gathering some new data.
- A need to involve a broad spectrum of people and interests in the Project. This involvement is necessary in order for credible and effective actions to be developed.
- A need to focus on activities and needs at the local level. This reflects the realization that many of the efforts that are likely to be undertaken will depend on efforts undertaken at the local level.

The Management Committee recognized that to be effective, the Project had to limit the number of issues to work on at one time. Therefore, the Management Committee attempted to identify a set of priority issues for the Casco Bay Estuary Project. However, a problem emerged about how to define issues. Should the priorities be set based on:

- the sources of pollution?
- the impacts of the pollution? or

- the types of pollution?

Each approach had limitations and none were adequate to handle the numerous interrelations that exist among issues. As time passed, the need to set priorities became acute. Therefore, a more structured priority-setting approach was undertaken. The first step was the preparation of six issue papers. They ensured that all members of the Management Committee had an understanding of the issues and their interrelationships. The topics of the issue papers were: toxics; pathogens; nutrients; depletion of marine resources; habitat loss and alterations; and aesthetics. Each paper included:

- a definition of each issue;
- a discussion of the known impacts of the issue in Casco Bay;
- an explanation of its effect on the ecology and human uses of the Bay;
- an identification of typical sources of the pollution or problem and mitigation strategies available to address them; and
- a description of the existing efforts in place to address the issue.

After receiving and discussing the issue papers, the next step was the development of a formal mission statement. The mission was designed to set the broad mandate for the program. Once the mission was set, the Management Committee developed a list of potential threats to Casco Bay and the criteria by which to judge them. The list contained 21 potential threats (hereafter referred to as issues) that included a mix of categories of pollution sources and activities that threaten the Bay. The Committee ranked each issue as high, medium or low on 12 criteria. The criteria were:

- Existing or potential impact on the ecosystem of Casco Bay.
- Existing or potential impact on the economic resources of the Bay.
- Existing or potential impact on public use of the Bay.
- Whether existing efforts addressing the issue are inadequate.
- Whether the Casco Bay Estuary Project could make a positive contribution to the issue.
- Whether there could be immediate action taken to address the issue.
- Whether addressing the issue would lead to a greater understanding of the Bay.

- Whether the efforts to address the issue could be replicated in other areas.

- Whether the efforts to address the issue could be precedent setting.

- Whether the issue fit within the Casco Bay Estuary Project mission.

- Whether the issue was of strong public concern.

- Whether public involvement was required to address the issue.

The ranking of issues by these criteria resulted in the emergence of a set of priority issues. The results were reviewed and adjusted by combining similar issues and by making sure no major omissions had occurred. The result was the selection of five priority issues. This narrowing of issues to five priorities was a difficult process. The Management Committee recognized that all 21 issues were important to maintaining the health of the Bay. However, the Committee realized only a few issues could be adequately addressed at one time. The five priority issues were turned into goal statements. They are:

- To promote environmentally appropriate use and development of land and marine resources.

- To minimize adverse environmental impacts from stormwater runoff and combined sewer overflows.

- To minimize adverse environmental impacts of individual wastewater systems.

- To determine the effect of existing sediment contamination on the health of Casco Bay.

- To promote responsible stewardship of Casco Bay and its watershed through increased public involvement.

After the priorities were set, the second year workplan was developed. The workplan addressed both the new priorities and many of the issues raised at the first public forum.

Public Input Revisited

The Casco Bay Estuary Project held a second public forum to get feedback on the five priority issues. Despite a spring snow storm, 30-40 people met to discuss the issues. Those present heard a summary of the priority setting process and attended small group discussions on the issues. Management Committee members were present to discuss how and why the priorities were selected and an expert in each field answered technical questions about the issue.

Developing Goals and Objectives

After the priorities had been set, the next step was to focus the goals into more specific objectives. The Management Committee agreed that each objective should contain the impact that was of most concern (the priority issues often had more than one impact) and one or two approaches that should be used to address the impact.

Having developed goals and objectives, the Management Committee then began developing action plans. The first step was to give each goal and objective to an "expert roundtable" composed of people from federal, state and local governments and research institutions who deal with the issues on a regular basis. Each goal and objective had its own roundtable. Participants of the roundtables brainstormed lists of possible actions and identified those that they felt were most important.

The Management Committee reviewed the results of the roundtables, reduced the number of actions, focused the actions more narrowly, and adjusted the priority of the actions. The action plans were structured to include a brief discussion of existing efforts underway, a series of short term actions, and discussion of future directions. The future directions point to where the Management Committee thought the actions should end up. The final recommendations depended on the outcome of the existing efforts and short-term actions.

Public Input Through Focus Groups

The draft action plans were taken to a series of focus groups. Each focus group was composed of people representing a particular interest that has a stake in the issues addressed in the action plans. The eight stakeholder groups were:

- Waterfront organizations and industry
- Homeowners, septage haulers and plumbers
- Fishing community, clam diggers, and marina owners and operators
- Real estate and land use, including brokers and contractors
- Local elected officials and planning board members
- Municipal government staff
- Environmental advocates
- Farmers and foresters

The participants in each focus group reviewed the two action plans of most interest to their group. Each group responded to three questions:

- Are the future directions outlined in the action plans appropriate?
- Will the actions achieve the stated goals and objectives?
- What opportunities and barriers exist for the implementation of the action plans?

The comments of the focus groups included suggested changes to the action plans and more general comments about environmental protection issues. However, six overarching themes emerged from the comments that cut across all the groups and issues discussed. These six themes were:

- Regulatory overload - People are overwhelmed by the maze of environmental regulations. The regulations are often unfairly applied and the people who try to comply have more trouble than those who ignore the rules.
- Cooperative approach - Government should be less adversarial and more supportive of people who are trying to protect the environment and play by the rules. There needs to be technical help on environmental and regulatory issues.
- Bottom-up approach - It is important to involve a broad range of people in the information gathering, priority setting and decision making which accompanies environmental protection. These efforts should not be restricted to only local, state and federal governments.
- Economic and taxes - There is a need to demonstrate the cost effectiveness of protective measures, the economic value of protection and the true costs of development. Current tax policies often drive unwise development and should be changed to provide the correct incentives.
- Logical Approach - Government should mandate goals and provide a list of options of how to achieve the goal rather than mandating the use of a specific option. This would allow the most practical approach to be used in a given situation. Resources for environmental protection should be targeted to address the most important concerns and achieve the biggest impacts.
- Public education - There was almost universal agreement that education is one of the most important ways to protect the environment. In particular, working with schools to teach children was seen as the best long-term protection measure.

The comments from all the groups, and the overarching themes, were taken to the Management Committee for review. The Committee revised the action plans based on the comments, including some major revisions, such as reworking the objectives of two of the action plans to clear up inconsistencies. These revised action plans were then taken to a public forum for additional input.

Another Check with the Public

A public forum was held to allow a broader public discussion of the action plans. Over 60 people attended and participated in small group discussions about two action plans of their choice. The comments from these small groups were brought back to the Management Committee for review, revision, and approval of the preliminary Casco Bay Plan for release.

Summary

- Involve the public early and often include all interested parties, publicize results.

- Provide structure to the public input and priority setting.

- Take public imput seriously reflect that input in data gathering, priority setting and activities

- Get local help develop goals and objectives by using technical experts and focus groups

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Storm Water Permitting: A Watershed Perspective

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

The Rouge River National Wet Weather Demonstration Project (Rouge Project) has provided a unique opportunity for a watershed-wide approach to municipal storm water discharge regulation under the Clean Water Act. This paper discusses some of the shortcomings of the existing storm water regulatory program as it offers solutions for removing the barriers to allowing a watershed-wide storm water permit, and presents the approach taken by the Rouge Project to initiate a watershed based permitting process.

The Rouge River, a tributary to the Detroit River in Southeast Michigan, has been documented as a significant source of pollution to the Great Lakes System. The Rouge River is about 128 miles within a watershed of approximately 467 square miles in three counties and is home to over 1.5 million residents. The eastern portion of the watershed consists of much of the old industrial areas of Detroit and Dearborn. The western and northern portions consist of newer suburban communities and areas under heavy development pressure.

Historically, the major sources of pollution to the river were industrial and municipal point sources, wet weather sanitary sewer bypasses, and combined sewer overflows (CSOs). The point sources and sanitary sewer overflows have been successfully controlled by an aggressive National Pollutant Discharge Elimination System (NPDES) permitting process administered by the Michigan Department of Environmental Quality (MDEQ). However, the river still fails to meet water quality standards due to a wide range of sources such as CSOs, storm water runoff, illicit connections, failing septic systems, leachate from abandoned dumps, and resuspension of contaminated bottom sediment.

The Rouge Project has developed its watershed-wide management program based on the concept that each citizen has the right to expect clean water from their upstream neighbor and are also expected to assure that their downstream neighbor is given the same courtesy. To restore water quality and beneficial uses in the Rouge River under current institutional arrangements, each jurisdiction must implement measures to eliminate pollution. It is increasingly more evident that managing water quality necessitates looking beyond political boundaries and focusing on the hydrologic units for assessment and remedial action.

The Rouge Project initiated the watershed-wide management approach in southeast Michigan by facilitating CSO control and permitting based on common requirements throughout the watershed. Rouge communities served by combined sewers have entered into permits with the MDEQ and the United States Environmental Protection Agency (U.S. EPA) requiring a base level of abatement construction throughout the watershed followed by assessment of water quality impacts and future construction phases to meet public health and water quality standards.

In the separated sewer areas of the Rouge River watershed, currently only one of the 48 communities and select industries are required to obtain NPDES stormwater permits. Stormwater permitting and management only in select areas of the watershed, combined with the CSO efforts, will not achieve the water quality and beneficial use objectives for the river. Therefore, the Rouge Project team, comprised of communities and counties, industries, local/regional agencies, MDEQ, and U.S. EPA, is working to develop a consensus-based design for a watershed-wide storm water management and permit program meeting the needs of all local communities while focusing on the instream water quality issues facing the Rouge River watershed.

The Rouge Project has defined a five component strategy designed to identify and overcome the barriers that have previously hindered watershed-wide permitting. The components are:

1. Define working groups with a focused local purpose;
2. Develop a common set of basic technical information;
3. Identify and prioritize specific sub-watershed problems;
4. Develop a long-term strategy and implementation process;

5. Allow for a watershed-wide NPDES permit or an alternate program.

The first component, define working groups with a focused local purpose, is the key to establishing the local interest and support fundamental to watershed issues. It is the intent of these groups to define the requirements of an effective storm water management program, and it is understood that these requirements will vary from one area of the watershed to another. The involvement of citizens and their local community officials is best encouraged by identifying a specific local issue that is a component of the overall watershed-wide problem. It is easier for the general public to understand how drainage affects their backyards than to comprehend the complexities of the entire watershed.

Within the Rouge watershed we have, thus far, established three working groups focused on specific sub-watershed areas. Each of these groups is facilitated by project staff working closely with community leaders to identify local issues of concern and to convene appropriate involvement from citizens and municipal officials. Once the issues are drawn along water quantity or quality lines effecting specific individuals, the problems associated with municipal boundaries can be overcome.

Our first working group was formed within the Upper Rouge 2 sub-watershed (see Figure 1). This area encompasses about two-thirds of the City of Livonia together with portions of five surrounding municipalities. Upon completing a sewer separation project in a small area of the city, Livonia will be required to obtain a Phase I NPDES municipal storm water permit. It was these impending permit requirements that became the catalyst for Livonia city officials to champion the working group involved in this sub-watershed. Their efforts are directed at developing processes and procedures to evaluate in-stream water quality as a determinant of needed Best Management Practices rather than undertaking the "end-of-pipe" analysis associated with previous permit requirements. This group is also examining institutional and financial barriers to watershed management at the local level. Incentives are also being identified to encourage a watershed approach to storm water regulation at the local, state, and federal levels.

The second working group has been formed within the Middle Rouge 1 sub-watershed, a relatively rural area facing intense development pressure. This effort was championed by a citizens group concerned with the condition of Northville Mill Pond, and has garnered the support of all upstream municipalities. The group is addressing issues associated with the effects of development on the river and on in-stream impoundments. A key activity for this group is implementation of consistent stormwater management requirements for new development in the six communities in the sub-watershed.

The third working group is comprised of communities within the Middle Rouge 3 sub-watershed. This area is comprised of older suburban communities which have areas served by both separate and combined sewer systems. This group is the most recently formed, and is beginning to consider the problems of storm water management in densely developed areas, and the equity issues created by the need to address both CSO abatement and storm water management within a single municipality. The findings and recommendations of these groups will provide the basis for expanding the watershed management effort to the entire Rouge River watershed.

The next component of the Rouge watershed storm water strategy, develop a common set of basic technical information, is required in order to provide benefit/cost information on alternative pollution controls to the watershed decision makers. This effort is based on the construction or implementation and evaluation of pilot pollution controls, as well as information from the literature, and is providing consistent information across the entire watershed. While local issues and priorities may differ, it is important that a common base be used to evaluate the proposed remedial measures from one sub-watershed to another. Additionally, it will become necessary to evaluate watershed-wide impacts of local improvement efforts.

The third component of the Rouge watershed storm water strategy is to identify and prioritize specific sub-watershed problems. This effort is initially being done by the working groups and will be expanded throughout the watershed. This effort is based on the extensive information being developed for the watershed, including comprehensive in-stream water quality monitoring and modeling programs (e.g., watershed analysis programs). This effort is identifying problems outside of local areas of concern and will prioritize these problem areas across the entire watershed. This approach may substantially reduce the costs and increase the effectiveness of wet weather pollution remediation measures in this large urban watershed.

The sources of pollution vary considerably by sub-watershed and the level of anticipated use for each reach of urban river is also different. It is therefore necessary to consider a number of factors in establishing priorities for addressing specific problems. These include bacterial contamination (i.e., human health concerns), flow variability, water column chemistry, aesthetics, and the ability to support an appropriate biological community as well as technical and economic limitations. The Rouge Project has developed an index system which is being used to define the present quality of river use in each sub-watershed and to compare and assess the impacts proposed management practices will make on the increased usability of the resource. This tool is proving useful for communicating complex and technical information to watershed stakeholders with widely varying technical backgrounds.

The fourth component of the Rouge watershed storm water strategy requires the integration of all local sub-watershed efforts through the development of a long-term strategy and implementation process. While problem identification and consensus building must proceed from the bottom up, it is critical that the process be established to unite the individual sub-watershed groups, and the municipalities they overlap, within a single strategy for managing the watershed on a long-term basis. Only if the initial watershed analysis programs are continued to be utilized after the initial remediation measures are implemented and future measures implemented as needed will progress toward meeting water quality goals be attained.

We believe that responsibility for the majority of remedial and preventive watershed management measures remains at the local community level. However, certain aspects of the long-term implementation may be best served by a watershed-wide association. These include baseline water quality sampling and analysis, regional pollution controls (where appropriate), consistent standards for new development, bank stabilization, and certain aspects of flow control and other urban problems associated with logjam removal, debris and sediment remediation.

The institutional arrangements required to implement this association will differ widely from watershed to watershed throughout the country. These arrangements will be based on specific issues being addressed, existing agencies or associations, state enabling legislation, and regulatory agency requirements. Yet, before any agreements can be forged between local units of government and the regulatory agencies, the basic foundation established through Rouge watershed storm water strategy components one through three must be in place.

The fifth component of the strategy presumes that the Rouge watershed management effort encompasses the purpose and intent of both NPDES point source and storm water efforts. This effort allows for a watershed-wide NPDES permit or an alternate program to be developed which will meet the requirements in a manner acceptable to both the local regulatory agency and the U.S. EPA.

For certain sources such as traditional point sources or CSOs, the existing NPDES permit process should remain basically unchanged but with modifications to consider the effects of specific outfalls on specific receiving water and watershed concerns. However, for non-point and urban storm water sources, an alternative to the formal permit issued to each municipality may be preferable. In these cases, the communities may be considered to be permitted by rule as long as they are actively participating in the watershed management process, supporting those general activities such as baseline sampling and analysis, and implementing the Best Management Practices called for within their particular sub-watersheds.

For this process to be successful, the regulatory agencies need also to redirect their emphasis. It is hoped that by mutually defining a program in the Rouge River watershed based upon local consensus to address storm water management, the river will realize improvement much earlier than would be realized through a protracted command-and-control permitting procedure.

The Rouge River National Wet Weather Demonstration Project is working to establish an enforceable stormwater management system on a watershed basis. Communities within the watershed have joined with state and federal representatives to implement a five component strategy to develop technical, institutional, and regulatory options to cost-effectively manage stormwater and other sources of pollution on a watershed basis. It is hoped that the lessons learned from this effort will be beneficial to others across the nation to achieve the goals of the Clean Water Act.

A Watershed Approach to Combined Sewer Overflow Control

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The Massachusetts Water Resources Authority (MWRA) provides wastewater service to 43 communities in the metropolitan Boston region. MWRA ratepayers have experienced significant increases in the annual cost of service, as a result of infrastructure improvements required for compliance with the Clean Water Act and to ensure system reliability. The four communities of Boston, Cambridge, Chelsea and Somerville and the MWRA have approximately 81 combined sewer overflows (CSOs) which discharge a mixture of sanitary sewage and stormwater to Boston Harbor and its main tributaries during wet weather. These receiving waters are shown in Figure 1. A combined sewer overflow control plan to reduce these discharges through construction of an extensive deep rock and connecting tunnel system was developed in the late 1980's and was expected to add an additional 1.4 billion dollars to the ratepayers' bill.

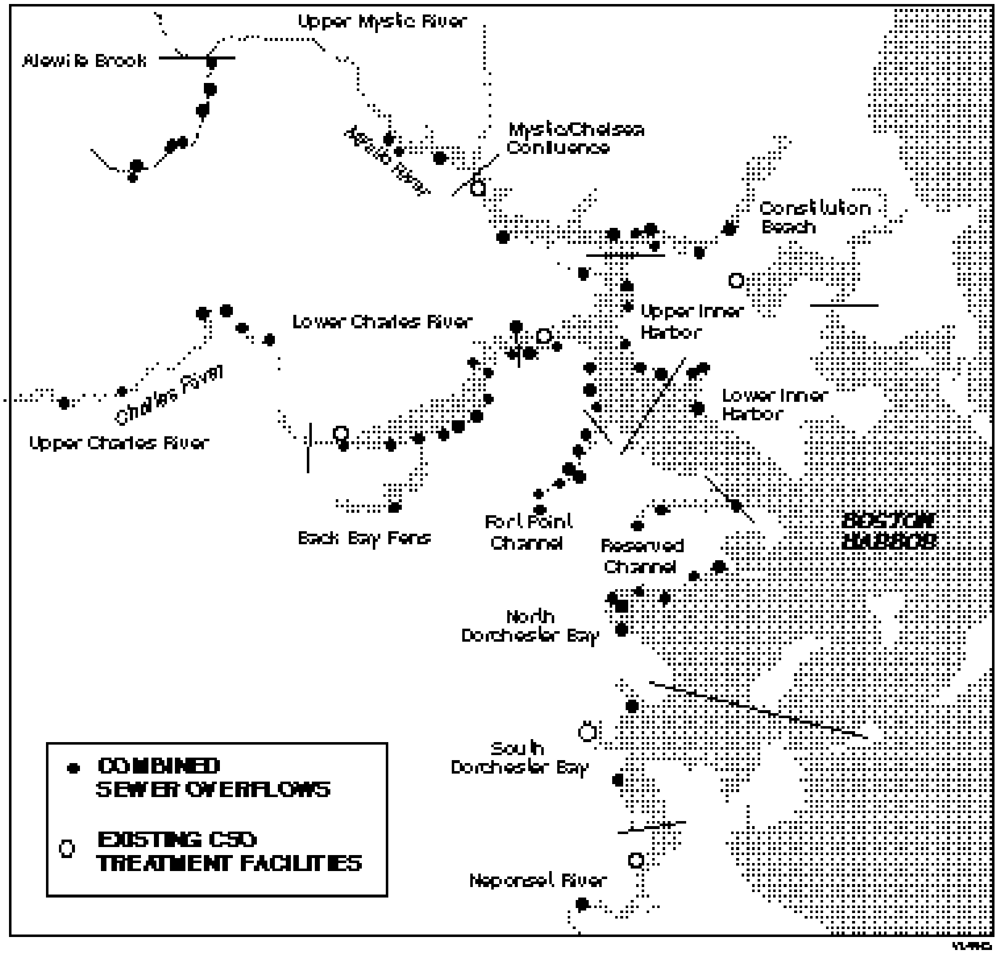

Figure 1. Receiving Water Segments and CSO Locations.

The Authority was able to negotiate with EPA to be allowed additional time to undertake more extensive monitoring of combined flows and to develop a more detailed understanding of the community and MWRA piping systems. At the same time, EPA on the national level was developing a new CSO control policy with input from municipal, state and environmental interests. This new policy was more flexible in that it allowed the permittee to demonstrate compliance with state water quality standards. This approach requires that the permittee (the MWRA and the four communities) have a thorough understanding of the receiving waters and of the impacts of CSO discharges and other sources of pollution on water quality.

The MWRA work plan for additional CSO planning was developed to be consistent with this new EPA policy and with the Massachusetts CSO policy. The end result is a new CSO control plan which provides equivalent or greater water quality benefits at a cost of 370 million dollars. For Boston Harbor and its tributaries, fourteen watersheds or sub-watersheds were delineated based on water quality, frequency and volume of CSO discharges, uses of the water body and adjacent shoreline, and water body hydrodynamics. Four major sequential tasks of a watershed approach were identified and are shown in Figure 2. North Dorchester Bay and the Lower Charles River can be used as representative examples of how these tasks were implemented.

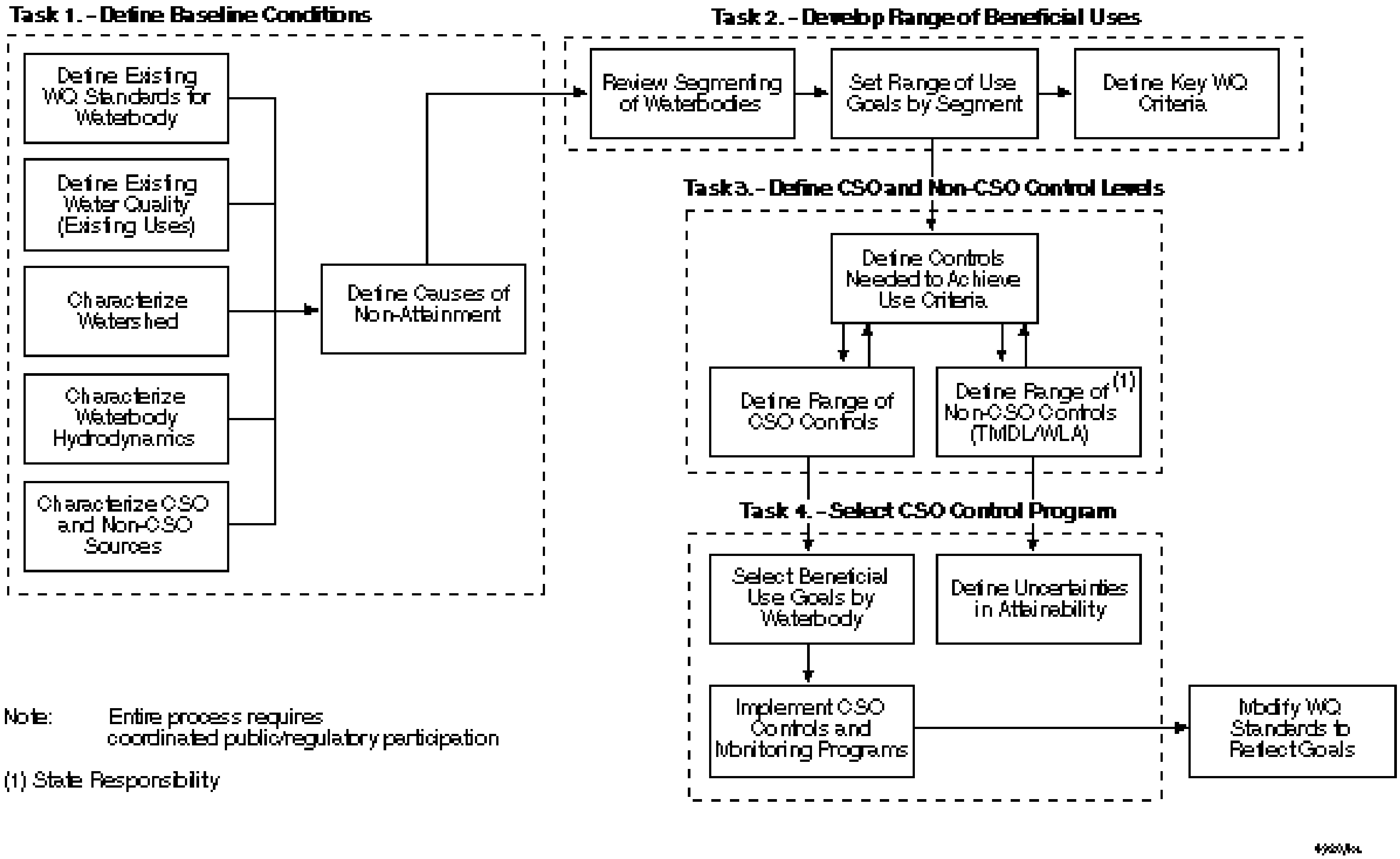

Figure 2. Watershed Approach To CSO Control Planning.

Task 1-Define Baseline Conditions

The development of baseline conditions involves definition of applicable water quality standards and existing water quality for each receiving water, and characterizing the watershed and the waterbody hydrodynamics which can greatly effect the temporal and areal impacts of CSOs. The next step focused on characterizing CSO and non-CSO sources. Information on the volume, frequency and location of CSO events was determined using comprehensive hydraulic models that were well calibrated and verified. CSO flows and pollutant loads were computed for various size storms and for a "typical" year. Flows and loads from upstream watershed sources, and from study area stormwater and CSOs were then input into water quality models for Boston Harbor and the Charles River to estimate wet weather impacts on receiving waters from key CSO-related pollutants. These models predict pollutant concentrations over time and space for each segment. These can then be compared to State water quality standards to estimate the impact of the various pollution sources on the attainment of beneficial uses. These models also distinguish the relative contributions of CSO and non-CSO sources.

For North Dorchester Bay and the Charles River, baseline conditions revealed very different stories. North Dorchester Bay is classified SB-Fishable/Swimmable with Restricted Shellfishing in approved areas. This receiving water segment contains several of Boston's public beaches and is the focus of a major "Back to the Beaches" campaign by state and local officials. Although significant shellfish resources are known to exist in the area, shellfishing is currently prohibited due to the fecal coliform levels in the overlying waters and to the presence of CSOs. Boating and fishing are also popular forms of recreation in this area. The area draining into this section includes portions of the South Boston and Dorchester areas of Boston with a mixture of parkland and typical urban land uses. Sampling done by the Boston Water and Sewer Commission indicates that the stormwater in this area is generally free from sewage contamination. Seven CSOs discharge to this segment and in a typical year, it is estimated that there are approximately 78 overflow events.

Existing water quality in North Dorchester Bay is generally good. Bacteria levels meet the swimming standard of 200 fecal coliform/100 ml in dry weather, and the boating standard of 1,000 fecal coliform/100 ml is met at all times. The restricted shellfishing standard (88/100ml) appears to be met in dry weather but not in wet weather. Daytime dissolved oxygen (DO), critical to aquatic life, generally meets the water quality standard but levels do appear to be depressed in both surface and bottom waters following heavy rains. An examination of the sources of fecal coliform bacteria indicates that in a 1 year design storm CSOs contribute more than twice the bacteria load from stormwater but the latter contribution is also significant.

The Charles River is classified as B-Fishable/Swimmable, and the lower Charles segment is heavily used for recreational boating including many sailing and rowing organizations. This segment is considered part of the Charles River Basin and is relatively wide and deep with virtually no current. The shoreline is predominantly parklands which are heavily used for seasonal river-based festivals or special events. The Charles River Dam and Locks are located at the mouth of the river and maintains the water level in the basin. Significant CSO discharges include flow from both the Cottage Farm CSO Treatment Facility and from Stony Brook. The Cottage Farm facility provides screening, floatables skimming, and disinfection of combined flows as well as 1.3 million gallons of detention storage which allows some reduction in sediment. In general, bacteria levels around the Cottage Farm discharge are not well correlated with rainfall indicating effective disinfection. Stony Brook flow discharges into the lower Charles River continuously but during wet weather this discharge includes significant amounts of stormwater and combined sewage and is a major source of most pollutants to the lower Charles River. Overall, this segment receives a much greater volume of stormwater than CSO flow but both of these sources are tiny relative to the upstream flow into this segment. These flows tend to have high concentrations of nutrients and toxic metals from upstream sources of pollution within the 35 cities and towns that comprise the watershed. The Charles River Dam at the downstream end of the CSO study area has the effect of trapping pollutants in the basin which tends to further exacerbate the water quality problems and putting this segment in continuous or wet weather nonattainment for many uses.

Task 2-Define Range of Beneficial Uses

The second task for the watershed approach was to use the baseline conditions information to set a range of beneficial use goals for which plans for CSO controls and control of non-CSO sources will be developed. In general, the receiving water goals were set to reflect the following three levels:

- Level I: meet or exceed water quality standards at all times and target key pollutants.

- Level II: meet water quality standards most of the time (except for 4+/- storm events per year) and target key pollutants in certain waters. This reflects the Massachusetts policy which allows a B(CSO) designation with an allowance for a specified number of overflows per year if sufficient justification is provided.

- Level III: Improve water quality, target aesthetics and target bacteria in certain waters. This was viewed as a short-term goal where baseline conditions indicate that significant water quality improvements are not feasible in the immediate future.

Improvements in aesthetics through floatables control was addressed at all levels.

For North Dorchester Bay it was feasible to consider an upgrade of the water quality classification from SB to SA-Fishable/Swimmable with unrestricted shellfishing as the Level I goal given the current high water quality and the relative contribution of CSOs to the wet weather bacteria problems for that segment. Based on the data collected, DO, nutrients and aesthetics criteria would also be targeted. The Level II goal would be to meet the restricted shellfishing and swimming bacteria standard (except for <4 overflows/year) and to meet all other Level I goals. Since North Dorchester Bay is the major beach area for much of metropolitan Boston, even the Level III goal was to meet the SB standard most of the time (<4 overflows/year) and to address the aesthetics criteria.

For the Lower Charles River segment, the Level I goal was to meet the swimming bacteria standard at all times, improve dissolved oxygen, reduce nutrients and reduce metals. The Level II goal would meet the swimming standard except for 4+/ overflows per year) and Level III goals reflect the existing water quality and would meet the boating standard at all times.

Task 3-Define CSO and Non-CSO Control Levels

CSO control goals were then developed to match the receiving water goals previously set. For North Dorchester Bay, the only CSO control goal which would allow an upgrade in the water from SB to SA (assuming that non-CSO sources of pollution were also controlled) is the elimination of all CSO discharges. To meet the Level II or III goals, untreated CSO discharges would need to be limited to <4/year. These goals lead to specific CSO strategies or technologies. To eliminate CSOs, two control strategies are possible: sewer separation or relocation of the CSO discharges to a less sensitive receiving water. To limit CSO discharges to <4/year, alternative strategies could include partial separation or storage of CSO flows.

The same range of CSO control goals were examined for the lower Charles with sewer separation as the mechanism for eliminating CSOs and meeting the Level I goal. Level II goals would again be achieved by limiting CSO discharges through a range of storage, flow removal, or transfer and optimization technologies.

Task 4-Select CSO Control Program

Once the control strategies were identified, the MWRA initiated a series of workshops for CSO community officials, state and federal regulators, ratepayer and wastewater advisory boards, and local environmental organizations to present the information. An alternatives rating and ranking process was used which considered water quality improvement, system performance, cost, and siting feasibility and preferred CSO controls were identified. These controls reflected the designated uses of the receiving waters but acknowledge the relative contribution and feasibility of controls for both CSO and non-CSO pollution.

For North Dorchester Bay, elimination of CSOs was a desired goal. Sewer separation and relocation of CSOs to a less sensitive area (Reserved Channel) were both feasible and roughly comparable in cost. Separation would mean new stormwater discharges to the bathing beaches and it was decided that relocation to Reserved Channel was preferred. A consolidation conduit would store up to a statistical one-year storm for later transfer to the main treatment plant and larger storms would be discharged from a new Reserved Channel screening and disinfection facility after treatment. Under this plan, all North Dorchester Bay CSOs are eliminated.

For the Charles River, it was decided that the bacteria and floatables associated with CSO discharges in larger rain events were the primary target. These flows contribute significantly to wet weather non-attainment. Other pollutants, such as total suspended solids and nutrients, were primarily associated with upstream or stormwater inputs and were not targeted in the CSO controls. The Cottage Farm screening and disinfection facility will continue to operate and be upgraded with new screens, dechlorination equipment and a new outfall diffuser. Stony Brook wet weather flows are proposed to receive screening and disinfection at a new facility to be constructed. All other Lower Charles River discharges either currently discharge less than four times per year or can be reduced to that level though additional MWRA or community system improvements. This provides immediate water quality benefits which are also cost-effective.

Overall, Task 3 was particularly valuable in that it highlighted the need to identify the range of non-CSO controls also necessary to fully achieve the water body goals. This portion of the task is outside the MWRA's scope of responsibility and is appropriately done by the State. Massachusetts has now implemented a watershed approach for all of its water quality investigations and permitting. At the same time, a non-profit environmental organization, the Charles River Watershed Association, has initiated a major study of that river. The MWRA is supporting this effort with both technical and financial resources. If this study identifies responsible parties and implementable solutions for control of non-CSO pollution, it is possible that the MWRA would be asked to revisit CSO control on the Charles River and implement a higher level of control.

Watershed Monitoring Program Supports Multiple Goals

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

The Bureau of Water Resource Management of Carroll County, Maryland, initiated a comprehensive water quality monitoring program for the Piney Run reservoir and watershed in 1993. This program is designed to satisfy multiple county goals of protecting the quality of the water supply source, managing a recreational facility, and monitoring the effects of changes in the watershed from new and potential pollutant sources. The data from the program is being used to evaluate operational practices, the performance of source protection measures, and the need for additional measures to protect this valuable county resource.

Multiple Reservoir Uses

The Piney Run Reservoir was constructed in 1975 by Carroll County and the Soil Conservation Service for the purposes of water supply, recreation, and flood control. The reservoir has served to successfully control downstream flooding, as well as to provide numerous recreational opportunities involving boating, picnicking, and passive nature activities. A water treatment plant is under design to provide up to an additional 3.5 mgd source of water supply to the growing area.

Watershed Composition and Protection Measures

The reservoir has a surface area of 298 acres at its normal pool elevation. The 10.6 square mile watershed is a mix of land uses, although predominantly zoned for agriculture. The current mix is approximately 63% agricultural, 18% residential, and 19% forested land uses. A number of policies have been specifically implemented to protect the surface water resources of the county. A Conservation Zone exists to restrict the intensity of development in the watersheds of the county's reservoirs, and in 1993, a stream buffer provision was implemented for new subdivisions to maintain in a natural vegetative state 100 feet of land from each top of bank for all county streams.

Monitoring Program Elements

The Piney Run monitoring program is a cooperative effort between Carroll County staff and Black & Veatch personnel; data is supplemented through the efforts of a group of citizen volunteers who have collected stream sampling information since 1989. Priority objectives of the current program are to establish a comprehensive baseline that can be used to evaluate long term reservoir behavior and trends, as well as to identify any immediate water quality issues.

The following are the six elements of the monitoring program:

- **routine reservoir sampling.**
- **routine tributary inflow sampling.**
- **stream flow monitoring.**
- **storm sampling.**
- **special and quarterly sampling.**
- **watershed surveys.**

Baseline data are collected from a total of five stations (Figure 1), three reservoir locations (Stations 1, 2, and 3) and from the two major reservoir tributaries (Stations 5 and 6). Streamflow quantities are measured at Stations 5, 6, and 7. Once the baseline has been established using

information from these five stations, site specific issues may require that additional data be collected from other locations, such as from several major coves receiving agricultural drainage.

Routine Reservoir and Inflow Sampling

Each of the five stations are sampled nineteen times per calendar year, weather permitting. Samples are collected monthly from November through March, and bi-weekly during the growing season, April through October. Samples are collected from two depths in the reservoir to separately depict activity in the aerobic (epilimnion) and in the anaerobic (hypolimnion) zones.

Secchi depth, dissolved oxygen, temperature, conductivity, pH, and turbidity measurements are collected using portable meters. Laboratory analyses are performed on the water samples for phosphorous, nitrogen, alkalinity, hardness, total suspended solids, total organic carbon, iron, manganese, chlorophyll a, and phytoplankton.

Stream Flow Monitoring

Continuous flow information is collected at the two reservoir tributaries and at the reservoir outlet. Stevens' brand level loggers are used to measure flow elevations. County-developed ratings curves are used to convert the water levels to flow data at each station.

Stormwater Sampling

Stormwater runoff samples are collected in the two main tributaries at Stations 5 and 6. The water level loggers are used to trigger sampling with the automatic sampler unit. Up to 24 samples are collected at pre-set 30-minute intervals for flow-weighted compositing by the laboratory. Stormwater samples are analyzed for total phosphorous, orthophosphate phosphorous, total Kjeldahl nitrogen, nitrate+nitrite-nitrogen, and total suspended solids. Samples from three storms are collected at both stations annually.

Special and Quarterly Sampling

Twice each year a special set of samples is collected at Station 3 which is near the intake of the future water treatment plant. The samples are analyzed for arsenic, organics, inorganics, synthetic organic compounds, and radionuclides as listed in the Safe Drinking Water Act. Quarterly samples are collected for calcium to evaluate the suitability of the reservoir for zebra mussel populations. A plate sampler for zebra mussels has been constructed and placed adjacent to the public boat launch, the most probable location for introduction of the nuisance mussels into the reservoir.

Watershed Surveys

In 1989 a stream walk was conducted by County staff to visually assess the condition of the streams in the watershed, to identify potential pollution sources, and to provide a baseline for future evaluations. The Citizen Monitoring Program was established in the same year to provide baseline water quality data. Seven stations were initially established in the Piney Run Reservoir watershed which are sampled monthly from March through October. Lamotte sample kits are used to analyze base flow concentrations of dissolved oxygen, phosphates, and nitrate. Air and water temperature as well as observed conditions are also recorded at the time of each sample collection.

Monitoring Program Results and Trends

Comprehensive monitoring of the reservoir and its tributaries began in April 1993 and will continue through August 1996. In late 1996, the three years of collected data will be evaluated, and the county will determine whether to continue at the current level of data collection, or whether certain elements can be reduced. Trends and hypotheses have been established through analysis of the current two year's of sampling and data analysis.

Trophic State

Carlson's trophic state indices (TSI); which relate variations in Secchi depth, chlorophyll a, and total phosphorus; varied considerably during the two years, but indicate that Piney Run is a borderline mesotrophic-eutrophic reservoir. Anoxic conditions in the hypolimnion and high concentrations of manganese in the bottom sediments during the summer are evidence that the reservoir continues to eutrophy.

Nutrients

Phosphorus and nitrogen are essential nutrients for growth of biological organisms. Phosphorus is the nutrient usually found in least supply in reservoirs and lakes, and becomes limiting to the growth of algae and higher plants.

Total phosphorous concentrations average 0.02 mg/L to 0.05 mg/L in the tributary baseflow samples while average concentrations in the reservoir water column range from 0.02 to 0.03 mg/L. Therefore, some deposition of phosphorus in the reservoir bottom sediments is occurring.

Total nitrogen concentrations in natural waters are reported in the literature usually within the range of 1 to 3 mg/L. However the concentrations measured in the Piney Run tributaries average 4.0 to 5.0 mg/L, and concentrations in the reservoir water column range from 1.2 to 1.8 mg/L.

Ratios of total nitrogen to total phosphorus during the spring, prior to establishment of thermal stratification, varied from 45:1 to 160:1 in 1994 and from 52:1 to 170:1 in 1995. These data demonstrate that the lake is phosphorus limited, and TN:TP ratios greater than 10:1 favor diatoms

over blue-green algae as the predominant algal form.

Phytoplankton and Chlorophyll Analysis

Phytoplankton analyses revealed a relatively sparse community of plankton algae in the reservoir. However, supersaturated dissolved oxygen concentrations suggest that algae were quite prolific several times during the year. Concern over the presence of blue-green algae focussed phytoplankton investigations during the summer and early fall months. Significant concentrations of silica were found, which in conjunction with the appropriate nutrient mix, can support a substantial diatom community.

Chlorophyll a is used as a surrogate measurement of algae in surface waters. Monthly chlorophyll a concentrations ranged from less than 3 to 28 µg/L, with an average of 7 µ/L. The highest chlorophyll a concentrations were observed during the colder months of the year, a characteristic of lakes dominated by diatoms.

Iron and Manganese

High concentrations of iron and manganese at the bottom of the reservoir during the summer and fall indicate the presence of anaerobic conditions, which foster the release of these metals from the sediments. Increased surface concentrations of iron and manganese are present following fall overturn. Removal of these metals will be required in the water treatment plant processes, if water quality problems are to be avoided.

Conclusions and Recommendations

The Piney Run Reservoir is in a borderline mesotrophic/eutrophic state, and it displays characteristics of a eutrophying reservoir. Several concerns are raised by this conclusion:

- **Eutrophic lakes provide a good environment for proliferation of algal populations which can cause taste-and-odor problems in drinking water.**

- **Lake overturn releases nutrients and minerals into the treatment column which cause significant water quality problems and treatment difficulties.**

- **Eutrophic lakes are highly productive environments for larger plants (macrophytes), in addition to algal populations. Overly productive algae and macrophytes populations create a nuisance for recreational uses of the reservoir and may negatively affect fishery populations in competition for oxygen in the water.**

- **A reconnaissance of the lake will be conducted to determine the extent and presence of**

algae. These may be growing attached to aquatic plants, or as mats in the shallow areas. Citizen monitoring efforts will be focussed on this issue as well.

- **The investment in the Citizen Monitoring Program has benefited the County immeasurably as the participating volunteers become advocates for the streams they monitor. The volunteers investigate the causes of irregularities observed in the sampling process, and they report incidents of dumping and illicit discharges.**

- **Data collected in the monitoring program can be used to calibrate a modeling effort to evaluate various land use scenarios in relation to the potential impacts to the streams and the reservoir.**

- **Protection of Piney Run as a water supply will be considered in the current effort to update the Sykesville-Freedom Comprehensive Plan. Monitoring data will be part of the evaluation of any changes to the Comprehensive Plan.**

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Staten Island Bluebelt Project: New York City's Watershed Approach with Multiple Benefits

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The Staten Island Bluebelt project is an effort by the New York City Department of Environmental Protection (NYCDEP) to provide storm water management for the last large unsewered area of the city which makes sense from both an environmental point of view and from the perspective of dollars and cents.

In a city where the conventional method of handling storm water is to put everything in a pipe, the NYCDEP is pioneering a different approach which preserves streams, ponds and other wetland areas in order to allow these systems to perform their natural functions to convey, store and filter storm water.

This approach is proving to allow not only for the preservation of scarce and valuable urban wetlands but is also saving equally scarce capital construction dollars. The NYCDEP has found that wetland preservation saves millions of dollars in infrastructure costs when compared to the conventional storm sewer system. This analysis is a model of how natural area preservation can have important long-term cost-saving implications.

Even though NYCDEP's specific mandate is the provision of drainage services, this project is truly multi-objective. The wetland preservation, underway and proposed, not only preserves natural drainage patterns for flood control purposes, but also provides for the filtering of storm water run-off, utilizing the natural cleansing functions of wetlands. In addition, the wetland and riparian corridors called Bluebelts provide important community open space amenities and diverse wildlife habitats.

Background

South Richmond, Staten Island, the most southerly part of New York City and State, is the last area of the City with a significant amount of vacant land. South Richmond is bounded by the Arthur Kill, Raritan Bay and the mid-Island area from Fresh Kills Landfill to Great Kills Harbor. Historically, land development in this area has been concentrated in villages which grew up around the stations of the Staten Island Rapid Transit System (SIRTS).

Since the opening of the Verrazano Narrows Bridge in November 1964 and the construction of the ancillary highway network, land development in South Richmond has been in a more scattered pattern of low density settlement. Since the area is virtually without sewers, that development has employed on-site waste disposal systems like septic tanks and package treatment plants and on-site storm water management measures like dry-wells and retention basins.

For the past 30 years, the idea of using the area's freshwater wetlands for storm water management purposes has percolated through City government. In the late 1960's during the Lindsay era, an effort to create a system of "fenways" in South Richmond was advocated by some city planners.

Not until the mid-1970's did the City act to preserve some of the stream systems on the southern end of the Island. In 1975 the City enacted the Special South Richmond Development District (SSRDD), a special purpose zoning district for the same southern end of the Island. A primary goal of the district was the preservation of the area's low density open character. One step taken to accomplish that goal was the creation of the Open Space Network (OSN), a system of about 700 acres which are to remain in their natural state. The purpose of the zoning designation is to preserve important natural features such as ponds and streams.

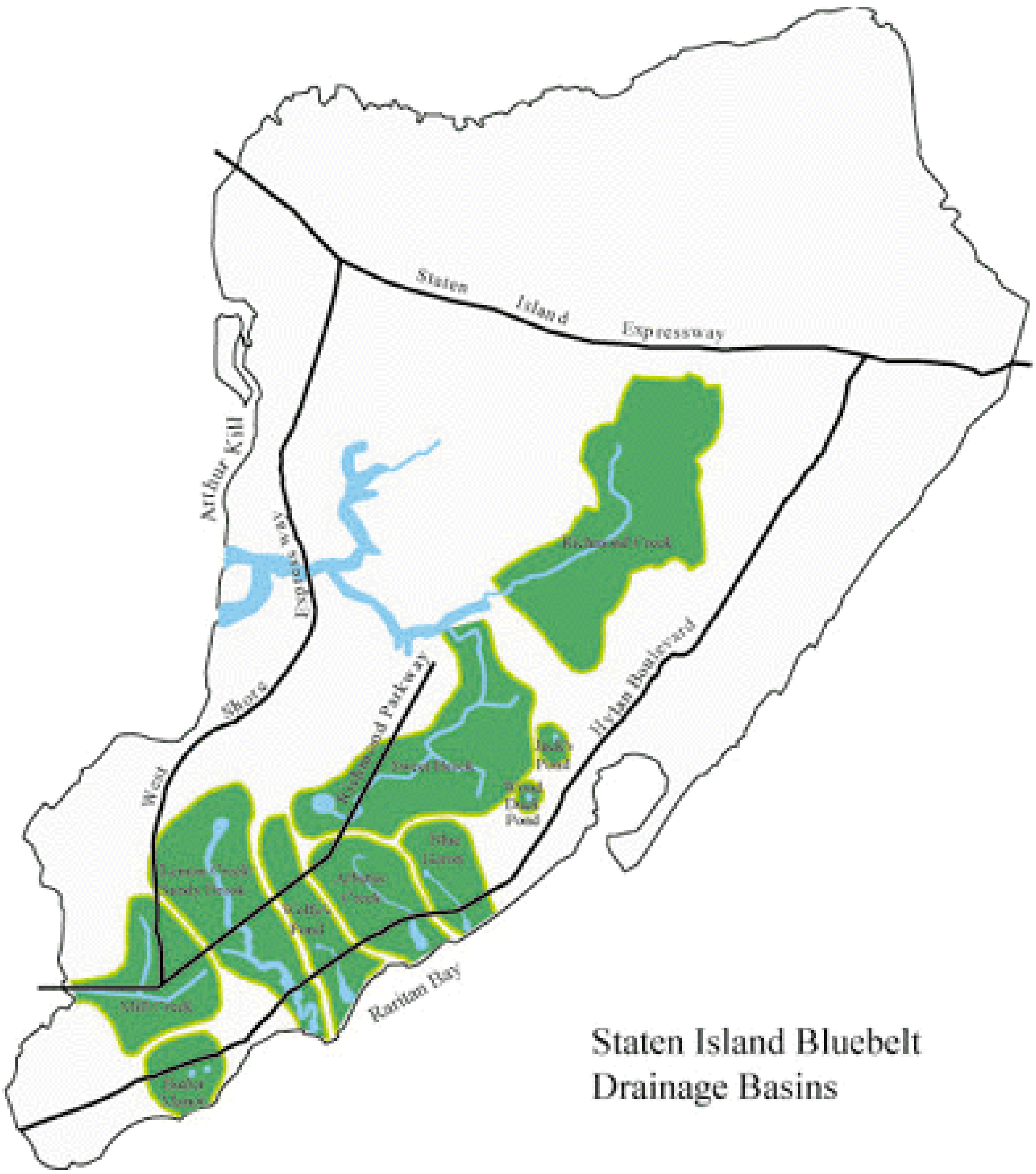
Following the creation of the OSN, the New York State Department of Environmental Conservation began regulating development in an extensive system of freshwater and tidal wetlands in South Richmond. During the 1980's, the State issued a series of maps for the freshwater wetlands on the Island which include the streams and ponds of importance for storm water management. The on-going regulatory program has resulted in the preservation of some wetland areas with significance for the overall drainage system.

Finally, capping off the activity of the 1970's and '80's, the Department of City Planning issued a report in October 1989 entitled the "South Richmond's Open Space Network An Agenda for Action: Storm Water and Open Space Management" which advocated using the OSN as a storm water management system. This effort propelled the NYCDEP into the latest phase of the project.

Bluebelt Land Acquisition

The Bluebelt systems are really land assemblages-puzzles with a variety of different pieces that have had to be constructed through a mastery of all the municipal bureaucratic processes involved. The various pieces include the following:

- City-owned property taken because of real estate tax delinquencies,
- the beds of mapped but unbuilt streets, called paper streets,
- properties acquired by DEP for Bluebelt purposes,
- privately owned property preserved by the OSN mapping,
- privately owned property preserved by State wetland regulation, and
- City parkland and State wetland preserves.



Staten Island Bluebelt Drainage Basins

In the last four years, NYCDEP has undertaken a major effort to acquire wetland properties in order to complete the continuity of the stream corridors and other wetland systems in the OSN. All eleven applications for site selection and acquisition of Bluebelt parcels have been fully approved under the City's Uniform Land Use Review Procedure (ULURP). The attached map shows the watershed areas within which wetlands were acquired; the drainage basins depicted cover about 6,100 acres.

The idea of acquiring wetlands in lieu of storm sewer construction was indeed a novel concept for New York City requiring a very detailed cost/benefit study. The studies, which were done for each of the acquisition projects in turn, used as the baseline old drainage plans for South Richmond done 30 years ago. The plans assumed the complete obliteration of the riparian and wetland systems and full storm sewering like that in the urban settings of the other four boroughs.

These plans done in the early 1960's before wetlands regulation, the OSN and the mapping of many City and State wetland preserves showed the paving over of the streams and other surface water features with all that storm water flowing in trunk sewer lines. The cost/benefit studies made a comparison between the very high cost of constructing those trunk sewer lines and the cost of the land. The thinking was that the trunk sewer lines would not have to be built if the stream and the adjacent floodplain property were preserved. If the storm sewer construction costs were greater than the wetland acquisition costs, then the project got the go-ahead. Altogether the Bluebelt project saves about $50 million over the conventional trunk sewer line approach.

The land acquisition will help to complete the Bluebelt corridors by building upon existing parks, other city owned properties and private land zoned as open space along the streams and other wetland systems.

Drainage Plan Revision

In addition to the acquisition program, the other major initiative of the Bluebelt project has been the effort to re-do the official drainage plans for South Richmond. The Bluebelt concept of making use of the wetland systems is to be applied by redoing the old official drainage plans for the last large unsewered part of New York City.

As mentioned above, the old plans done 30 years ago assume complete obliteration of the riparian and wetland systems and full storm sewering like that in the urban settings of the other four boroughs. The mapped street network which generated this drainage plan assumes a grid pattern of streets, laid over the landscape without regard for any natural features. Following the logic of these preliminary designs for the sewer system, streets mapped on ponds, streams or other wetlands are not at all inappropriate since those water features would have been eliminated anyway by the adopted storm water sewerage system.

The old plans are obviously not usable any more. In June of 1995, NYCDEP began work on the new plans with the engineering consulting firm of Hazen & Sawyer. The new drainage plans will incorporate the preserved wetland systems into the overall storm water management network.

An important consideration in the preparation of the drainage plan will be the issue of the water quality of the urban storm water runoff running into the preserved wetland systems. NYCDEP will employ innovative designs for best management practices to reduce pollutant loadings. How to design retention basins for quality control of urban storm water, in addition to their more conventional quantity control functions, will be an important issue in the study. What can be done at the storm sewer/wetland interface to reduce the impact of the discharge into the wetlands is a related issue. Constructed wetlands for the treatment of storm water may be one approach for the Bluebelt system.

The new plan will guide the agency in its on-going capital construction program in southern Staten Island. The resulting combination of natural systems with some necessary constructed sewer networks will be a model of how urban wetlands can be incorporated into a drainage scheme for a fast developing area.

Stream Water Quality Response to Agricultural Land Uses in Erath County, Texas

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

In response to concerns about nutrient levels in the North Bosque River, the Texas Institute for Applied Environmental Research (TIAER) has monitored storm water quality in the upper North Bosque River (UNBR) watershed since early 1991. The UNBR watershed encompasses about 93,150 ha (230,000 acres) forming the headwaters of the North Bosque River and has been the focus of three separate TIAER studies documenting the degree and effects of agricultural nonpoint source pollution (Nelson et al., 1992; Hauck et al., 1994; Hauck and McFarland, 1995). The monitoring network, while continually evolving, contains storm water sampling sites which monitor water quality from the diversity of agricultural land uses within the watershed. Dairying represents the basin's major agricultural enterprise with 94 dairies and a combined milking herd size of about 34,000 cows. Production of peanuts, range cattle, pecans and forage hay also represent significant agricultural practices in the area.

One of the major objectives of the monitoring network is to associate land use with in-stream water quality. While the direct causal mechanisms underlying enhanced nonpoint source pollution, such as soil disturbance and movement, are not addressed by in-stream monitoring, in-stream monitoring can be used to associate various land-use patterns with water quality constituent levels using correlation and regression analysis (Meals, 1992; Byron and Goldman, 1989). This information can then be used in watershed-level planning for determining "hot-spots" and for promoting best management practices (BMPs) to land uses or areas that are major contributors of nonpoint source pollution. The objectives of this paper are to examine the relationships of storm water quality to land use from 16 storm water monitoring sites within the UNBR watershed and to discuss the implications of these relationships on land-use management within the watershed. Nitrogen and phosphorus constituents are emphasized due to their role in the eutrophication of receiving waterbodies.

Methods

The distribution of each land use within the watershed was determined using Landsat TM imagery digitally manipulated into a GRASS-based geographic information system layer. Rangeland, improved pasture, winter wheat/summer grain pasture, woodland, orchards, peanuts, urban, barren and water were the nine land-use categories specified. Ground truth was used to assist imagery classification and to validate results. Information from the Agricultural Stabilization and Conservation Service (now the Farm Service Agency) was used to validate the location and size of peanut fields. The size and location of animal-waste application fields were obtained from Texas Natural Resource Conservation Commission (TNRCC) dairy permits and available waste management plans. Animal waste in almost all cases was applied to improved pasture or winter wheat/summer grain pasture. The land-use categories of improved pasture and winter wheat/summer grain were combined and re-categorized as either animal-waste application fields or forage fields not used for waste application. Dairy cow density was also derived from estimates of dairy herd numbers compiled from TNRCC records and surveys conducted by TIAER. The drainage area associated with each sampling site was delineated using a digital elevation map. To normalize the data between sites, land-use areas above each sampling site were converted to percentages based on the total drainage area associated with each site. The range of values for each land-use category for the 16 sites is as follows:

Woodland	11-37%
Rangeland	25-61%
Waste Application Fields	0-45%
Forage Fields	3-38%
Urban	0-2 %
Peanuts	0-7%
Barren	0-3%
Orchard	0-1%
Water	0-1%
Dairy Cow Density	0-1.68 cows/ha

An automatic sampler was activated at each site by about a 4 cm (1.5 inch) rise in water level into a programmed collection sequence. The actual sequence varied from site to site depending on the drainage area size and typical hydrograph experiences at a given site. In general, the most frequent sampling occurred at the beginning of a storm event with fewer samples collected as storm water levels subsided. The water quality constituents measured included ammonia-nitrogen (NH3-N), nitrate-nitrogen (NO2-N), nitrate-nitrogen (NO3-N), total Kjeldahl nitrogen (TKN), orthophosphate-phosphorous (OPO4-P), total phosphorus (total-P) and total suspended solids (TSS). Water level data was also collected at five-minute intervals throughout each storm event. Manual measurements of water flow were used to develop stage-discharge relationships for each site allowing determination of flow from the water level data.

Since water quality can vary greatly within a given storm event, a volume-weighted mean value was calculated for each water quality constituent for each storm event at a given site. Volume-weighted means were calculated by combining the storm flow with the water quality data for each storm event. The flow hydrograph was divided into intervals based on the date and time when water quality samples were taken using a midpoint rectangular method between water quality samples (Stein, 1977). Constant flow was assumed between each five-minute level measurement to estimate the water volume associated with each water quality sample. These volume-weighted mean values for each storm event were then used to characterize the storm water quality at each stream site by averaging across a number of events at each site (Byron and Goldman, 1989). The geometric mean across storm events for each water quality constituent at each site was used in the correlation and regression analyses with land-use characteristics. The storm events included were monitored between March 1992 and March 1995 (see McFarland and Hauck, 1995 for a detailed account of the storm water quality at each site on an event-by-event basis).

Results

The results of the correlation analysis are presented in Table 1. Positive correlation coefficients were generally associated with land uses representing more intensive agricultural practices, while negative correlation coefficients were generally associated with less intrusive land uses. The percent land area in waste application fields and dairy cow density associated with each site consistently showed the highest positive correlations with water quality constituents. The similarity in the correlations associated with these two independent variables was expected since the amount of land needed for animal-waste application is a function of the number of dairy cows in a given drainage basin. This significant positive correlation indicates that as the percent of land used for waste application (or dairy cow density) in a drainage basin increases, the concentration of water quality constituents in storm water runoff and downstream reservoirs increases. The percentage of woodland and rangeland in each drainage basin was generally associated with fairly high negative correlations with water quality constituents. The negative correlations associated with woodland and rangeland represent a "trade-off" in each drainage basin between relatively intensive and less intensive land use categories, i.e., drainage basins with a high percentage of woodland and/or rangeland generally have less land available for waste application and vice versa. Since TIAER studies indicate that phosphorus is the primary water quality constituent of concern in the watershed (McFarland and Hauck, 1995), a graph presenting the full regression analysis for OPO4-P for stream sites versus percent waste application fields is presented in Figure 1.

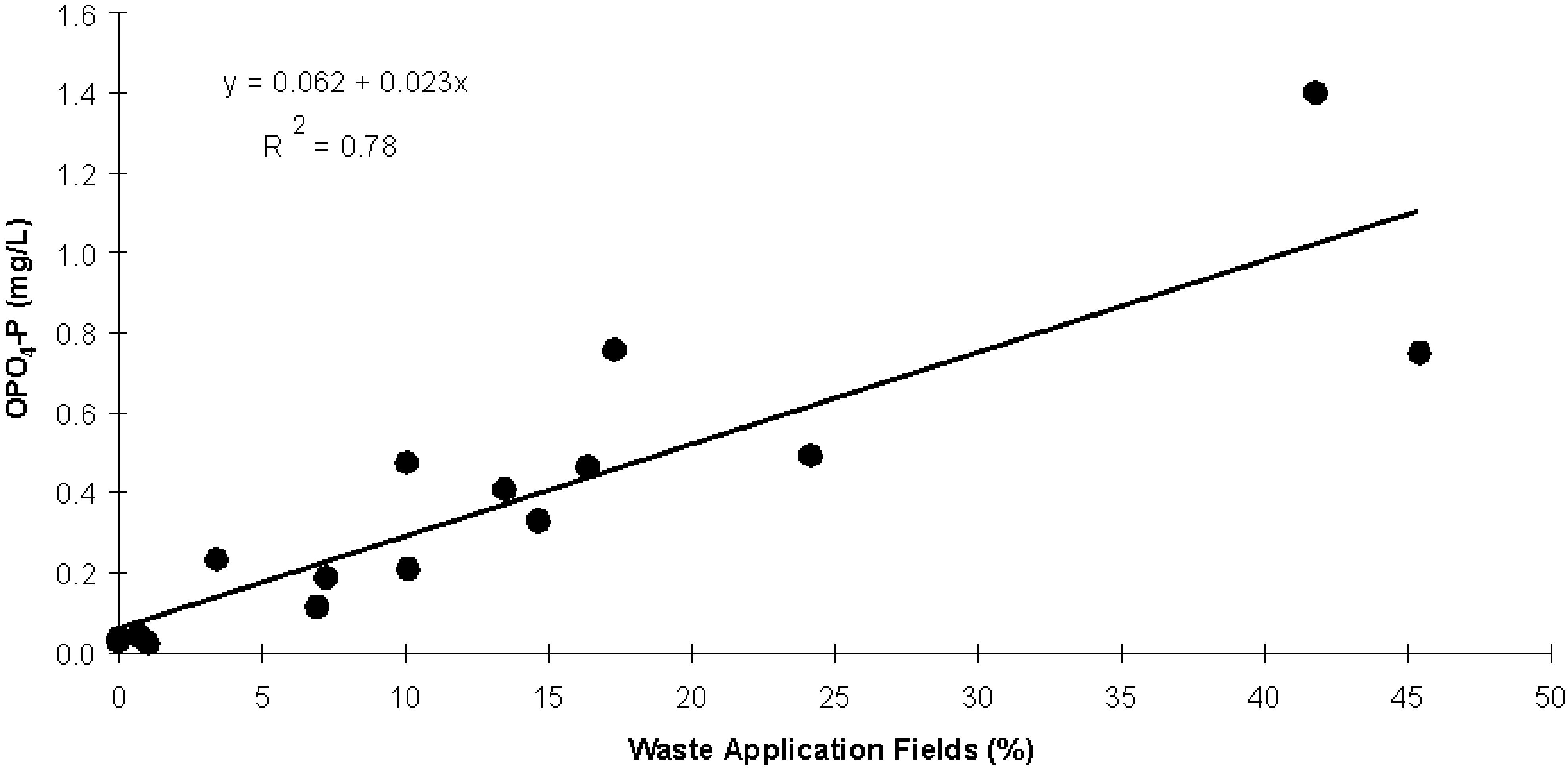

Figure 1. Relationship of geometric mean OPO 4-P levels to percent waste application fields in the drainage area above each sampling site for storm events monitored between March 1992 and March 1995.

Implications of Land Use Patterns on Water Quality

While there are many potential sources of nutrients in the upper North Bosque River watershed, runoff from dairy waste application fields appears to be the predominant land use impacting surface water quality in storm water runoff from agriculturally dominated drainage basins. In the land application of animal waste, nutrient and sediment losses can vary greatly. Nutrient and sediment losses depend primarily on the degree of incorporation of the animal waste and the long-term build-up of phosphorus and nitrogen in the soil. The State of Texas confined animal feeding operation (CAFO) regulations restrict the application of dairy manure and lagoon effluent to the agronomic nitrogen requirements of the crop. Under the nitrogen plant requirement restriction, phosphorus is typically over-applied by a factor of 2-1/2 to 3 times crop requirements. The over-application of phosphorus allowed in the regulations recognizes that phosphorus has a high capacity to bind with most soils (adsorption of phosphorus to clays) which makes the phosphorus much less available for transport to surface or ground waters. Present CAFO regulations allow phosphorus build-up in the top 6 inches of the soil to an extractable phosphorus level of 200 ppm (mg/kg), at which time the phosphorus requirements of the crop controls manure and lagoon effluent application rates. Complicating the issue of phosphorus in surface water runoff is the surface application of manure without incorporation. The predominant waste application fields in the UNBR watershed are of coastal Bermudagrass or coastal Bermudagrass overseeded in the winter with wheat or rye. Manure is generally surface applied without incorporation to maintain these permanent pastures. With surface application, soil erosion is minimized, but soluble runoff of nutrients is increased from direct exposure of the manure to rainfall and restricted adsorption of manure phosphorus to soil particles.

Intensive efforts have been made to implement BMPs for manure application (Upper North Bosque River Hydrologic Unit Project, 1994). While these efforts have been quite successful, phosphorus still appears to be a potential concern in the watershed when compared to screening levels1 (0.2 mg/L for OPO4-P) recommended by the TNRCC (1993). Many of the stream sites indicated OPO4-P levels well above the 0.2 mg/L screening level and these levels increase significantly with an increasing percentage of waste application fields in a drainage basin. Phosphorus runoff is dependent on three factors: (1) sediment transport, (2) the capacity of the soil to adsorb phosphorus into the solid phase, and (3) the dissolved phosphorus concentration in the soil surface layer. All three factors need to be considered in controlling phosphorus levels in surface and subsurface runoff from waste application fields. Based on rough estimates of soluble phosphorus (as represented by OPO4-P) to total-P in storm water runoff, soluble phosphorus losses appear to increase as the percent waste application fields increase in a drainage basin (McFarland and Hauck, 1995). Many proven erosion control technologies exist to manage particulate losses of phosphorus. The control of dissolved phosphorus forms may be a greater management challenge than the control of particulate phosphorus forms since factors controlling the concentration of soluble phosphorus in runoff are not as well understood as those controlling particulate phosphorus (Daniel et al., 1993). The need to develop and promote BMPs for the control of soluble phosphorus from animal-waste application fields in the UNBR watershed appears apparent from the empirical relationships between OPO4-P and this land use (Table 1 and Figure 1).

The relationships between land use and water quality can also be used as a planning tool for the future siting of dairies and waste application fields in the watershed. Although these relationships are only estimates and do not explain all the variability in nutrient levels, they provide a planning guide in evaluating the potential impact of proposed changes in land-use on nutrient water quality within a drainage basin. These relationships are specific to the upper North Bosque River watershed, although further research should indicate whether they may be extrapolated to similar watersheds.

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Accessing U.S. Geological Survey Water Resources Data on the Internet

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Abstract

The U.S. Geological Survey (USGS) is making many of its information products available on the Internet. These include historical and real-time streamflow records, digital cartographic data, and interpretive reports of water resources studies. The USGS Node of the National Geospatial Data Clearinghouse is the main electronic pathway to USGS's vast collection of geographic information system (GIS) data. Many of the data sets, such as hydrologic unit boundaries and digital elevation models, are critical for watershed management. Hydrologic data and the National Geospatial Data Clearinghouse are offered on the Internet using the World Wide Web. Lessons learned in serving these data sets using this new technology are discussed. A statistical profile of World Wide Web "customers" who access water data also is examined.

Introduction

Few technical advances will affect the distribution of water-resources information as much as the World Wide Web (WWW). More than 100,000 individuals "visited" USGS water resources WWW sites in 1995, the first year of operation. They saw data on historical and real-time streamflow, read on-line reports and abstracts, downloaded GIS data sets, and examined fact sheets on a wide variety of water issues. Feedback from users is very positive, and usage is projected to at least double in 1996.

The scope of information products offered by USGS on the World Wide Web now includes many of critical importance to watershed studies. This paper describes some of these products and shows how to access them. It also examines the demographics of the customers and points out some surprising findings about who is accessing the data.

Information Products

The USGS Water Resources Information home page (http://h2o.usgs.gov/) should be the first stop for anyone desiring water information. In addition to "headlines" for feature articles and current hydrologic events, it includes links to all USGS water applications, such as the ones described below.

Historical Streamflow

In January 1995, USGS began serving historical daily streamflow records for nearly all stations in its data base. This comprises more than 19,000 stations throughout the United States. As the data for each State was reviewed by the local USGS office, the records were opened for public access. Records for more than half the States were available by January, 1996.

Upon selecting a State, the user is presented with an "imagemap" of counties and watersheds. Pointing the cursor and clicking on a county brings up a scrolling list of stations within that county. Upon selecting a station with the cursor, the user sees background information for the station, including the periods of record for data collection. After choosing a time period, the user may either see a graph of the streamflow or retrieve the record directly. The whole process takes less than two minutes.

Some local offices have augmented the basic software supplied by USGS Headquarters with image maps for selecting stations and other alternatives for finding and selecting stations. Multi-station retrievals of data via file transfer protocol (FTP) also are available. Further upgrades were in progress at the time this paper was written.

USGS has never offered its streamflow data in a format with anything close to this level of convenience. Data used to be hard to obtain, and downloading it required relatively high levels of computer skills and knowledge of the system. Now the data and a simple graph are available to anyone quickly and at no charge.

Current Streamflow Conditions

The current streamflow conditions pages bring streamflow data "from the stream to your screen." Some stream-gaging stations transmit data directly to USGS via satellite, usually on a 4-hour update cycle. As of February, 1996, 19 states were serving this "real-time" streamflow data on World Wide Web. This application offers users a plot of the streamflow data for the most recent 7 days.

"Real-time" streamflow data are, of course, provisional and subject to later changes as stations are reviewed and calibrated. Nevertheless, this service has proven immensely popular not only with traditional water-resources professionals, but also with whitewater enthusiasts and fishermen.

Geospatial Data Sets

The USGS Node of the National Geospatial Data Clearinghouse (http://nsdi.usgs.gov/nsdi/) was opened in January, 1995 as the primary Internet access point to USGS's vast holdings of spatial data. Among the many data sets available at this World Wide Web site are some that are critical to watershed planning, including hydrologic unit maps and digital elevation models.

Hydrologic unit maps delineate the hydrographic boundaries of major river basins and show numeric codes assigned to each river basin. The maps were prepared in a cooperative project between the USGS and the U.S. Water Resources Council. Boundaries and numeric codes are depicted for 21 regions, 222 subregions, 352 accounting units, and 2,100 cataloging units. River basins are delineated that have drainage area greater than 700 square miles. State maps are published at a scale of 1:500,000; the U.S. map (unfortunately, out of print) is at a scale of 1:2,500,500. The report "Hydrologic Unit Maps", (USGS Water-Supply Paper 2294), describes the maps and contains the numeric codes for the river basins.

Digital data sets for hydrologic units are available at scales of 1:2,000,000 and 1:250,000. Each includes metadata-also available on-line-that describes the data set in compliance with Federal Geographic Data Committee metadata content standards (Federal Geographic Data Committee, 1994) Attributes of the 1:2,000,000-scale version include basin names. These data sets may be found in the Clearinghouse either by a Wide Area Information System (WAIS) search on keywords, or by a variety of "browsing" paths through the Clearinghouse pages. The metadata includes a choice for on-line retrieval.

Digital elevation models (DEM's) are a valuable tool for defining drainage patterns or delineating watershed boundaries. Elevation data spacing varies from 30 meters for 7.5-minute DEM's (corresponding to the USGS quadrangle series of the same scale) to 3 arc-seconds for 1:250,000 scale maps. Complete U.S. coverage is available only for the 1:250,000-scale digital line graph (DLG) data, which may be retrieved on line. An on-line status map gives the availability of 7.5-minute DEM's. As with all data sets in the Clearinghouse, metadata describes the data sets and gives ordering instructions.

Hydrologic units and digital elevation models are only a few of the many geospatial data sets available in the National Geospatial Data Clearinghouse. Among the many offerings of geospatial data sets are hydrography, transportation, satellite images, and aerial photography.

Customer Profiles

Like many other WWW sites, the USGS Water Resources Information pages have seen spectacular growth. Thirty local and regional water sites have shown similar growth. Log records indicate that more than 100,000 individuals accessed the system in 1995.

The vast majority of users are in the private sector. A core of at least 2,400 outside users makes extensive use of the system, accessing it at least twice per month.

User feedback has been highly favorable. It plays a big role in developing support for further enhancements and in shaping the design of the pages. Electronic mail from users also clearly indicates that many are not from the professional water-resource community that has comprised the traditional customer base of USGS. The enthusiasm and numbers of these "non-professional" users, while not anticipated, is a welcome response.

Conclusions

USGS has been serving water-resource information on the WWW for more than a year. By any standard, this has been a great success and is very popular with the public. In terms of costs, speed, convenience, and availability, the benefits of using the WWW for distributing water-resource data and reports are compelling. The message is clear: The WWW will play a big role in how you get water resources information products from USGS and other government agencies in the future.

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Small Watershed Studies: Analytical Approaches for Understanding Ecosystem Response to Environmental Change

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

Introduction

Biogeochemical studies in small watersheds provide an analytical approach to understand how ecosystems respond to natural climatic variations and human-induced environmental change. Small watersheds, usually less than 5 km2, are small enough to permit characterization and understanding of ecosystem processes within relatively simple, homogeneous biological and physical settings; yet they are large enough to incorporate more complex processes and element cycles than can be studied at plot scales. Watersheds comprise discrete hydrochemical environments allowing quantification of hydrologic, element, and energy budgets. Element budgets, or mass balances, can be quantified as the difference between the mass of a solute that enters a watershed in wet and dry deposition and leaves a watershed in streamflow. Element budgets are primary tools used to investigate biogeochemical processes. Monitoring various aspects of element budgets to assess ecosystem health and stability is analogous to measuring the pulse or blood chemistry of a patient. Monitoring streamwater chemistry, basic climate, soil, and biotic variables provide a means to integrate complex biogeochemical processes and evaluate trends in water quality. Small watershed studies provide a scientific basis to develop predictive models of watershed function.

Major emphases of small watershed studies include investigation of hydrologic and chemical responses to natural climate variation, anthropogenic stressors, and alternate forest-management practices. The nature and significance of biogeochemical research in small watersheds is reviewed by Moldan and Cerny (1994). The U.S. Geological Survey, U.S. Department of Agriculture Forest Service, and other federal agencies support several long-term small watershed studies to provide insight into a variety of ecosystem processes. Long-term records are essential to distinguish trends resulting from natural climatic variations or other stressors. The following sites, with noted periods of records, are examples of intensively studied forested watersheds in eastern USA supported by federal agencies:

- Coweeta Hydrologic Laboratory, North Carolina, (1939-present), Swank and Crossley (1988).
- Hubbard Brook Experimental Forest, New Hampshire, (1956-present), Bormann and Likens (1979).
- Sleepers River Research Watershed, Vermont, (1958-present), Shanley et al. (1995).
- Walker Branch Watershed, Tennessee, (1967-present), Johnson and Van Hook (1989).
- Catoctin Mountains Research Site, Maryland, (1982-present), Rice and Bricker (1995).
- Catskill Stream Network, New York, (1983- present), Murdoch and Stoddard (1992).
- Panola Mountain Research Watershed, Georgia, (1985-present), Huntington et al. (1993).

Small watershed studies also provide essential baseline information for understanding variations in water quality and element cycling in "pristine" ecosystems that can be used as benchmarks to evaluate anthropogenic impacts and alternate watershed management practices. This paper provides examples of how analytical tools developed through watershed research provide insight into ecosystem processes and can contribute to the management of watershed resources.

Case Studies

Six reservoirs in the Catskill Mountains provide 75% of drinking water supplies to New York City. Episodic acidification and nutrient leaching from forest soils are major concerns for resource managers in these watersheds. Results of long-term studies in streams of the Catskill Mountains indicate that nitrate concentrations in streamwater increased from 1970 to 1991, then decreased sharply and have remained low through 1994 (Murdoch and Burns, 1995). During the same period, sulfate concentrations steadily decreased in both deposition and streamwater (Murdoch and Stoddard, 1992); these changes appear to be associated with variability in nitrogen and sulfur deposition, drought periods, and air temperature. Air temperature also influences soil microbial activity. Correlations between deposition, air temperature, and stream nitrate concentrations would not have been detected without the long-term intensive monitoring of hydrochemical processes characteristic of the watershed approach.

Long-term, intensive data sets on element budgets generated from watershed studies are needed to distinguish between natural climatic variability and the effects of different stressors. For example, Huntington et al. (1994a) determined that variations in sulfate export were governed more by annual differences in runoff quantity rather than differences in precipitation or atmospheric deposition of sulfate. This work was extended by Aulenbach and Hooper (1994) who demonstrated that adjusting for annual differences in run-off distributions was critical to detect trends in water quality. Comparing flow-weighted annual average concentrations, as is typically done, induced false positive and false negative trends. These improved trend-detection techniques assist in environmental assessment and design of more cost-effective monitoring studies. Rice and Bricker (1995) also used long-term, intensive data sets to identify seasonal hydrologic and geochemical processes that can be used to design more cost-effective monitoring studies.

Small watershed studies also include the collection of ancillary data, such as soil-water chemistry and ground-water quality, that provides stronger evidence to explain why changes are occurring. Huntington et al. (1994a) determined that the sulfate concentration-discharge relation changed substantially following changes in hydrologic conditions. Streamwater-sulfate concentrations decreased during normal to wet years following dry years (Figure 1), mirroring changes observed in soil-water lysimeters. These patterns indicate that a relatively labile pool of sulfate accumulates during dry years and is slowly released during subsequent years of normal to above average rainfall.

Element-mass budget calculations also can be useful in detecting the potential for nutrient depletion and consequent effects on the sustainability of long-term forest productivity. Watershed studies conducted on highly weathered soils with recovering forests on abandoned agricultural lands in the southeastern USA indicate that calcium leaching and timber harvest removals exceed atmospheric inputs and weathering resupply (Johnson and Todd, 1990; Huntington et al., 1994b). Soil calcium stores in these ecosystems are relatively small and atmospheric deposition of calcium appears to be declining. Budget calculations suggest that ecosystem storage could be reduced by about 50% in two or three harvest rotations (Table 1).

Comparative analyses of suspended-sediment yields among three intensively studied small watersheds provide information on controls of sediment generation and transport in Puerto Rico and the Georgia Piedmont (Larsen et al., 1995). Land use is the dominant control, however, storm runoff, storm intensity, relief, and availability of stored sediment are important secondary controls that affect sediment yields. Effective watershed management to minimize sediment yields should recognize the relative importance of all factors that influence the generation and transport of sediments. Suspended-sediment data from forested watersheds provide information on background levels of suspended sediment, which are useful in evaluating the impacts of alternate land uses and in predicting sediment loads to reservoirs under minimal disturbance conditions.

Nitrogen cycling has been identified as an important indicator of ecosystem stability. In a number of montane forest ecosystems in northern Europe and U.S.A., high rates of atmospheric deposition of nitrogen and streamwater exports_which equal or exceed inputs_have occasionally been associated with "forest decline". Excessive nitrogen may be responsible for reduced frost hardiness, accelerated soil and foliar cation leaching, increased susceptibility to insect pests and pathogens, and a number of other ecosystem processes (Gundersen and Bashkin, 1994). Although substantial uncertainty remains concerning these hypotheses, watershed studies have shown that monitoring nitrate concentrations in streamwater can allow disruptions to normal ecosystem processes to be detected and the concepts of critical loads and ecosystem health to be evaluated.

Key processes involved in episodic acidification of surface waters were identified using small watershed studies (O'Brien et al., 1993; Wiggington et al., 1992; Campbell et al., 1995). Episodic acidification is caused by a number of factors, including pulses of sulfate, nitrate, organic acids, or sea salt. In all areas, changes in flowpath through the shallow subsurface affects the temporal and hydrochemical characteristics of episodes. Identification of these processes can assist land managers and legislators to understand how changes in climate, land use, forest-management practices, and emissions are likely to effect various ecosystems, depending upon local geology, soils, and atmospheric acidic deposition.

Research conducted in the U.S.A., particularly at Coweeta Hydrologic Laboratory in North Carolina and at Hubbard Brook Experimental Forest in New Hampshire, has been used to investigate the effects of forest-management practices on surface-water hydrology and water quality. Decades of research have resulted in a better understanding of basic principles of streamflow generation, evapotranspiration, and hydrologic responses to a variety of forest-management practices under different forest types. Swank et al. (1989) quantified relationships between forest-cover alternatives and water-yield responses under a variety of management and forest type combinations. Watershed studies have quantified soil losses (Swift, 1988) and losses of dissolved nutrients resulting from forest harvesting in several ecosystems (Swank et al., 1989; Hornbeck et al., 1986). Studies such as these provide a scientific basis for land managers to evaluate alternative management strategies.

Challenges for Future Research

One of the biggest limitations to broader application of watershed studies is uncertainty regarding how well an understanding of ecosystem processes at the small watershed scale can be transferred to significantly larger landscape units. The challenge for watershed scientists is to develop new methods for scaling processes up from a small watershed to the river basin. There are large uncertainties about the relative importance of different processes at different spatial scales. For example, processes determined to be of key importance at the scale of 1 km2 may be unimportant or overwhelmed by other processes that operate only at scales greater than 100 km2. Hypotheses developed at the small watershed scale must be tested at larger scales to determine the controlling processes at each scale. Recent advances in geographic information systems (GIS) and access to increasing digital data bases should be exploited to select target watersheds to test new hypotheses. Primary consideration should be given to nested basins, which provide the opportunity to compare alternate land-use and land-management practices and their influences on water quality.

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Watershed Management Decision Support System

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Introduction

There is a growing consensus that an effective way to control nonpoint source pollution and enhance the long-term sustainability of agriculture and rural communities is through locally-based planning and management at the watershed scale. The total watershed management viewpoint is supported by the National Water Agenda for the 21st Century which supports the following conclusions: "1) it can be argued scientifically that watersheds constitute the most sensible hydrologic unit within which actions should be taken to restore and protect water quality, 2) watersheds allow for the development of total resource protection plans that are tailored to the conditions in the area of interest, and 3) management institutions organized by watershed provide far better opportunity to resolve intergovernmental or interjurisdictional conflicts through collaborative, consensus based techniques" (Water Environment Foundation, 1992).

Watershed planning and management is superior to single-objective resource management for several reasons. First, it recognizes that human activities within a watershed are motivated by multiple and often conflicting objectives and/or constraints, such as maximizing farm income, protecting soil and water resources, and securing and maintaining drinking water supplies. When conflicts occur among watershed management objectives there are tradeoffs between the beneficial uses of watersheds. Second, total watershed management accounts for the interactions among socioeconomic conditions, land uses and environmental quality. Crop and livestock production affect not only income and social status of farmers but also storm runoff, water quality and ecological processes. Conversely, excessive soil erosion reduces crop yields which lowers potential farm income. Third, the spatial configuration and connections among landscape elements in a watershed influence the profitability of agricultural activities, natural resource quality and ecological performance. Landscape elements include: parcels in cropland, grass, brush and forests; and sizes and composition of riparian areas. Fourth, since total watershed management is comprehensive and knowledge-based, it is more likely to generate solutions that are acceptable to diverse stakeholders in a watershed.

While watershed management is widely supported, the spatial information on socioeconomic and physical processes needed for comprehensive evaluation of alternative watershed management plans is not readily accessible to local decision makers. Advances in remote sensing, geographic information systems (GIS), multiple objective decision making, and physical simulation make it possible to develop user-friendly, interactive, decision support systems for watershed planning and management. A user-friendly, interactive, watershed management decision support system (WAMADSS) incorporates these advances. The decision support system (DSS) adopts a landscape perspective which is a way to view interactive parts of a watershed rather than focusing on isolated components.

Objectives

The study has two objectives: (1) design a user-friendly, interactive WAMADSS that identifies the relative contribution of sub-watershed areas to agricultural nonpoint source pollution and evaluates the effects of alternative land use/management practices (LUMPs) on farm income, soil erosion and surface water quality at the watershed scale; and (2) demonstrate the utility of WAMADSS in identifying and/or evaluating LUMPs for controlling soil erosion and surface and ground water pollution in Goodwater Creek watershed.

LUMPs included in WAMADSS are: crop rotations, tillage practices, conservation practices (grass waterways, terraces), pollution prevention practices (timing, rate and method of application of fertilizers and pesticides) and other landscape elements such as improved vegetative cover in riparian areas.

Study Area

The agricultural watershed is Goodwater Creek watershed in Boone and Audrain counties, Missouri (Figure 1). This is the site of the Missouri Management Systems Evaluation Area (MSEA) project. This watershed, which is 77.43 square kilometers, is selected for two reasons: (1) atrazine and alachlor concentrations in the surface runoff are 10 to 100 times higher than the current drinking water standards during the late spring and early summer period following chemical application; and (2) extensive water quality monitoring has been conducted in Goodwater Creek watershed which can serve to validate results obtained from environmental simulation models.

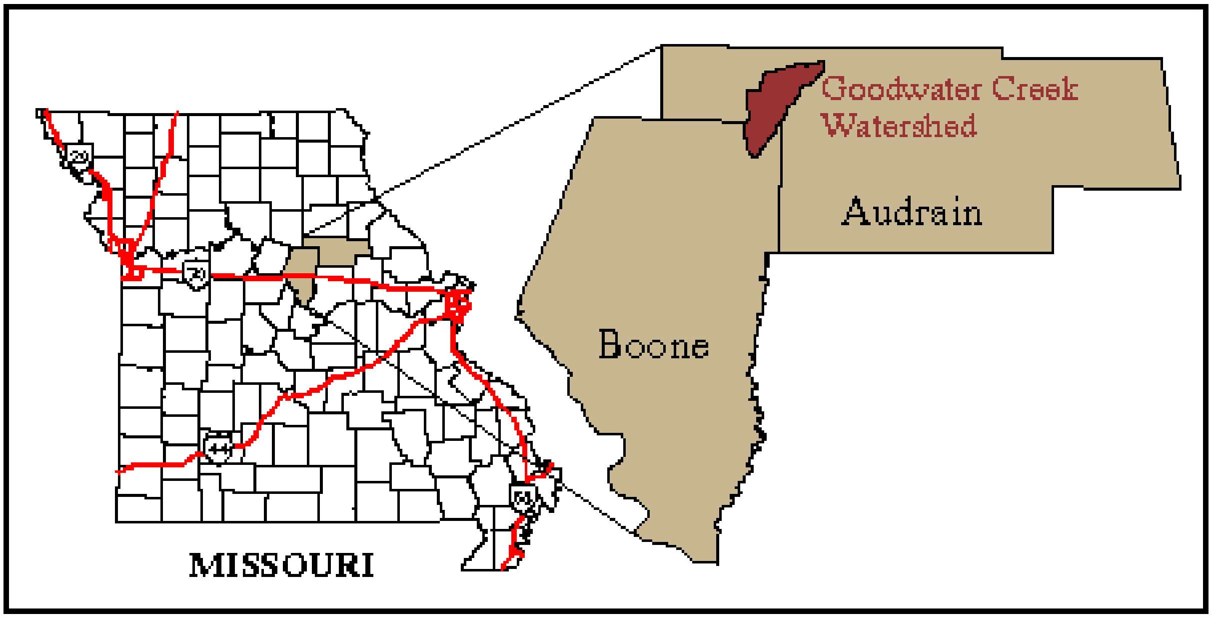

Figure 1. Study Area.

Methods

WAMADSS is a knowledge-based computer system which integrates data, information, physical simulation models and economic analysis to identify alternative LUMPs for solving specific watershed problems. The DSS has three components: a graphical user interface (GUI), a GIS, and a modeling system. The interface enables the decision maker to manipulate land use alternatives, run the simulation models, execute the economic model, and view results in an interactive session.

Graphical User Interface

A GUI provides the user with access to the GIS and modeling system. The GUI contains menus which allow the user to select LUMPs, parameters and evaluation criteria needed to run the models. A menu provides an interactive interface for entering all the parameters needed to execute a complex operation. The user provides information (filling in blanks, checking boxes or answering questions) by interacting with visual objects called widgets. Since the DSS is designed for users with diverse, nontechnical backgrounds, the graphical appearance of menus and program functionality is consistent across all menus. On-line help and feedback will be incorporated as they are critical elements of the GUI.

Geographic Information System

ARC/INFO software is the GIS used in WAMADSS. A GIS is often defined as the complete sequence of components for obtaining, processing, storing and managing, manipulating and displaying spatial data. Incorporating a GIS in the DSS significantly improves the user's ability to manipulate the spatial and non-spatial data needed to evaluate alternative watershed management plans. This approach enhances the "best judgement" decisions offered by conventional environmental models. ARC/INFO is a widely used commercial software product that contains modules for interfacing models in a decision support system. Specifically, the GRID module in ARC/INFO generates the elevation surface parameters (slope, aspect, slope length). The Arc Macro Language (AML) module generates the GUI menus and ties the components together. The INFO database management system stores, maintains, manipulates and reports all spatial and non-spatial attribute data relevant to the DSS. The ARCPLOT module is used to graphically present water quality/economic results of baseline and alternative LUMPs.

Modeling System

The modeling system consists of environmental models and an economic model. Two environmental models are incorporated into WAMADSS. AGNPS (AGricultural Non-Point Source Pollution model) simulates erosion, sediment, runoff, and nutrient (nitrogen and phosphorus) transport from agricultural watersheds for individual storm events. SWAT (Soil and Water Assessment Tool) is a continuous daily time-step model which simulates the impacts of alternative land use management practices on surface and ground water quality. The purpose of incorporating both AGNPS and SWAT in WAMADSS is to offer the user more options for evaluating the impacts of alternative LUMPs. The GIS is well suited for managing the input parameters for each model.

The economic model evaluates the effects of a particular spatial configuration of LUMPs on annualized net returns at the field and watershed scales. A spatial configuration refers to the LUMPs applied to each and every field in the watershed as specified by the user(s). WAMADSS calculates annualized net returns on an acre, field and watershed basis using the Cost and Returns Estimator (CARE). The spatial input data needed to calculate annualized net returns include: set-aside requirement, total acres per field, planted acres per field (total acres times proportion planted), initial crop yields and cost of production per acre. Cost of production is estimated based on crop yield, LUMP and average costs of farm labor, fertilizer, pesticides, fuel and machinery/equipment.

WAMADSS Input Parameter Generation

All the parameters required for the economic and environmental models are stored as relational tables and accessed through the GUI. Some parameters are based on physical attributes extracted from the various layers (hypsography, landuse, soils, hydrology) while other parameters are based on input elicited from the user via the GUI. WAMADSS' open architecture and modular framework supports the refinement, addition and interfacing of new components. WAMADSS allows the user to specify the criteria used to evaluate watershed management plans. Based on the results of WAMADSS, the user can modify the LUMPs until a desired management plan is achieved.

The three components that comprise WAMADSS are accessed from one common interface. Specifically, AGNPS and SWAT and the economic model are linked to ARC/INFO via the ARC Macro Language or AML. AML is the programming language used to interface the simulation models and the economic model in a seamless decision support system framework. This programming language handles all simulation-related activities, including generating input files, executing the environmental and economic models, and viewing results in the GIS. In terms of input parameter generation, AML programs are used to create the GUI for entering model input parameters and transform input parameters from the GIS to a AGNPS or SWAT compatible input file format. WAMADSS permits the end user to modify land use activities by prompting the user through a series of menus which are used to update the parameters for the selected LUMPs.

Conclusions

WAMADSS, makes complex and technical information and knowledge available to decision makers in a user-friendly graphical user interface. It allows users to: organize information based on existing data and scientific knowledge, design alternatives and assess consequences of new watershed management plans or policies, and evaluate and compare alternative watershed management schemes (Fedra et al., 1993). The DSS has three components: a graphical user interface, a geographic information system (GIS), and a modeling system. A GIS can be used to minimize the time involved to manually enter or manipulate the large amount of input data required to describe the spatial detail of a watershed. A GIS also minimizes human error and inconsistencies in distinguishing landscape characteristics across a watershed that would otherwise be collected by conventional methods.

Coordinated resource management of a watershed requires the simultaneous consideration of physical and socioeconomic interrelationships and impacts. In order to address these considerations, it is necessary to integrate a large amount of spatial information and knowledge from several disciplines. While knowledge about the interactions among socioeconomic and physical processes in a watershed is essential for improving sustainability of agricultural production, the mere generation of such knowledge is insufficient. The knowledge must be delivered to potential users in a way that maximizes its usefulness in watershed planning and management. Long-term agricultural sustainability can be advanced by achieving the twin goals of: a) increasing knowledge/understanding regarding the spatial and temporal interactions between economic and environmental processes and how these interactions are altered by LUMPs at the watershed scale and b) developing decision support aids which make this knowledge/understanding accessible to and usable by individuals and groups involved in watershed planning and management. WAMADSS contributes to both goals.

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A Modular Modeling Approach to Watershed Analysis and Ecosystem Management

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Introduction

Recent developments in the areas of federal forest-ecosystem and water-resource management have indicated a need for the development of tools to assist resource managers in assessing the effects of alternative land-management strategies on a variety of environmental issues (FEMAT, 1993; Montgomery et al., 1995). These needs include the ability to (1) build spatially explicit landscape scenarios based on externally supplied rules such as harvest levels and environmental constraints; (2) characterize and parameterize these scenarios for hydrological and ecological models to evaluate the effects of alternative scenarios on key system behaviors; and (3) iterate with decision models to modify scenarios to identify optimal resource management strategies. To address management needs, a database-centered decision-support system that couples hydrological and ecological process models with resource-management models (RMMs) is being developed.

The interdisciplinary nature and increasing complexity of forest-ecosystem and water-resource management problems require the use of modeling approaches that can incorporate knowledge from a broad range of scientific disciplines. Selection of a model to address these problems is difficult given the large number of models available and the wide range of study objectives, data constraints, and spatial and temporal scales of application. Coupled with this are the problems of characterizing and parameterizing the study area once the model is selected. Guidelines for estimating model parameters are few and the user commonly has to make decisions based on an incomplete understanding of model details.

To address the problems of model selection, application, and analysis, a set of modular modeling tools, termed the Modular Modeling System (MMS) (Leavesley et al., 1995) is being developed. MMS uses a library of compatible modules for simulating a variety of water, energy, and biogeochemical processes. A model is created by selectively coupling the most appropriate process algorithms from the library to create an "optimal" model for the desired application. Where existing algorithms are not appropriate, new algorithms can be developed.

MMS provides a flexible framework in which to develop a variety of physical process models that can be coupled with RMMs for use in addressing a wide range of management issues. The management of forested ecosystems is an application being addressed jointly by the U.S. Forest Service (USFS) and the U.S. Geological Survey (USGS) under a collaborative research project. Initial work is focused on coupling MMS with selected RMMs for use in the northwestern United States. This work will be expanded to other regions as tools are developed and tested. The purpose of this paper is to provide an overview of MMS and the database-centered approach to linking MMS with RMMs.

MMS Overview

The conceptual framework for MMS has three major components: pre-process, model, and post-process (Fig. 1). The pre-process component includes the tools used to prepare, analyze, and input spatial and time-series data for use in model applications. The model component includes the tools to develop and apply models. The post-process component includes tools to display and analyze model results, and to pass results to management models or other types of software. A graphical user interface (GUI) is being developed to provide user access to all the components and features of MMS. The current framework has been developed for UNIX-based workstations and uses X-windows and Motif for the GUI. The GUI provides an interactive environment for users to access model-component features, apply selected options, and graphically display simulation and analysis results.

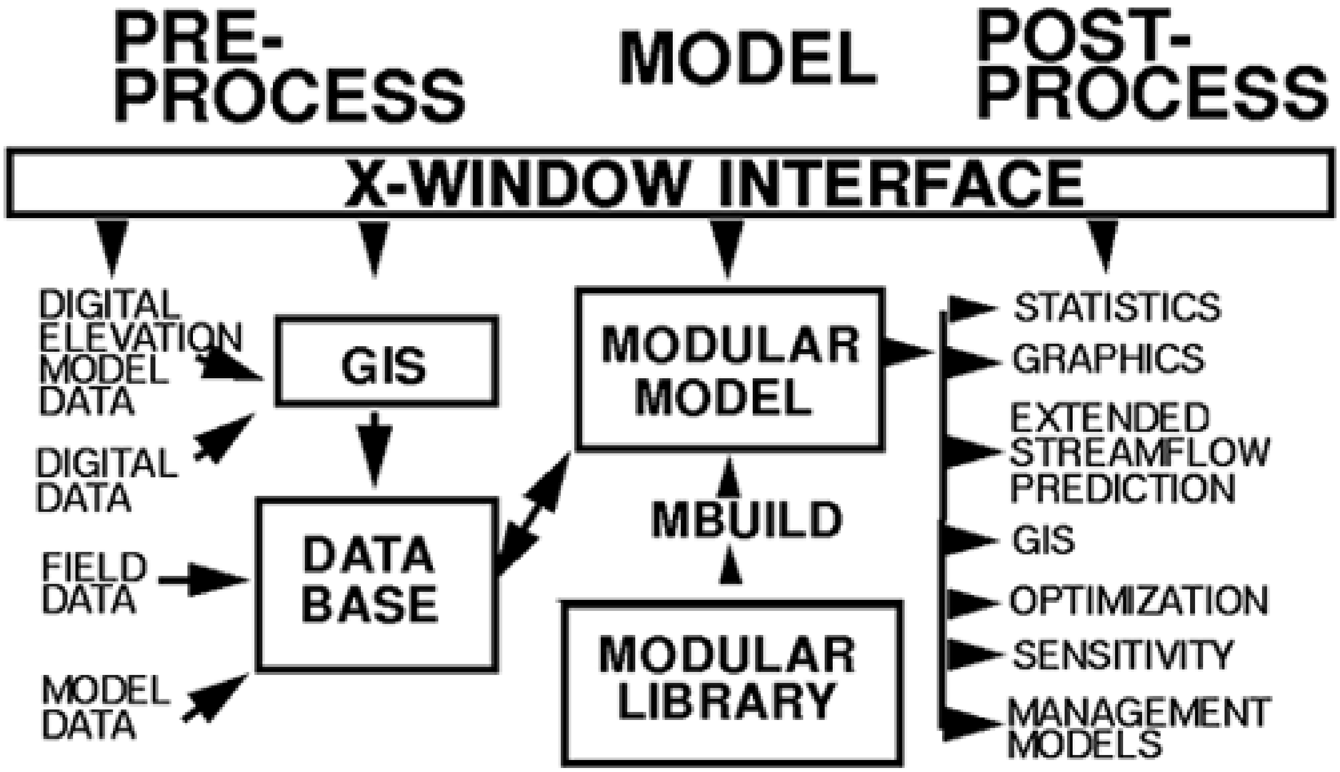

Figure 1. A schematic diagram of the components of the Modular Modeling System (MMS).

Pre-process Component

The pre-process component includes all data preparation and analysis functions needed to meet the data and parameterization requirements of a user-selected model. A goal in development of the pre-process component is to take advantage of existing data-preparation and analysis tools and to provide the ability to add new tools as they become available. Spatial data analysis is accomplished using GIS tools that have been developed and tested in both the Arc/Info system (ESRI, 1992) and the Geographical Resources Analysis Support System (GRASS) (U.S. Army Corps of Engineers, 1991). Functions developed include the ability to (1) delineate and characterize watershed subbasin areas for distributed-parameter modeling applications; (2) estimate selected model parameters for these subbasins using digital elevation model (DEM) data and digital databases that include information on soils, vegetation, geology, and other pertinent physical features; and (3) generate an MMS input parameter file from these estimates. Time-series data from existing databases as well as from field instrumentation are prepared for use in selected model applications by generating and combining these data into a single ASCII flat file.

Model Component

The model component is the core of the system and includes the tools to build a model by selectively linking process modules from the module library and to interact with this model to perform a variety of simulation and analysis tasks. The library can contain several modules for a given process, each representing an alternative conceptualization or approach to simulating that process. The user, through an interactive model builder interface (MBUILD), selects and links modules to create a specific model. Once a model has been built, it may be saved for future use without repeating the MBUILD step. This capability allows 'canned' versions of models to be provided to users.

Post-process Component

The post-processing component contains the tools to analyze model results. These include a variety of statistical and graphical tools as well as the ability to interface with user-developed special purpose tools. Statistical and graphical analysis procedures provide a basis for comparing module performance and can be used to aid in selecting the most appropriate modeling approach for a given set of study objectives, data constraints, and temporal and spatial scales of application. A GIS interface provides tools to display spatially distributed model results and to analyze results within and among different simulation runs. A modified version of the National Weather Service's Extended Streamflow Prediction Program (ESP) (Day, 1985) also is available and provides forecasting capabilities using historic or synthesized meteorological data.

GIS Interface

A geographic information system (GIS) interface component is being developed for MMS to facilitate model development, parameterization, application, and analysis. This interface permits application of a variety of GIS tools to lumped- and distributed-parameter modeling approaches and permits development and testing of a variety of objective characterization and parameterization techniques. The GIS interface also permits visualization and analysis of the spatial and temporal distribution of model parameters and simulated state variables. Within the model component, the GIS interface provides an animation tool to enable the visualization of the spatial and temporal variation of simulated state variables during a model run. Selected images from this animation for user-defined time periods can be stored and used in a post-modeling analysis to compare simulated and measured spatial and temporal variations in the selected state variable.

Database-Centered Decision Support System

The physical process models in MMS are being linked with RMM via a common database, thus providing a database-centered decision support system (Fig. 2). Software is also being developed to provide GIS, statistical analysis, and data query and display capabilities that will be shared by MMS and RMM. In the current project, the database is an ORACLE (Oracle Corporation, 1987) based system. However, this approach is not limited to ORACLE but can be used with any relational database system. MMS and RMM access the database through user-written data management interfaces (DMIs). Users can use a variety of standard DMIs, or write customized DMIs in any standard programming language that has database interface capabilities, to access data from a variety of data repositories, including other relational databases. Changing the central database requires only that the DMIs be modified to support the selected database. No changes need to be made in MMS or RMM.

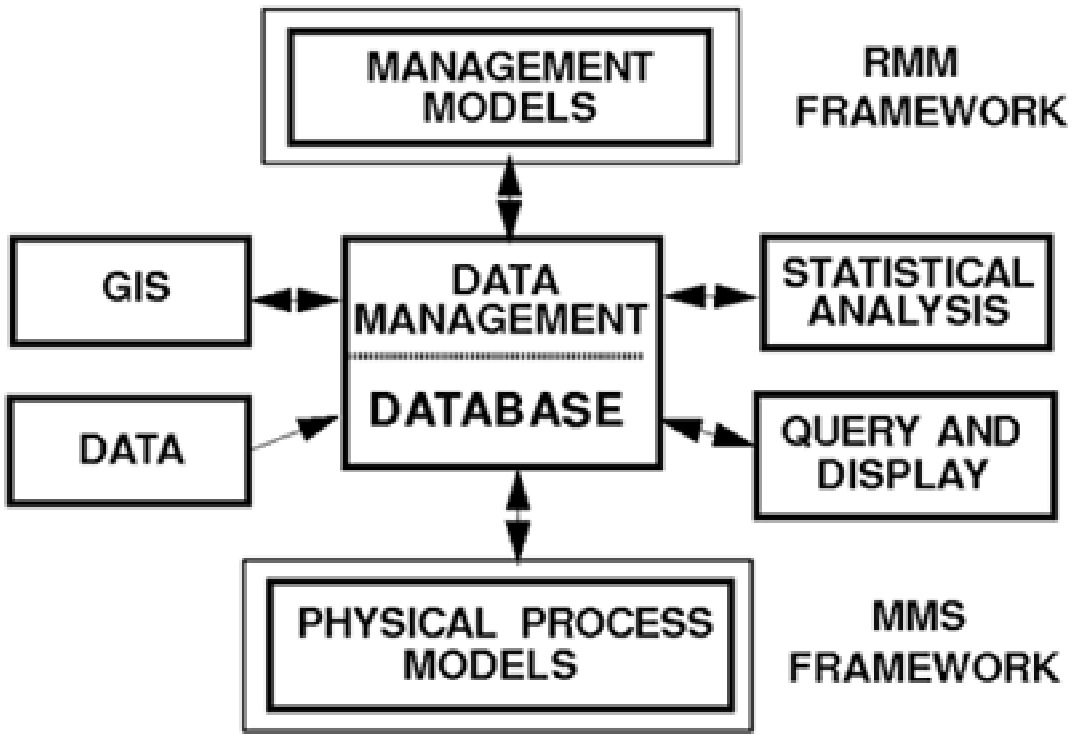

Figure 2. Schematic of the database-centered decision support system.

Communication between MMS and RMM is being designed to use a scenario file in the database. A scenario is defined as a sequential list of modeling operations to be run using MMS and RMM. Different scenarios can be developed to address a range of resource-management decisions. The scenario file is accessed by both modeling systems and the specified models are executed in the order listed. A given resource-management decision may require the results of one or several models in both systems. Model results from MMS are written to the database for use as inputs to RMM and vice versa. This exchange of data and model results is an iterative procedure, the magnitude of which is dependent on the complexity of the decision process.

An example of such a procedure would be the analysis of forest-management alternatives for a selected watershed within the constraints of competing resource users and selected environmental constraints. A scenario of MMS and RMM runs might begin with the execution of landscape-generation models in RMM that would provide measures of landscape characteristics for selected management options over a 200-year forest cutting rotation. Management option scenarios might range from maximum timber yield to maximum habitat protection. The following steps would then be executed. Watershed characterization and parameterization procedures would be run in MMS to create the parameter files for each scenario. Next, a watershed model in MMS would be called to provide estimates of the daily time series of water, sediment, and selected chemical constituents for each scenario. RMM would be executed to analyze the MMS model results. RMM analyses might eliminate scenarios that exceed selected threshold criteria but indicate that more information is needed for the remaining scenarios. Additional process models would be run in MMS for selected time periods, watershed areas, or stream reaches. RMM then would be run again using the additional information to further refine the management options.

Summary

MMS is an integrated system of computer software that has been developed to provide the research and operational framework needed to support the development, testing, and evaluation of water, energy, and biogeochemical process algorithms and to facilitate the integration of user-selected sets of algorithms into operational models. MMS provides a common framework to develop and apply models that are designed to address problem-specific needs. MMS is being coupled with RMMs using a common database interface to provide a database-centered decision support system for use in forest-ecosystem and water-resources management.

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Hydraulic Modeling to Support Wetland Restoration in Coastal Watersheds

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Introduction

Coastal wetlands are highly productive ecosystems which provide spawning and feeding habitats for many aquatic organisms. Coastal wetlands also provide other benefits relating to flood protection, water quality, waterfowl habitat, erosion control, biological diversity and recreation. Similar to freshwater wetlands, it has been estimated that about half of the tidal wetlands in the United States have been destroyed, resulting in negative impacts on large scale watersheds.

Restoration and enhancement of coastal wetlands offers an opportunity to reverse such negative impacts and should be pursued as part of an overall management plan for both large and small scale watersheds. As part of a New Jersey Department of Environmental Protection water discharge permit for Public Services Electric and Gas Company's (PSE&G) Salem Generating Station, PSE&G is implementing one of the largest wetland restoration and preservation programs in the country. The program scope includes:

- Restoration of 4,000 hectares of degraded coastal wetlands.

- Preservation of a 1,800-hectare tract of coastal wetlands and adjacent buffers.

- Installation of 5 fish ladders on Delaware Estuary tributaries.
- Implementation of a comprehensive bay-wide biological monitoring program.
- Improvements to the Station's intake system to increase survivability of aquatic resources.

With the addition of other wetland restoration projects in the State of Delaware, over 80 square kilometers of coastal wetlands and wetland buffers will be enhanced and preserved for perpetuity within the Delaware Estuary.

Among the lands that are suitable areas for coastal wetland restoration and enhancement are diked farming areas, such as salt hay farms. These farm areas occur along the New Jersey bayshore where dikes and sluice gates (or other water control structures) have been installed to control tidal inundation, and thereby promote the growth of salt hay (Spartina patens). Because only occasional tidal inundation is allowed on these farms and the salt hay is mowed and removed from the land, these farms contribute very little to the aquatic productivity of the Delaware Estuary. In addition, these areas provide ideal breeding grounds for the saltmarsh mosquito (Aedes sollicitans) and are susceptible to colonization by invasive species such as common reed (Phragmites australis).

Project Description

Woodward-Clyde Consultants (WCC) was retained by PSE&G to conduct baseline studies, develop engineering designs, prepare a Management Plan and prepare permitting documents for the restoration of coastal wetlands at two sites along the New Jersey bayshore.

WCC's designs for these salt hay farm sites have the objective of restoring tidal inundation and drainage to these areas through the construction of new inlets and major channels based on detailed hydraulic studies at each site. With the return of the normal daily tidal flow, these areas will 1) again contribute to the enhancement of the marsh/estuary food web through the export of detrital production; 2) provide refuge, feeding habitat and nursery grounds for various estuarine animals; and 3) be less favorable as breeding areas for the saltmarsh mosquito.

Site Description

The Maurice River Salt Hay Farm Restoration Site is a 445-hectare diked salt hay farm located in Cumberland County, New Jersey. The site is bordered by Delaware Bay to the south and by tidal creeks to the east and west. The eastern tidal creek ranges in size from 30 to 100-meters wide and has a small freshwater flow. The western tidal creek is 12 to 30-meters wide and has no freshwater flow.

Salt hay farming was conducted at the site for several decades but was discontinued several years ago. The perimeter dikes and their associated outlet structures were constructed in the late 1960s and early

1970s to protect the salt hay farm from flooding. However, lack of maintenance on the dikes and outlet structures has led to their deterioration and as a result, many breaches in the dikes have formed. These breaches now control the tidal flow into and out of the restoration area.

The topography across the site is generally flat. Elevations are lowest in the center of the site and increase towards the perimeter. The site has experienced settlement and consolidation of the sediments as a result of the restriction of tidal flows. Elevations within the perimeter dikes vary from -0.31 to 0.92 meters NAVD. Tides range from a Mean Low Water (MLW) of -1.01 meters to a Mean High Water (MHW) of 0.75 meters with a Mean Tide Level (MTL) of -0.13 meters.

The existing drainage channels are not sufficient to convey tidal flows throughout the site. The major interior channels of the site are borrow areas/pits for the construction of the dikes and are located on the inboard side of the perimeter dikes. These channels are not interconnected and are generally hydraulically isolated during periods of lower water. Currently, tidal flows are conveyed throughout the interior of the site predominantly by overland flow.

Methodology

The objective of the hydraulic study was to develop a conceptual design of a channel system that would convey tidal flows throughout the wetland with minimal channel erosion and tidal attenuation. Therefore, the methodology selected for performing the hydraulic analyses had to be:

- Capable of predicting the extent of flooding and draining for different channel configurations and sizes.
- Capable of predicting overland and channel flow velocities.
- Flexible enough so that different channel configurations and sizes could be simulated.
- Proven, widely accepted, and therefore defensible in front of the client, the regulatory agencies, an independent advisory committee, and the scientific community.

In general, a comparison between average tidal conditions and site topography can help evaluate the extent to which the wetland restoration goals can be met. However, such an evaluation does not define the period of inundation, the potential for erosion or the ability of channels to convey tidal water into the site. To estimate these, a hydraulic model is necessary. The US Army Corps of Engineers Waterways Experiment Station RMA-2 two-dimensional finite element hydrodynamic model was selected to analyze different design alternatives proposed for restoration of the site. The version of the model included the front and back-end interface FastTABS. One important feature of the model is its ability to simulate wetting and drying of a system such as occurs in a coastal wetland. Also, the model has been applied to several water bodies across the United States and is widely accepted by regulatory agencies.

In order to conduct the modeling, detailed topography of the site is needed. Over 25,000 digitized aerial survey data points complemented with field survey data of the adjacent tidal creeks and larger interior channels were used in the study. This original data set was reduced to a finite element mesh consisting of approximately 6000 nodal points and 2500 elements. This resulted in a grid of approximately 122 by 122 meters for the flat areas and approximately 5 by 5 meters for the breaches and interior channels. The RMA-2 model grid for existing conditions is presented in Figure 1.

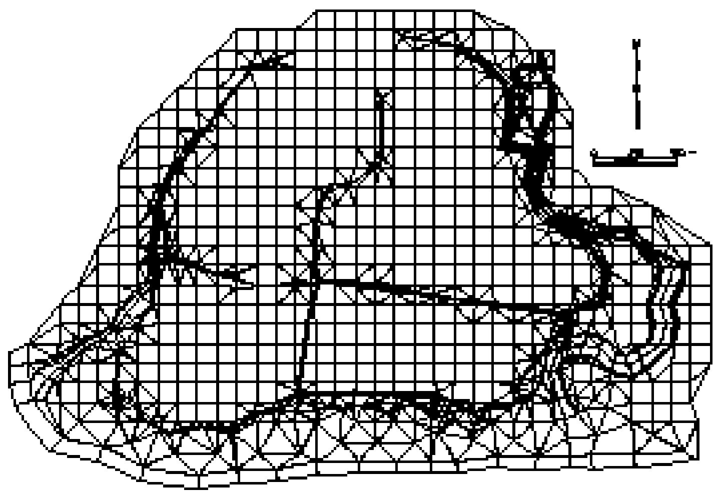

Figure 1 Two-dimensional model grid

Figure 1. Two-dimensional model grid.

Design alternatives were modeled using RMA-2 by modifying the grid from the existing conditions to the proposed conditions. The inlet and channel locations and sizes were modified to maximize flooding and draining with minimal channel erosion. One of the design goals was to mirror the size and distribution of channels in the adjacent natural marsh systems. The flexibility in the model allowed the design to be optimized to meet this design goal.

Results

The modeling indicated that four inlet and channel systems are required to fully inundate and drain the site: one connected to each adjacent tidal creek and two directly connected to the Delaware Estuary. The final design of the inlet and channel configuration is shown on Figure 2. These results are consistent with observations of the distribution of tidal channels in surrounding natural tidal marsh areas.

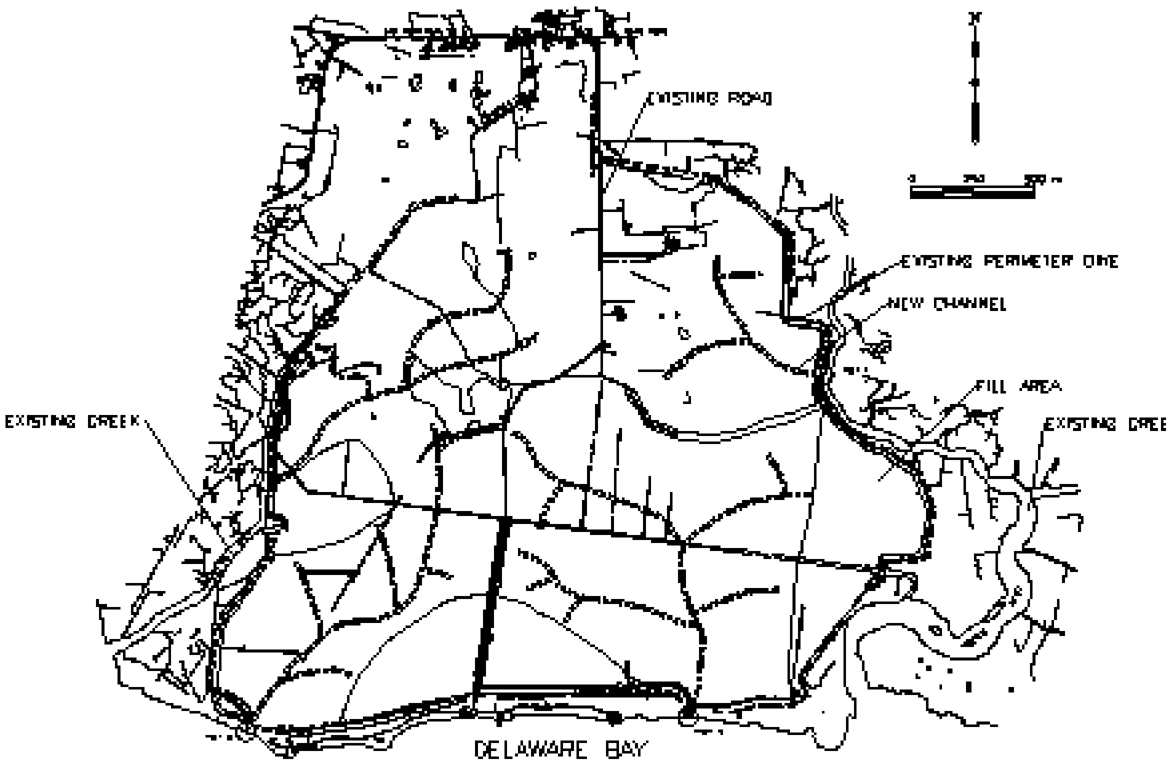

Figure 2. Final Design

Figure 2. Final design.

In total, about 12,200 linear meters of channels will convey tidal flows throughout the site. The higher order channels, channels directly connected to an inlet, will have bottom widths ranging from 9 to 45 meters, and top widths ranging from 25 to 60 meters. The lower order channels, channels farther from an inlet, will have bottom widths ranging from 1 to 6 meters with top widths ranging from 18 to 23 meters. All channels will have 4:1 to 5:1 (horizontal to vertical) side slopes. The maximum velocities predicted by the model range from less than 0.5 m/sec in the channels to almost 1.6 m/sec in one of the inlets. The predicted 1.6 m/sec peak velocity is higher than the pre-established velocity criteria of 0.6 m/sec; however, such peak velocities will be localized and of short duration.

Conclusions

This paper showed that a two-dimensional model is a useful tool to understand and characterize tidal flows into an impounded coastal wetland. The model selected was the USACOE RMA-2 model which proved to be a flexible tool to assist in the design of appropriate channel configurations and sizes to reestablish tidal flows necessary for successful wetland restoration.

Development of a Spatially Distributed Hydrological Model for Watershed Management

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

The conversion of excess rainfall into surface runoff is traditionally analyzed by means of lumped models. These models assumed that excess rainfall and geographical conditions over a whole watershed is uniform and the conversion process is described by the familiar convolution integral and an instantaneous unit hydrograph for linear system. In practice, the excess rainfall and geographical conditions over a middle or large watershed are non-uniform, so errors can be caused if the lumped model is used to simulate the rainfall-runoff process. To overcome this deficiency, really distributed models were proposed (Laurenson, 1964; Mein, et al., 1974; Boyd, 1978, 1981; Diskin, et al., 1978, 1984) with which the whole watershed was divided into a number of sub-watersheds or cells with the uniform excess rainfall and geographical conditions. Two types of sub-watersheds or cells are recognized by Diskin, et al. (1984), exterior cells, which have only excess rainfall as input, and interior cells having both excess rainfall and channel inflow as input. The excess rainfall input to each exterior cell is transformed into the corresponding output which is the input to the channel of the next interior sub-watershed or cell. This inflow is routed through the channel and the excess rainfall over the interior cells is transformed and forms the total output at outlet of the interior cells that is the input to the next interior cell.

The water movement in a watershed can be divided into two types of flows: overland flow and channel flow. Based on fluid mechanics laws, the overland or channel flow velocities depend on the value of the flow discharge. The larger the discharge, the higher the flow velocities. Many authors (Askew, 1970; Kellerhalls, 1970; Mein, et al., 1974; and Pilgrim, 1977) suggested that a power relationship between discharge and flow velocities is valid. For a watershed, the time of concentration of both a channel and an overland flow is inversely proportional to the flow velocities. Therefore, the nonlinear relationship between the concentration time of watershed and discharge exists.

In this paper, a watershed is treated as a complex system which consists of a number of the first order sub-watersheds and each of which will be further divided a number of sub-watersheds and so on until the lowest order sub-watersheds are obtained. The excess rainfall and geographical conditions are approximately uniform on each of lowest order sub-watersheds. Two types of the lowest order sub-watershed are recognized, exterior and interior sub-watersheds. Excess rainfall on the exterior is only its input which will enter the channel of next adjacent interior sub-watershed. A linear and nonlinear distributed hydrological simulated models can be derived and model parameters can be determined from the geographical features.

A New Version of Linear Distributed Watershed Hydrological Model

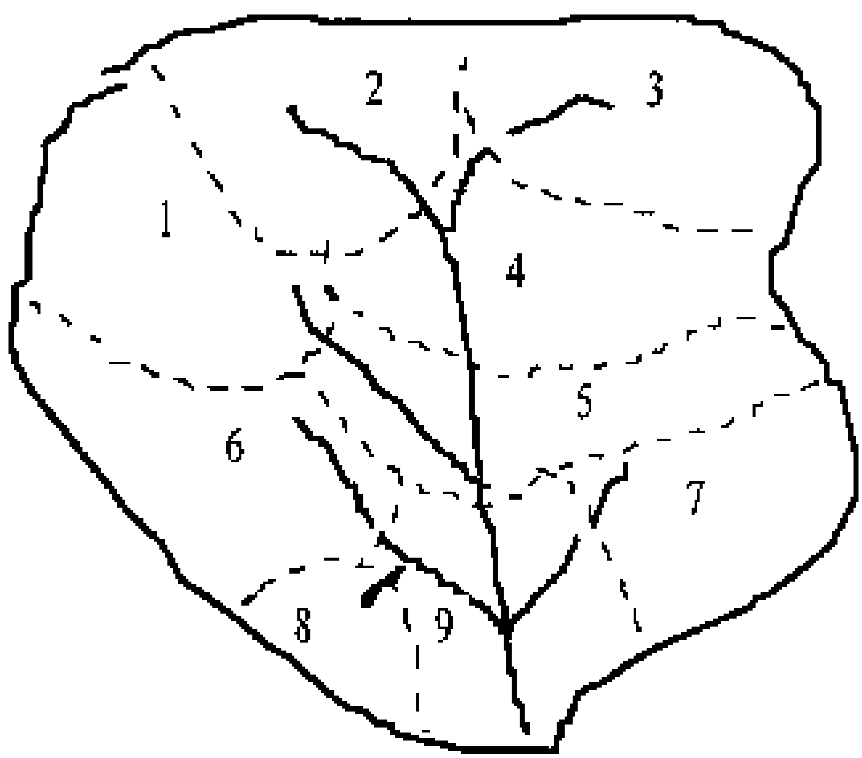

Figure 1. A mountainous watershed.

Watersheds are complex systems that consist of a number of sub-watersheds, such as forested, agricultural, mountainous, water-covered, urban-developed, or wetland sub-watersheds. Each of these sub-watersheds can be further divided into a number of lower order sub-watersheds. In studying a watershed system, we can choose to focus on the detailed behavior of the lowest order sub-watersheds which are approximately uniform for rainfall and physical geographical conditions. Taking a mountainous watershed as an example, the watershed is divided into 9 sub-watersheds that are classified into exteriors and interiors (see Figure 1). Sub-watersheds one, two, three, six, seven and eight are exterior and the rest interior. For exterior sub-watersheds, excess rainfall is the only input. Based on water balance, storage-release equation and system analysis theory, the ordinary differential equation is obtained as following:

(1)

Where, Q9 is the output from the ninth sub-watershed; k1 . . . k9 are the model parameters representing the characteristics of the sub-watersheds, respectively; C1 . . . C9 are the model parameters representing the channel characteristics of the sub-watersheds, respectively. D = d/dt is differential operator.

The ordinary differential equation (1) stands for the mountainous watershed. Similarly, the ordinary differential equations for forest, agricultural, urban watersheds etc. can be written. These ordinary differential equations will be assembled in series or parallel to form the general ordinary differential equation of the whole watershed system of a larger scale.

Using a unit step function to represent the discrete excess rainfall input (Wang, 1983) and Laplace transform, one can obtain the following equation for calculating runoff hydrograph:

(2)

Equation (2) can be used to estimate runoff hydrograph from rainfall over the 9 sub-watersheds each of which includes channel and overland flows. In practice, the output from exterior sub-watersheds indeed enters the channel of the next adjacent sub-watershed which is the interior one and the flows in channel and overland are quite different. Therefore, the new version of the distributed hydrologic model is more useful in simulating real watersheds.

Nonlinear Distributed Hydrological Model

As mentioned above, the concentration time of watershed is related to the discharge, the larger discharge, the shorter the concentration time of a watershed. The relationship between the concentration time and discharge of a watershed can be also derived from the nonlinear storage-release equation, that is:

(3)

where m is the exponent which stands for nonlinear relation of a sub-watershed differentiating equation (3) and:

(4)

We also take the mountainous watershed as an example. For the first sub-watershed of 9, the water balance equation is:

(5)

Solving equations (4) and (5) simultaneously, resulting in:

(6)

In the same way, we can write another 12 equations for the rest of the sub-watersheds. These equations are first order, nonlinear differential equations which involve 13 unknown variables that can be obtained by solving these equations simultaneously.

Discussion and Conclusion

The models have the following advantages:

1. The channel flow and excess rainfall of the sub-watershed are transformed into the corresponding output, respectively. This is reasonable to simulate a real sub-watershed because the characteristics of flow in a channel and overland are quite different and so are the parameters. The model proposed in the study expresses the distinction between the channel and overland flows by using a different values of model parameters.

2. The model involves a channel routing model and a watershed model, it can be used for predicting flood hydrograph from a more complex watershed system which consists a number of sub-watersheds and channels. Theoretically, the model can be used to predict the flood hydrograph from a large watershed, provided all the information of the watershed is available to estimate the model parameters and rainfall storm data over the whole watershed are provided.

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IWMM-an Integrated Watershed Management Model with a Watershed Protection Approach

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Abstract

IWMM (Integrated Watershed Management Model) is being developed with a watershed protection approach to evaluate the impact of land use and watershed management practices on water quality. The hydrologic module of the model simulates the processes of canopy interception, throughfall, evapotranspiration, snow accumulation and melting, surface and subsurface flow, stream and reservoir hydraulics. The water quality module simulates the nitrogen cycle,

phosphorus cycle, oxygen cycle, algal dynamics, major cations and anions, pH, alkalinity, organic acids, temperature, pesticides and sediments in the watershed. Application to Te-Chi Watershed over a two-year period, 1992-1993, indicates that the model successfully simulates hydrological and biochemical processes under influence of human activities. The model was incorporated with a user interface that was designed to make the model user-friendly. The model is operated through Microsoft Windows with multitasking and multiwindowing capabilities. The model input can be imported from GIS and updated from the monitor screen through dialog boxes. The model output can be displayed by either the user interface or GIS software. The linkage of simulation model and user interface enables the model to play what-if scenarios and to evaluate the alternatives of the watershed and reservoir management schemes.

Introduction

Systech Engineering, Inc. has developed an Integrated Watershed Management Model (IWMM) consisting of a GIS based user interface and a simulation model. This model considers the reservoir and its watershed as one system. It follows the flow path to simulate the physical, chemical and biological processes through canopies, soil layers, rivers, and reservoirs (lakes). The simulation model is comprised of hydrologic and water quality modules. The hydrologic module simulates the processes of canopy interception, throughfall, and evapotranspiration; snow accumulation, sublimation, and melting; water infiltration, percolation, lateral flow, and surface runoff; river and reservoir hydraulics. The water quality module simulates the processes of canopy exudation, nitrification and washoff; litter fall and breakdown; snow leaching, rock weathering, cation exchange, anion absorption, chemical equilibrium, nutrient cycling, oxygen cycling, pesticide decay, and sediment transport.

In the hydrological calculations, the model outputs snow pack depth, soil moisture contents, river flow rate, and either reservoir surface elevation or reservoir outflow. In the water quality calculations, the model outputs the water temperature, pH, total alkalinity, and concentrations of ammonium, calcium, magnesium, potassium, sodium, chloride, sulfate, phosphate, total phosphorus, nitrate nitrogen, nitrite nitrogen, ammonia nitrogen, organic nitrogen, organic acid, dissolved oxygen (DO), three kinds of algae (Peridinium, diatoms and green algae), three kinds of pesticides (carbaryl, methomyl, mevinphos), three kinds of sediment (sand, silt and clay).

The simulation model is a FORTRAN program modified from the Integrated Lake-Watershed Acidification (ILWAS) model (Chen et al., 1983). It adapted some equations and formulas from several existing models. The ability to simulate erosion from subcatchments was added by using equations employed in the ANSWERS (Beasley, D.B., 1991) model. Pesticides are simulated using the approach of the CREAMS model (Knisel, 1980). Simulation of dissolved oxygen and algae in the reservoir, is based on the equations used in the WASP5 (Ambrose et al., 1991). Reservoir hydraulics can be simulated as a one dimensional layered system using the ILWAS code or in two dimensions using the CE-QUAL-W2 code (Environmental and Hydraulics Laboratories, 1986).

The input data can be categorized into two types. One type is the static data that will be read in once when the model is started. The other one is the dynamic data that will be read in at certain time interval when the model is running.

The static data include: (1) geographic data such as longitude, latitude, elevation, catchment slope and aspect, the lengths and slopes of river and reservoir segments, etc. (2) land use data such as percentage of each land use, leaf area index of each kind of canopy, chemical content of canopy, mineral and soil solution, etc. (3) rate coefficients related to the hydrological and chemical processes in canopies, snowpacks, soils, and water.

The dynamic data include: (1) meteorological data, air quality data, rain quality data, fertilizer application data, pesticide application data, point discharge data, and reservoir depth or outflow data.

The geographic data can be imported from GIS and updated from the monitor screen through dialog boxes. If a watershed has its DEM (Digital Elevation Models) files, the user interface can import the DEM files and then delineate catchments, river and reservoir segments and calculate slope and aspect of each catchment and river reach elevations. Any graphic object can also be imported from GIS database or Windows Metafiles (WMF). The graphic objects contained in the imported file format will be converted to IWMM's format. The model output can be displayed by either the user interface or GIS softwares.

A more detailed description of the user interface is presented a companion paper (Gomez et al., 1996). This paper will focus on a specific application of the model to the Te-Chi Reservoir watershed in Taiwan.

Model Application

Te-Chi Reservoir watershed is at the upstream of Da-Chia River in Central Taiwan. Its average elevation is above 2000 meters. The climate is favorable for growing fruit trees and vegetables. About 6.4% of the watershed area have been cultivated to orchards and vegetable farms. This region is a famous travel attraction due to its extraordinary scenery and public accessible orchards. The agricultural and touring activities have created sediment erosion and water quality problems. Particularly, the Te-Chi Reservoir has become eutrophic since 1976. In order to control the point and nonpoint pollution sources in the watershed, Te-Chi Reservoir Watershed Management Commission and Water Resources Planning Commission of Taiwan Government conducted a long-term water quality monitoring program and sponsored Systech Engineering, Inc. to adapt the IWMM to this area.

At current stage, the Te-Chi Reservoir watershed is divided into 32 subcatchments, 26 river segments and a 30-layer reservoir (for one-dimensional simulation) or 30-layer and 6-section reservoir (for two-dimensional simulation). Although the model allows the user to select any time interval for model calculation, the default and preferred time step of the model simulation is one day.

There are two meteorological stations and ten precipitation stations in the watershed. Each subcatchment is assigned to use one of the meteorological data collected at these stations based on the relative location and elevation of the station. The air and rain quality data collected seasonally at one station is used for the whole watershed. The soil data collected seasonally at ten locations is distributed to individual subcatchment based on the location and land use of the subcatchment. The data of fertilizer and pesticide applications is compiled from the information of agricultural almanac in this area. The point source data is generated by extrapolation of three measurements over the past years. The reservoir outflow data as well as the reservoir depth data is provided by the Taipower Company that operates a hydro-power plant at the Te-Chi Reservoir.

We have been calibrating the model with 1992-1993 river and reservoir data. So far the simulated flow, temperature, calcium, magnesium, potassium, and dissolved oxygen demand match the data pretty well. The simulated phosphorus, ammonia nitrogen, organic carbon, alkalinity, and pH agree fairly well with the data. Nitrate and chlorophyll-a do not match the data very well. We expect additional iteration of calibration and verification to reach a good model calibration and verification.

Figure 1 shows the flow and DO comparisons at river segment 12. The model results match with the data very well. Figure 2 shows the temperature and alkalinity at the surface of reservoir. The temperature has a very good agreement between the model results and field data. The alkalinity has a fair match.

As shown in Figures 1 and 2, the user can make several comparisons between model results and field data and among various locations. The user interface allows users to open multiple windows, thus various locations and comparisons, as they want. In addition to the time series plots, the user interface can display spatial distribution plots. The spatial distribution plots provide a snapshot of what is happening throughout the watershed at one point in time. To change the date of the plot, the user can simply place the cursor on the day, month or year of the date shown at the upper right hand corner of the display and click on the up and down arrows next to the date. With these capabilities, the model enables the decision makers to play what-if scenarios and to evaluate the alternatives of the watershed and reservoir management schemes.

Conclusion

IWMM employs state-of-the-art methods in both its user interface as well as in its simulation component. The model is operated through Microsoft Windows with multiwindowing and multitasking capabilities. The model input can be imported from GIS and updated from the monitor screen through dialog boxes. The model output can be displayed by either GIS or the user interface. The simulation component is comprised of an integrated set of time tested models capable of simulating most constituents and most processes that occur in a watershed system. The results of its application to the Te-Chi Reservoir watershed endorse the model capability. The combination of ease to use and simulation robustness makes the model an ideal tool for administrators and scientists as well. Improvements will continue on both the user interface and the simulation components.

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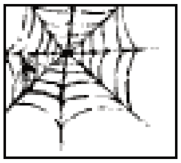
Keywords

watershed
modeling
water quality
watershed protection approach
geographic information system
watershed management model



Note: This information is provided for reference purposes only. Although the information provided here was accurate and current when first created, it is now outdated.

Upper Sligo Creek: An Integrated Approach to Urban Stream Restoration

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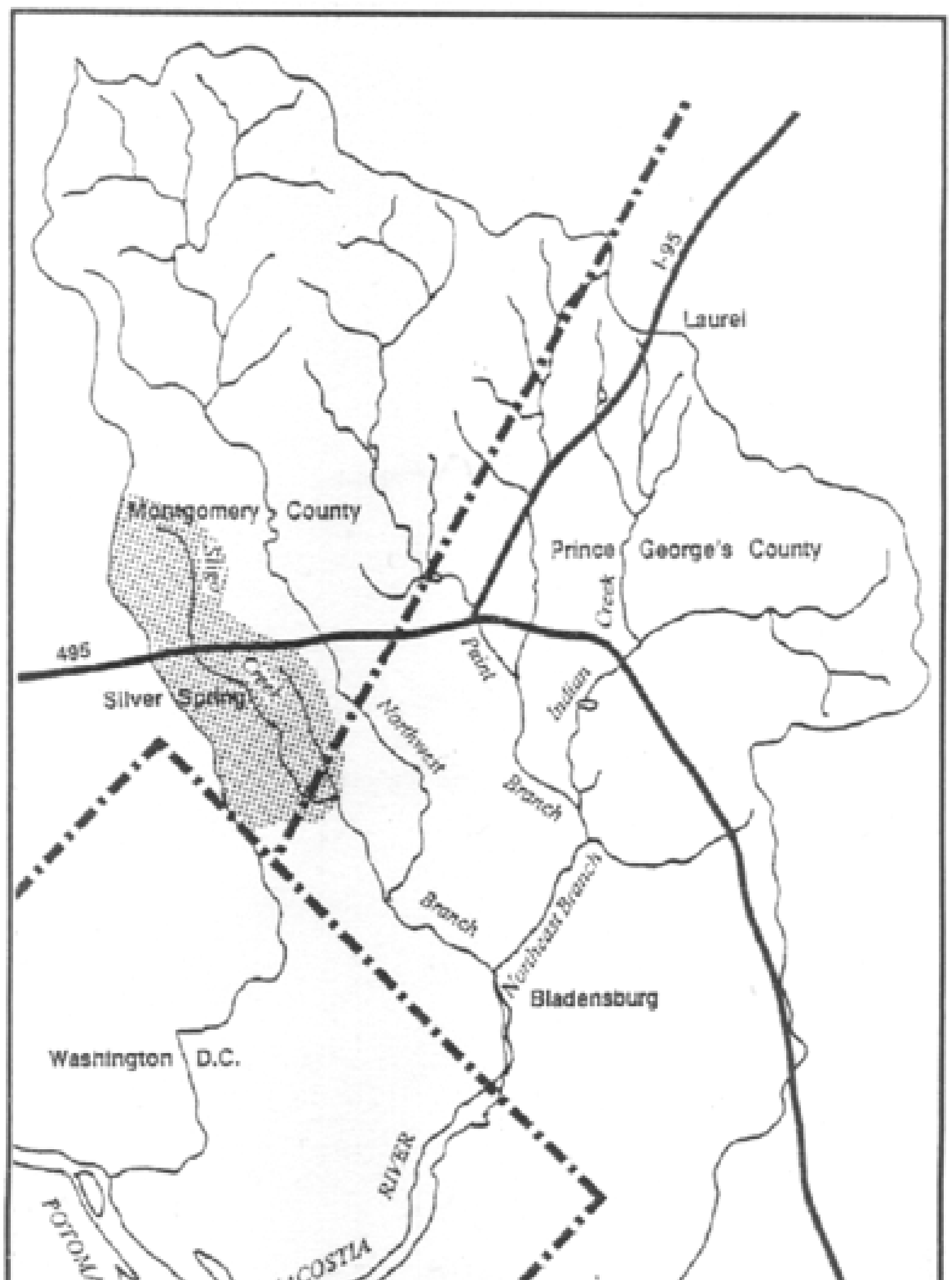
Abstract

The restoration of degraded urban streams to near pre-development conditions is both a formidable and expensive challenge. Upper Sligo Creek is a typical degraded 3rd order Piedmont stream which flows though an older suburban area located in Montgomery County, Maryland. Since 1989 an interagency effort, as part of a larger Anacostia River restoration initiative, has been underway to restore 7.5 km of the stream and its environs. The restoration strategy has consisted of the comprehensive employment of stormwater retrofits, structural stream habitat creation and rehabilitation, riparian reforestation, wetland construction and native fish and amphibian reintroductions. A wide variety of fish habitat enhancement structures, such as rootwads, stone wing deflectors, log drop structures, boulder placement, brush bundles, etc. were employed. The project was performed in three phases. Biomonitoring of fish and macroinvertebrates was conducted before, during and after each construction phase of the project. In addition, physical habitat, hydrological and chemical conditions were monitored in the last phase. The number of fish species living in the system has risen from a low of three in 1988 to 27 in 1995. Monitoring results were used to adjust fish stocking strategies, document recruitment success, and to help

critique the overall success of the restoration effort.

The restoration of the Upper Sligo Creek stream system exemplifies the basic subwatershed restoration approach being employed throughout much of the 400 km² Anacostia River watershed (Figure 1). Functional changes which each subwatershed had experienced were evaluated and appropriate stormwater retrofits and stream restoration alternatives were identified. Candidate stream restoration sites were linked directly with an upstream stormwater retrofit project. Restoration of in-stream habitat did not occur until after upstream stormwater controls became operational. Extended detention wetpond/marsh systems were selected on the basis of their proven ability to reduce pollutant loads and stream channel erosion problems and to create additional wildlife habitat. Additional restoration measures included riparian reforestation, artificial wetland and vernal pool creation and the employment of parallel pipe storm drain systems. These measures were used to replace lost or damaged functional components of the ecosystem. The ultimate goals of this $2 million demonstration project in the Upper Sligo Creek system were to improve the aquatic and riparian conditions, increase fish and wildlife habitat, create refugia for reintroduced native fish species and improve the community value and use of the resource.



Biological Monitoring Protocols

Biomonitoring and habitat assessments during all three phases were based upon U.S. Environmental Protection Agency protocols (Plafkin et al., 1989), with some modifications on habitat assessments (Barbour and Stribling, 1991). The condition of each site under study was rated as a function of its capacity to support a healthy biological community. Fish monitoring was conducted by backpack electrofishing. Amphibian relative abundance and species richness was determined via visual encounter surveys.

Phase I_Wheaton Branch Restoration and Monitoring (1990-1991)

Restoration components completed in Phase I were performed on Wheaton

Branch, a tributary to Sligo Creek, and included: a) construction of a three-celled wet extended detention stormwater management pond/marsh, b) restoration of 300 meters of stream habitat; and c) creation of two vernal pools and riparian reforestation along a 350 meter stream corridor.

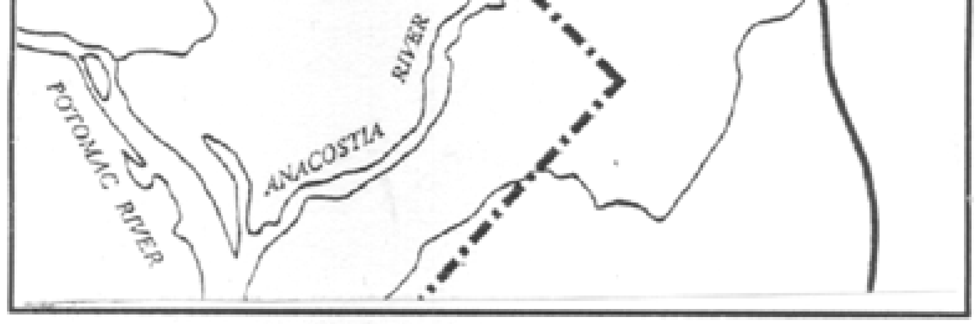


Figure 1. The Anacostia Basin with the Sligo Creek subwatershed (shaded).

Figure 1. The Anacostia Basin with the Sligo Creek subwatershed (shaded).

Phase I biological assessments at four stream sites found low taxonomic diversity and levels of abundance of fish and benthic macroinvertebrates. Exceptions in the upper Sligo Creek drainage were located within Wheaton Branch, where samples usually had the greatest numbers of macroinvertebrates and were dominated by Hydropsyche or Chironomidae. It was determined that, for a brief period of time, there was organic loading into Wheaton Branch from a sewer line leak, and possibly, non-retention of organic particulates by the recently completed stormwater management retrofit. These conditions contributed to the extreme dominance of the net-spinning (i.e., filter-feeding) caddisflies (Hydropsyche and Cheumatopsyche) and the relatively low number of benthic macroinvertebrate taxa. Fisheries surveys found only three species of fish; blacknose dace, northern creek chub, and goldfish. These species are all highly pollution tolerant (Plafkin et al. 1989). The blacknose dace accounted for 77 percent of all individuals captured. An indication of environmental stress was that 11 percent (20 of 182) of the northern creek chubs collected had either fin erosions, skin lesions, external fungal infections or combinations of these external symptoms. These symptoms are associated with environmental degradation such as chronic, sublethal exposure to contaminants, low dissolved oxygen, or high levels of suspended solids (Wedemeyer et al., 1990). Generally low density and taxonomic diversity in the Sligo Creek mainstem was attributed to a combination of scouring stormflows, pollutants associated with urban runoff, and the possibility of unknown toxicants (Stribling et al., 1989).

Due to existing downstream blockages, normal fish movement and migration in the system is restricted, thus preventing the natural re-establishment of a more diverse fish community in both Wheaton Branch and the Upper Sligo Creek mainstem. In response, Phase I recommended experimental transplant stocking of selected native fish species into Wheaton Branch to augment the recovery of fish populations in Sligo Creek. The general strategy involved the reintroduction of non-game species indigenous to the area, and featured a local citizen volunteer component. Gamefish were intentionally not stocked because of expected problems with predation on the establishing minnow populations and, from experience, gamefish species such as sunfish tend to be introduced rapidly by local anglers. Stocking was phased in order to account for expected changes in water and habitat quality and to permit less prolific species to establish themselves prior to the introduction of more prolific species. If water quality showed a marked improvement over pre-restoration conditions, future stocking of more pollution-intolerant/less-prolific species such as the common shiner and rosyside dace was to be attempted. Approximately 10-20 individuals of each species were stocked into pools or riffles, depending on species habitat preference and size and depth of individual pools or riffles.

Phase II and III_Upper Sligo Creek Mainstem and Flora Lane Tributary Restoration and Monitoring (1992-1995)

While no major restoration construction work was performed in Phase III, Phase II included: a) completion of a two-celled wet extended detention pond/marsh stormwater retrofit, b) selective restoration of approximately 7.0 km of Upper Sligo Creek mainstem stream habitat, c) construction of a 300 m long parallel pipe system along the Flora Lane tributary, d) creation of a 0.1 hectare marsh, and e) riparian reforestation of 2.0 hectares along Sligo Creek.

Biological conditions from Phase I to Phase III. A site for which representative changes between the three phases can be examined is on the Sligo Creek mainstem just downstream of its confluence with Wheaton Branch. For macroinvertebrate collections in both spring (1990, 1993) and fall (1990, 1992), changes in numbers of individuals were generally much greater than 50 percent from Phase I to Phase III, as were numbers of taxa. For the latter, the spring samples changed from number of taxa ranging from 4-7 (1990) to 7-13 (1993); similarly, fall samples ranged from 5-7 taxa in 1990 to 12-15 in 1992.

Although, in themselves, high numbers of species or other taxa should not be the ultimate indicator of improving ecological conditions, these changes do signal a general improvement in habitat conditions in Wheaton Branch, the Flora Lane tributary and Sligo Creek since completion of construction. Often, improving conditions are reflected in benthic macroinvertebrate assemblages by one or a few taxa not being overly dominant (Cummins and Stribling, 1992). This characteristic is in part described by the metric "percent contribution of dominant taxon." Thus, when conditions improve, there are typically lower values for this metric. In the spring samples, there was a change from 50-80 percent dominance (1990) to approximately 37-45 percent (1995). Percent dominance changed from a range of approximately 67-93 percent in 1990 to 39-63 percent in 1992. Similarly to the change in numbers of taxa, substantial changes are seen from Phase I to Phase II, with less change evident between Phase II and Phase III (Figure 2). While the total number of invertebrate taxa still remains relatively low compared to unimpaired streams, these changes signal improving conditions in both Wheaton Branch and Sligo Creek.

Conclusions

Upper Sligo Creek's stream habitat and its macroinvertebrate, fish and amphibian communities recovered considerably from Phase I to Phase III. The general increase in the number of macroinvertebrate individuals together with the decrease in the dominance of the most common taxon signal both an increasingly healthy stream and improved food base for fish. The fish assemblage, particularly that of Wheaton Branch, appears far healthier. For example, the percentage of fishes with external anomalies such as tumors or infections decreased to negligible levels. Overall, fish community structure showed their greatest gain in the Sligo Creek mainstem. The number of fish species residing in the Upper Sligo Creek mainstem has increased from three in 1988 to twenty-seven in 1995. The system presently features a wide diversity of native non-game and gamefish species and supports relatively pollution intolerant species, such as the rosyside dace (Clinostomus funduloides), northern hogsucker (Hypentelium nigricans) and the mottled sculpin (Cottus bairdi). With regard to the amphibian assemblage, vernal pool and wetland creation areas now provide habitat for both native resident and reintroduced species. Natural colonization and successful reproduction by five of these species has been documented. In addition, all of the in-stream habitat enhancement structures remain in good condition and functioning as designed.

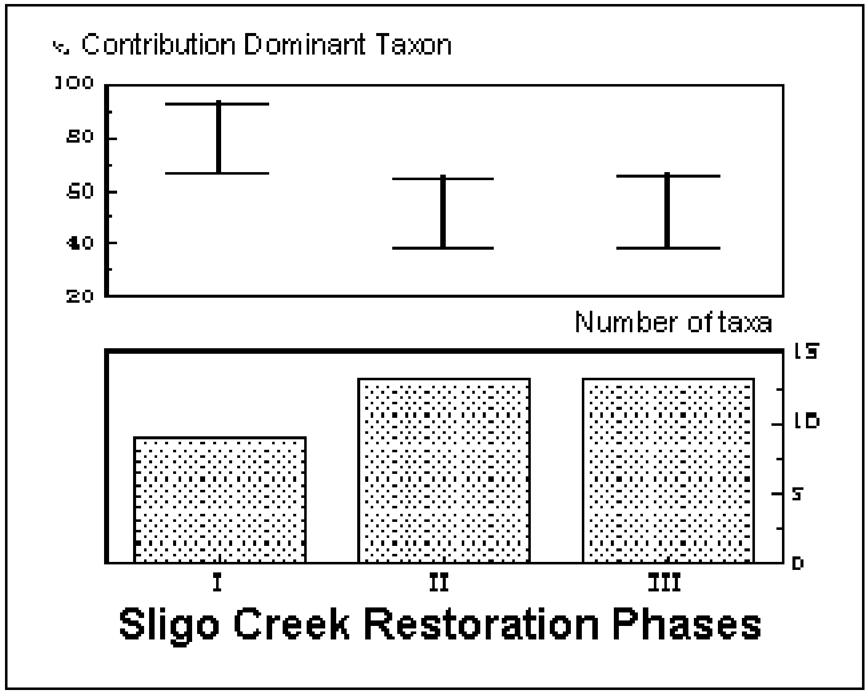


Figure 2. Metrics "percent contribution of dominant taxon' (bottom panel). Range of values is presented for the former; cumulative totals for the latter. values used are from winter sampling events, Phases I - III. Sites WB1, WB2, SL2, SL3.

However, there remains room for improvement, particularly in the area related to control of stormwater runoff in both the Wheaton Branch and Flora Lane tributaries. At the end of Phase III, even the best of the sites studied remained well below the reference site conditions. With the exceptions of a few short selected reaches, the uppermost Sligo Creek mainstem fish communities have not recovered. Currently, recruitment success of several of the key pollution intolerant fish species has not been confirmed. While the general goal of restoring the fish community to a near pre-development condition has been partially met, additional monitoring to measure long-term success is recommended.

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Airborne Thermal Remote Sensing Of Salmonid Habitat For Restoration Planning In Pacific Northwestern Watersheds

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Many technologies that have roots in defense-related applications have been successfully transferred to civilian, commercial use in environmental analysis, planning, and many other applications. As part of the Environmental Technologies Initiative (ETI), we examined the utility of military-origin remote sensors for water quality monitoring applications. Overseen by EPA, this project was carried out in cooperation with research laboratories of the U.S. Forest Service and the U.S. Army Corps of Engineers. Our project focused on using forward-looking infrared (FLIR) imagery as a monitoring tool for assessing salmonid habitat in several rivers and streams in Oregon, Washington, and Idaho.

FLIR systems were originally designed for military night surveillance applications, however they are now utilized extensively in medical operations, law enforcement, fire reconnaissance, search and rescue, and environmental monitoring because they are relatively portable and provide real-time thermal imagery that may be captured digitally or recorded on video tape. Because FLIRs are so portable, they may be easily operated from air (fixed-wing and helicopter) or ground-based platforms, making them ideal for terrestrial and aquatic resource assessment (Luvall and Holbo 1991). Our primary use of FLIR was to supplement water temperature information from in-stream data loggers with spatially continuous thermal image data composing entire river reaches. We were able to integrate temporally continuous, spatially limited temperature monitor data with spatially continuous, temporally constrained FLIR imagery.

Aerial videography and remote sensing techniques are increasingly being applied operationally in inland water resources and fisheries research to address issues of aquatic habitat assessment and restoration (Rango 1995, Crowther et al. 1995, Hardy and Shoemaker 1995). Multispectral aerial videography can provide high-resolution, spatially continuous information on stream channel morphology, the distribution of aquatic habitat components, such as riffles and pools, and riparian vegetation characteristics and areal extent. Thermal infrared mapping using FLIR imagery, coupled spatially with videography in the visible spectrum, records continuous water temperature patterns and facilitates identification of cool-water refugia important for coldwater fish species (Torgersen et al. 1995). Longitudinal stream profiles of thermal patterns can be obtained with airborne video thermography. The frequency, total area, and average surface area of cool-water areas, i.e. tributary confluences, ground water seeps, and subsurface stream outflow areas, can be identified in entire reaches known to be vital for spawning salmon.

Stream temperature is a critical issue particularly in the Columbia River basin in Oregon, Washington, and Idaho where historical and present land-use pressures, such as logging, road building, grazing, and mining, have limited the spawning distribution of salmon to only the uppermost river reaches where the water is cool and tolerable to salmon and trout (Beschta et al. 1987, Platts 1991, Wissmar et al. 1994). Some anadromous salmonids migrate from the ocean and enter natal streams in the spring, several months before spawning, when water temperatures are still within preferred tolerance zones for migration. The salmon must then remain in headwater streams throughout the summer, often exposed to high ambient stream temperatures and low flow conditions. Energy expenditure in coldwater fishes increases at elevated temperatures, so the reproductive performance of spawning salmon with finite energy reserves may be compromised when stream temperature rises above preferred tolerance zones. Ambient water temperatures in spawning and holding reaches for spring chinook (Oncorhynchus tshawytscha) in the Middle Fork and the Mainstem John Day River frequently exceed both the thermal optima cited for spring chinook migration (16C) and spawning (14C) as well as the upper zone of thermal tolerance (22C) (Armour 1991, Bjornn and Reiser 1991).

Approximately 1600 river kilometers of FLIR coverage were obtained for analysis during the heat of the summer, 1995, and these data, combined with limited FLIR imagery from 1994, formed the basis of this project. Thermally intact and impaired river reaches of ecological significance to anadromous salmon and trout were aerially surveyed in the following drainages in 1995: Asotin, Grande Ronde, Lolo, Tucannon, Umpqua, Yakima, as well as the Main, Middle, North, and South Forks of the John Day River. Thermal infrared data (5-55øC) were recorded in S-Video format on Hi-8 video tapes at 425 meters above the ground using an Agema 1000 FLIR vertically mounted on the underside of a helicopter. Digital images with ground resolutions of 25-30 cm were captured from the analog video tapes in the laboratory using a TARGA+ frame grabber and DiaQuest video animation controller. GPS coordinates and SMPTE time-code recorded in-flight permitted each image to be integrated with spatially-explicit data layers in the Arc/Info geographic information and ERDAS Imagine image processing systems.

We developed diurnal water temperature curves from selected data logger locations to predict expected stream temperature on the hottest days of summer when coldwater fishes are likely to experience thermal stress. The diurnal curves were used to interpret whether the FLIR imagery, collected between 12:00 and 18:00, represented a probable daily maximum. The imagery proved useful for both classifying river reaches according to thermal characteristics and detecting cool-water refugia of critical importance to salmonids. With the aid of radio-telemetry in 1994, we were able to track the movements of tagged salmon and observe their use of cool-water areas identified in the thermal imagery (Torgersen et. al. 1995). The imagery also proved effective for locating and assessing the relative influence of warm-water inputs, such as irrigation inputs and tributaries. Specific reaches identified in 1994, a relatively hot summer, as important thermal refugia for salmon were re-examined using imagery from 1995, a comparably cooler summer (Figure 1). Preliminary analysis suggests that relatively cool reaches, possibly influenced by groundwater inputs, are predictable on a year-to-year basis. These predictably cool reaches also appear to be consistently utilized by salmon. This has important implications for stream habitat management and restoration because critical areas may be protected while reaches with habitat potential may be enhanced with riparian restoration efforts to increase shading.

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Brinkley Manor Run: A Case Study in Geomorphologically-Based Stream Restoration Design in Prince George's County, Maryland

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Introduction

Stream restorations using fundamental principles of fluvial geomorphology and natural materials are being increasingly and successfully implemented across the country. Properly applied, the new techniques result in restorations which are not only less expensive than those using conventional armoring methods, but are properly sized and configured to ensure stability, natural appearance, habitat value, and equilibrium in the sediment transport and depositional patterns. Located within the

Washington, DC Metropolitan area, Prince George's County, Maryland is developing a stream restoration program incorporating these new approaches within an overall framework of comprehensive watershed management. This will facilitate the County's efforts to improve environmental quality and integrity, achieve the goal of sustainable uses of natural resources, and encourage economic revitalization. Uncontrolled storm water runoff has had a great impact on the historically rich streams of Prince George's County. Many of the County's streams are in the process of downcutting and widening, resulting in lost or impaired habitat and eroding property, which in some cases threatens homes as well. Stream restoration in urban and suburban settings often poses special challenges due to significant constraints including private property encroachment, proximity of structures, wetland and forest disturbance, access, and conflict with utilities. Brinkley Manor Run is an example of an actively degrading stream in a residential area and was selected as a pilot project. The objective was to apply the most current techniques of stream restoration to determine if a new channel could be designed to fit the existing constraints and meet geomorphological stability criteria. A geomorphologically-based approach has been utilized in analyzing and designing a restoration plan for this stream. Lessons learned in dealing with the all too familiar problems and constraints encountered in this case study will help Prince George's County implement similar measures countywide.

Geomorphological Approach

Stream channel stability is not a static state. Rather, natural stable streams are characterized by a condition of dynamic equilibrium. Sediment supply is in equilibrium with sediment transport. Slow rates of erosion on the outside of meander bends are matched by similar rates of deposition on point bars. Disequilibrium can come about as a result of a change in any one of the variables that govern stream morphology. A disturbance which creates a change in one variable sets up a series of concurrent changes in the others resulting in altered channel patterns. Stream morphology is therefore the result of an integrative process of mutually adjusting variables. One of the disturbances that can result in disequilibrium is the increase in frequency, magnitude, and duration of bankfull flows that result from extensive land development.

There is a close relationship between drainage areas and stream channel dimensions that holds throughout regions of similar climate and physiography (Dunne and Leopold, 1978). There is also a relationship between channel dimensions and the magnitude of runoff from frequent storm events. It has been established that the peak discharge from a storm which occurs on an interval of from 1 to 3 years produces the flow which shapes, sizes and maintains stream channels (Leopold, Wolman and Miller, 1964). This peak flow is called the bankfull flow.

It follows that a substantial increase in frequency, magnitude, and duration of the peak discharge which generates the bankfull flow will result in more stress on stream channels with concomitant morphological adjustment. In a landmark paper Thomas Hammer determined that stream channels in developed areas can enlarge ten to twenty times their cross sectional area in a process that does not return to equilibrium for decades (Hammer, 1973).

When dealing with complex natural systems, a good classification system is invaluable in providing a consistent and reproducible frame of reference for analyzing data and communicating findings. The Rosgen Classification System (Rosgen, 1994) is widely used to describe natural channels. The classification is based on morphological parameters that are used to describe channel condition and predict stream behavior.

The measurements used in the Rosgen Classification System include: entrenchment ratio, width/depth ratio, sinuosity, slope, and channel material size. A Classification of Natural Rivers (Rosgen, 1994) includes a table presenting 42 major stream types. An important application of the Rosgen Classification System is the ability to interpret channel geometry to determine if the channel is in equilibrium with its flow regime. Because bankfull flows have the most influence on the shaping and maintenance of channels, it follows that there is a relationship between the dimensions of the stream channel and the bankfull flow. A properly restored channel will reduce stress in the near bank regions, maintain sediment transport capacity to handle sediment delivered by watershed runoff, but significantly reduce sediment supply from stream bank erosion. In this study, the Rosgen System was used to classify the stream, help establish the bankfull discharge, and guide the design of a stable channel geometry within the existing field constraints.

Overall Assessment

Brinkley Manor Run is located in the southern portion of Prince George's County, Maryland, in the coastal plain province. The land use in the 1. 6 square kilometer (0. 6 square mile) watershed is comprised of small lot residential development with some commercial development on the periphery of the drainage area. Most of the stream corridor is forested. Near the center of the study area the channel had been dammed by a large earth and concrete structure to impound a shallow lake approximately three acres in size. The dam was destroyed in 1972 by Tropical Storm Agnes and the lake area has since reverted to forest. The basin is traversed by several main thoroughfares and other wide streets. The land development in this watershed occurred prior to the requirement for stormwater management controls resulting in a dramatic increase in frequency, magnitude, and duration of peak flows. This increase in runoff initiated a process of channel enlargement which destabilized the stream.

The channel is filled with excess sediment evidenced by shallow, sediment-filled pools and has a low width/depth ratio, with eroding banks as high as 2. 5 meters (8 feet) in places. Trees are being undermined along most of the stream. In the vicinity of the failed dam the eroding banks are up to 3. 6 meters (12 feet) in height, where headcutting occurred through the sediment that had accumulated behind the structure. Residential properties abut the stream at the rear of the backyards along significant portions of the channel. Conversations with the property owners revealed serious concerns regarding the current state of the stream, with some long-term residents able to recall a previously smaller unentrenched channel with a healthy recreational fish population. Many of the homeowners have made futile attempts to arrest the erosion of the stream banks using brush and other yardwaste. One house is located approximately 3. 6 meters (12 feet) from an eroding bank. Such constraints are often encountered in urban streams, making the design of new stable channels challenging.

The stream channel has incised and abandoned its historic floodplain. In fact, the bankfull elevation is as much as 1. 8 meters (6 feet) below the abandoned floodplain. The significance of this is that large flows, which would normally spread over a wide floodplain, are confined in the channel exerting excess stream power on the bed and banks. This condition worsens in a process of bank erosion supplying excess sediment which creates depositional features resulting in more bank erosion downstream, which generates more excess sediment, and so on. The stream will not return to equilibrium until it has moved enough sediment to create a new flood plain at the new, lower base elevation. It was decided that restoration could both reduce sediment supply from bank erosion and improve sediment transport so that the stream could move sediment that would be supplied by the watershed.

Both G and F streams are usually characterized by a process of channel incision and widening, with steep eroding banks contributing excess sediment. Gravel is present throughout but is obscured in the upper reaches and highly embedded in the others by the quantity of fine particles present. Field measurements determined most of the stream to be in a G4 or F4 configuration. The uppermost portion of the study area is characterized by G5 and F5 segments. Relatively short lengths of channel at the downstream end of the study area are classified as C4 and DA4. The degraded G and F reaches of the stream comprise roughly 600 meters (2000 feet) of channel. A restoration design was undertaken using the Rosgen Stream Classification System to determine parameters for stable channel geometry based upon a B4 stream type.

Design considerations

Measurements of channel cross sections, slopes and material size were used to estimate the bankfull discharge, which was found to be about 1. 84 cubic meters per second (65 cubic feet per second). These measurements were used in Manning's Equation with roughness estimated by using Rosgen's bankfull stage roughness coefficients by stream type (Rosgen, 1994).

The estimate of bankfull discharge was corroborated by Maryland Geological Survey gauge station data from a watershed with similar climate, physiography, and landuse using a proportional area method (Carpenter, 1983). This "design bankfull discharge" was used to determine the desired channel dimensions in the following procedure. Considering the valley slope, the choices for restored stream types allowed either a "C" or "B" stream class. Considering the fact that the stream was already deeply entrenched and constrained by backyards and forests, a "B" stream type with a low sinuosity was chosen. In order to create the low well-developed floodplain necessary for a "C" stream type, excavation as much as 1. 8 meters (6 feet) deep over a wide area would be necessary to accommodate the required meander belt width, encroaching on private property and destroying valuable woodland. A width/depth ratio consistent with the Rosgen Classification System was selected. Manning's Equation was then solved for width and depth using the design bankfull discharge of 1. 84 cubic meters per second (65 cubic feet per second) and a roughness coefficient commensurate with a B4 stream type. Figure 1 presents the concept of "G" to "B" restoration in cross section.

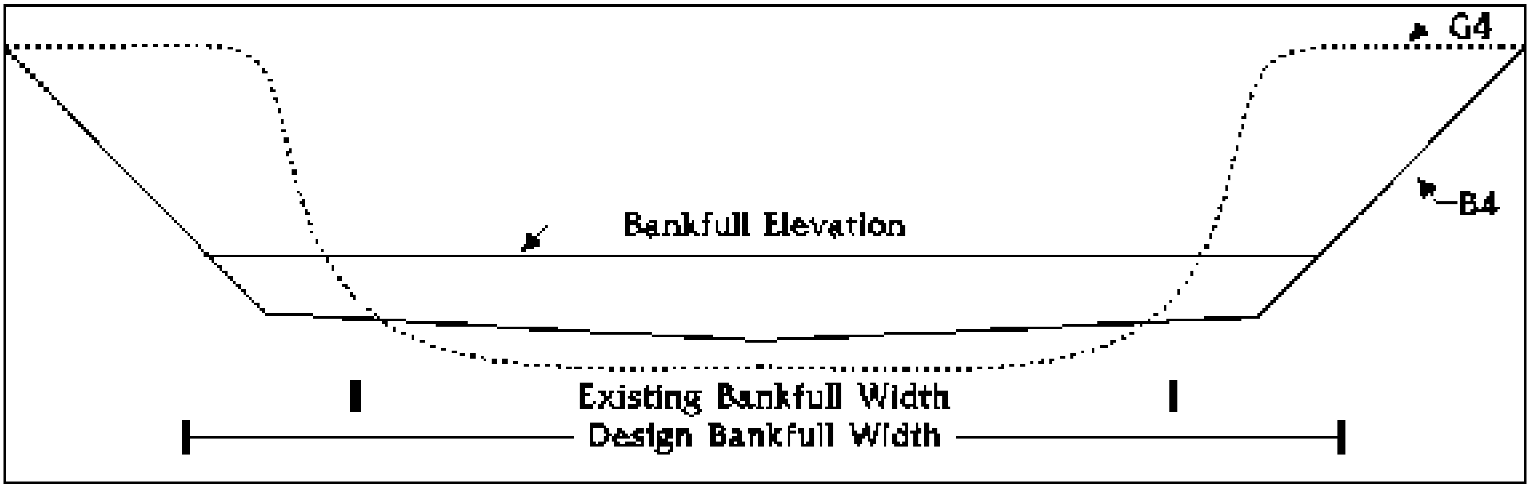

Figure 1. Conceptual G to B channel restoration in cross section

A restoration design for Brinkley Manor Run was prepared using the Rosgen Classification System to diagnose its instability and determine stable parameters for restoration. Root wads will be used to stabilize banks on meander bends, and vortex rock weirs will be used to provide grade control in straight reaches. Typical root wads and vortex rock weirs are shown in Figures 2 and 3.

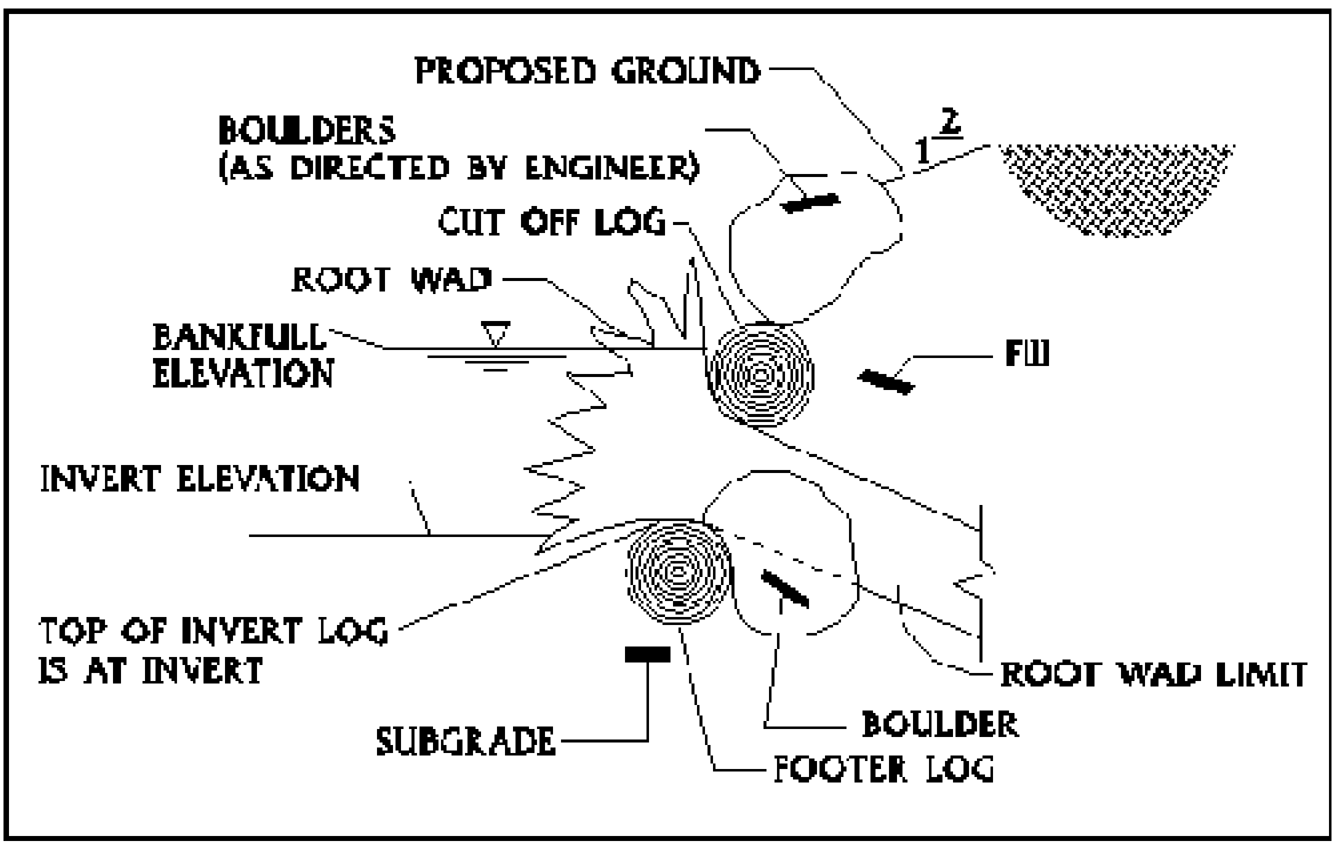

Figure 2. Root wad revetment (typical section)

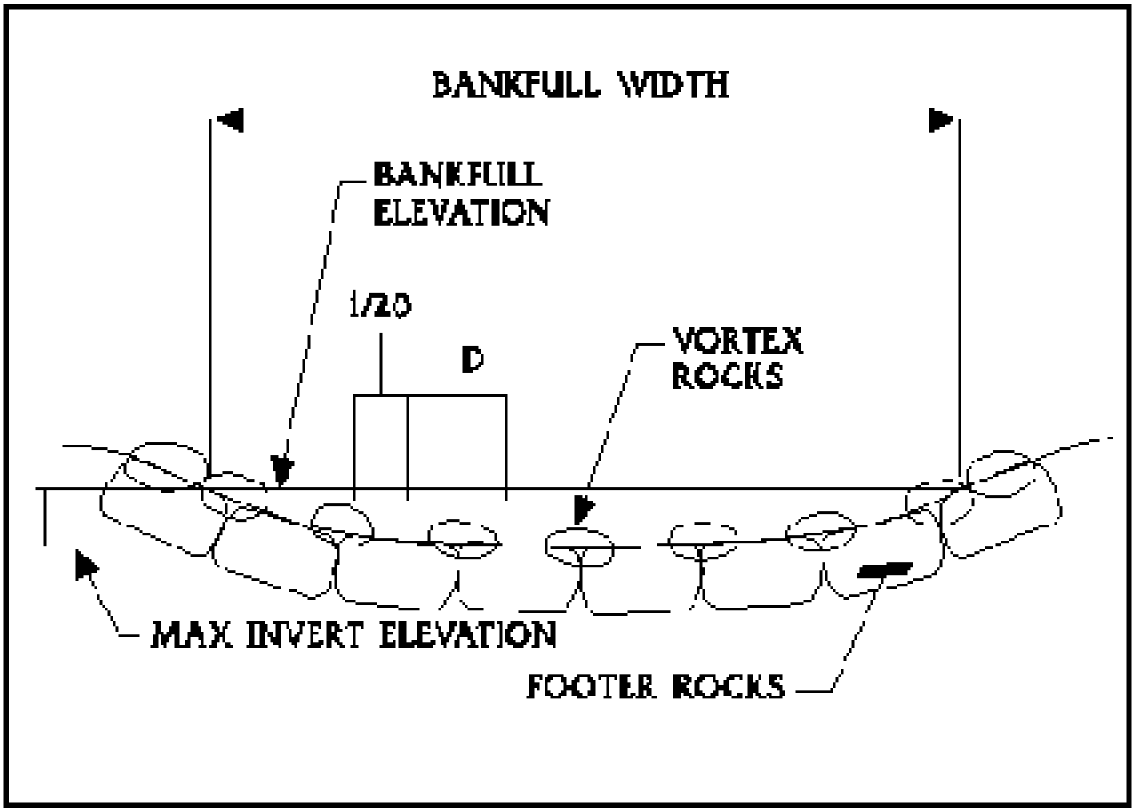

Figure 3. Vortex rock weir (cross section)

Root wads provide a temporary revetment for up to twenty years until they decay and disintegrate. Willows are planted immediately behind the root wads and will establish a deep and dense root system to provide permanent vegetative stabilization. Vortex rock weirs are placed in straight reaches and the upstream and downstream ends of meander bends. They provide grade control and enhanced fish habitat. They also are designed to maintain sediment transport as a result of the spacing between rocks. Their "V" shape, with an upstream apex, causes stresses due to high flows to be directed away from near bank regions, thereby reducing the tendency toward bank erosion. This direction of stress resulting from high flows into the center of the channel also creates a controlled scour, which gives increased depth for fish habitat.

Conclusions

This pilot project provided an opportunity to apply a geomorphologically-based approach to stream restoration to a problematic degraded stream in Prince George's County, Maryland. In a variety of ways, this stream is typical of many steams in the County, especially those in developed areas, which are often subject to severe constraints due to the proximity of forest and structures. This project indicates that even given significant restrictions imposed by development, designs can be accomplished for natural looking restored streams which can fit the constraints and meet geomorphological stability criteria. The next phase of this project, construction and monitoring, will continue to help Prince George's County develop its stream restoration program further and implement similar measures countywide.

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Watersheds and Cultural Landscapes: Sustainable Development through Heritage Areas

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Introduction

Rivers involve significant human history and settlement that can be addressed in watershed planning, building greater public support through an integrated effort that respects the cultural aspects of watersheds. Watershed planning should recognize human history and communities, and multiple human objectives for life in the watershed, or efforts to restore or enhance water quality and aquatic habitat will fail to build the significant level of public support and commitment required to succeed.

The key element unifying communities and rivers is the land they share. This linkage is the basis for the following logical sequence of points on why watershed planners should address broader community issues for added environmental gains:

1. Environmental programs can no longer address a river's water quality apart from the lands it drains: the insight that drives watershed planning.

2. The health of a river is not judged by water quality alone_living resources (birds, fish, mammals, plants) must also be helped to thrive, primarily through addressing habitat, much of it land-based;

3. Once land is to be involved in an environmental program, it is vital to enlist communities, citizens' groups, and property owners, for these are the actors that are directly involved in land management, and are closest to both the problems and the solutions to be addressed through watershed planning.

4. Water-quality programs enlisting communities, citizens' groups, and property owners are most likely to engage them by addressing the things they enjoy and want to enhance in their environment, beyond clean streams: outdoor recreation, nature study, attractive scenery, historic sites, and economically healthy and sustainable communities.

5. The massive public investments already made in "restoring" the water quality of many rivers are threatened in the near future by inappropriate development from population growth and the increase in nonpoint source pollution from many sources.

6. The future health and vitality of a given river is often jeopardized not so much by current environmental threats as by the lack of a shared agenda among those in the basin who could address the river's needs.

7. This shared agenda must, first and foremost, recognize the idea that community empowerment is key to continued environmental improvement in any given watershed. Sustainable development approaches that recognize "economics, environment, and equity" naturally incorporate community empowerment. One such approach is that of forming "heritage areas."

Heritage Areas Defined

The National Coalition for Heritage Areas states that:

Heritage areas are most often regions with a distinctive sense of place unified by large-scale resources: rivers, lakes or streams, canal systems, historic roads or trails, railroads. They may include both rural and urban settlement, and are cohesive, dynamic environments where private ownership predominates, and will continue to predominate, but where change can be creatively guided to benefit both people and place.

Heritage areas encourage both the protection of a wide variety of environmental, scenic, and cultural resources and sustainable development for tourism and other economic opportunities. They educate residents and visitors about community history, traditions, and the environment, and provide for outdoor recreation.

Heritage areas most often comprise more than one jurisdiction, with regional management that combines public and private sector leadership and engages grass-roots enthusiasm for celebrating community assets.

A Sampling of Heritage Areas

Most people who are at least familiar with heritage areas in the United States have heard of three "national heritage corridors" designated by Congress and serviced by the National Park Service: the

Illinois and Michigan (I&M) Canal outside of Chicago, with a wide variety of transportation history dating from the earliest European exploration of the region; the Blackstone River Valley in Rhode Island and Massachusetts, considered the earliest cradle of the American Industrial Revolution; and the Delaware & Lehigh (D&L) Canal National Heritage Corridor, which traces the Industrial Revolution's effects on a remarkably intact cultural landscape in eastern Pennsylvania, including a 150-mile trail along both rail corridors and canal towpaths from Wilkes-Barre to Bristol. All three corridors have rivers at their hearts_the Illinois, the Blackstone, and in the case of the D&L, both the Lehigh and the Delaware_and all three address the environmental needs of these rivers.

Beyond these examples, there are many more heritage-based initiatives proposing to integrate tourism, recreation, and resource conservation around a host of American stories. Some have involved the National Park Service; others have not. Their hallmarks are that they involve more than one community with some kind of regional management structure, and they are interdisciplinary, with a balanced commitment to interpretation, tourism, recreation, and resource protection. A very few have been started as the result of state programs in Pennsylvania, New York, and Massachusetts. (California is in the process of developing a heritage program that was established "on the books" several years ago; Maryland has introduced legislation for a program; and Colorado and possibly North Carolina are exploring the level of state support that might be possible for local efforts.) The organizers of heritage development initiatives have sometimes emerged from the historic preservation movement, but just as frequently they are leaders from the tourism industry, economic development, or the arts, or museum administrators, or recreation enthusiasts. The ability of such interest groups to forge alliances almost naturally on the basis of an agenda new to all is one of the most intriguing features of the heritage development movement.

The best way to gain a sense of the purpose and enthusiasm of heritage areas is to take a brief tour around the nation of selected, on-going efforts to define, interpret, and develop these special cultural landscapes:

- The Hudson River Greenway, the spectacular early American landscape that became home to the early 19th-century Hudson River School of American landscape painters and has been a part ever since of the nation's history of landscape awareness and environmental protection (see accompanying paper by David A. Sampson).

- The story of ranching and water rights on the Cache La Poudre River in Colorado.

- America's last fully operable hand-operated canal on the Fox River running from Lake Winnebago to Green Bay, Wisconsin.

- A seven-mile canal along the Savannah River that still powers mills in Augusta, Georgia, the heart of the South's manufacturing and munitions production during the Civil War.

- The National Road in running through western Maryland and Pennsylvania, America's first civil work.

- The two-county region in northwestern Pennsylvania where oil was first discovered.

- The El Camino Real, a corridor following the ancient trails of Native Americans and Spanish Explorers across a large part of eastern Texas, under the protection of a special commission of the state highway department.

- Southern Indiana counties_26 of them_showing off their covered bridges and agricultural heritage;

- RiverSpark, one of New York's earliest urban cultural parks in its twelve-year-old program, promoting the canal and manufacturing history of Cohoes, Watervliet, and other small towns near Albany;

- The Pocomoke River heritage corridor, started originally to address protection of the significant wetlands and scenic river on Maryland's Lower Eastern Shore;

- Tracks Across Wyoming, a 400-mile stretch of the active Amtrak line following the old Union Pacific railroad.

- The Ohio & Erie Canal corridor, involving towns from Zoar to Cleveland, relating to recreation along the Cuyahoga River and the Cuyahoga National Recreation Area.

- The Quinnebaug and Shetucket (Q&S) National Heritage Corridor, a lovely untouched corner of Connecticut, inspired by a history similar to that of its neighbor, the Blackstone River Valley, and federally designated in late 1994.

- The Cane River National Heritage Corridor, celebrating the Creole culture and historical sites in northwestern Louisiana, and federally designated in late 1994.

- The Delaware Coastal Heritage Greenway, encompassing the entire Delaware River and Bay shoreline of the state of Delaware, using an exemplary approach to both the cultural and natural history of the region along with an emphasis on the recreational and environmental qualities of this largely unspoiled East Coast shoreline;

- Silos & Smokestacks, encompassing the Cedar River Valley in Iowa and interpreting the development of agriculture as an industry, using meatpacking and tractor factories in Waterloo as well as the spectacular farm landscape in the valley.

- The South Carolina heritage corridor, an ambitious program for the 14 counties along the state's Savannah River border, to develop driving tours interpreting the state's historical settlement patterns from tidewater to piedmont to mountains.

- A trans-national heritage area developed with participation of communities in both Texas and Mexico along the Rio Grande from Brownsville to Laredo, addressing early military and settlement history along our mutual border.

The Heritage Areas Movement

The phenomenon of American regional heritage areas has been growing in the past two decades, since the creation of the federal commission for Lowell National Historical Park (Massachusetts) that dealt with the privately owned surroundings of the site in the late 1970's. The subsequent adaptation of the commission idea to the I&M National Heritage Corridor, with no federally owned "core"_designated in 1984_sparked the imagination of a number of communities and regions. By the late 1980's, a movement was clearly discernible, although the federal commission innovation has fallen out of favor as less flexible than other mechanisms for promoting regional and inter-agency collaboration.

With the rising level of interest, the National Park Service began considering the idea of a program for heritage areas as early as 1989. In late 1994 just as the 103rd Congress was closing, the House passed legislation, which was not considered in the final hours of Senate deliberations. As of this writing, both the Senate and the House are considering legislation for passage by the end of the 104th Congress in the fall of 1996.

Other important advancements that have influenced early leaders in heritage development include the creation in the 1970's of "urban cultural park" systems in Massachusetts and particularly New York, and the formation in the late 1980's in Pennsylvania of a non-legislative inter-agency committee that encouraged state-sponsored heritage areas interpreting the state's industrial history. Canadian heritage regions, English national parks, and French regional natural park_all places where people and communities remain undisturbed in the process of recognizing and cultivating a distinctive regional identity_have provided international experience from which to draw.

The National Coalition for Heritage Areas was founded in 1993 to link the many constituencies and localities across the nation interested in heritage development, to develop programs to serve its members and the needs of all heritage areas, and to develop forums that enable various governmental agencies, nonprofit organizations, and other service providers to exchange information and establish mechanisms for collaboration. It participated in the notable effort during the White House Conference on Travel and Tourism in late 1995 to define and propose steps for private and governmental support for cultural tourism; it publishes a newsletter; and it sponsors and supports conferences and training.

National Legislation for Heritage Areas

Heritage areas recognized nationally currently gain their status via ad hoc, project-by-project lobbying to achieve an act of Congress. Efforts are now underway to systematize this process through federal legislation that would establish a universally applicable procedure, when requested by local governments, to provide federal recognition, technical assistance, and a modest level of funding. An act of Congress would remain central to this process and a special program to advise and support heritage areas would be created most likely within the Department of the Interior (National Park Service), but local supporters of the heritage areas themselves would remain in the lead.

Efforts to promote this legislation have fallen afoul of property rights objections involving owner consent and compensation. This is despite the reliance in both House and Senate bills on strictly voluntary participation by local governments, and federal recognition that in no way regulates private property.

The National Coalition is a participant in efforts to support legislation, primarily through advising the Congress on principles to be met by any act establishing such a program and making sure that its members remain informed about the process. Principles include such concepts as flexible administration, processes that build enduring local commitment and capacity, development of supportive state or regional programs, and reliance on existing programs for resource conservation and development.

The National Coalition's vision is that an organized national program will result in "the conservation of resources in the nation's distinctive regions, representative of the diverse origins of our uniquely American character and vital to our national heritage and identity. Limited federal investment and involvement will stimulate innovative partnerships and economic development_private and public, local, state, and federal_across geographic regions. Heritage areas will create a greater sense of a shared natural and cultural heritage and new and renewed connections, leading to greater commitments to conservation, education and recreational opportunities in the public realm."

Links to Watershed Planning

The link of heritage area planning and development to watershed planning is significant. As the above examples illustrate, many heritage areas are centered on rivers and valleys. They often incorporate (or are even known as) greenways_an approach that can reinforce either watershed planning or heritage areas, or as implied here, both. Scenic byway corridor planning is another compatible approach to the large-scale planning needed for heritage areas and watersheds; some leaders in the movement, in fact, suggest that "heritage areas" with specific boundaries may be only one approach for heritage development. The heritage tour route developed by the Southwestern Pennsylvania Heritage Commission, linking nine counties with their multiple parks, heritage sites, and heritage areas, is an example of a different, equally compatible approach to heritage development in a cultural landscape. This approach is reflected in the South Carolina heritage corridor, and has also been suggested as appropriate to the interpretation of the multi-layered cultural history of the Potomac River watershed in combination with renewed efforts to enlist local communities in addressing nonpoint source pollution.

Planning a heritage area is a variation on standard planning, greatly resembling watershed planning: steps include an assessment of the region's resources and interpretive themes (the "narratives" or "stories"); a review of the issues involved in recognition (sometimes calles a feasibility study); an agreement to move forward with substantial planning (at the federal level, this involves an act of Congress); the identification or development of an entity to coordinate the planning effort; the actual planning; and implementation. Throughout the process, local commitments are developed for concerted action under existing law and funding for initiatives newly identified through the planning process (e.g., marketing or development of a unified signage system). Public education and participation are integral to all stages.

Conclusion

In conclusion, watershed planning that incorporates an approach to heritage assessment, protection, and development may result in the achievement of multiple objectives:

- Natural resource protection and enhancement, including water quality improvement.
- Cultural heritage preservation, including archeology and historic preservation, including the cleanup of hazardous sites involving historic structures.
- Appreciation of community and folk traditions.
- Improvement of recreational opportunities.
- Creation of education programs celebrating geography, the environment, human history, and their interaction.
- Sustainable economic development supporting heritage resources (both natural and cultural), including but not limited to heritage tourism.
- Development of physical linkages through greenways, trails, scenic byways and auto tour routes.
- Enhancement of community pride and self-reliance.
- Linkage of competing and fragmented local, state and federal programs.

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The Hudson River Valley Greenway-A Regional Success Story

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The Hudson River Valley Greenway Act of 1991 created a legal structure of regional connections and cooperation within New York's 10-county, 3 million acre Hudson River Valley. The Act took two existing organizations-the Hudson River Valley Greenway Council and the Heritage Task Force for the Hudson River Valley-and gave them a new focus and a new mandate.

The Council, created in 1988 to study environmental and economic trends in the Hudson Valley, was restructured within the Executive Branch and asked to work with local and county governments to create a voluntary, regional planning compact in the Hudson River Valley. Under the compact, communities will be able to design a process for regional decision-making that utilizes common planning ideas and criteria. If they do so, they receive financial and procedural incentives unavailable elsewhere in New York State.

At the same time, the Legislature created the Greenway Conservancy for the Hudson River Valley as the organization that could assist the Valley's communities and organizations in implementing the ideas and projects that arose out of the planning process.

The Conservancy's main legislative directives are to assist the Council in establishing the compact; work with local governments in the establishment of a Hudson River Trail System east and west of the Hudson; develop a strategy that would allow the Hudson River Valley to promote itself as a single tourism destination area, and work with the agricultural community to promote and protect the industry of agriculture in the Hudson River Valley.

The two organizations, although separated by budget and structure, have established a close working relationship and have become integral parts of each other's programs.

The closeness of the Council and the Conservancy appears to justify the initial decision of the Greenway study council to create two separate organizations; one for planning and the other for project implementation. The Council chose this path after visiting the California Coastal Conservancy and Coastal Commission and seeing how planning and the political questions it sometimes raises was separated from specific projects such as trails, dockage and other waterway projects.

The Conservancy has worked closely with the Council as it develops a model community program that will lead to the regional compact envisioned in the legislation. The Council has been a partner with the Conservancy's development of a strategic plan that will help to implement the visions and goals of the communities and organizations in the Greenway area.

What controversy there has been and it has been centered largely in one community-has been about the Greenway idea as a whole and has not been specifically focused on the Council or the Conservancy.

It is the combination of planning and projects-of visions and the means to attain portions of these visions-that has led to early successes within the Greenway region.

There are 10 "model" Greenway projects underway in the Hudson Valley involving 23 communities. Several involve more than one community, highlighting the Greenway premise that local political boundaries should not prohibit regional thinking and planning. Four other communities have voted to become part of the Greenway officially, and scores of others have worked with the Greenway on various projects.

Two Greenway cities-Newburgh and Beacon-have developed a cross-river partnership that has incorporated planning, a cross-river "Trail of Two Cities" and the proposed reinstitution of ferry service.

The Greenway planning process involves the creation of a local Greenway committee, the development of a community planning profile, and the subsequent development of a vision based upon several public meetings.

One of the keys to the success of the program has been the idea that, as a broad community vision is developed, small, doable physical projects should be identified and implemented to give substance to the planning process.

In some cases, this process has led to the total revision of a Town master plan (Stuyvesant), the development of a specific waterfront strategy (Troy), and the development of a common trail and tourism strategy (Croton and Ossining.)

As the community planning process has progressed, the Hudson River Greenway Trail has reached more than 100 miles and will probably double that amount in 1996. A voluntary, participatory process similar to the model community process is used in each community for trail development. A regional tourism strategy that will seek to take advantage of one of the most historically important areas of the United States was completed in late 1995.

The Hudson River Valley Greenway is relentlessly bipartisan, and has received excellent cooperation from both sides of the aisle in Albany and from mayors, supervisors and city managers, regardless of political affiliation.

The Model Community program has not been without its mistakes, leading Greenway staff to explain "That's why we call them 'model' communities."

Initially, for example, the Greenway sent too many staff members to local Greenway meetings, thus not allowing the local committee to assume a life of its own.

The Greenway also concentrated too much initially on zoning, master plans and other traditional planning mechanisms. The local committees wanted to talk about visions for the community and how specific projects could help achieve those visions. Thus, zoning became the last part of the discussion, not the first.

The Greenway also learned early on that, no matter how well-intentioned its membership was, there were significant groups such as the sports and recreation community who felt they needed direct representation on the Council and Conservancy. There is much more to be done-to date only 25 of the Valley's 242 communities have asked to participate-but the first five years of existence have laid a solid foundation on which the Greenway can be built.

The Czech-Hudson Greenway

The Hudson River Valley Greenway has established a special relationship with a Greenway Project in the Czech Republic running from Prague to Vienna.

The partnership followed a visit by the Hudson River Greenway in 1992 to what was then Czechoslovakia to explain to the newly freed country about the Hudson Greenway process. That visit was funded through a grant from the World Monuments Fund.

Proponents of the Czech Greenway enlisted foundation support to bring a delegation of Czech mayors to the Hudson River Valley in the fall of 1993. That visit was followed in spring of 1994 by a Hudson Valley delegation trip to the Czech Republic.

The exchanges have been profitable for both Greenways. In the Czech Republic, Greenway has become a Czech word, replacing Zelene Stesky. The mayors of the Czech Greenway have created a working coalition and have begun to meet regularly to discuss issues of common concern. Ideas on tourism, agri-tourism and open space protection imported from America have begun to take hold.

In return, the Czechs have added to the Hudson River Greenway by lending expertise on trails, signage and an infectious love and respect for the land and history. Additionally, exchange programs have been instituted by the Culinary Institute of America and by the sister Greenway cities of Newburgh and Beacon.

Both exchanges were underwritten by foundation grants from the American Express Foundation, The Trust for Mutual Understanding, and the German Marshall Fund of the United States.

Helping Communities Make Watershed-Based Land Use Decisions: Three Successful "Real World" Examples that Make Use of GIS Technology

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At some point, all watershed management efforts must confront the common denominator of local land use policies. Local land use decision-makers_whether elected or appointed, professional or volunteer_need assistance in overcoming the many barriers to making watershed-based, environmentally sound land use decisions. Among these barriers are the narrow focus of most land use boards and commissions, their high turnover rate, their inability to predict or track cumulative impacts, and their decision-making framework defined by political boundaries.

The key to addressing these problems is education and information. Perhaps the most unexplored tool for supporting educational and informational programs is geographic information systems, or GIS. GIS is increasingly used at the federal and state levels of government for natural resource management, including many new watershed-based studies and inventories. At the local level, GIS, where used at all, is most often applied to problems like school bus routing or property tracking for the tax rolls. However, the use of GIS as a tool to help municipal officials protect their water resources is being explored by relatively few. GIS images can convey an enormous amount of information in a succinct, understandable format especially useful to busy decision-makers needing to put their actions into a "bigger picture."

This panel session brings together three groups of projects in New England that are making use of GIS to help communities change the way they look at land use decisions. All are educational projects spearheaded by the Cooperative Extension Service (CES), in partnership with other agencies. In Connecticut, CES is teaming with The Nature Conservancy to do two watershed projects in the lower Connecticut River, one of 40 places designated as a "Last Great Place" by the Conservancy. The projects make use of a wide range of digitized data, including cutting-edge remotely-sensed land cover data, to create educational products and programs. Through the use of GIS parcel (property) data, these programs are targeted to specific audiences. In Rhode Island, CE staff are not only using GIS as an educational tool, but they are training local officials in the use of GIS. In addition, GIS information is used to run a new risk assessment model that estimates nonpoint nutrient loadings. In New Hampshire, extensive data from the state GIS system was combined with ten years of water quality data collected by citizen monitoring programs to analyze subwatersheds of the Squam Lakes system, with regard to their impact on water quality and wildlife habitat. GIS is also being used to help communities inventory, evaluate and prioritize their natural resources.

Taken together, these projects demonstrate the wide range of creative ways that GIS can be applied to watershed projects_from visualization to loadings analysis to audience targeting, with a few stops in between. This panel is not about technology, but about education and the use of this new technology to better inform the local land use process. We hope that it will stimulate discussion of new and better ways to tackle watershed management at the all-important local level.

The Tidelands Watershed Projects: Using Computerized Natural Resource Information to Promote Watershed-Based Decision-Making at the Local Level

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The Nature Conservancy, Connecticut Chapter, Middletown, CT

Overview

The University of Connecticut Cooperative Extension System and The Nature Conservancy, Connecticut Chapter are collaborating on two innovative watershed projects in the lower Connecticut River, an area designated as a "Last Great Place" by The Nature Conservancy in 1993. The Chester Creek and Eightmile River watershed projects are non-regulatory, non-advocacy natural resource management public education initiatives, conducted in close cooperation with local residents and town officials. The projects were begun with seed funds from the Environmental Protection Agency, and are continuing with ongoing USDA funding through Cooperative Extension, and the support of The Nature Conservancy.

During the course of the projects, a multi-disciplinary team from Cooperative Extension and The Nature Conservancy conduct a series of educational workshops on a number of natural resource management issues including nonpoint source pollution, forest stewardship, and environmentally-sensitive property management. The workshops, planned and conducted with input and guidance from a local advisory committee, are supported by maps and information collected by the project on a geographic information system, or GIS. GIS is used not only to collect, analyze, and display data, but to target the educational message to key audiences. While these projects are relatively young, there are already strong indications that this approach is an effective one at helping both individuals and municipal entities adopt a watershed perspective, and become stewards of their natural resources.

A Last Great Place

In March, 1993, the Tidelands of the Connecticut River region was designated by The Nature Conservancy (TNC) as one of forty "Last Great Places" in the western hemisphere. The Tidelands region encompasses the lower 37 miles of the Connecticut River, from the Rocky Hill/Glastonbury area of Connecticut to the mouth at Long Island Sound. The region is the southernmost portion of the Connecticut River watershed, a major basin which incorporates an extensive area surrounding the River from the Canadian border down through Vermont, New Hampshire, Massachusetts and Connecticut. The Tidelands stretch of the River was singled out because of its exemplary complex of high quality salt, brackish and freshwater tidal marshes, and the many threatened and endangered species that the complex supports.

The "Last Great Places" initiative constitutes a commitment by TNC to preserving the ecological integrity of areas far too large to be addressed solely by TNC's traditional methods of land protection. Such large-scale efforts require that public agencies and private organizations work together to promote and assist natural resource conservation at the local level. Land use and resource management issues at the regional or watershed levels are complex, and have not lent themselves well to resolution through conventional regulation and enforcement approaches. In the Northeast, the strong tradition of local "home rule" also serves to work against "broad brush" solutions mandated by federal or state authorities. Education_of local officials, of individual landowners, of the general public_can be an effective, nonregulatory method for addressing these complex issues.

This paper describes the ongoing development of an education-driven approach to watershed management. At the time of the Tidelands announcement, the University of Connecticut Cooperative Extension System (CES) Nonpoint Education for Municipal Officials (NEMO) Project had been working with coastal communities in Connecticut on the issue of nonpoint source water pollution. Over the past four years, the NEMO project team has developed an effective educational methodology using geographic information system (GIS) computerized mapping as a tool to help municipal officials understand the impacts of land use on water quality and options available for managing those impacts (Arnold et al., 1994). With the "Last Great Places" designation as a catalyst and the NEMO model as a programmatic basis, CES and TNC staff conceived the Tidelands watershed projects, which were given a crucial boost from two one-year "start-up" grants from the Environmental Protection Agency.

Project Areas

As part of the "Last Great Place" designation, TNC-Connecticut Chapter had identified 17 "core sites" in the Tidelands, based on their assessment of habitat value. The first step in selecting a project site was to view these core wetlands not as isolated units, but as natural resources affected by the activities in the local watershed subbasins draining to them. Of the 17 areas, potential project sites were considered based on the natural resource base, land use patterns, availability of digital data, watershed size, and the number and enthusiasm of the affected towns. Based on these criteria, Chester Creek watershed was chosen for the first project in late 1993, and a year later the Eightmile River watershed was selected for the second project.

The Chester Creek watershed is a 14.5 square mile basin located on the western side of the lower Connecticut River, approximately 25 miles upstream of Long Island Sound (Figure 1). Almost 80% of the watershed is in the town of Chester. The 63 square-mile Eightmile River watershed lies just across the River on the eastern side, and includes major acreage in three towns. In addition to the critical tidal marsh habitat to which both of these watersheds drain, each area has significant upland biological and aquatic resources (Nelson and Arnold, 1995).

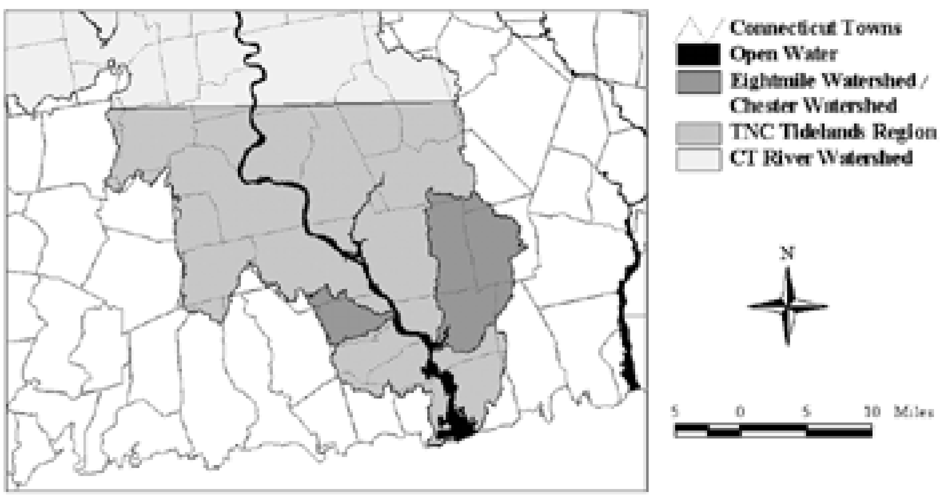

Figure 1. Tidelands region and watershed project areas.

Key Project Elements

The Tidelands watershed projects have several key elements that we wish to highlight. The first is the partnership between Cooperative Extension and The Nature Conservancy. While private-public partnerships may be fairly common these days, truly successful ones are a bit more scarce. The Tidelands partnership creates overall benefits for the watershed projects that go beyond the skills and expertise of the individual team members. Both TNC and CES are organizations with non-advocacy, research-based philosophies. However, the "Last Great Place" designation gives the projects a regional framework and a "reason for being" that the University alone could not provide. In return, the experience of CES in dealing with property owners and municipal officials on land use and conservation issues provides the projects with an educational "track record" at the local level that TNC alone could not match.

The second key element is yet another partnership_that between the project team and the towns with significant acreage in the watershed. A key criteria for selection of the two project sites was the strong support of the chief elected officials of each town involved. After that step, advisory committees were formed of key land use and other officials from each town. These committees meet frequently with the project team to review the GIS maps, discuss local concerns, and assist in planning and publicizing the educational workshops. The goal is to have these committees, or some combination of the groups that they represent, take complete ownership of any resource management initiatives resulting from the projects' education and information.

The third key element is the educational use of GIS technology. While GIS is often used for natural resource planning and analysis at the state and federal level, at the local level it is typically reserved for things like tracking property taxes or routing school buses. Through the NEMO project, the University of Connecticut CES has been exploring the use of GIS to educate municipal officials. The emphasis is not on the analytical ability of GIS so much as the ability of well-crafted, colorful maps to convey complex issues and relationships in a simple and understandable manner. In the case of NEMO, the focus is on portraying the links between land use and water quality through the display of satellite-derived land cover information.

The Tidelands watershed projects expand on this basic NEMO methodology in several important ways. The start-up grants enabled the projects to hire a private GIS consulting firm to collect, and in some cases digitize, a wide variety of information on the watersheds. Data layers include land cover, water features, open space, soils, drainage basins, wetlands, roads, zoning categories, and parcel boundaries (property lines). This list goes well beyond what is available for any of our NEMO programs, and allows the project team to expand the range of the educational programs beyond nonpoint source pollution to include other topics relevant to the watershed. In the Eightmile project, for instance, we are planning programs on forest stewardship, open space management, and streamside property management.

An expanded list of educational topics translates to a longer list of target audiences, broadening the constituency base for the projects. While the nonpoint source and open space programs remain targeted at municipal officials and local groups like land trusts, the forestry and property owner programs are largely aimed at individuals. With a slight twist to our use of GIS, we have devised a technique to help us reach these individual audiences. Using the parcel data layer, we can identify specific target audiences for a given educational program. For example, in Chester Creek the GIS was queried to identify all properties within the watershed over 5 acres in size with predominately forested land cover. Linking this list to a tax assessor's database gave us the names and addresses of the owners of the properties, which we then used to do a direct mailing announcing a forest stewardship workshop. The turnouts at programs for which we have used this targeting method have been very impressive. In the next few months, we'll be using information similar to that portrayed in Figure 2 to promote streamside property owner programs in the Eightmile watershed. The addition of individual land owners as a target audience for our watershed programs, and the targeting of this critical sector via GIS, is an improvement on the NEMO educational model that we think will greatly enhance the success of these projects.

Figure 2. Map used to target streamside property owners.

So, Is it Working?

Our experience suggests that it often takes years for natural resource management educational programs to bear fruit in the form of significant changes to local land use policies or practices. While working to change individual practices may have a somewhat faster turn-around time, working with local officials, many of whom are volunteer members of town commissions, takes thoroughness, patience, and often considerable repetition. The Chester Creek project conducted its first educational program in June of 1994, while the Eightmile River project programs began in early 1996; thus, these projects have been in town for only a brief period.

That being said, we feel that significant progress has been made, and that the potential exists for even greater gains. In Chester, a year of educational programming was followed by a quiet period, during which the various audiences digested and discussed the information provided to them. It now appears that the "digestion" period is over and the real work of institutionalizing change has begun. In August of 1995, the project advisory committee submitted a report to the Board of Selectmen, with recommendations for actions to be taken by the town to protect the watershed. The Selectmen then formally appointed this ad hoc committee to a two-year term, and charged them with pursuing implementation of these actions. The recommendations include development of comprehensive watershed management and open space plans; multi-commission review of water quality issues and forest management strategies; continuation of environmental studies focused on the Chester Creek watershed at the elementary school; and, investigation of the development of a town Natural Resources Center. With the town committee now as the driving force behind this strategy, the CES/TNC project team will provide technical support in the form of continuing educational programs that will be tailored as needs arise. Clearly, Chester is well on it's way toward local ownership of project initiatives.

While it is too soon to report such progress for the Eightmile River project, the productive sessions with the ten-person, three-town advisory committee have been very encouraging, as has the positive reaction to the educational programs done to date. This project, which is perhaps a more representative model based on the watershed's size and number of political jurisdictions, is already reinforcing our belief in the effectiveness of GIS-based education to promote the watershed approach. With the watershed maps serving as the common denominator among the advisory committee members, watershed-wide issues can be discussed while still recognizing the dominant role of municipal policies and individual actions in determining land use.

It's been said that "knowledge is power." In our experience, maps can be a uniquely effective tool for transferring knowledge, with their ability to convey complex information in a succinct and understandable way. Once armed with this knowledge, it appears that local officials and land owners are much better able to work together to prioritize problems, discuss solutions, and chart courses of action. While this may seem an obvious point, it doesn't make the implementation of such a program any easier. The trick is in crafting the right maps and devising appropriate educational programs to accompany them, and in providing long term assistance to local decision-makers and residents to facilitate their use of this information.

With our NEMO experience and the commitment of TNC and CES staff to working with these communities over the long haul, we are confident of our ability to meet these requirements. However, we are still working on the problem of making the GIS data readily available and useable to the locals, independent of our involvement. None of the towns involved with these two projects has its own GIS system, and Connecticut, as yet, has no centralized GIS repository. Hard copies of the maps can and will be provided, but this falls short of the goal of true accessibility. The project team and towns are exploring various options to rectify this situation.

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Promoting Watershed Based Land Use Decisions in New Hampshire Communities: Geographic Information System Aided Education and Analysis

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Introduction

In New England we place great importance in the local decision making process. These local decision makers are primarily elected or appointed or may be volunteers. They may or may not have the direct assistance of a planning or environmental professional. They often do not have, or lack access to, the proper resource information and education on which to base their decisions. Yet, these local officials are responsible for evaluating development, subdivision, residential, industrial, commercial and recreational projects all of which can have significant impact on a community's natural resources. They are also responsible for the implementation of land use and zoning regulations and the development of the community's master plan which affects the future land use of their community. Thus, while local decision making is the key to watershed based community resource protection, the information and education required to make informed decisions is often lacking or severely limited.

Watershed assessment and protection efforts have generally been driven by more "reactive" approaches in which wetlands and waters that show signs of degradation are examined and the resulting diagnostics are used to attempt to mitigate the damage. A more proactive approach is necessary for the high quality wetland or water body, typical of New Hampshire, since a major concern is to keep the ecosystem in as pristine a condition as possible. Information and understanding of connectedness, linkages and interrelationships between land use activities and the watershed resources are critical to local decision makers and landowners alike.

In an attempt to address these complex issues, various method manuals have recently been developed to assist local officials and interested citizens in finding or assembling the information necessary for planning and decision-making. These valuable manuals include methods for evaluating the functional values of freshwater and coastal wetland systems (Amann and Lindley-Stone, 1991; Cook et al., 1993) as well as a handbook on community natural resource inventories (Auger and McIntyre, 1992). This latter work offers suggestions and provides examples of a resource inventory process that is based within the political boundaries of the community. This resource inventory process has also been adapted to demonstrate this approach in the context of a watershed based assessment and analysis (Schloss and Ruben, 1992).

The advent of Geographic Information Systems (GIS) has brought a new and potentially powerful inventory, analysis and educational tool to watershed investigators and decision makers. Although GIS natural resource applications are currently being developed and explored on a statewide and regional scale there has been less effort to transfer and utilize the technology at the local level. This paper presents two examples of approaches undertaken by University of New Hampshire Cooperative Extension educators and other to use GIS as an information, analysis and education tool. The first case study presented involves towns that are part of a multi-jurisdictional lake watershed and the second involves multiple wetland watersheds within a single town.

GIS Inventory and Analysis of the Squam Lakes Watershed

As part of a model watershed study under the direction of the NH Office of State Planning, a multi-agency task force worked to create a GIS based resource inventory of the Squam Lakes Watershed (Scott et al., 1991). The state's GIS , GRANIT (for Geographically Referenced Analysis and Information Transfer) is housed at the University of New Hampshire but linked to state agencies and regional planning commissions. Data "layers" used in this GIS study included bedrock geology, hydrology (streams, wetlands, lakes, ponds and aquifers), soils, elevation, land use zoning, land cover (from aerial photographs and satellite images) and wildlife habitats. This was in addition to a base map of roads and political boundaries. Also included was ten years of water quality data, collected weekly during the ice free season throughout the lake, by volunteer monitors of the Squam Lakes Association under the direction of the NH Lakes Lay Monitoring Program.

A conventional GIS analysis of land capability was undertaken to displays all of the developable area remaining in the watershed. The GIS was also used to analyze information on zoning specific to each town (i.e., land area required for each house lot) and provide a "buildout scenario" that could estimate the number of new houses by town and by subwatershed, and the resulting increase in population. When this was done for the Squam Lakes watershed it was found that about 12 percent of the watershed was currently developed or protected, about 52 percent was constrained or restricted to development, and almost 37 percent of the watershed was left to be developed. While, as a whole, the lake displayed excellent water quality and was relatively pristine in nature, there were areas within the lake with less desirable water quality conditions. Thus, the problem was defined: areas of the lake were already showing signs of water quality degradation yet current laws and regulations would allow development within the watershed to expand over three times the area of what was already developed. What was still needed was a method to locate critical lake areas and produce additional GIS products to educate and support decision makers and their communities.

With that in mind, it was time to go beyond the traditional GIS approaches and "push the envelope" by exploring GIS data display and visualization. Displaying the water quality data spatially, it became apparent that many of the small coves and embayments were areas of more degraded water quality. The data suggested that the lake did not react uniformly to watershed inputs; that it was not just one big reaction vessel or "bathtub" as is commonly assumed for many large systems. This concept was further enhanced by taking the bathymetric map (depth contour plot) of the lake and using the GIS to create a 3-D model of the lake bottom. No experience in topographic readings was necessary to be able to see how the lake was really made up of multiple basins connected together and that each of these basins had high sills around them.

With the basins defined, they could be associated through the GIS with the abutting subwatersheds. This would allow for analyses of what characteristics of the land around the basins had an influence on the basin's water quality. While our study team had the luxury of an extensive GIS data-base of land cover (down to the type of tree stand from aerial photography !), we started with some basic GIS analysis using information that would be more readily available to localities across the state. With some relatively simple data analyses, areas of the lake that react more critically to nutrient loading were defined. A land cover analysis found that land cover within the shoreland zone (a 250 foot area from the lake shore) explained less water quality variation than the total subwatershed land cover. Thus, although shoreline regulations are important for the Squam Lakes, activities throughout the watershed also have a major impact. The results of these applied analyses and others were then built into our community educational programs.

Through community advisory groups we learned that other aspects of the watershed besides water quality held equal if not greater importance. To that end, a GIS layer of loon habitat (provided by volunteers of the NH Loon Preservation Society), bass nesting areas, cold water fish reefs and holes, and smelt brooks (from NH Fish & Game and volunteer surveying) was created. The GIS could then reference the various in-lake and shoreline wildlife extent contained in each of the basins. Now the GIS was complete with information of in-lake water quality conditions and wildlife resources. From this information the GIS was used to locate the lake's most critical areas. For each basin and adjoining subwatersheds the GIS simply averaged together all of the criteria scores. The resulting integration was best visualized by draping a color (light or "cold" for less critical, reddish or "hot" for most critical areas) over the 3-D plot of the lake basins.

A color slide program that best visualized the procedures and concepts of this demonstration study was developed and presented at educational sessions to communities throughout the state. However, the materials produced for the communities and decision makers in the watershed had to be more functional; Towns and most citizens still do not have easy access to GIS systems so a more "low tech" set of products were developed. For the town decision makers, a map of the watershed area was provided, delineating the various subwatersheds and subbasins of the lake labeled by number. These numbers were then referenced to a printed table which contained the water quality and resource information of both the basins and the abutting sub-watersheds. Thus, instead of having to decide on the approval of a project based solely on information provided by the applicant, the decision maker can look up the subwatershed where the project is being proposed, check on the important lake resources that may be impacted, weigh benefits and concerns, and have the applicant address specifically how they will minimize loss or impacts to that resource. Tabled information could also be captured to a spreadsheet or a data-base system and digital maps could also be provided to those with GIS display systems. However, there have been no requests for GIS products at this level of sophistication to date.

GIS Analysis of Local Wetland Buffer Options for Deerfield, NH

This past fall, a new guidance document was published on riparian buffer function that included recommendations for regulatory and nonregulatory buffer widths (Chase et al., 1995). It represents a collaborative effort between the Audubon Society of New Hampshire, NH Office of State Planning, UNH Cooperative Extension and the USDA Natural Resources Conservation Service. The guidebook focuses on water quality and wildlife habitat as two key functions of upland buffers. It provides municipalities with both a scientific rationale and practical actions for protecting and preserving naturally vegetated upland areas that border surface waters and wetlands. Ultimately, local decision makers will need to determine the most appropriate buffers to suit their needs and the means for establishing them. In an effort to introduce this new tool and to demonstrate how GIS might be used to assist in the decision making process, a pilot project was undertaken and the results presented to a statewide audience at a GIS workshop for decision makers sponsored by the NH Office of State Planning and the University of New Hampshire.

The Town of Deerfield, NH completed a comprehensive inventory of its natural resources in the spring of 1991 extensively using GIS (see Appendix D in Auger and McIntyre, 1992). For investigating the various buffer scenarios it was first necessary to take an inventory of the water resources of concern. From the GIS base map, surface waters are already delineated. The GIS soils coverages were used to delineate wetlands areas (from Hydric soils classifications). Other options for NH towns to delineate wetlands include digitized or hard copy National Wetland Inventory maps and Landsat derived wetland classifications, both available through GRANIT. The inventory of Deerfield disclosed that wetlands comprise 86% of the town's water resources acreage and many are connected and lie within stream corridors that run throughout the town.

The existing regulatory buffers and setbacks in the town were analyzed using GIS. Two sets of state laws and regulations are already concerned with maintaining a vegetated buffer at the shoreline of lakes and streams. The Comprehensive Shoreline Protection Act requires that a minimum tree basal area must be maintained at greater than 50 percent within 150 feet from the shore of lakes greater than 10 acres and 4th order or greater streams (except those in the NH Rivers Program). State forestry regulations also maintain this requirement for land within 50 ft from a perennial stream or brook. There is also a setback of 75 feet for buildings and septic systems bordering wetland areas required under town regulations. The

GIS display of these overlay zones indicates the existing acreage of these areas as 434 acres under the Shoreland Protection Act, 577 acres under the forestry regulations and 2880 acres bordering wetlands with town mandated setback restrictions.

Through a review of the current scientific literature and recommendations of other states, and with priority focused on water quality protection, a "reasonable" minimum buffer width of 100 feet is recommended in the buffers guide. A larger buffer is recommended for sensitive wetlands (bogs, fens, white cedar swamps), prime wetlands, endangered or threatened species protection, or to support wildlife habitat more thoroughly. Through the use of GIS, maps were produced that visualized the extent of lands that would be impacted by the new recommendations. Imposing the 100 ft buffer overlay for wetlands and streams about doubles the protective acreage around streams and adds another thousand acres that border wetlands. This represents a 40 percent increase in the protected areas. Using an overlay of the town tax map the decision makers are now able investigate the degree to which different lands might be affected by various regulatory approaches.

Through use of the NH Method (Ammann and Lindley Stone, 1991) the Town of Deerfield evaluated the functional values of all of its major wetland areas and is proposing some of these for designation as prime wetlands. As the buffers document suggests a buffer larger than 100 feet, our study explored the use of a 200 foot buffer in our analysis. An overlay of this buffer was created to visualize the impact and to discern whether the size chosen was adequate to serve both water quality and wildlife habitat concerns. The resulting analysis indicated that with the 200 ft buffer some wetlands in the sample area would be connected to each other, but others would not. If habitat considerations are a goal, the GIS analysis indicated that other, perhaps nonregulatory, methods would be needed to establish habitat connections among all of the critically important wetlands.

Nonregulatory approaches to buffer protection were also explored with GIS analyses. For purposes of wildlife habitat and travel corridor protection and to maximize the benefits of conservation lands, acquisition of larger buffer areas may be required. To achieve this level of protection a town may have to rely on land acquisition and/or conservation easements. Use of the GIS information regarding the wetland and stream locations, existing and proposed buffer overlays and habitat land cover information along with property or tax map overlays and existing conservation lands can help decision makers choose the most cost-effective way of achieving their goals.

Conclusion

All of the community and watershed based inventory processes and guidance documents discussed in this presentation offer a proactive approach for decision making, resource protection, and stewardship. They encourage the community to become involved in defining what resources are important and why. They also provide the information required to develop protection and management strategies. The use of GIS in educating the local communities, especially exploring and visualizing the extent, impacts and benefits of various protection and management alternatives, can greatly enhance the local decision making effort.

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Training Local Officials in Watershed Management Using User-Friendly Geographic Information Systems

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Targeting Local Officials for Nonpoint Training and Technology Transfer

Rhode Island cities and towns, like other New England communities, play a key role in protecting water quality. They develop community plans, review subdivision proposals, approve zone changes, and manage community water supply systems. Through these routine land use decisions, local officials have the opportunity to control nonpoint pollution. Yet, volunteers serving on planning and zoning boards, town councils, and other boards making these decisions often have limited expertise in watershed management. Perhaps more importantly, water quality protection is only one of many competing and sometimes conflicting issues that local decision makers face. Unless there is an immediate threat to community water supplies or economically important recreation or shellfishing areas, pollution prevention may not be perceived as an urgent priority, especially when economic development needs and other local issues vie for local attention and available funds.

With support from the Cooperative State Research Education and Extension Service (CSREES), the University of Rhode Island (URI) Cooperative Extension has developed a technology transfer/education program for local decision makers that addresses the unique challenges of dealing with municipal audiences. The aim of this project is to reduce nonpoint inputs to Narragansett Bay, an EPA-designated national estuary, by providing local officials with the skills and resources they need to manage nonpoint pollution in local watersheds. Our strategy is to capture local interest by focusing on local resources and problems through the use of Geographic Information Systems (GIS) map products, offer a mix of training opportunities to meet various levels of interest, and supply practical nonpoint assessment tools to identify and manage nonpoint pollution problems. Unlike many GIS-based education programs, local staff are also trained in the use of GIS software so they can continue to take advantage of its analytical capabilities long after training workshops and demonstration programs are completed. The purpose of this paper and our panel presentation is to describe successful application of GIS technology as an education and analytical tool using three approaches:

1. Enhance awareness of local resource values and illustrate the relationship between watershed land use and water quality using GIS products.

2. Provide decision makers with an analytical tool for watershed-level nonpoint management using a GIS-based pollution source identification and nutrient loading model currently under development.

3. Teach municipal officials to incorporate geographic data in routine planning and land use decisions through introductory workshops that demonstrate GIS capabilities and hands-on practice in using the ArcView GIS software.

Geographic Information Systems as an Education Tool in Local Nonpoint Education

Local Outreach Strategies

Local officials are often eager to learn practical techniques for dealing with immediate problems but they have busy schedules with little time for generalized training. To overcome this initial barrier the URI training program relies on tiers of training strategies to reach various municipal audiences based on their level of commitment or time constraints, and their level of expertise. Our objective is maximize our limited staff resources to reach as many local land use decision makers throughout the Narragansett Bay watershed while concentrating our efforts in priority subwatersheds. Our target audience is planning and zoning board members, planners, conservation commissioners, council members, water suppliers, and others involved in local land use.

We offer three tiers of training and assistance to towns: (1) Brief presentations that can be scheduled during regular board meetings, evening workshops, and one to three day conferences on priority topics such as stormwater controls, wetlands protection, and wastewater management. These attract both new and experienced board members and professionals from throughout the watershed. The time commitment is minimal but gives local officials an opportunity to improve skills when they are ready. Attendance in one workshop frequently leads to participation in other workshops and interest in the next level of training. (2) Intensive watershed-level short courses in watershed management for board members and town staff in priority subwatersheds. This is where we can best use GIS as an educational tool to enhance awareness of local resource values and nonpoint problems. (3) Follow-up assistance in implementing nonpoint source controls based on interest generated from topical workshops and short courses above. This includes, for example, assistance in developing local ordinances and nutrient loading analysis to identify relative impacts of nonpoint sources and control options.

Watershed-Based Training

Short courses in watershed management target all local officials from two or more communities within a priority watershed. Through a series of six to thirteen workshops, this intensive program is ideal for building relationships among board members within a town and among communities within a watershed. These sessions cover topics such as the relationship between watershed land use and water quality, development review techniques, watershed protection strategies, stormwater and wastewater management techniques, board procedures and legal issues, and coordination among local boards. Because the watersheds selected are normally small, 15,500 acres or less, it is also an ideal opportunity for using powerful GIS imagery to illustrate the relationship between watershed land use and nonpoint pollution sources.

This watershed-based training focuses on watershed aquifers and reservoirs to incorporate GIS analysis, local case studies and field training sites. Because they are predominantly interested in local water supplies and shellfishing areas, local officials learn best from these targeted examples. Using coverages available through the Rhode Island Geographic Information System (RIGIS) GIS products are used to illustrate land use patterns and to describe watershed features such as subwatershed boundaries, aquifers, well head areas and wetland resources and to illustrate the relationship between sensitive water bodies and riparian areas with high risk land uses (McCann et al., 1994). Following the NEMO approach used by the University of Connecticut Cooperative Extension (Arnold et al., 1993), percent impervious cover under existing land use and potential land use with build out under present zoning are also analyzed.

The geographic analyses generate awareness and interest in watershed protection issues which are then explored at the parcel-scale through subdivision and commercial development case studies. Generally, two or three case studies are used repeatedly in several sessions to illustrate a range of realistic nonpoint problems and practical control options. For example, one subdivision may be used to demonstrate a variety of techniques, such as subdivision review procedures, creative zoning or cluster options to reduce impervious area, specific stormwater controls, and wetland protection options. A field review of at least one site is conducted to improve map reading and plan interpretation skills, demonstrate field assessment techniques and promote discussion of local regulatory issues. Following this progression from watershed-scale GIS analysis to the parcel-level site evaluation, we may select one area of the watershed for more detailed analysis of nonpoint control options based on local interest. Other features of the watershed-level training are summarized below:

- Target local interests that are compatible with pollution prevention. Because water resource protection are usually one of many local concerns, we focus attention on opportunities to achieve local land use goals through implementation of nonpoint control. For example, discussions of techniques to minimize impervious area focus on reducing pollution, minimizing the size of stormwater facilities needed, and preserving community character. Stormwater management practices discussed emphasize designing for low maintenance as well as water quality enhancement.

- Work closely with municipalities to develop and conduct the training series. Planners and board members are surveyed to determine their areas of interest. Survey results are used to select course topics and identify priority areas for in-depth evaluation of nonpoint pollution sources and control options. To ensure local commitment to participate in development of the program, a Memorandum of Agreement (MOA) between URI and each municipality is developed and signed.

- Collaborate with other university groups, state regulators and planning staff and federal partners in developing and conducting the program. Watershed-level training areas are selected based on state nonpoint priority watersheds and local interest.

- Design each session to promote discussion and sharing of local expertise. Provide opportunities for board members to build relationships with each other and with state regulators, resource managers and consulting professionals from the region people they can call on for assistance long after the training is completed.

Tools for Watershed Management GIS-based Nutrient Loading

Assessments of high risk land uses and impervious coverage are useful as a first cut analysis of nonpoint problem areas, but municipal officials considering adoption of costly and perhaps controversial nonpoint control measures often need stronger evidence to justify the need for additional controls and to demonstrate their benefits. As a second tier of assistance to these communities, the URI Cooperative Extension is developing a practical nutrient loading method (Kellogg et al., 1995) that land use decision makers can use to compare nonpoint impacts under present and future land use, and to evaluate the effectiveness of alternative best management practices. Known as MANAGE: a Method for Assessment, Nutrient-loading, and Geographic Evaluation of Nonpoint Pollution, the method is designed to estimate nitrogen and phosphorus loading to surface waters and nitrogen loading and concentrations in aquifers. It also estimates average annual runoff and infiltration volumes and mass-balance nutrient loading using readily available RIGIS based on land use as well as soil hydrologic group and riparian area relationships.

The following case study illustrates one application of GIS-based nutrient loading analysis, using a simplified phosphorus mass balance model developed by the R.I. Department of Environmental Management, to identify nonpoint management options and to promote adoption of best management practices as a spin-off project of a watershed-level short course.

Case study: St. Mary's Watershed, Portsmouth, Rhode Island

The Problem: As a result of concern over water supply protection generated in a URI watershed management short course on Aquidneck Island, R.I., a local watershed group was formed, known as the St. Mary's Watershed Group. This group was initiated by members of the local Portsmouth Agricultural Advisory Committee who participated in the training program, with support by the Eastern Rhode Island Conservation District. Other members of the group included local planners, administrators, the municipal water supply company and Cooperative Extension. St. Mary's watershed was selected for analysis because of its small size and mix of residential and agricultural land uses. Because previous studies had suggested that both residential and agricultural land uses were contributing to eutrophication of the water supply, the group set out to conduct a detailed watershed assessment to identify the relative nonpoint pollution inputs and suitable control measures. Using the results of field analyses conducted by the Conservation District, URI updated the GIS land use coverage and subwatershed boundaries.

Results: A nutrient loading conducted by the District and URI showed the following.

- The amount of phosphorus moving into the St. Mary's pond is estimated to be roughly five times higher that the pond can assimilate without excessive algal growth.
- agricultural activities and polluted runoff from residential land contribute phosphorus to St. Mary's pond in roughly equal proportions.
- A combination of both agricultural conservation practices and stormwater controls are needed to effectively reduce phosphorus concentrations to approach acceptable levels.

Action:

- The members of the St. Mary's watershed group prepared a fact sheet summarizing their findings, using the results of the GIS-based nutrient loading and GIS watershed map, as shown in Figure 2.
- The group presented their findings to the Portsmouth planning board and Aquidneck Island Planning Commission. Both boards agreed to support efforts to construct stormwater basins and seek funding through Section 319 of the Clean Water Act.
- Portsmouth local officials and Newport Water Supply Company are continuing discussions to determine locations of basins and to resolve issues relating to ownership and maintenance of basins.

Setting Up Local GIS Capability

With the advent of user-friendly Geographic Information System software the possibility that local planners can incorporate geographic data in their land use decisions is no longer just wishful thinking. In comparison to full-scale GIS systems, software technologies developed or improved within the last few years are relatively low cost, easy to use without extensive training, and run on computers with 486 or Pentium processors typically found in most offices. These new technologies enable local planners to easily access and view extensive resource databases and perform fairly sophisticated watershed analysis with minimal investment in equipment and staff time. For Rhode Island cities and towns, the incentive to use GIS is particularly attractive. The state RIGIS database is one of the most comprehensive, high-quality and up-to-date compiled for a large area and the data is readily available at low cost. All municipalities are familiar with GIS products, having received State-supplied GIS coverages of their community for use in updating local comprehensive plans.

Hands-on short courses in user-friendly GIS software, as a third tier of nonpoint training, enables planners and other municipal staff to set up and use a local GIS. Since local planning is a dynamic process, constantly evolving as development pressures and management opportunities arise, this capability is essential to continued use of geographic data for watershed management over the long term. Thirteen Rhode Island municipalities have participated in GIS training to date; almost all of these communities have either established or are developing a local GIS.

Summary and Future Direction

The URI Cooperative Extension municipal training program demonstrates the effectiveness of a tiered approach to nonpoint education and the value of incorporating GIS as both an educational and analytical tool. Based on the success of the program we plan to continue offering a range of training opportunities for local officials to meet their interests and educational needs, including workshops on priority topics and watershed-level short courses in watershed management. We are continuing to develop the MANAGE method as a GIS-based watershed assessment and nutrient loading tool. To promote use of geographic data in local planning we will continue to offer workshops and short courses in application of the user-friendly GIS software. In addition, we will provide technical assistance to municipalities in implementing local nonpoint source controls as a follow-up to training in priority watersheds.

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Maryland Volunteer Water Quality Monitoring Association: A Model Alliance

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What is the Maryland Volunteer Water Quality Monitoring Association?

The Maryland Volunteer Water Quality Monitoring Association (MVWQMA) is a coalition of organizations, agencies, businesses, schools, and individuals who work to promote and support volunteer environmental monitoring in Maryland.

History and Background of MVWQMA

In 1991, the Alliance for the Chesapeake Bay, the Maryland Department of Natural Resources, and the Chesapeake Bay Trust cosponsored the first Chesapeake Bay regional volunteer monitoring conference at Solomon's Island, Maryland. As part of that conference, participants attended state breakout sessions designed to foster communication among various constituencies involved, or interested in, volunteer monitoring.

Representatives from environmental organizations, watershed associations, university professors, teachers, as well as personnel from state and county agencies attended the Maryland breakout. During our discussion that day, we discovered that there was a tremendous amount of volunteer monitoring activity taking place around the state, more than any of us realized. However, as we began to talk about who was doing what and where, two overall problems became evident:

- Left hand-right hand syndrome. Organizations monitoring different parts of the same watershed, or monitoring similar parameters, had no knowledge of each other and, therefore, were unable to share information, combine efforts, or seek guidance from each other. Further, this lack of awareness was not limited to volunteer monitoring. Counties did not know what data were available from the state or from other local jurisdictions. Staff of the two state resource management agencies, the Department of the Environment (MDE) and the Department of Natural Resources (DNR), often did not know what their counterparts in the other agency were doing. In short, there were no mechanisms available to find out which watersheds were being monitored, how they were being assessed, and by whom.

- Volunteer monitoring is nice, but. Even among people who recognized the educational value of volunteer monitoring, there was a great deal of skepticism that volunteer collected data could be useful to resource managers and watershed management programs. The notion that volunteers could collect technically credible data was not widespread throughout the community of people and institutions concerned with water quality.

Many of us attending this session felt the need to continue discussions beyond the conference and, about 15 people decided to form an ad hoc committee to explore ways to increase communication among ourselves and to build support for volunteer monitoring throughout the state. Very quickly, this committee came to the conclusion that a more formal mechanism would be needed if we really wanted to promote volunteer monitoring. Clearly, a coalition, or alliance, dedicated to volunteer monitoring and the use of volunteer-collected data would speak with a stronger_and more credible_ voice than any one organization or agency. In addition, a formal association would foster the development of relationships among watershed stakeholders by providing a framework where we could work together to accomplish goals common to us all. Finally, a statewide organization potentially could serve as a clearinghouse of the who's, what's, and where's of volunteer monitoring and data.

In 1992, after a year spent developing initial goals and objectives, writing bylaws, incorporating and applying for tax-exempt status, and building support, the Maryland Volunteer Water Quality Monitoring Association was born. It is the first statewide association in the country dedicated to the goal of promoting volunteer water and watershed monitoring and to the use of data collected by volunteers as a method of improving the health of our environment.

It was important to us that we maintain a strong presence of actual volunteer monitors in a decision-making capacity. Therefore, it was written into the bylaws that at least 20 percent of the board of directors had to be people who participated in volunteer monitoring as volunteers, as opposed to project managers, agency representatives, teachers, consultants, or equipment manufacturers. Further, the bylaws state that although anyone is welcome to join MVWQMA, voting membership is reserved for appointed representatives of organizations, agencies, and businesses who are directly involved in volunteer monitoring in some capacity. Initial funding for MVWQMA was provided through membership dues and a grant from the Chesapeake Bay Trust.

Our first annual membership meeting was held in 1993, and an initial board of directors was elected that would carry out the primary work of the Association. That first year, over 30 organizations, schools, agencies, and businesses involved in volunteer monitoring became members of the Association. The initial board of directors consisted of representatives from the U.S. Fish and Wildlife Service, Audubon Naturalist Society, Magothy River Association, MDE, DNR, Montgomery County, Anne Arundel County, Alliance for the Chesapeake Bay, Save Our Streams, Charles County, Sawmill Creek Watershed Association, Seton Keough High School, Middle Patuxent River Project, and the University of Maryland in Baltimore County. Of the 15 original board members, 5 were volunteers.

MVWQMA's Objectives

The Association has developed written objectives in two overall categories, networking and education, to guide and focus our work internally and to characterize the organization to potential supporters and members:

Networking

- Foster communication among member organizations and between the association and various water quality monitoring groups in federal state and local governments.

- Develop and maintain a statewide directory of citizen and government water quality monitoring groups and activities.

- Help new volunteer monitoring groups define and refine their project goals.

- Act as a liaison between manufacturers of monitoring equipment and monitoring groups to ensure that equipment is effective and accurate.

- Participate in regional and national volunteer monitoring networks.

Education

- Offer interested leaders and volunteers training, workshops, seminars, guidance materials, and other opportunities to develop effective monitoring skills, techniques, and procedures.

- Promote volunteer monitoring methodology that meets scientific criteria and standards of quality assurance.

- Provide guidance and technical assistance for water quality monitoring activities, including referral to water quality experts.

- Determine how best to use monitoring data collected by volunteers to improve the condition of our waterways.

Putting Our Objectives into Action

Having a set of written objectives has provided a structure for organizing MVWQMA's work over the last 3 years. Through the formation of board subcommittees, we have been able to formulate specific ideas and then produce programs and materials that meet our objectives. Periodically, during board meetings, and especially at each annual membership meeting, we can revisit these objectives to see how we have done and where we need to focus increased activity.

Guidance Manual for Volunteer Water Quality Monitoring in Maryland

Developing technical guidance and supporting comparable methods for volunteer monitoring projects was one MVWQMA's first priorities and the subject of many early discussions. The Association decided early on that we would not strive for standardization among groups, but rather promote comparable techniques and protocols to look at data within and across watersheds. We also wanted to emphasize that the level of technical expertise needed depended on the goals of the volunteer monitoring group. Groups monitoring primarily for educational purposes would not need the same level of sophistication as groups that wanted their data used by government agencies. Further, we realized that government agencies would be more likely to look at volunteer-collected data that were based on methods that they helped develop. Therefore, our Protocols and Methodologies committee was cochaired by representatives from MDE and DNR. Their first task was to collect information on how groups in the state monitored different parameters and water bodies and to develop guidance for volunteers, based on existing methods and project goals.

The first edition of our Guidance Manual was produced early in 1995. To date, over 350 copies have been distributed to volunteer groups and teachers within Maryland. The document provides information on what types of waters are found in Maryland and why, where, when, and how to assess the state's water quality and watersheds. The manual is far from comprehensive or complete, but it is a significant first step toward promoting the use of comparable methods among Maryland's volunteer monitoring community.

Directory of Maryland Water Quality Monitoring Programs

Designed as a companion to the Guidance Manual, this document was compiled from surveys distributed to organizations, agencies, and schools throughout Maryland. It lists information on who is monitoring, what watersheds are being monitored, and what parameters are being studied. In this way, a person who reads the Guidance Manual to learn about monitoring Secchi depth can then find a list of programs that are currently monitoring that parameter. Also, someone interested in compiling data on the Potomac River can find a list of groups that collect data on that watershed. The survey also collected a variety of other information, including length of time programs have been monitoring, whether the program has a quality assurance plan, and who the primary data users are.

Our goal is to update the survey and the Directory, as well as the Guidance Manual, at regular intervals. Both documents are distributed together in a 3-ring binder so that updates can be mailed and inserted easily without having to recreate either document.

The Sampler

What organization is complete without a newsletter? The Sampler serves as the primary continuing networking and informational tool of the Association. It is a place for programs to highlight projects, recruit volunteers, seek advice, and offer suggestions. It is also a valuable publicity tool, serving to introduce potential members and funders to the Association. Although the goal is for this publication to be produced on a quarterly basis, since 1994, it has been published twice a year. Regular features of the newsletter include upcoming events announcements submitted by member organizations; Why I Monitor, a section devoted to the personal experiences of volunteer monitors; and Watershed Notes, which profiles community activity in a specific watershed.

Annual Workshops

Each year, MVWQMA holds an annual business meeting and workshop in a different part of the state. During these meetings, board members are elected and association members have an opportunity to discuss how the organization should proceed for the coming year. Through keynote and other speakers, these meetings have also provided an opportunity to hear various perspectives on volunteer monitoring. For example, past speakers from DNR, MDE, and the U.S. Environmental Protection Agency (U.S. EPA) have addressed members on the use of volunteer data in state water quality assessment, volunteer monitoring as a part of watershed management, and what's happening with volunteer programs around the country.

Each annual meeting has also contained a variety of classroom presentations and field training on topics such as quality assurance, fundraising, biological monitoring, habitat assessment, physical/chemical assessment, macroinvertebrate taxonomy, student programs, wetland delineation, vegetation surveys, urban monitoring, and data presentation.

Local Government Outreach

In an effort to increase and improve communication between local governments and to encourage collaborative efforts among jurisdictions sharing watersheds, the Association has embarked on an ongoing program of local government outreach. Work has included a day-long forum for county and state personnel that highlighted existing programs that utilize volunteer monitoring for resource management and offered time for participants to explore opportunities for joint ventures. During this forum, the entire afternoon was devoted to a roundtable discussion that enabled participants to begin honestly, and informally, discussing challenges and obstacles and to begin strategizing collaborative ways to eliminate or minimize those problems and promote the growth of volunteer monitoring on a watershed basis.

Participation in the Regional and National Volunteer Monitoring Communities

Since the Association's inception, members have participated in volunteer monitoring conferences and events at the regional and national levels. In 1994, board members from MVWQMA facilitated a discussion on forming a statewide association at the 3rd National Volunteer Monitoring Conference in Portland, Oregon. This year, MVWQMA is represented on the steering committee of the 4th National Conference which will be held in Madison, Wisconsin, in August 1996. We have also attended preliminary meetings with other Chesapeake Bay regional groups to discuss the formation of a regional volunteer monitoring organization. Perhaps even more important, MVWQMA serves as a source of guidance and support for groups in other states that want to form similar coalitions. Our experience hopefully will enable other states to get organized, adapting what is useful, learning from our mistakes, and applying what has worked.

Maryland Water Monitoring Council

This year, Maryland has embarked on the formation of the Water Monitoring Council to serve as a statewide collaborative body to achieve effective collection, interpretation, and dissemination of environmental data and to improve the availability of information for sound decision making on environmental policies and natural resource management. Modeled on the national Intergovernmental Task Force on Water Quality Monitoring, and spearheaded by Maryland DNR, the Council will establish a forum for all constituencies involved in watershed monitoring to come together_including volunteer monitoring. Members of MVWQMA served on the original planning committee for this effort, and the Association has elected two members to represent us on the permanent Steering Committee. It is important to note that both of our representatives are themselves volunteers and are serving as peers with resource managers from county, state, and federal agencies on this Council. Other members of the board will serve on the Council's work groups, dealing with a variety of issues including method comparability, framework, and interagency collaboration. This means that volunteers and volunteer_collected data will be included in discussions and decisions regarding monitoring in Maryland. It also means that volunteer monitors will be part of these discussions and decisions as they are happening.

MVWQMA's Future

The development of MVWQMA and its visibility over the last few years has ensured that the interests and perspectives of volunteer monitoring are addressed as part of overall monitoring issues at the state level. Over the next year, we will be focusing energy on recruiting new members and developing a more stable funding base, hopefully allowing us to hire part-time staff. The Association's membership has also identified analysis of volunteer data as a area of concentration so that information can flow from the monitors to the managers more effectively, thereby increasing the use of this information in watershed management and planning.

Acronyms

MVWQMA Maryland Volunteer Water Quality Monitoring Association

MDE Maryland Department of the Environment

DNR Maryland Department of Natural Resources

U.S. EPA U.S. Environmental Protection Agency

U.S. FWS U.S. Fish and Wildlife Service

National Cattlemen's Beef Association's Water Quality Information Project

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Partnerships come in differing shapes and sizes. In dealing with water quality, beef cattle operations will mostly be involved with partnerships at the watershed management level. There are also the partnerships that are forming at the national and state level among organizations and agencies. The focus of this presentation deals with the latter type of partnership.

However, there needs to be a clear understanding that some cattlemen are hesitant to participate in partnerships because there is a strong feeling they will lose control of their management options when they bring others into the process of making business decisions. Most beef cattle operations are on private lands where there is a vested interest in both property and water rights. Having complete control of these rights in the past make it difficult to understand why these rights should be tampered with in addressing broad environmental issues. Effective local watershed partnerships need to recognize the concerns of the property owners and ensure their involvement from the very beginning and not as an afterthought.

Grazing lands, the most extensive agricultural land use in the United States, and beef cattle feedlots are the basis for this industry and both have been perceived to impact water quality. The National Cattle

Association (NCA), through it's 1992 Strategic Plan on the Environment has recognized it's role as an association in water quality protection, as well as with other environmental issues. NCA initiated the Water Quality Information Program in 1992 as a positive action of the NCA Strategic Plan. The NCA was incorporated into the new National Cattlemen's Beef Association (NCBA) in January 1996.

The National Cattlemen's Beef Association Water Quality Information Project started with concerns over national water quality assessments and the lack of understanding the processes used to identify water quality impairments and the development of nonpoint source control programs. Phase I of the project evaluated national assessments and studied ten individual state water quality programs. The individuality of the state approaches to water quality and the ability of the state beef affiliate associations to address water quality issues suggested that the continuation of the NCBA Water Quality Information Program be supportive of state level efforts. Thus Phase II was initiated with the following goals and objectives:

Goal

To provide materials and leadership for a voluntary response among beef cattle producers to meet the challenges of water quality management as appropriate for local conditions.

Objectives

1. Promote a climate for livestock producers to function effectively in local water quality management programs at a level suitable to the state's problems and abilities. An emphasis to be placed on the state Beef Cattle Affiliate(s) program.
2. Conduct an information program that encourages voluntary participation and the implementation of management programs at the landowner's request and under his control.
3. Supplement existing NCBA resources and the resources of other water quality programs and partnerships with materials and NCBA training workshops.
4. Utilize approaches and materials suitable to a variety of livestock producer audiences.

During 1995, a survey of the state Beef Affiliate Associations (with 34 responses) was conducted. The responses emphasized the diversity among the states in terms of staffing, interests in water quality as an issue, and what the associations needed from NCBA in terms of support. Phase II recognizes these differences and suggests a number of ways to provide information utilizing existing NCBA resources and the resources of agencies and other organizations. NCBA participated in a number of national workshops and with other organizations in both legislative and program matters relating to water quality.

A major task in Phase II is a Water Quality Directory. It is in the process of being developed by a project team consisting of NCBA staff, state affiliate staff and beef cattle operators. The target audience is the beef cattle producer and the directory will address the following topics:

1. Background and rational for the directory,

2. Water Laws - national water quality laws and state water right laws,
3. Why cattlemen should be involved,
4. Self analysis/assessment,
5. Prevention, maintenance and corrective measures,
6. Management process approaches - watersheds, water basins, water authorities,
7. Lists of resources and assistance sources
8. Glossary

Efforts continue to utilize resources within NCBA to exchange information on successful programs at the state affiliate and individual producer levels. One very successful program is the use of the NCBA Environmental Stewardship Award winners which represent seven regions throughout the US. These seven winners are selected each year to exemplify beef cattle operation's inclusion of environmental goals in their buisness management. The use of electronic information systems, such as the world wide web and internet, is just beginning.

Finally, NCBA is working with a number of partnerships including the Grazing Lands Conservation Initiative, Know Your Watershed, Save Our Streams and the national Agricultural Water Quality Task Force. Partnerships make use of each others resources and the ability to reach different audiences, but the individuality of each partner needs to be respected in order to achieve success.

The Pork Industry's Environmental Partnerships

Jeff Gabriel, Director, Environmental Services
National Pork Producers Council

Thank you for the warm and generous introduction and a personal thank you to Carl Myers for inviting me to present at Watershed `96. As you are all aware the pork industry has been at the center of attention this past year. Given this attention we have had in the environmental area, I tell my family it's job security not job displacement.

The environment, not surprisingly, is one area we, in the pork industry, have identified as extremely important. How is the pork industry going to remain profitable, but yet respond and comply with all the environmental requirements now and in the future? And what, if anything, can producers do to minimize that impact? Will the public regain its trust in our industry to be sound land stewards? Those as well as other questions we must be willing to answer as our industry is dissected under the environmental microscope.

Agriculture and the environment have a dynamic and symbiotic relationship. Agricultural productivity depends upon a quality environment. Likewise, a quality environment depends upon the wise use of our natural resources. Although this natural link exists, the debates over agriculture and the environment often take on an "us versus them" mentality. It doesn't have to be this way.

Agricultural and environmental interests share a number of the same goals. Unfortunately, we've been on opposite sides of the table for so long, that we no longer stop find what we have in common. When the pork industry made the decision to be proactive on environmental issues, we started listening to what others had to say. When we began to understand the environmental needs of our producers, we recognized that we needed help in providing effective service and sound information. And most amazing of all, when we have asked for help we have found hundreds of people who are willing and able to help our industry meet the needs of our producers. Its a win-win proposition for us and for the environmental community. And it is the beginning of the pork industry's new environmental partnership.

Today's Pork Industry

The pork industry has changed dramatically during the past twenty years. In the olden days, you might expect to find a few hogs on every farm. Pork's profitability back then earned the hog the title of "The Mortgage Lifter." Today, the pork industry is still a profitable investment, but the picture of where hogs are raised has changed. The U.S. Census numbers estimate there are approximately 249,500 pork producers. Since that number include 4-H and FFA students who sell hogs at the county fair, our estimate runs closer to 180,000 active, full-time producers. When you look at those numbers, 7% of those producers produce 60% of the hogs. On the flip side, 62% of our operations produce just 5.5% of our nation's production.

The National Pork Producers Council is a trade association that represents 85,000 producers across the country. Our Council is made up of 45 state pork producer associations. Producers join their state or county pork producers group to gain membership in the National Pork Producers Council. The Council offers a variety of programs, both on the national level and through state associations that are designed to promote pork to consumers, improve the quality of our product, and increase producer profitability.

The Pork Industry's Environmental Programs

As an industry, pork producers are working to protect the environment. Our program involves a four-part approach to serving producer's needs and ensuring fair environmental policies. The components to our program are: 1. Research; 2. Education; 3. Policy; and 4. Law. While we are conducting individual projects within each of these areas, the grand design is to integrate these components into meeting the overall objectives of helping producers protect the environment and remain profitable. For example, research is needed to help shape policy decisions. Likewise, our research results will have to be an integral part of our producer education programs.

Our Environmental Partnerships

All of our programs are built on the principles of partnership and cooperation. There are four specific examples I believe should be highlighted. First, our industry developed The Guide To Environmental Quality In Pork Production to serve as a tool for our members to use in planning and managing their operations. The purpose of the Guide was to create an awareness within the pork industry about the key principles of environmental management. While we were developing the Guide, we sent copies to EPA, USDA, state water quality agencies, and a number of others for input and comment. This partnership in the development of educational materials helped us produce a better product and helped shape future educational programming.

Second, pork producers teamed up with SCS and Region VII EPA to build "The Choice Farm", an educational model emphasizing total farm resource management. The model shows how thirty different conservation and environmental practices can fit together in a total farm resource management plan. The Choice Farm has been featured at three major farm events that has allowed us to reach over 50,000 people with the total farm resource message.

Third, pork producers have teamed up with the EPA, SCS, ASCS, Extension Service, state water quality agencies, state departments of agriculture, and others to sponsor state livestock environmental workshops for producers. The programs have featured the producer's responsibilities under state water quality laws, what technical and financial assistance is available, and how producers can improve their nutrient management. In two years, our state associations have sponsored over 60 workshops that attracted more than 5,000 producers.

Finally, our next major step is the implementation of the pork industry's Environmental Assurance Program. Developing the program and materials used for teaching environmental responsibility involved local, state and federal government officials, allied industry members, producers, academics and environmentalists. This program is a training and educational program focused on changing environmental management at the farm level. We have teamed-up with state associations to implement this program. Under the program, producers will attend local Assurance Workshops to review nutrient management, facility management-including worker health and safety, air quality, and aesthetics and neighbor relations. This program has been well-received by state associations and producers.

From my perspective, Environmental Assurance has set the standard for the agriculture industry. Formal, voluntary environmental education, developed and delivered by the industry association has important social, economic, political, and environmental benefits. We won't replace Extension or other traditional delivery mechanisms, but will use these resources as part of our continuing education effort. Socially, our industry must demonstrate our willingness to protect the environment while producing healthy, nutritious pork. Economically, preparing for future environmental challenges gives us a competitive advantage against other livestock sectors and international competitors. From the environmental perspective, a message of environmental quality from the industry has more credibility with producers than the same message delivered by government or other sources.

How We Can Make Things Happen Together

Recent environmental events that have plagued our industry is a shock of reality we could have done without. Since 1991, the pork industry had been actively involved in increasing and heightening produce awareness about environmental issues. Although these events are not pleasant to hear or read regularly in the news, we must not be overshadowed with despair or angry. Episodes like those we experienced this past summer give us the opportunity to accelerate our efforts to demonstrate we are responsible land stewards. While aggressively adopting the latest technology or tools to better our environmental record, we must also not condone those who blatantly pollute.

Pork producers will continue to develop and implement environmental programs because we recognize our industry's responsibility and the needs of our producers. To be successful, however, we need the technical input of water quality agencies and conservation professionals to develop material and shape programs. We need financial resources-this is not a cry for help, merely a statement that our limited dollars cannot do the job alone. Financial partnerships leverage our producer's funds as well taxpayer dollars. And finally, we need ideas. The educational process depends on creativity and marketing. We know we don't have all the answers, so we are looking for people who can add positive input.

Our partnerships are a two-way street. We offer the opportunity to reach thousands of producers in a farmer-friendly manner. Its a win-win proposition for a new environmental partnership. The opportunity is ours.

HOW HIGH IS UP: Water Environment Research Foundation Develops a Practical Guidance Document for Conducting Use-Attainability Analysis

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The foremost goal of the Clean Water Act is that water quality should fully support aquatic life and human recreation wherever those beneficial uses are attainable. Initially, each state was responsible for identifying the beneficial uses for waters within their borders. Slowly, they began the overwhelming task of surveying and officially designating those uses.

By 1983, most of the waters of the U.S. were designated to support aquatic life and recreational uses. Many states had elected to make these uses the "minimum" standard for surface waters within their jurisdiction. In the event that the designation turned out to be inappropriate, EPA had provided a means for making adjustments: Use Attainability Analysis.

Use Attainability Analysis is a structured scientific assessment of the chemical, physical, biological conditions in a waterway. The comprehensive evaluation focuses on water quality, available habitat, flow regimes, and other factors which are necessary to support aquatic life. The detailed review also includes an analysis of social and economic impacts associated with attaining the designated beneficial uses.

After the 1987 Clean Water Act Amendments, EPA issued new regulations which required states to provide scientific justification wherever a surface water was not designated to protect aquatic life and/or recreation uses. A Use Attainability Analysis is required to meet the applicable evidentiary requirements. In addition, the classification decision must be reviewed every three years to determine if the "limiting factors" still apply or whether the stream designations should be upgraded.

In most states the aquatic life beneficial uses are fairly broad. Certain sub-classifications, such as warm vs. cold water and fresh vs. salt water, are also fairly common. But, in general, if a waterway is designated to protect aquatic life, it is assumed that all forms of aquatic life may potentially live there. As such, the water quality must also be high enough to support all species of aquatic life. Very few states have made official distinctions based on available habitat conditions, flow regimes, or other factors which determine which forms of aquatic life are most likely to colonize and flourish in a given lake or stream.

As the interest in water quality-based regulation increased, so has the interest in Use Attainability Analysis. One group wants to apply Use Attainability Analysis as a means of demonstrating that formerly undesignated waters are in need of greater protection. The other group wishes to employ Use Attainability Analysis to demonstrate that prevailing water quality standards are more stringent than necessary to fully protect the aquatic ecosystem. Use Attainability Analysis (UAA) serves both applications well.

The vast majority of UAA's completed since 1983 have been to redesignate unclassified waters to protect aquatic life. The rules for such a reclassification are clear: if any aquatic life is present in the waterway at any time then that existing beneficial use must be designated and protected. The evidence required is also relatively straightforward: biological surveys can be used to show that aquatic life is present.

When Use Attainability Analysis is used to demonstrate that a waterway cannot support aquatic life, regardless of water quality, the rules and required evidence are not nearly so simple. This probably accounts for why so few UAA's of this nature have been initiated and why even fewer have been successful.

There is a strong presumption that all waters of the U.S. could support aquatic life if water quality is good. The presumption may only be overcome by a very limited set of conditions. And, the evidence necessary to demonstrate these conditions must be gathered as part of a Use Attainability Analysis. These conditions, given in 40 CFR 131.10(g), are:

1. Naturally occurring pollution prevents use attainment

2. Flow conditions prevent attainment

3. Human-caused pollution prevents the attainment and cannot be remedied

4. Dams or other channel modifications prevent attainment

5. Physical habitat conditions prevent attainment

6. Cost of attainment would cause unreasonable social & economic impact

EPA has developed and distributed considerable guidance on how to conduct a Use Attainability Analysis. Most of this guidance focuses on how to design the structured scientific assessment of chemistry, aquatic biology, habitat conditions and the like. There is also guidance available for how to conduct an analysis of social and economic impacts.

While the available guidance does an good job of describing how to gather evidence, it does not tell the UAA-researcher how to interpret the evidence. Most important, it does not tell the local decisionmakers how to evaluate the scientific conclusions in order to set standards (beneficial uses and water quality objectives).

This is particularly problematic for those who seek to use UAA to justify less stringent regulations. In many of these cases, both the water quality and the habitat conditions are unsupportive of designated beneficial uses. The researchers must demonstrate that even if water quality were better, the uses would remain unattained because other conditions limit attainment. They must show that existing water quality does not cause or contribute to reduced density or diversity of species in the affected waterbody. And, in essence, this means they must "prove the negative."

It is appropriate to have a presumption in favor of environmental protection. And, it is appropriate to force the burden-of-proof on those who seek variances from accepted national standards. However, in such a decision system, it is also essential that clear thresholds of proof be established for when the burden has been met.

Imagine, for a moment, what it would be like to run a race where there was no defined finish line. Use Attainability Analysis is such a race. There are well-defined rules for initiating and conducting the review but, no fixed boundary for knowing when adequate proof has been presented.

The absence of decision thresholds, often referred to by scientists as "critical values," causes many Use Attainability Analyses to degenerate into arguments among the experts over how to interpret the data. The process often appears arbitrary and vulnerable to non-scientific (read: political) influences. More guidance is necessary to make Use Attainability Analysis a useful tool for watershed management.

The Water Environment Research Foundation (WERF), under grant from the EPA, commissioned a group of select scientists to develop better guidance for Use Attainability Analysis. Their recently published work provides more detail for how to design scientifically-sound UAA's. In particular, they reviewed dozens of successful UAA's conducted throughout the country and synthesized a model to guide other researchers.

Just as every waterbody is unique, so must every Use Attainability Analysis be designed on a site-specific basis. General models provide an excellent starting point but, success depends on customizing the model to local conditions, local stakeholders and local decisionmakers. There is no "cookbook" recipe for designing UAA. And, the absence of a standard formula frequently frustrates those who want to apply Use Attainability Analysis to their situation.

Recognizing the need to customize their model, the Water Environment Research Foundation commissioned a companion volume to their UAA Guidance. This is the companion volume. It was written by a team of UAA practitioners who have considerable "real-world" experience designing, executing, interpreting the structured scientific assessments called Use Attainability Analysis.

In addition, the authors have come to recognize that having good science is only half the battle. Convincing others that the science is good enough to justify a certain action is the other half. As a rule, successful UAA's do not wait until the end of the process to find out what's convincing. The process must begin with very hard questions to all of the stakeholders (including the regulators).

The questions should derive from the regulatory requirements and specific evidentiary demonstrations needed to meet those requirements. There is a strong tendency by everyone involved in UAA to avoid the tough questions. They may defer but never duck the responsibility. Ultimately, the questions must be answered in order to make a decision for or against designating or subclassifying a waterbody.

What questions? Questions like: when is a use "impaired?" When is a use "fully attained?" How do you resolve evidentiary conflicts (e.g., chemical exceedences but biology looks good)? How much adverse economic impact is too much? When is water quality "better than necessary to protect the use?" Like trying to define the difference between art and obscenity, Use Attainability Analysis can become a terribly subjective activity.

This document is structured to identify the key concerns which arise during a UAA and to suggest questions which should be asked, and answered, BEFORE the Use Attainability Analysis begins. This volume also contains recommended "critical values," called Decision Criteria, to help researchers and regulators design a study which will focus on the real policy issues. These decision criteria are intended to start the debate, not end it.

No one should consider initiating a Use Attainability Analysis without first understanding that the process will be long, expensive and frustrating. But, considering the stakes (on both sides), that's as it should be. Compared to the cost of installing advanced waste treatment where it may provide no benefit, Use Attainability Analysis is still the most cost-effective tool for developing regulatory alternatives despite the overall expense. Even though UAA's may run into hundreds of thousands (sometimes millions) of dollars, the approach can save up to $1000 for every $1 invested in comprehensive chemical and biological review of the watershed.

The secret is getting all the stakeholders (including the regulators) to participate in the design and conduct of the UAA from day one. From the outset, the participants must be willing to draw a line between acceptable and unacceptable proof. The issue of what constitutes "sound scientific evidence" is the focus of WERF's Practical Guidance Document for Planning and Conducting Use-Attainability Analysis (GUIDE).

The GUIDE is written to assist those who are considering whether and how to conduct a Use-Attainability Analysis. It is not so much a cookbook as it is a manual for asking the right questions. All existing UAA guidance is, unavoidably, too generic. Because a Use-Attainability Analysis focuses on highly sensitive environmental protection issues, they can generate considerable controversy. Minimizing the hostility depends on defining the decision process very early in the process. To do that, on a site-specific basis, requires that the participants ask and answer the right questions.

The GUIDE is divided into four sections. An introductory section lays out the rationale for doing Use-Attainability Analysis. Section two describes the planning process which governs the development of a UAA. The third section provides a hypertext system for defining the crucial regulatory requirements and scientific burdens-of-proof in a format which will facilitate the development of interagency groundrules for conducting UAA. In the final section, WERF's other UAA guidance document is summarized and indexed.

Framework For Watershed Management

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Background and Project Purpose

Federal, state, and local governments have spent billions of dollars over the past quarter century to establish criteria, tools, and programs for protecting and restoring our nation's water resources. Despite tremendous effort and corresponding successes in many areas, including reduction in point source pollution and remediation of sites contaminated by hazardous wastes, national assessments indicate that numerous problems and threats to public health and ecosystem integrity remain. The indicators are many, ranging from Pacific salmon population declines in the northwest to Giardia and Cryptosporidium outbreaks in public water supplies throughout the country.

Agencies and additional stakeholders in the management process are searching for alternative ways to use existing means to solve remaining problems, rather than creating even more regulations and programs. Many programs are giving renewed emphasis to watersheds as functional, hydrologically defined geographic management units for coordinating management efforts. Watersheds work well for organizing management because they are readily identifiable landscape units that integrate terrestrial, aquatic, geologic, and atmospheric processes. Numerous initiatives of several government agencies, however, have produced a myriad of watershed management protocols that are not entirely consistent and have led to confusion and difficulty in implementation. For the Water Environment Research

Foundation (WERF), the Cadmus Group, Inc. and the Center for Watershed Protection (Cadmus team) proposed a framework for coordinating and integrating watershed management among local, state, and federal participants.

Recommended Framework Elements

Nine essential elements are recommended for a unifying watershed management framework: (1) geographic management units, (2) stakeholder involvement, (3) a basin management cycle, (4) strategic monitoring, (5) basin assessment, (6) a priority ranking and resource targeting system, (7) capability for developing management strategies, (8) management plan documentation, and (9) implementation (Figure 1).

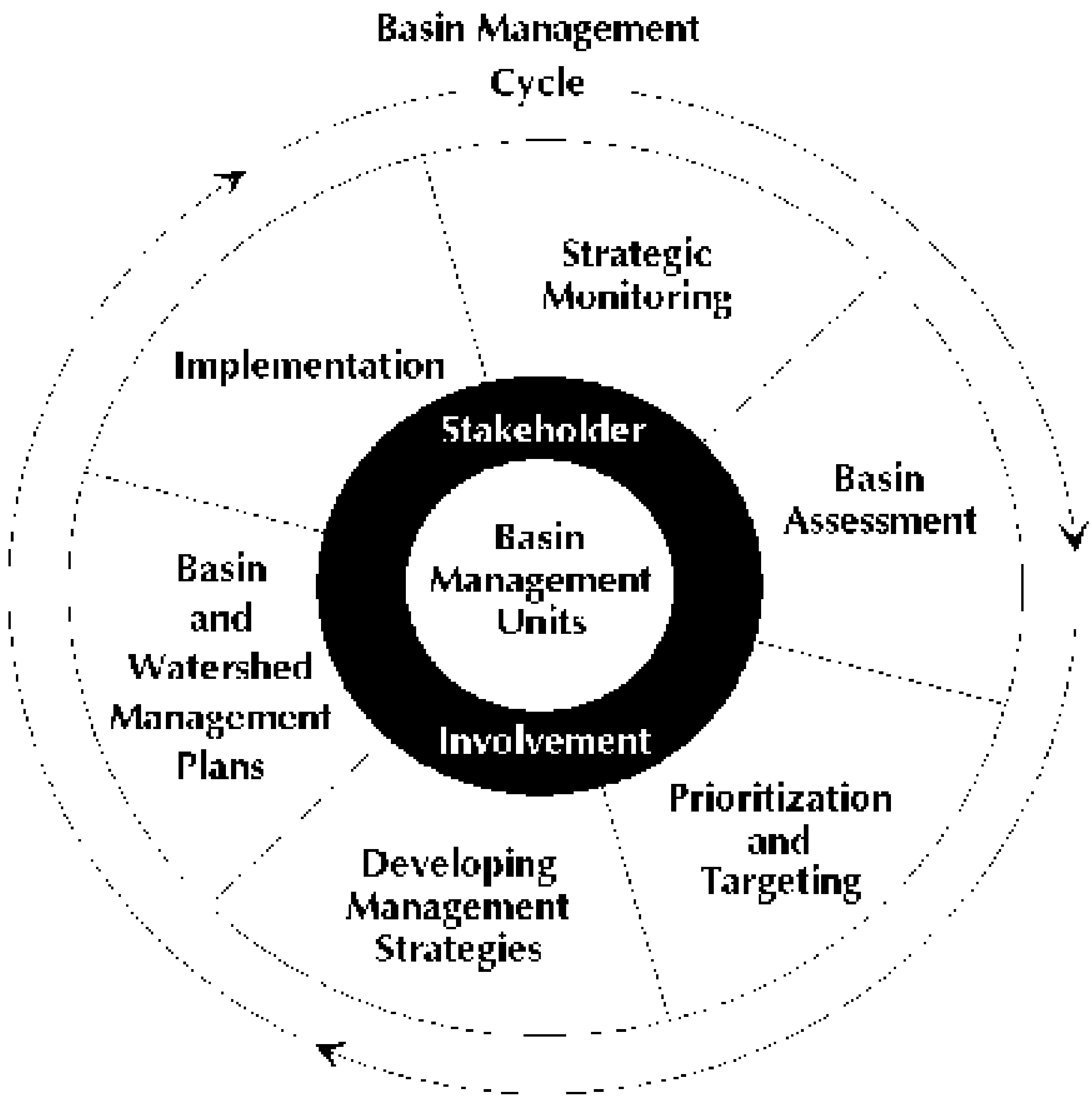

Figure 1. Nine essential elements of a watershed management framework.

Under the proposed framework, a state is divided into large, hydrologically delineated geographic management units called basins to provide a functional spatial unit for integrating watershed management efforts in a state. Smaller geographic units (e.g., sub-basins and watersheds) that nest within basin boundaries can be delineated to support coordination of activities at varying scales. Next, stakeholders are defined as any entity involved in or affected by watershed management activities within a basin management unit. Stakeholder roles and responsibilities are identified and coordinated for six core activities: strategic monitoring, basin assessment, prioritization and targeting, developing management strategies, management plan documentation, and implementation. A fixed time schedule for sequencing activities across basins throughout the state, called the basin management cycle, is determined by partners in the framework. The basin management cycle balances workloads for stakeholders over time, while still maintaining spatial focus. The cycle is repeated for each basin at fixed intervals to ensure that management goals, priorities, and strategies are routinely updated and progressively implemented.

Although the recommended framework is developed at the state level, the approach is not limited to state water quality programs. Rather, statewide watershed management frameworks should link all local, state, and federal efforts at the state level. The rationale for organizing framework development at the state level is based on a combination of factors, including legal structure, efficiency, effectiveness, and practicality.

The Process for Developing a Statewide Framework

The recommended process for developing and implementing a statewide framework is divided into four stages: (1) organizing statewide framework development, (2) tailoring statewide framework elements, (3) making the transition, and (4) operating under the statewide framework. The final WERF project report (Clements et al., 1995) lists a series of milestones recommended for each stage. Practitioners can use these milestones to plan their approach and measure progress toward implementation. Initial milestones reflect achievement of an understanding of underlying concepts of watershed and basin management, a step that is critical for recruiting partners and establishing a common purpose. Participants are then encouraged to build the foundation of the framework_determining who will lead, what methods will be used for building elements, how to maintain communication, and how resources will be directed toward the effort. The agreed-upon process should involve the definition of anticipated roles and responsibilities for each stakeholder in all six core activities (i.e, monitoring, assessment, prioritization, strategy development, plan documentation, and implementation), along with the organizational and administrative structures (i.e., management units, management cycle, and mechanisms for stakeholder involvement) for scheduling and carrying out those activities. Finally, recommendations for implementing the tailored statewide framework include developing a plan for transition from current operations and resolving issues that pose barriers to implementation.

Watershed Management Using the Framework Elements

A statewide framework should define and formalize teams or other organizational forums to facilitate stakeholder collaboration on the development and implementation of individual basin and watershed plans including, for example, a technical basin team, local watershed management teams, and a citizen advisory committee. Stakeholder groups are encouraged to work together through a series of steps, which are defined during statewide framework development (Figure 2). Steps are translated from the essential watershed elements, then tailored to meet specific needs. Stakeholders reach consensus on specific roles and responsibilities for each watershed planning and management step. The watershed planning cycle is iterative and establishes a long-term management structure within which local, state, and federal activities can be integrated.

Successful Collaboration Among Local, State, and Federal Stakeholders

Bringing key stakeholders to the bargaining table is often very challenging because of a historical lack of trust among many participants. Successful collaboration among responsible and impacted parties requires some form of incentives (e.g., flexibility in application of regulations, funding, and promise of progress on joint objectives). Adequate outreach should precede efforts to secure commitment to the framework. Emphasis should be placed on balanced participation and adherence to an agreed-upon structure and scientific, resource-driven planning process to determine priorities and implement solutions.

Targeting Management Resources to Priority Concerns

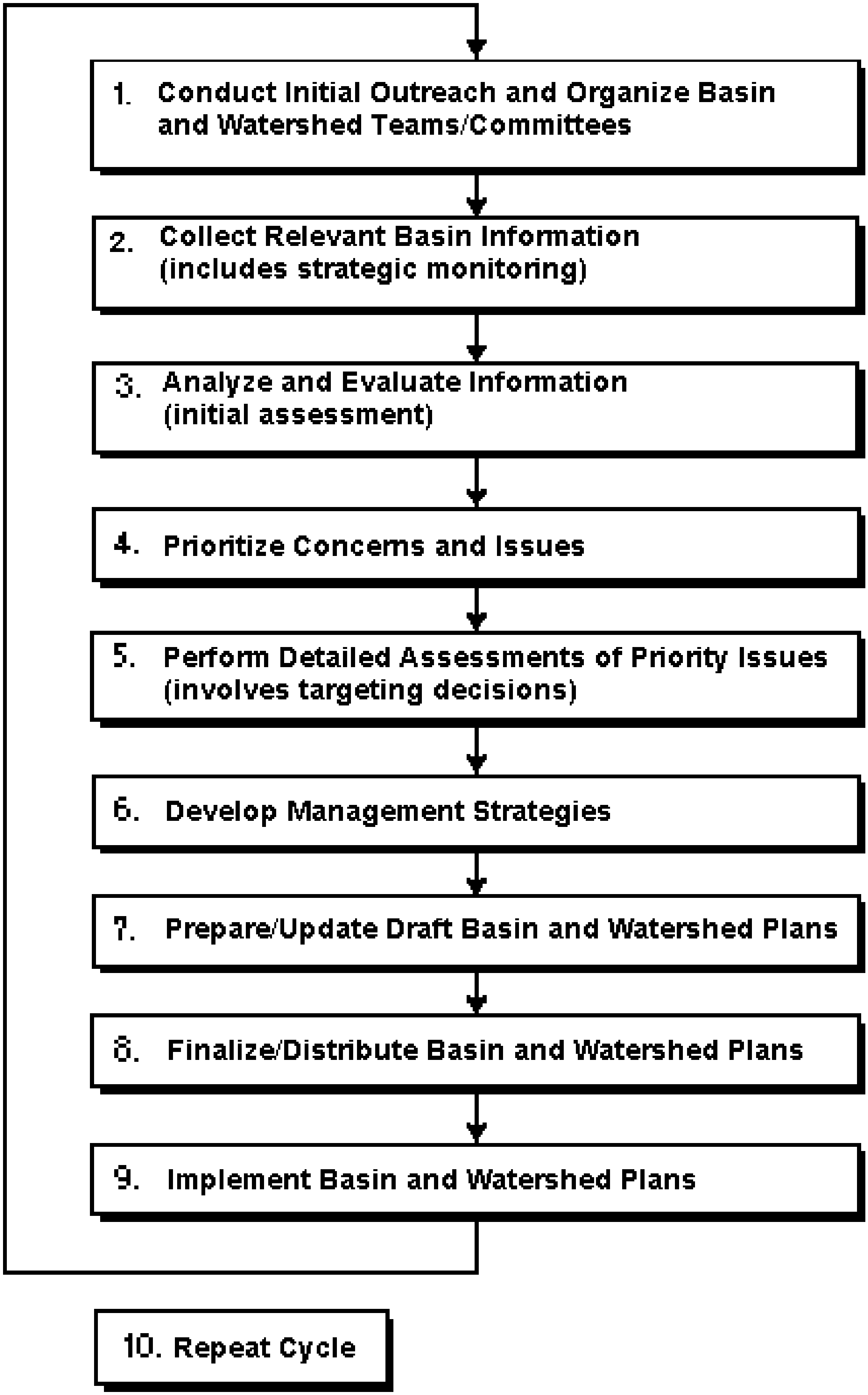

Figure 2. Operating steps under the statewide approach

A fundamental purpose of the framework is to distinguish during each cycle iteration which watersheds or issues within major river basins merit the most attention, because attempting to address all problems simultaneously is impractical in light of program resource constraints. Targeting resources to high-priority issues is a cost-effective management strategy that provides the largest overall environmental benefits. Targeting may, however, require additional flexibility from funding agencies and ultimately from legislative sources to achieve greater participation and coordination among nontraditional stakeholders.

Defining Local Roles Within the Framework

The most significant contribution of the framework to local implementation is the structure, guidance, and forum that it provides for coordinating discussions among stakeholders. The proposed framework calls for a nested approach to planning and documentation in which local watershed efforts are integrated with state and federal efforts. Local stakeholders must take the lead role in specifying local watershed management activities and implementation schedules, especially in sensitive areas such as land-use zoning and growth management planning.

Integrating Efforts Over Large Geographic Areas

The difference in scale between basin management units and local watersheds is typically large, sometimes exceeding two orders of magnitude. The proposed framework involves the use of entities such as basin coordinators, basin management teams, and basin stakeholder advisory committees to achieve integration. The flexible nature of the framework elements makes it possible to apply the principles at any geographic scale. A state agency may be in the best position to lead basin management efforts, whereas local or regional agencies will often be better suited to lead watershed management efforts. Federal agencies have a natural coordination role when basins cross state or national boundaries.

Technical Credibility of the Process

Local stakeholders are more likely to participate in activities if they believe that the process will result in more objective management plans than are currently produced. The environmental information that drives the watershed planning process must be comprehensive, of the best possible technical quality, and understandable to stakeholders. Pooling or leveraging of resources through the framework should create more opportunities for greater use of tools, such as geographic information systems (GIS), that enhance capabilities and lend greater credibility to decisions.

The Role of Legislative Action

The statewide watershed management framework should not become overly burdened with planning requirements mandated by legislation; rather, flexibility will allow for incremental and phased implementation so that activities with consensus support can get underway. Legislation can help clarify performance standards, but solutions should not be prescribed in the law. The framework should allow partners to establish the most cost-effective solutions for meeting performance standards. Legislatively approved flexibility should also extend to funding allocations; that is, let resource protection or restoration priorities drive allocation of resources to planning and implementation activities rather than restricting funds to specific, isolated activities under the purview of a single program.

Current Status and Future Direction of Statewide Frameworks

An increasing number of states (currently 17) are developing or have implemented statewide frameworks. Momentum is substantial at all levels of government for more coordinated action and stronger partnerships with a broader range of stakeholders. The public has clearly responded in a positive manner when the opportunity to participate meaningfully has been extended to them. Legislative barriers have not prevented the implementation of successful statewide frameworks. Many federal and state regulatory agencies have demonstrated a willingness to extend direct assistance and flexibility to promote watershed approaches. Furthermore, framework development in several states is beginning to emphasize multi-objective goals, whereby both natural resource and economic sustainability are recognized. There has never been a better time for local agencies to consider the use of a comprehensive watershed management framework.

Several next steps are recommended for facilitating watershed management framework development and implementation. Given the current economic climate in which additional infusion of capital resources is unlikely, partners in the watershed management process should focus on practical, cost-effective actions that will engage the public directly to increase confidence and commitment:

Stakeholders should not wait for legislative mandate or solution. Stakeholder participation is not based on regulatory requirement. Rather, the statewide framework depends on its ability to successfully promote collaboration based on complementary objectives and cost-effectiveness. The first step is to begin scoping the configuration for a framework in your state.

Managers can commit to support new functional relationships. Implementing a statewide framework will require many government agencies to move from a traditional guidance-based, program-centered approach to a system that requires greater flexibility. Agencies will need to recognize resource protection and restoration priorities and opportunities and respond accordingly to achieve buy-in and participation of local partners that want management efforts tied to tangible natural resource benefits. Commitment from top-level managers will encourage state and federal agency staff to support the team concept and operate cooperatively with local partners rather than from a top-down approach.

Local partners can implement regional-scale watershed planning and implementation programs. Local governments can initiate local or regional watershed forums that operate in tandem with a statewide framework. Local activities can be synchronized with any existing basin management cycle; in the absence of an existing statewide framework, a local management cycle can be developed, which would demonstrate the benefits of the approach to potential statewide partners.

Agency stakeholders can revise guidance to encourage statewide watershed management framework development. All agency stakeholders should review guidance or policies that restrict or impede stakeholder participation or any other aspect of watershed management framework development and implementation. Identifying areas where flexibility can be enhanced will likely encourage others to support the approach.

These steps can serve as catalysts for more detailed framework development. The authors hope that this paper restores and supports the vision of those frustrated with the current status of our ability to balance protecting the environment and meeting other community needs.

Establishing Watershed Management Process and Goals

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

In the United States, water quality goals are defined in terms of the designated use of the water body based on which water quality standards for the water body are defined. The statutory water body uses specified by the CWA include aquatic life protection and propagation, recreation in the water body, and human health. When states designate water body uses such as the statutory uses of aquatic life protection and propagation and recreation as well as special uses such as drinking water supply, irrigation, etc. considerations must be given to whether such uses can be attained. If the state does not intend to designate uses that would comply with the goals of the Clean Water Act, the Use Attainability Analysis (UAA) must be performed to justify the downgrade of the use. The same study can and should be used to select the watersheds needed watershed management and to establish water quality goals.

Water Quality and Watershed Management

Even though point source control programs defined by the BAT effluent standards have been essenti-ally completed, an appreciable number of surface water bodies and coastal waters are still not meeting water quality goals. This portion may actually increase when recently issued standards for toxic contaminants (US EPA, 1992, 1993 and 1994) in water and sediments are fully enforced. One reason for this situation is the fact that many water bodies are impacted by unregulated mostly nonpoint sources of pollution, by past discharges which contaminated the sediments, by changes in hydrology of the watershed as a result of urbanization, drainage and development and by physical alteration of the aquatic habitat. In a situation where the water quality goals are and/or will not be met after implementation of mandated point source controls, water quality and watershed management and protection should be considered. The watershed management approach "provides the framework to evaluate a natural resource problem using a natural system approach. It is well suited to track holistic cause-and-effect water quality relationships since it can link upstream uses with downstream effects."

Integrated Approach

Although many environmental factors have been instrumental in the evolution of an aquatic ecosystem, Karr et al. (1986) have documented that these factors can be grouped into five major classes: chemical, biological, hydrological, habitat, and energy. Altering any of these factors and parameters will have an impact on the ecosystem and the biota which is its integral component. This obviously leads to an integrated approach to point and nonpoint pollution abatement. The integrated approach to pollution abatement must be emphasized; sole reliance on control of some sources and leaving other sources unregulated and uncontrolled is counter-productive and may lead to inefficient and sometimes unrealistic solutions. To the biota residing in the receiving water body it does not matter whether the pollutant originates from a single source, multiple sources, point or nonpoint sources. A control of a single factor as well as a simplistic approach may fail an attempt to remedy water quality and ecological integrity of the aquatic system. The ecosystem integrated approach differs from past technology driven approaches (Committee on Wastewater Management, 1993).

Use Attainability Analysis and the Planning Process

If a water body has been classified as partially supporting or not supporting the designated use the States or designated agencies perform an Use Attainability Analysis (UAA) to determine the proper use of a waterbody. The Use Attainability Analysis is a structured scientific assessment of the factors affecting the attainment of the use which may include physical, chemical, biological, and socio-economic factors. A manual on the Use Attainability Analysis has been published by the Water Environment Research Foundation (Novotny et al., 1996).

The process of the Use Attainability Analysis is the most important planning component of the integrated approach to environmental protection of water resources and their most important beneficial uses (aquatic life and human health protection). The logical steps evolved from the Clean Water Act and subsequent regulations (for example, 40 CFR 131). Based on the UAA it is possible to modify or change non-existing designated water use or establish subcategories within the designated uses. There are six reasons listed in the regulations (US EPA, 1983, 40 CFR 131(g)) which allow a downgrade and/or a modification of the use which include natural and/or irreversible man-made causes as well as socioeconomic reasons (wide spread adverse socioeconomic impact due to the cost and/or other socioeconomic consequences of remediation).

A Use Attainability Analysis has three components (U.S. EPA, 1983; Novotny et al, 1996): (1) Water

Body Assess-ment; (2) the Total Maximal Daily Load (TMDL) process; and (3) Socio econo-mic Impact Analysis. Figure 1 shows schematically UAA steps as they would be used in targeting watersheds for management.

If nonattainment of the use is caused by natural water quality contamination and/or past untraceable pollution discharges and/or unregulated nonpoint sources and/or irreversible physical alteration of the habitat, then the society (i.e, government at all levels or public management institutions) may be responsible for remediation. The management agency can make the following decisions:

1. Improve the waste assimilative capacity and restore the water body and its habitat (typically when nonattainment is caused by past physical alteration of the habitat or by sediment discharges from unregulated sources); and/or

2. Expand the regulation of discharges to include presently unregulated nonpoint sources; and/or

3. Use economic incentives and pollution load trade-offs to induce abatement of unregulated sources; and/or.

4. Accept the fact that the designated use is not attainable and downgrade or modify the use; and/or

5. Rely completely on mandated point source controls.

Alternatives 1-3 will require a Watershed Management Plan and establishment of the Watershed Management Unit. Alternative 4 is acceptable only if natural causes are such that the designated uses can not be attained or when all possible remedial actions were found as being technically unacceptable and/or causing wide spread adverse socio-economic impact on the population. A downgrade of the designated water body use would essentially convert a water quality limited water body to that which is effluent limited. Alternative 5 for water quality limited water bodies, though still common and preferred by some state regulators, is also not acceptable since it would force expenditures upon the regulated dischargers that might not bring about the expected water quality benefits and the resources on clean-up would be used inefficiently.

Watershed and water quality management using public funds makes sense only if for the water body in question, water quality and ecological integrity goals can not be achieved by application of mandated effluent treatment technologies (BATs) pursuant to Sections 301 and 306 of the Act for point sources and application of enforceable Best Management Practices for nonpoint sources. Such water bodies are classified as water quality limited. For effluent limited water bodies, water quality goals can be achieved by enforcing NPDES permits and enforceable BMPs with subsequent monitoring of compliance.

The impaired waters definition introduced by the EPA specifies water bodies at which water quality goals cannot be achieved and uses attained without additional actions to control nonpoint pollution. According to the proposed Water Pollution Prevention and Control Act State may expand the impaired watershed to include waters (a) threatened with impairment; or (2) an Outstanding National Resources Water (ONRW) body. An impaired watershed includes all land areas contributing to the water body which has been declared as impaired.

In the water quality-watershed management planning process the following alternatives approaches should be considered concurrently by the UAA:

1. The entire burden of abatement is achieved by reduction of loads from regulated point sources only, by implementing further reductions over those mandated by effluent (technology based) limitations. This alternative will mostly rely on "discharger pays" principle, i.e., the dischargers are made responsible for the additional cost of the pollution load reduction. Point - point source waste load trading (transferable waste load allocation) may provide the most optimal allocation of allowable waste loads among the regulated point sources.

   Due to the fact that reduction of nonpoint loads is difficult to enforce and requires generally public funds to be given as incentives to nonpoint dischargers, the alternative of putting the entire burden of clean-up on regulated point dischargers is favored by the regulators.

2. The required pollution load reduction is achieved by an additional control of both point (regulated) and nonpoint (unregulated) sources. This approach will require a mix of "discharger pays" and "benefits received" payments and economic incentives. The planning process should consider trading of allocated waste loads between the point and nonpoint sources.

   The "benefits received" funding approach is feasible when there is a "willingness to pay" by the beneficiaries of the improved water quality. Such groups range from general taxpayers who are willing to accept increased taxes and fees for water quality improvement to riparian property owners on a particular water body.

3. Water Body Restoration which includes enhancement of Waste Assimilative Capacity and/or riparian land (wetland) acquisition and restoration. This approach again requires mostly funding which is based on the "benefits received" rather than "discharger pays." However, in cases where a point source of past contamination of sediments has been identified and the site has been declared as hazardous the discharger can be made responsible for the cost of the water body restoration and in-situ clean-up.

Figure 2 shows a concept of optimal allocation of the three categories of abatement in a watershed plan. It should be emphasized that for point sources abatement only incremental costs over the BAT technology based mandated abatement should be considered. It was already established that the BAT point source controls are affordable and, according to the "discharger pays" principle, the point source dischargers are responsible, within their economic means, for the cost of abatement.

On Figure 2 the point WAC(0) represents the waste assimilative capacity of the receiving water body adjusted by considering the nonpoint (unregulated) discharges. If no watershed management is considered the mandated (BAT) point discharges would cause the total daily load to be EWQ(0). The solid line from EWQ(0) represents the cost of further reduction of regulated point discharges. To reach WAC(0) would require additional expenses on point source clean-up, mostly borne by the dischargers, corresponding to the point EWQ(m). The dashed line starting from WAC(0) represents the cost of WAC enhancement and/or clean-up of unregulated nonpoint sources. This cost is borne by public and/or by regulated dischargers in a form of point-nonpoint trade-offs. If the WAC is increased WAC(i) or unregulated nonpoint source loads reduced by the same amount at a cost to the beneficiaries represented by the point C(wac) the additional point source control can be accomplished at a cost C(ps)and a total cost of C(t). An optimum allocation of resources may be reached when both public and private financing as well as point-nonpoint trade-offs are considered.

A watershed management plan should consider innovative funding and seek additional funding sources. An example of the small increase of automobile license fees in Wisconsin for funding of abatement of nonpoint sources is an innovative funding approach that retains the characteristics of "discharger pays" principle and provides sufficient financial resources for nonpoint source abatement, including remediation and restoration of water bodies impacted by nonpoint sources. In Florida, funds for riparian land acquisition along several important water bodies are derived from a fee on land transactions. Over $300 million were generated for wetland restoration and flood plain buffer zones in the St. John River Water Management District.

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Use of Watershed Concepts to Address Sanitary Sewer Overflows1

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

A sanitary sewer overflow (SSO) is a spill of raw sewage from a separate sanitary sewer collection system that occurs before the sewage can reach a treatment plant. SSO types include basement backups, and discharges from manholes onto streets or into streams.

Sanitary sewers are intended to carry all of the wastewater put into them to a treatment plant. Chronic SSOs, therefore, are often symptoms of sewer collection system deterioration, improper pipe connections, or inadequate size. Chronic SSOs often occur during wet weather conditions when rain, snow melt or ground water enter and overfill a system through improper connections to houses and businesses, and breaks in sewers and manholes. Undersized pipes and pumps, and blockages from roots and debris can also cause SSOs.

SSOs can present health and environmental risks. They can also damage property including home basements, and cause utility customer complaints. While the national scope of this problem is not well known, many sewer systems are believed to overflow. The U.S. Environmental Protection Agency (EPA) is examining the problem of SSOs, both because they are prohibited under the Clean Water Act, and because the combined SSOs from many communities could affect public health and water quality. Considering SSOs as an urban watershed pollution control problem offers the potential to manage SSOs from many sources and communities in a coordinated and cost-effective way.

Sanitary sewer collection systems represent a significant portion of the nation's investment in urban wastewater management. The collection system of a single large municipality is an asset worth billions of dollars and that of a smaller system could cost many millions to replace. Rehabilitating sewers to reduce or eliminate SSOs can be expensive, but the cost must be weighed against the value of the asset and the added costs if the collection system is allowed to deteriorate further. Ongoing maintenance and rehabilitation add value to the original investment by maintaining the system's capacity and extending its life. The costs of rehabilitation and other measures to correct SSOs can vary widely by community size, and the type and condition of the system. Those being equal, however, cost will be highest in communities that have not put regular preventive maintenance or asset protection programs in place.

SSO Policy Dialogue

In recent years the Agency has improved its traditional process of developing policies and regulations by increasing the use of consultation and consensus-building with people and groups outside the Agency. These collaborative efforts improve EPA program effectiveness and foster better public understanding and acceptance. "Policy dialogues" are one kind of consensus-building process. The objective of a policy dialogue is to obtain advice, and sometimes consensus recommendations, on policy issues through a series of public meetings involving a balanced group of affected interests, or, "stakeholders." If a consensus recommendation is achieved, the Agency gives it the highest possible consideration.

A number of interested stakeholders have asked the EPA to develop a national policy to ensure that SSOs are addressed more consistently and effectively under the National Pollutant Discharge Elimination System (NPDES) program. In December 1994, EPA established an advisory committee and initiated a policy dialogue to address these issues.

The policy dialogue is exploring ways to enhance the performance of sanitary sewer collection systems and thereby reduce SSOs. The Agency will evaluate and incorporate watershed approaches into these efforts. The policy dialogue has already recommended an outline approach attached as Figure 1. While details of the diagram will be refined, it suggests several concepts, including:

- Minimum Operational Principles - Operational principles appropriate to collection systems can be identified. These will help prevent system deterioration and other causes of SSOs.

- Screening Process - When SSOs occur and are reported, a screening process can identify the appropriate response. In the approach suggested by Figure 1 an evaluation of health and environmental risks with other factors is used to identify two classes of SSOs. The first calls for a short-term response, while the second class is evaluated in the context of additional planning.

- Short-term Response - SSOs presenting an immediate risk to human health or the environment, or that can be addressed by modifying operating procedures without large capital costs are addressed through a comprehensive site-specific remediation plan.

- Long-term Planning - SSOs presenting no immediate risk to human health or the environment, or which cannot be addressed without incurring large capital costs, can be evaluated and ranked in the context of detailed and long-term remediation plans. The approach provides two options for developing a long-term plan to address SSO problems. Under the first option, the long-term plan is developed in context of a comprehensive wet weather watershed evaluation. Under the second option, a long-term plan is developed independently of watershed considerations.

Watershed Considerations

In the United States, urban watersheds play an important role in pollution control because of population density. About two-thirds of the nation's population lives in urban settings, yet urban lands account for only 2 to 4 percent of the nation's land area. Also, much of the nation's urban population is found near oceans or the Great Lakes. Polluted urban drainage to these valued water bodies can significantly impair their quality, and the high population in these areas subjects urban waters to significant contact and use.

Since urban watersheds are subjected to several pollutant sources, urban municipalities are faced with multiple water pollution control objectives, particularly during wet weather. The municipalities may need to control discharges from sewage treatment plants, sanitary sewer overflows, storm drains, and overflows from "combined sewers" which carry mixed sanitary sewage and storm runoff. Challenges associated with applying watershed principals to these discharges include:

- Using regulatory and non-regulatory tools to optimize coordination among urban municipalities.

- Providing a framework for identifying control priorities among the various urban discharges in a watershed.

- Providing the regulatory flexibility to ensure that resource uses correspond to priorities.

- Ensuring that municipalities have adequate institutional frameworks (e.g., funding, legal authorities, and staffing) to address priority pollutant sources.

Applying Watershed Principles to SSO Controls

Although watershed planning may increase the planning cost and start-up time required to implement control strategies, its appropriate use can improve cost-effectiveness and bring greater environmental and health benefits. The policy dialogue has agreed to introduce watershed concepts into several key SSO areas, including:

- Monitoring.
- Discharge Locations.
- Discharge Standards.
- Operational Partnerships.

Monitoring

While the location of some SSOs is well known, others are hidden underground and discharge only under wet weather conditions. This is particularly true of some older sewer designs such as "common trench" systems, which have a high potential for overflows. Watershed management fosters coordination of water quality monitoring efforts. As an example, storm sewers and sanitary sewers usually serve the same areas. Efforts to find and characterize storm sewer discharges can also find SSOs. This is doubly important because SSOs leaking into storm sewers can cause high levels of fecal coliform and bacteria.

The shifting emphasis from traditional end-of-pipe water quality monitoring to ambient monitoring and other performance measures applies to SSO programs, too. Ambient monitoring combined with performance measures, such as beach and shellfish bed closures and restricted recreational and commercial activities, can provide a more thorough picture of water quality conditions and related health risks. Ambient monitoring can help identify priority water pollution control projects.

Discharge Locations

One proven approach to environmental risk management is to move discharges from high-risk areas to lower risk areas. This principal can be applied to SSO management by providing relief discharge points to relatively low-risk locations during emergency and other anticipated overflow conditions. The policy dialogue is considering the use of such constructed discharge points called "wet weather facilities" to reduce basement backups and SSOs to streets and other public areas, and sensitive receiving waters.

Discharge Standards

Remediation of severely deteriorated collection systems can be expensive since, typically, comprehensive remediation aims to reduce peak flows and to manage overflows. Several large municipalities with such systems have estimated that comprehensive remediation will cost each more than $1 billion. Other municipalities estimate these costs to be hundreds of millions of dollars. One significant project cost factor is the required level of treatment for any discharges authorized from "wet weather facilities." Selection of the level of treatment as part of a watershed planning process will be important in determining how some municipalities use limited funds for water quality improvement projects. A goal of the NPDES program is to allow the use of limited funds to correspond to water quality priorities.

Operational Partnerships

In many urban sewerage systems, the ownership and responsibility for operating and maintaining the collection system is split among several municipal entities and the public. Often a special district or other municipal entity has responsibility for operating treatment plants and major components of the collection system, such as interceptors and pumps stations. The municipal entity with land use authority often retains responsibility for collection and connecting sewers. Typically, however, "service laterals" which connect sewers to privately-owned buildings are privately owned. Loose, badly-designed and broken building laterals can allow large flows of ground water and rain water to enter the sewers during wet weather, causing SSOs. Municipalities often report that more than 50 percent of the leakage into their collection systems is from building laterals. The policy dialogue is exploring ways to encourage partnerships among collection system owners to encourage public programs to address problems with service laterals, which could include maintenance standards and oversight.

Further, municipalities will benefit from coordinating monitoring and remediation efforts. The policy dialogue is exploring ways in which to encourage effective partnerships between the different owners of a collection system to ensure that adequate preventive maintenance occurs and, where rehabilitation efforts are necessary, the most cost-effective solutions are employed.

Managing Stormwater Runoff: A New Direction

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Introduction

It is easy to see, as watersheds are converted from natural and agricultural areas to urban developments, that changes in land use and hydrology can trigger a corresponding cascade of adjustments that occur downstream. Because of more efficient delivery systems that are part of the urban development infrastructure (e.g., curbs and gutters, and storm sewer systems), an increased volume of stormwater runoff reaches receiving streams quicker and with greater velocity. This increased runoff can cause severe degradation, including stream channel erosion, sedimentation, flooding, physical destruction of biota, and loss of stream and riparian habitat. Because the hydrology of a watershed is a closed system, with increased surface runoff there must be a decrease in the amount of baseflow. The stream and its aquatic habitat are therefore subjected to larger and more frequent high flows, and lower baseflows.

The intent of most stormwater management laws are to control the hydrologic peak of storm events to prevent flooding and protect the physical and biological integrity of receiving streams. This paper addresses two major concerns with the present method of implementing stormwater management measures: where impacts to streams are measured and what factors are considered in the design process.

Concerns with Existing Stormwater Management Programs

Presently, the point of investigation for modeling the effects of stormwater management structures is usually at the property line of the site under consideration. A problem with this methodology is that potential impacts to the stream are rarely, if ever, considered. In fact, there is no provision in most stormwater regulations to identify the stream that will be receiving the stormwater. It is not clear how individual streams can be protected under the current regulations if they are not investigated during the planning and design phases of management.

The second concern is the focus on controlling the hydrologic peak of storm runoff. This design criteria does not normally result in practices that reduce runoff volume and can still result in bank full flows in the active stream channel for protracted periods. These high flows can result in the erosion of the channel and stream banks. Channel morphology can change very rapidly, often resulting in deep channels with very steep banks, the loss of ripples and natural meanders, and, in some cases, a complete loss of habitat.

Based on the above observations, we must conclude that many existing stormwater management programs do not always meet the objectives of stream protection and water quality enhancement. In fact, there is evidence that current programs can adversely effect stream channel erosion rates and produce additional sediment pollution. McCuen (1979) found that, even when the decrease in natural storage capacity of watersheds (infiltration, interception, and depression storage) was offset by stormwater quantity control measures, there is an increased volume of direct runoff that remains uncontrolled.

In recent years, due to the focus on restoring the Chesapeake Bay, water quality concerns have been addressed in Maryland's stormwater management program. The problem with focusing on water quality control is that there is no comprehensive definition of what exactly it means. Therefore, it is difficult, if not impossible, to construct water quality goals for stormwater management. Traditionally, water quality control has meant one of two approaches: the use of a particular removal efficiency met with specified design standards or the adoption of "rule of thumb" practices that are assumed to provide some level of pollutant removal.

An example of the first approach can be found in the EPA guidance on management measures for use in meeting the requirements of Section 6217(g) of the Coastal Zone Act Reauthorization of 1990. This guidance document (which originates from Delaware's regulation) requires a design standard of 80% average annual removal of total suspended solids (TSS). And example of the second approach is the requirement for infiltrating the first half inch of runoff over the impervious area of the drainage area of concern. This criteria is used quite often in Maryland where natural wetlands are receiving stormwater runoff. Unfortunately, there is little or no direct relationship between these design standards and the protection of streams impacted by development. According to EPA (1993), 80% removal of TSS was selected because it "is assumed to control heavy metals, phosphorus, and other pollutants." As far as the use of "rule of thumb" methods, there is only the assumption that the use of a particular practice will control the hydrology to a point that mitigates impacts. There is no proof that this is the case. A procedure is needed that focuses on the receiving stream rather than on design criteria. This approach would be better suited to meet the intent of stormwater management laws.

Proposed Modifications to Stormwater Management Programs

The current nationwide focus on comprehensive watershed management, cumulative impacts, and biological criteria for water quality standards, presents an opportunity to re-examine the basic assumptions and intent of stormwater management regulations and to recommend broad based changes that will refocus stormwater management programs. To truly manage stormwater runoff and protect streams, we must adopt an approach that considers the watershed as a system and focus on the total impact runoff will have on the streams. This approach starts with a greater consideration of watershed hydrology and of the point at where the hydrology and stream impacts are measured. The primary goal of managing stormwater runoff should include the protection of natural stream and biological characteristics. With this new approach, physical characteristics of streams would be used as limiting factors that would determine how stormwater management practices are designed at a development site. This method would also demonstrate that non-structural practices can be tightly woven into the same design framework and have the potential to result in lower implementation and maintenance costs.

The newly proposed goal of stormwater management should be to limit the post development, bankfull flow frequency, duration, and depth to pre-development values. These criteria replace the control of the 1-year storm which is a surrogate for controlling channel erosion. The new goal could also just be used as a check to verify compliance with bankfull flow requirements, once the stormwater management design for a development is completed.

Two terms, bankfull flow and active channel, should be defined before proceeding. For bankfull flow, a definition similar to that by Wolman and Miller (1960) can be adopted. Their definition for bankfull flow is the flow event that controls the geometry of the channel which would relate to flows that result in the covering of unconsolidated point bars. An active channel is a short-term geomorphic feature subject to change by prevailing discharges. The active channel must be the primary factor in stream analysis in watersheds that have undergone periodic urbanization events, since the geometry of the stream channel may be quite complex and have numerous benches.

Consideration must be given to where the criteria will be evaluated. The idea is to protect the channel downstream from the development site as well as at the immediate point of discharge from the property to the receiving water. To accomplish this, some point downstream of the development site must be selected for the evaluation. This location should be chosen based on the relationship of the flow in the receiving water to the flow from the site in its developed condition (without any controls). For now, we propose a 10:1 ratio of peak discharge from the 1-year storm for the developed site to the discharge in the stream for the same frequency storm. This means that the point of investigation would be a location downstream of the development site at which the peak discharge from the 1-year storm would be equal to 10% of the peak discharge in the stream. Bankfull flow would be determined at this downstream point and at the point of discharge from the property into the receiving stream. This would give two locations at which to meet the above bankfull flow volume criteria. If the discharge is less than 10 % at the site, then only one point of investigation is needed. Once the criterions are set, stormwater management controls at the site would be designed to meet the goals at these two locations.

The components of a stormwater management program (design criteria, environmental site design practices, waivers . . .) cannot be modified independently of one another. They are all integral to successful implementation of the program. The goal is to control the volume and timing of flow from the developed site so that it does not degrade the stream channel and habitat. Measures such as forest buffers, open section roads and swales all effect the volume of runoff that leaves a site and the timing of hydrographs. Currently, the Natural Resources Conservation Service (NRCS) methods are the required design tools in many states. We may need to re-examine the capabilities of these methods to meet our goals. The rule of thumb with the NRCS methods are that they predict peak flow more accurately than volume. A number of methods exist that integrate both water quantity and water quality. The EPA SWWM model and PSRM-Qual, the latest version of the Penn State Runoff Model, are good examples.

Economic Considerations

During this time of fiscal restraint and anti-regulatory attitudes, any newly proposed regulation is regarded with suspicion, if not hostility. However, we believe that this proposal, if implemented, will benefit both developers and local jurisdictions in a variety of ways. It will produce a win-win situation for both the economy and the environment.

The initial economic benefit of the proposed regulation will go to developers and their customers. Once the stormwater management designers learn how to apply the new regulations, design costs should decrease as the focus of the program shifts away from structural BMPs. In addition, the developers will realize significant savings on construction costs. The use of traditional, more expensive stormwater practices will be discouraged. These practices include closed section roads with curb and gutter; storm drain systems with concrete pipes, manholes and outlets, and detention, retention and infiltration ponds. Practices such as riparian buffers, proper grading, surface roughening, open section roads, and clustering will instead be used to reach stormwater management goals.

Local jurisdictions will also benefit financially. Many of these jurisdictions currently have long-term burdens of inspecting and maintaining ever-growing numbers of structural BMPs. These costs can be substantial but are frequently under funded by public works departments with tight budgets and limited personnel. As a result, these costs are being passed on to the future. In addition, if maintenance is not performed, there may be a serious threat to public safety as these ponds begin to fail. Using non-structural, environmental site design practices can produce a sharp reduction in growth of these maintenance activities. The use of natural systems to augment or replace the current stormwater management structures will significantly reduce the cost and magnitude of required maintenance for future stormwater management structures. For example, forested buffers will only improve over time with little or no maintenance. Prince George's County, Maryland is now conducting a low impact development project because they have reached the conclusion that they cannot afford the maintenance on stormwater management structures now in place, much less the new structures needed for future development.

Conclusion

In summary, this proposed methodology will make on-site stormwater management dependant upon the impact of runoff on the receiving stream. If the increase in runoff is substantial enough to raise streamflow above the erosion rate for the stream, then stormwater controls will be adjusted at the site to reduce the runoff going to the stream. This approach would also give impetus to stormwater management designers to use environmentally sensitive, nonstructural practices in their plans. Using this new approach, sites would be designed so as to reduce runoff, and developments would be produced that are less intrusive to the environment and more appealing to home buyers. The economic benefits of this approach would extend to the private and public sectors alike as fewer stormwater management structures would have to be constructed and maintained.

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Funding Regional Flood Control Improvements in Fort Bend County, Texas

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The greatest obstacle to implementing a storm drainage, or flood control plan is often funding. Of course, many types of regional utility projects have difficulty finding financial support. But the sporadic nature of flood flows creates additional issues. A public outcry for improved service during wet periods may die away during dry years. Many drainage and flood control agencies can offer examples of flooding problems that became nonexistent when the cost of an improvement plan of was presented, especially if several years of dry weather occurred during the planning and design period. It is usually when a regulatory agency places restrictions, or even a moratorium, on new development that the search for funding options begins in earnest.

This was basically the situation facing those wishing to develop in Fort Bend County's Middle Oyster Creek watershed during the mid- and late-1980's. Located southwest of Houston, Fort Bend County ranks among the fastest-growing counties in the nation. Even with the downturn in the petroleum industry in the early 1980's, the population of Fort Bend County experienced a growth rate of almost 250 percent resulting in a population of 179,732 by 1986. Population projections indicate more than one million people will call Fort Bend County "home" by the year 2030.

The Oyster Creek watershed in Fort Bend County is a very complex watershed. The creek parallels the Brazos River from Jones Creek in the northwest corner of the county almost to the southwest county line. At that point Oyster Creek is blocked by a levee (Sienna Plantation development) and has been diverted to the Brazos River. The Galveston County Water Authority owns a flowage easement on Oyster Creek and uses three dams on the channel to store water in the reach from Jones Creek to the beginning of the reach discussed in this paper. The water stored in the creek is sold for industrial and agricultural uses. Portions of the Oyster Creek flow are diverted to the Brazos at two additional points, one upstream of the three dams, and at Flat Bank Creek which is between the third dam and the Sienna levee. The total area of the Middle Oyster Creek watershed, including the Flat Bank Creek diversion and Stafford Run tributary sub-watersheds, is almost 13,350 acres.

In 1986 approximately 25 percent of the Middle Oyster Creek watershed was developed, with a population of 23,300 dispersed among several master planned communities. Unfortunately, although Middle Oyster Creek was an improved channel throughout most of its reach, there was not enough capacity for the additional storm water runoff that more development would generate. Several subdivisions had been built close to portions of both Stafford Run and Middle Oyster Creek, limiting the land available for right-of-way to widen the channel. The Flat Bank Creek diversion, which directed flows to the Brazos River, crossed undeveloped pasture and range land and no right-of-way existed to allow for construction of any drainage improvements except by the landowner.

Therefore, Fort Bend County, through platting requirements enforced by the County Engineer and the Drainage District Engineer, required new development to provide on-site detention limiting developed runoff to the pre-development rate, or c cfs/acre. These restrictions were supported by the cities having jurisdiction over portions of the watershed: Sugar Land, Missouri City, and Stafford. Even with these restrictions, the frequency and severity of nuisance street ponding was increasing, leading to public concern for drainage improvements. In July 1987, water, up to three feet deep in places, remained in residential streets for more than 36 hours after an intense summer storm followed several days of wet weather.

By that time several efforts had already been started with the goal of improving the drainage for the existing residents, as well as providing additional drainage capacity needed for future development. Stafford and Missouri City had jointly sponsored a drainage study for Stafford Run that recommended a combination of channel improvements and regional detention and provided a phasing plan for the improvements. Local developers, through the utility improvement district, had also established a plan for widening Middle Oyster Creek. Fort Bend County planned channel improvements to Flat Bank Creek and had started negotiations with the landowners for easements.

All these efforts were thwarted, however, because the funds required for such a massive regional drainage project were not available. Neither the cities, nor Fort Bend County could fund capital improvements through bond sales without taxpayer approval. Since the majority of the voters in Fort Bend County would not derive any benefit from the project, passage of a bond election was doubtful. None of the smaller government jurisdictions (utility improvement districts) were capable of funding the entire project.

State legislation provided the vehicles to fund and implement this regional project. Article 1434a, Vernon's Texas Civil Statutes ("Article 1434a") authorizes creation of a nonprofit water supply corporation to provide for, among other things, flood control and drainage. Therefore, Fort Bend County created the Fort Bend Flood Control Water Supply Corporation (WSC) to be "operated for the benefit of Fort Bend County, having the specific and primary purposes of providing a flood control and drainage system for towns, cities, counties, other political subdivisions, private corporations, individuals and other persons of Fort Bend County. "1 Although a "duly constituted authority of Fort Bend County2," the WSC is not a political subdivision. Article 1434a essentially authorizes the WSC to finance drainage improvements by issuing tax-exempt revenue bonds "on behalf of" Fort Bend County.

The total construction cost of the regional flood control improvements to Middle Oyster Creek, Stafford Run and Flat Bank Creek was estimated to be $21,219540. The Fort Bend County Drainage District agreed to fund $1,000,000 and $1,000,000 was obtained from the prepayment of impact fees. The WSC then applied to the Texas Water Development Board (TWDB) for $20,325,000 in financial assistance to fund the balance of the construction, and the bond issuance costs. The WSC bond issue was purchased by the TWDB which used funds allocated to them by the State of Texas. Since the WSC had only recently been created and organized; it had no credit history. The cost of issuing bonds to the public, if possible at all, would have been substantially greater than the cost obtained through the TWDB.

The WSC cannot levy taxes. To make sure the TWDB would recover its investment an "Installment Sales Agreement" was executed between the WSC, Fort Bend County and the Fort Bend County Drainage District. This agreement provided that payment of the principal of and interest on the WSC bonds would be from collection of taxes levied by the Fort Bend County Commissioner's Court and developer impact fees collected by the Drainage District.

Chapter 395 of the Texas Administrative Code (TAC) governs financing capital improvements required by new development through impact fees. By definition, an impact fee is a "charge or assessment imposed by a political subdivision against new development in order to generate revenue for funding or recouping the costs of capital improvements or facility expansions necessitated by and attributable to the new development3." Dedication of right-of-way or easements, or construction of on-site drainage facilities are not considered impact fees. For example, the acreage dedicated for the channel right-of-way is not included in the calculation of the acreage subject to the impact fee.

The items payable by the impact fee are limited by the legislation to the following:

- the construction contract price;
- surveying and engineering fees;
- land acquisition costs, including land purchases, court awards and costs, attorneys' fees, and expert witness fees; and
- fees paid to a financial consultant, or an independent engineer, who is not an employee of the political subdivision, for preparing or updating the capital improvements plan.

If the impact fees are used for the payment of principal and interest on bonds or notes, the projected interest charges and other finance costs may be included in determining the amount of the impact fee.

Impact fees cannot be used to pay for:

- any improvements or facilities not identified in the capital improvements plan;
- repair, operation, or expansion of any existing or new facilities;
- upgrading, expanding, or replacing existing capital improvements to serve existing development in order to meet stricter standards; and
- upgrading, expanding, or replacing existing capital improvements to better serve existing development.

Impact fees may be collected before the capital improvement plan is implemented, but when a political subdivision begins collecting impact fees, it commits to begin construction within two years, and have the service available within a reasonable period of time, but no longer than five years.

The maximum impact fee is determined by dividing the costs of the capital improvements that will serve new development by the number of projected service units. For the Middle Oyster Creek, Stafford Run, Flat Bank Creek Capital Improvement Plan (CIP) the impact fee was calculated by dividing the $12,391,000 projected cost of the improvements attributable to new development by the 6241 acres of additional land that would, be served by the project. The initial impact fee was $1,985. In the developments that were already providing detention, the impact fees were prorated based on the effectiveness of the detention in reducing the developed flows entering Middle Oyster Creek. The Fort Bend County Commissioner's Court passed a resolution adopting the impact fee in September 1988, allowing the Drainage District to begin collecting the fee.

After the bonds were issued July 5, 1989, interest began accruing. The impact fee has been escalated monthly in order to recoup the finance charges, also. The current impact fee (as of January 5, 1996) is $2,291. On February 5, it will increase to $2,933. Including the prepaid impact fees, more than $2,560,000 has been collected from almost 1500 acres since the impact fee was established.

In 1995, the WSC reviewed their budget for the CIP and determined that an additional $5,000,000 would be needed to complete the project as originally presented. Several factors contributed to the need for these additional funds:

- and acquisition costs were substantially greater than originally estimated;
- changes in the state sales tax laws resulted in contractors having to pay more sales tax on their transient equipment used in construction. This increased the cost of construction;
- the scope of the channel for Flat Bank Creek originally proposed increasing the capacity to only

60 percent of the ultimate requirement. This scope was revised and the channel was constructed to 100 percent of the ultimate capacity;

- utility relocations within subdivisions that were not anticipated; and

- unforeseen soil conditions that required specialized construction method.

The WSC obtained an additional loan from the TWDB to cover the shortfall. The average debt service payment by Fort Bend County was estimated to be approximately $490,000, which equates to $0.0054 per $100 valuation based on the current assessed valuation. If impact fee payments, or assessed valuations increase, the tax rate necessary to pay the debt service will decrease.

Chapter 395 also specifies the elements of the capital improvement plan. The capital improvements or facility expansions must have a life expectancy of three or more years and be owned and operated by, or on behalf of a political subdivision. A developer cannot be required to construct or dedicate facilities and to pay impact fees for those facilities. However, a developer may construct or finance the capital improvements or facility expansion and the costs incurred can be credited against the impact fees that would otherwise be due.

The capital improvements plan must be prepared by a licensed professional engineer and contain specific enumeration of the following items:

- a description of the existing capital improvements with the service area and the costs to upgrade, improve, expand, or replace the improvements to meet existing needs;

- an analysis of the total capacity, the level of current usage and commitments for usage of the capacity of the existing capital improvements;

- a description of the portion of the capital improvements and their costs necessitated by and attributable to new development in the service area;

- the specific level or quantity of use, consumption, generation, or discharge of a service unit;

- the total number of service units necessitated by and attributable to new development within the service area;

- the projected demand for capital improvements required by new development projected over a reasonable period of time, not to exceed 10 years.

The engineering studies that were already completed were combined to form the CIP for the Middle Oyster Creek watershed. Construction of the initial phase of the project began in September 1989 and is substantially complete. As-built drawings of the 150-acre detention pond site are being finalized and construction is nearly complete along the most upstream reach of the Stafford Run portion of the project. With the channel construction and as-built surveys completed, final computer models of the project will be generated and final project costs tabulated. When this information is available, the actual costs to new development can be calculated and the CIP and impact fee will be revised accordingly. Preliminary calculations indicate the updated impact fee could be almost $2,500, based on the revised construction costs. Portions of the project are already being maintained by the Drainage District pursuant to the Installment Sales Agreement. In a separate agreement, Stafford and Missouri City agreed to maintain the detention area as a park while the Drainage District maintains and operates the drainage and flood control improvements.

Fort Bend County has already begun to realize substantial economic benefit from the portions of the CIP that have been constructed. The completed improvements have provided drainage capacity for a significant portion of the master planned community of First Colony, which would not have been possible without the Middle Oyster Creek improvements. The continued development in First Colony has added more than $106,300,000 in taxable assessed value providing in excess of $700,000 in annual county tax revenue. Using the estimated increased assessed value of $400,000 per acre realized in First Colony, the full 6,241 acres of development that will have drainage capacity will generate a total of $2,500,000,000 in assessed values and $16,500,000 in annual tax revenues, based on the current tax rate. Using the current tax rate of $0.66 and these values, development of only 1,000 acres will be sufficient to service the WSC bonds.

References

1. Articles of Incorporation of Fort Bend Flood Control Water Supply Corporation.

2. Resolution Authorizing the Creation of Fort Bend Flood Control Water Supply Corporation; Approving the Articles of Incorporation Thereof; and Containing Other Provisions Relating Thereto.

3. Section 395.001 TAC.

Development of Cost-Effective Stormwater Treatment Alternatives

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Introduction

In recent years, much effort has been expended in the State of Florida to create innovative stormwater treatment facilities. In addition, much has been learned about the effectiveness of various best management practices (BMPs) in removing stormwater pollutants. This expanded body of knowledge provides the facility designer with a wide range of potential stormwater treatment options, and allows the prediction of pollutant removal, given the chosen BMP and resulting design. This information is particularly important for the design of retrofit stormwater treatment facilities, since more traditional methods of design, as related to new development, are generally less appropriate.

What has been lacking in the design of retrofit facilities, however, is a framework that allows the selection of one or more BMPs that results in the creation of the most cost-effective stormwater treatment alternative, as defined by minimizing cost for a fixed pollutant removal goal or maximizing pollutant removal for a fixed budget. Production theory provides a framework for this process, which includes the creation of BMP production functions that compare technology effort (e.g., sweeping frequency, pond volume) to the fraction of pollutants removed over an extended time period, and cost functions that compare technology effort to the cost of implementation. Production and cost functions allow the unit cost of pollutant removal to be determined for each BMP alternative, and the most cost-effective alternative to be chosen.

The use of production and cost functions is demonstrated by a project completed by CH2M HILL for the City of Lakeland in February 1995, called the Lake Hollingsworth Watershed Management Plan. This study involved the evaluation of five stormwater treatment technologies, including street sweeping, dry bottom retention ponds, curb-cut swales, wet detention ponds, and wetlands. Four production functions were developed for this study, which are described in the following paragraphs.

Use of the production and cost functions for the Lake Hollingsworth Project allowed the evaluation of nine BMP alternatives, including three alternatives each for three total suspended solids (TSS) removal goals (20, 50 and 80 percent). The resulting analysis presented the unit cost of TSS removal for each of the nine alternatives, which allowed the most cost-effective alternative to be identified for each TSS removal goal. This approach allows the facility manager to make fiscally responsible decisions regarding stormwater treatment, particularly when creating retrofit facilities for areas with existing development.

Production and Cost Function Development

The street sweeping analysis was performed with the RUNOFF Block of the Storm Water Management Model (SWMM), which allows simulation of pollutant deposition and washoff and pollutant removal by street sweeping, as defined by sweeping frequency and sweeper pickup efficiency. The test sub-basin defined for this analysis was an urban street 300 feet long by 14 feet wide that is directly connected to a stormwater collection system. Sweeping intervals and the corresponding level of effort (sweeping frequency, expressed in sweeper passes per day) ranged from once per year (0.00274 passes per day) to once per day. Street sweeper pollutant pick up efficiency is defined as the fraction of available street gutter pollutants removed by a single pass of the street sweeper. Efficiencies of 0.1, 0.2, 0.3, 0.4, 0.5 and 0.6 were used in the simulations.

Given the simulated pollutant removals, a regression analysis was completed for each of the six street sweeper efficiencies, and street sweeping production functions were created that relate the street sweeping pollutant removal fraction (PRF) to sweeping frequency (Xsw) and sweeper pick-up efficiency (Eff). Street sweeping costs were estimated using information obtained from the City of Lakeland Construction and Maintenance Department. Street sweeping costs totaled approximately $33.38 per curb-mile.

Storage/infiltration technologies include dry bottom ponds and swales. Their analysis began with the simulation of 10-year runoff arrays using SWMM for three sample sub-basins that represent a range of hydrologic conditions. The CH2M HILL computer program Wet-Weather Facilities (WWFAC) was then executed using the three runoff arrays as input. Given a particular combination of storage volume and infiltration rate, WWFAC determines the long-term average capture and treatment (infiltration) of the storage/infiltration system. System storage volume (Vs) was reported as a normalized storage volume ratio (Vs/Vr), where Vr is the average annual runoff volume discharging to the facility. The annual infiltration volume (Qi) was reported as a normalized infiltration volume ratio (Qi/Vr), where Qi is the volume of water that will infiltrate in a one-year period, given an average infiltration rate (qi) and a constant supply of water. The purpose of the normalizing Vs and Qi is to develop dimensionless ratios that allow the resulting production functions to be applied to storage/infiltration systems of varying sizes and locations.

Regression analyses were then used to develop storage/infiltration system production functions (Figure 1), where the stormwater capture fraction (SCF) is presented as a function of Vs/Vr and Qi/Vr. SCF is the fraction of Vr that the facility will annually store and infiltrate. Construction cost estimates were created for a range of dry bottom pond sizes and curb-cut swale lengths, using an appropriate list of quantities and unit prices and typical pond/swale cross-sections. The relationship between Vs and construction cost was then analyzed using linear regression, which produced the following cost functions: dry bottom pond (cost = $4,700 + [Vs x $41,145/acre-feet]) and curb-cut swale (cost = $3,450 + [Vs x $112,300/acre-feet]). These cost functions do not include property costs or annual operation and maintenance (O&M) costs.

Wet detention systems include wet detention ponds and wetlands. These systems were analyzed in a manner similar to storage/infiltration systems. The three runoff arrays were input to the CH2M HILL WETPOND computer program, which simulates long-term removal of TSS achieved by dynamic and quiescent sedimentation processes. Dynamic sedimentation occurs during a runoff event when there is flow through the wet detention system. Quiescent sedimentation occurs during dry inter-event periods, when there is no flow through the system. The WETPOND simulation calculates the dynamic and quiescent TSS removal achieved during each event and inter-event period, and tracks long-term solids removal for a range of wet detention system storage volumes and depths. Pond water surface area (Ap) was reported as a normalized pond area ratio (Ap/Aws), where Aws is the watershed drainage area.

The wet detention system dynamic removal production functions were created that relate the dynamic TSS removal fraction (Rd) to Ap/Aws and Vr (inches). In addition, wet detention system quiescent removal production functions were created that relate the quiescent TSS removal fraction (Rq) to Vs/Vr and pond depth. The total TSS removal fraction (Rt) for a specified wet detention facility is equal to the sum of Rd and Rq. The relationship between Vs and construction cost was analyzed, producing the following cost functions: wet detention pond (cost = $20,500 + [Vs x j], where j = $56,030, $35,900, and $30,330 per acre-foot for pond depths of 2, 4, and 6 feet, respectively) and wetland (cost = $19,000 + [Vs x $95,250/acre-feet] for a 1-foot pond depth). These cost functions do not include property costs or annual O&M costs.

Application Of Production And Cost Functions

A review of field conditions and the existing stormwater infrastructure allowed the delineation of 16 potential stormwater pond sites within the Lake Hollingsworth watershed, as related to the construction of dry bottom retention ponds, wet detention ponds, and wetlands. The length of street curb in each sub-basin was also determined, as related to the construction of curb-cut swales and the application of street sweeping. Each BMP was evaluated over a range of efforts. Street sweeping within each sub-basin was evaluated using nine different sweeping intervals (from daily through once per year). Dry bottom ponds, wet detention ponds, and wetlands were evaluated over a range of site development fractions (SDF), which describe the fraction of potential pond site that is used for the construction of a stormwater treatment pond or wetland. Curb-cut swales were evaluated over a range of curb fractions that describe the fraction of the total curb length in the sub-basin that is assigned an adjacent curb-cut swale.

The production functions were used to determine the fraction of TSS removed for each BMP level of effort. Each of these removal fractions was multiplied by the average annual TSS load available to the BMP, which provided the average annual TSS load removed by the BMP for a particular level of effort (TSS removed = available TSS x PRF, SCF or Rt). Cost functions were used to estimate the present worth cost associated with a particular BMP and an identified level of effort. Finally, the present worth unit cost of TSS removal (cost per pound of TSS removed) was determined for each BMP level of effort, as summarized in Figure 2.

Summary Observations And Alternative Evaluation

1. Production functions are not watershed- or site-specific because normalized values are used to identify level of effort and can be used throughout the planning area.

2. Figure 2 allows the comparison of the unit costs of TSS removal for the selected BMPs, which rank as follows (least to most expensive): wet detention ponds (6 feet depth), wetlands, dry bottom retention ponds, curb-cut swales, and street sweeping.

3. The relative unit cost of street sweeping would be less if land and O&M costs were added to the other unit costs presented in Figure 2.

4. The production functions demonstrated that retention ponds and curb-cut swales require significantly more land area than wet detention ponds or wetlands for the same fraction of TSS removal. If land costs are included, wet detention ponds and wetlands become even more cost-effective than dry bottom ponds and curb-cut swales. For example, given a TSS removal fraction of 0.75, the corresponding ratio of retention pond site area to wet detention pond site area is approximately 7:1.

These observations were used to create three alternatives for each of the three pollutant removal goals

(20-, 50-, and 80-percent TSS removal). TSS removal was related to the removal of other pollutant types through the use of regression formulas. Each of the three alternative categories emphasized a different BMP approach, including wet detention ponds (Category A), infiltration ponds (Category B), and curb-cut swales with street sweeping (Category C). The lowest and highest unit cost of TSS removal in each alternative group were provided by the "A" and "C" category, respectively. The total present worth cost estimated for each of the TSS removal goals for each alternative category is provided in Table 1.

As provided by Table 1, the present worth cost of a stormwater retrofit alternative can vary dramatically, depending on the desired fraction of pollutant to be removed and the selected combination of stormwater treatment technologies.

Wastewater and water treatment plant managers have long been required to provide cost-effective facility designs. Stormwater facility managers must now demonstrate the same fiscal responsibility when designing stormwater treatment alternatives. Production and cost functions allow the facility manager to identify the most cost-effective stormwater treatment alternative for a given pollutant removal goal.

References

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A National Non-Point Source Pollution Monitoring Program for the National Estuarine Research Reserve System

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

Estuaries are dynamic ecosystems that respond readily to large scale perturbations from natural and anthropogenic events. The wetlands associated with estuaries are often the ultimate receiving waters and catchment basins for both point and non-point source pollution runoff. Estuaries are therefore model systems for tracking pollutant levels and for assessing the effectiveness of management practices designed to curb runoff and environmental degradation (Albert, 1988). The National Oceanic and Atmospheric Administration's (NOAA's) National Estuarine Research Reserve System (NERRS), comprised of over 400,000 acres of estuarine waters, wetlands and upland habitat, is a national system of wetlands research sites that provide a stage for monitoring changes in the health, integrity and biodiversity of the Nation's coastal ecosystems and their living resources. The NERRS is a system of 22 estuarine ecosystems located around the United States (Figure 1). Each NERRS site was selected to serve as a natural estuarine laboratory for conducting field and monitoring research while protecting the ecological, economic, recreational and aesthetic values of the selected estuarine ecosystems.

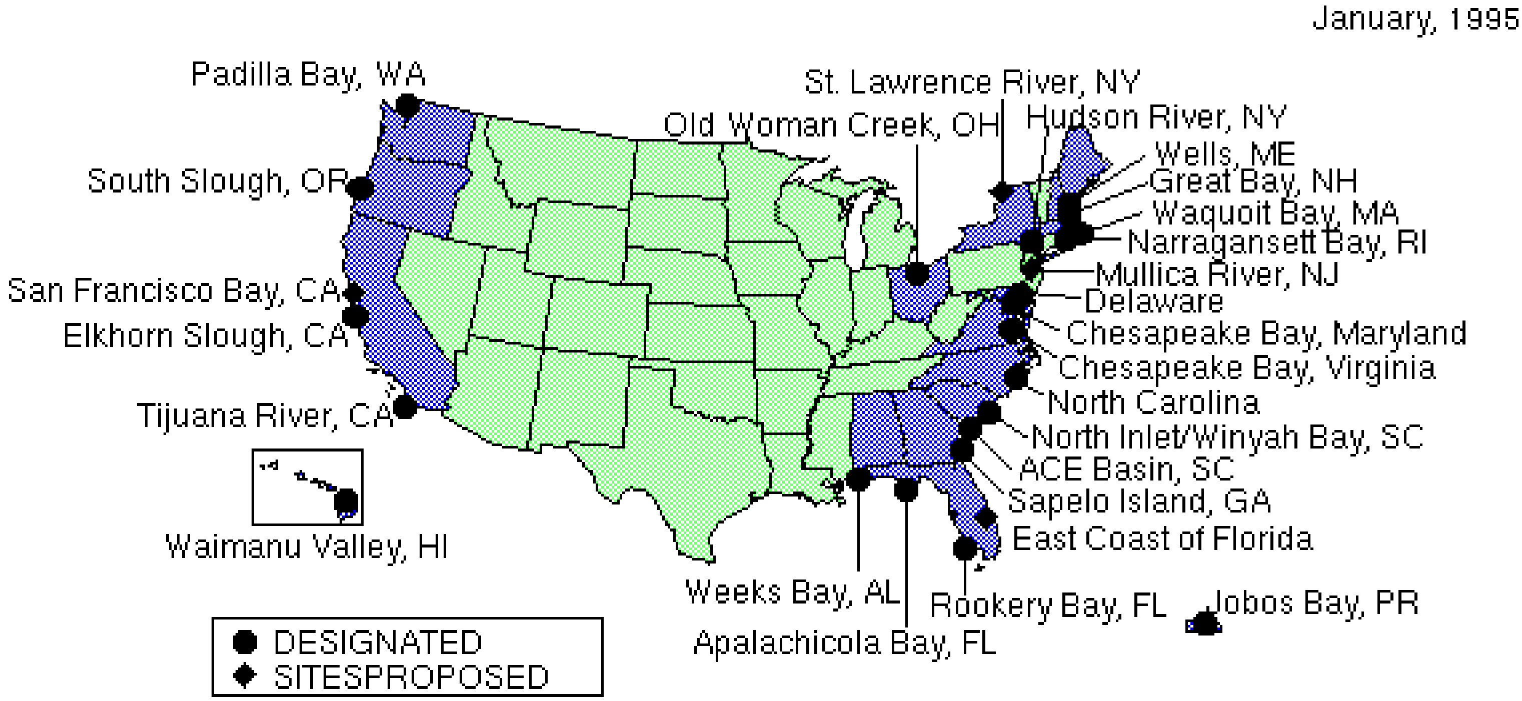

Figure 1. Map of the National Estuarine Research Reserve System.

This paper presents an overview of the NERRS National Monitoring Program and highlight two examples of the monitoring data and their utility for managing non-point source pollution in estuarine ecosystems. The programmatic goal of the NERRS national monitoring program is to "...identify and track short-term variability and long-term changes in the integrity and biodiversity of representative estuarine ecosystems and coastal watersheds for the purposes of contributing to effective national, regional, and site-specific coastal zone management." Critical baseline data and integrated monitoring records are not yet available to many coastal zone managers in a format that allows them to evaluate the importance of large- and small-scale changes in water quality parameters. New databases are needed from a nationally coordinated system of reference sites in order to track instantaneous variability among physico-chemical and biological variables over a meaningful range of spatial scales (local, regional, national) and temporal scales (minutes, hours, days, months, years) that are appropriate for coastal zone decision making. The NERRS national monitoring program is designed to describe and document changes in the health, integrity, and biodiversity of the Nation's coastal ecosystems and their living resources.

Phase I Methods

Each NERR is deploying a minimum of two YSI Model 6000 dataloggers. One datalogger is deployed as a long-term control in a "pristine" location within each NERR. All additional dataloggers are deployed at each site to test specific non-point source pollution questions within each reserve (Table 1). At every site, water temperature, conductivity (salinity), pressure (depth), pH, and turbidity are collected. Nutrients (nitrogen, phosphorous) and other ancillary data (e.g. fecal coliform) are collected at specific sites where this information addresses specific non-point source pollution questions. Beginning in 1996, weather data (wind speed and direction, air temperature, relative humidity, rainfall, barometric pressure, photosynthetically active radiation) will be collected at each Reserve allowing local weather events to be related to runoff observations.

Following data collection, the raw data is processed using a rigorous Quality Assurance-Quality Control procedure at each site. The processed data is then transmitted to the NERRS Centralized Data Management Office (CDMO) housed at the North Inlet-Winyah Bay NERR, Belle W. Baruch Institute of Marine Biology and Coastal Science, SC. The CDMO summarizes the processed data into standard graphical products which are made available over the internet to researchers, coastal zone managers, and the general public. Site-specific data files will be available upon request. The CDMO home page address is http://inlet.geol. scarolina.edu/nerrscdmo.html.

Example 1: Important Estuarine Baseline Data for Restoration Efforts and Water Quality Model

At the South Slough NERR, YSI-6000 dataloggers are currently collecting baseline information on the water quality and hydraulic flushing patterns through tidal wetlands. This information is being collected to characterize the flushing cycles of the semidiuranl tides between a reference and management-treatment monitoring stations prior to initiation of marsh restoration efforts in 1996. Data from late May and early June at South Slough illustrate strongly periodic temperature, salinity, pH, and dissolved oxygen values that fluctuate in synchrony with the ebb and flood of daily tidal cycles. Bottom temperatures, salinity and pH values all decrease with falling tides and increase with flooding tides. In contrast, dissolved oxygen values (both DO % saturation and mg/l) are highest during low tides and decrease during high tides. These cyclic and synchronous fluctuations can be readily explained by the warming of shallow estuarine waters as they flow into the upper regions of the South Slough, and they provide a characteristic signature and understanding for the dynamics of bottom waters in the tidal channels during late spring and early summer. The South Slough water quality data provide a valuable record of tidal amplitude and timing differences between the reverence and management-treatment sites, and document unexpected temporal patterns and a strong autocorrelation between DO, temperature, and tides.

Example 2: Coastal Development Pressure in South Carolina

The ACE Basin NERR's monitoring program is focusing on documenting the effects of urban runoff on this Reserve. Development pressure is increasing, largely from residential and resort development in areas surrounding the Reserve. Increased expansion of high and low-density development dispersed throughout the area will likely fragment existing natural habitat. Depletion of groundwater by increased development may also result in destruction of saltmarsh. Hydrologic modifications have already occurred to a limited extent within portions of the Reserve through construction of small access canals, impoundments, and the Intracoastal Waterway. Increased boat traffic through these manmade canals could result in increased erosion of marsh vegetation. Population trends in the more developed portions of the Reserve are indicative of rapid population growth and resultant demands for residential, commercial and industrial development being experienced n other parts of coastal South Carolina. This contrasts with areas of the Reserve that are undergoing little or no development pressure. Comparisons between the developed and undeveloped wetlands at ACE Basin NERR will allow the effects of commercial development on water quality to be quantified within the Reserve.

Future Monitoring in the NERRS

Phase II of the NERRS National Monitoring Program, which is scheduled for implementation in 1996-97, will begin monitoring changes in ecological conditions such as biodiversity and the abundance or percent cover of key wetland species. Phase III of the monitoring plan will couple coastal watershed landuse patterns to the NPS pollution data collected at each Reserve. For this phase we will make use of satellite imagery, aerial photography, in situ monitoring and research data, and other collateral data organized within the context of a Geographic Information System.

A major goal of the NERRS monitoring program is to serve as the baseline from which the effectiveness of different coastal watershed management practices within the NERRS will be gauged. Additionally, the NERRS Monitoring Program aims to collect data that is directly relevant to addressing cross-cutting coastal management issues related to non-point source pollution. Successful integrated coastal management requires several essential characteristics: 1) effective communications, coordination, and interaction among disciplines and programs relating to coastal and ocean management, 2) ongoing monitoring, evaluation, and adaptive management, 3) application and sharing of fiscal, human, and technical resources, and 4) effective interaction between science and policy development (NOAA/NOS, 1995). The NERRS monitoring program is specifically designed to include all of the elements of successful integrated coastal management within the NERRS and state-based CZM efforts.

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Water Quality Data Evaluation and Analysis for the Florida Everglades

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

Introduction

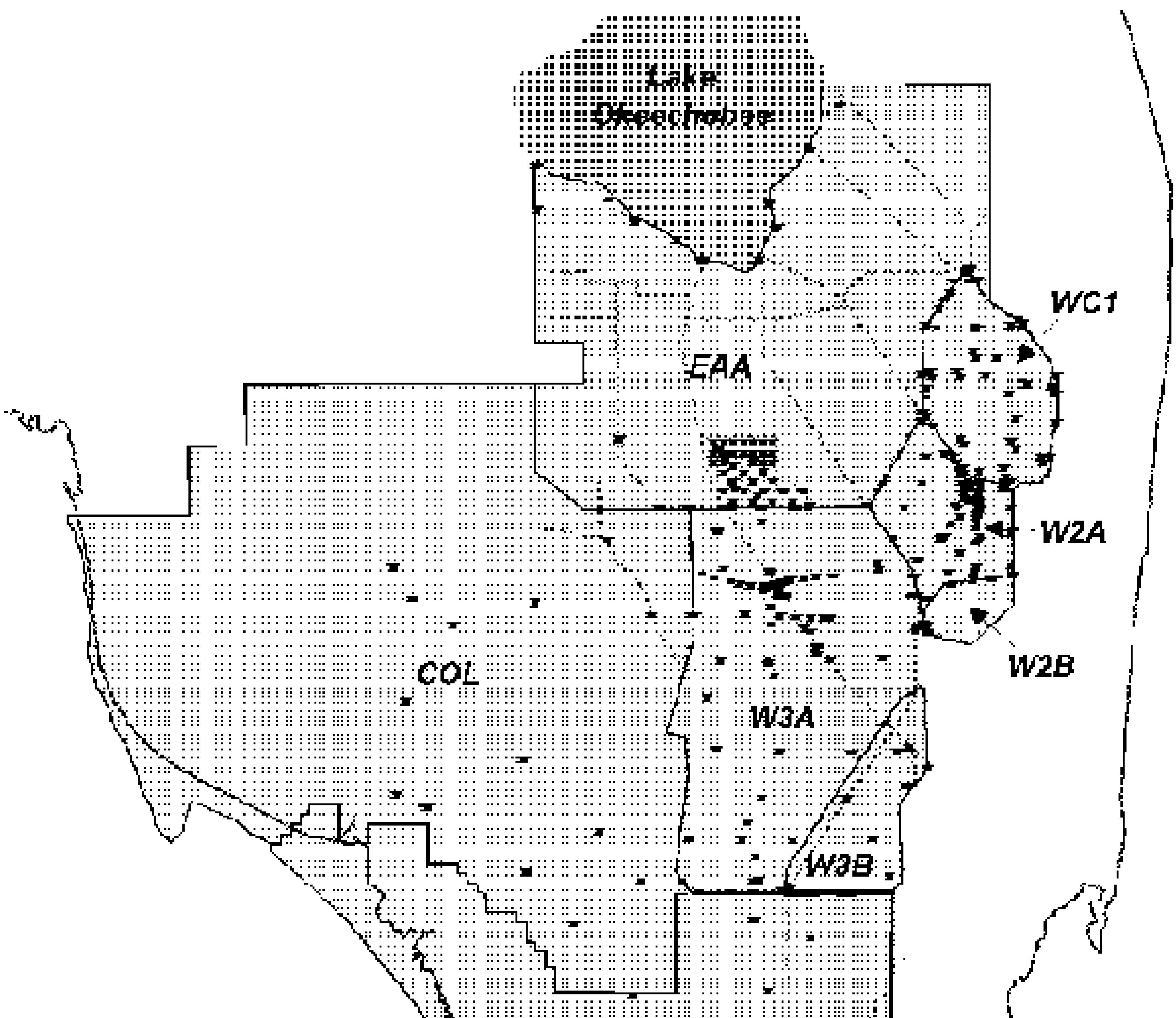
The Florida Everglades are a unique watershed in southern Florida. The Everglades provide extensive habitat and serve many other purposes including water supply, flood control, and recreation. These competing needs are often in conflict. In 1994, the Everglades Forever Act (EFA) was adopted to restore and protect the ecological integrity of this threatened wetland resource (State of Florida, 1994). In order to address specific goals defined in the EFA, the South Florida Water Management District (SFWMD) and the Florida Department of Environmental Protection (FDEP) developed an Everglades Program Implementation Plan (SFWMD and FDEP, 1994). The plan consists of fifty-five individual projects within eight elements, and includes research and monitoring (RAM) projects targeted at key questions and issues regarding water quality, water quantity, and the invasion of exotic species. The first RAM project (RAM-1) addressed the EFA requirement to review and evaluate available water quality data in the Everglades and tributary waters. The purpose of this paper is to report on the results of this comprehensive review and evaluation (Limno-Tech, 1995). The results of this watershed-based analysis of the Everglades have been used to guide other RAM activities and projects.

Study Methodology

The technical approach consisted of a data search and compilation followed by a three-tiered data evaluation focused upon State of Florida Class III parameters and water quality criteria. The time period examined was extended over fourteen water years from 1979 through 1993.

The study area covered eight subwatersheds within the Everglades (Figure 1).

Figure 1. Subwatersheds, canals, and monitoring stations.



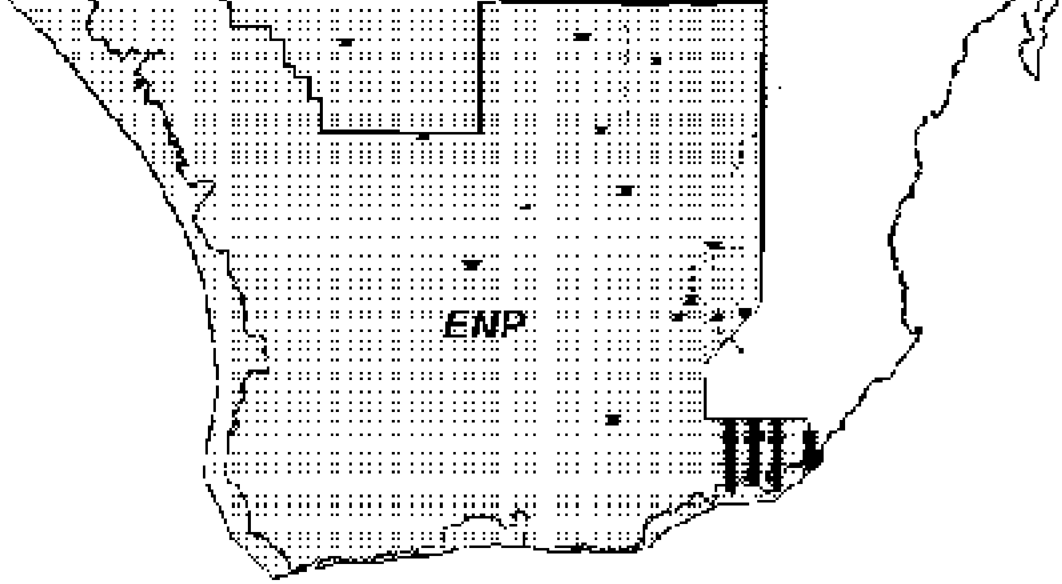


Figure 1. Subwatershed, canals, and monitoring stations.

The subwatersheds and water quality monitoring stations are described below:

- Select stations within the Everglades Agricultural Area (EAA).
- All stations within Water Conservation Areas 1 (WC1), 2A (W2A), 2B (W2B), 3A (W3A) and 3B (W3B).
- All stations within the Everglades National Park (ENP).
- Select stations in eastern Collier County (COL).

Data Management

Water quality data was retrieved from the central data base at the SFWMD. Several data management activities were required to prepare the data for review and analysis, including:

- GIS coverages for subwatershed boundaries, water quality stations, and canals and structures were used to confirm station locations and station names within the study area. Stations were evaluated according to station names, aliases, and reported latitude and longitude in order to identify unique station locations and to assign a dominant station name where more than one name had been used.
- Data was screened to ensure consistency with the boundary of the study area and period of interest, to search for obviously spurious values, and to eliminate records identified as data base duplicates (not field duplicates).
- Procedures were applied to estimate values reported as "nondetects" in order to include this information in the statistical analysis. For parameters that do not have numeric water quality criterion, one-half of the reported detection level was used as an estimate of the concentration for

values reported as nondetects. For parameters that do have numeric water quality criterion, one-half of the reported detection level or one-half of the criterion, which ever was less, was used as an estimate of the concentration for values reported as nondetects.

- Logical groupings of stations were developed in order to compare spatial and functional differences in water quality within the study area. Groupings subdivided the study area into units smaller than subwatersheds. Two types of groupings were defined: interior stations where water movement was typically slow; and structural stations where water movement was controlled and typically more rapid.

Parameter specific data files were produced following the data management activities. In certain instances it was necessary to extract and associate concurrent hardness, pH, and temperature data with other parameters in order to facilitate a comparison of observed values with water quality criteria.

Data Evaluation

The data analysis involved three levels of complexity corresponding to the significance of the data with respect to characterizing environmental conditions in the study area.

1. Level 1 analysis consisted of developing station summaries on the occurrence and characteristics of data at individual stations by parameter, including a comparison with water quality criteria where applicable. Summaries for subwatersheds, groupings, and for all stations were also developed.

2. Level 2 analysis consisted of more detailed statistical and graphical analysis of a subset of parameters. The subset included all of those parameters where the percent of excursions from water quality criterion equaled or exceeded one percent. Total phosphorus and total nitrogen were included because of widespread interest in these parameters. Level 2 included development of percentile analyses of station median values by subwatershed; map graph analyses showing the location and relative percent of excursions from water quality criterion; and time plots of excursions.

3. Level 3 analysis consisted of trend analysis for total phosphorus and total nitrogen for select stations and groupings at the interface of the EAA and the Water Conservation Areas, and at the interface of the Water Conservation Areas and the ENP.

Comparisons with Water Quality Criteria

The comparison of water quality data with water quality criteria was an important aspect of the study as it provided a means to identify potential problems. Several caveats regarding this comparison are:

- The comparison of pH was based upon criterion for fresh water except for a select grouping of stations located in the southeast panhandle of ENP, where brackish conditions existed, and comparison with criterion for marine waters was appropriate.

- The comparison of specific conductance was based upon the maximum criterion of 1,275 umhos. The water quality criterion states that conductance shall not be increased more than 50 percent above background or to 1275, whichever is greater. Use of the 25th quartile value for each subwatershed as a conservative approximation of background produced values lower than 1,275 when increased by 50 percent, making 1,275 umhos the appropriate criterion.

- The water quality criterion for turbidity states that turbidity should be less than or equal to 29 NTUs above natural background conditions. In order to approximate natural background conditions, the 25th quartile value for each subwatershed was used as a conservative approximation for the comparison with water quality criterion.

- The analysis of ammonia and the comparison of unionized ammonia with water quality criterion was complicated because the conversion of ammonia to its unionized fraction requires concurrent pH and temperature data. A direct comparison of unionized ammonia with water quality criterion was conducted for the data where concurrent pH and temperature values were available (approximately 65 percent of the ammonia data). A separate comparison of all of the ammonia data utilizing a conservative estimate for missing pH and temperature data (95th percentile by subwatershed) was also conducted.

- For most of the metals data, including arsenic, cadmium, chromium, copper, lead, nickel and zinc, the data base contained only the total fraction of these metals, with no information on the total recoverable fraction. Florida water quality criteria for metals are expressed as the total recoverable fraction. Therefore, the comparisons were not true comparisons, but were conducted in order utilize the existing data in a constructive manner.

Results and Conclusions

The SFWMD data base contains a vast amount of historical water quality data, and the data were found to be generally quite adequate for characterizing water quality. Nearly 500 water quality stations were identified. Data for 121 water quality parameters including conventional water quality measures, nutrients, metals, pesticides and organic compounds were analyzed. All of the outstanding questions about the existing data base were addressed in this review and analysis. While it would be impossible to document all of the results and conclusions herein, highlights and examples from each of the three levels of analysis are presented.

A summary of Level 1 results for select parameters is presented in Table 1. The results of the Level 1 analysis quantified and determined:

- The amount of data available by parameter and by station.
- The spatial and temporal coverage of the available data.
- The statistical characteristics of the available data.
- The number and percent of excursions from water quality criterion.

The results of the Level 2 analysis for specific parameters determined that:

- The lowest pH values were found in the WC1 subwatershed, where 9 percent of the observations were below the criterion of 6.0 to 8.5 units.
- Excursions below the dissolved oxygen criterion of 5.0 mg/l were common (65 percent) and widespread throughout the study area, suggesting temperature and other natural conditions as contributing factors.
- Excursions above the turbidity criterion occurred primarily at structures and in canals, suggesting pumping and other operations as contributing factors.
- For ammonia data associated with concurrent pH and temperature data, excursions above the criterion for unionized ammonia (1.5 percent of the observations) occurred primarily in canals and structures, and were broadly scattered throughout the study area.
- Excursions above metals criteria were generally infrequent (less than 1 percent) and exhibited a different spatial pattern for each parameter.

The results of the Level 3 analysis were limited to trend analysis. The trend analysis over the period of interest detected a negative trend for total phosphorus at Station S5, the northern inflow point to WC1. No other positive or negative trends for total phosphorus were detected. For total nitrogen, negative trends were detected at all stations or groupings at the interface of the EAA with the Water Conservation Areas, and the interface of the Water Conservation Areas with the ENP.

In summary, the comprehensive watershed approach utilized to analyze the spatial and temporal characteristics of water quality data in the Florida proved to be very effective. The results from this analysis provide a solid platform for future Everglades research and management activities.

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A Water and Weather Monitoring System for an Urban Watershed

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***Web Note:** Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

The water supply for the City of Vancouver, B.C., Canada is drawn from the nearby Capilano, Seymour and Coquitlam watersheds which total 225 square miles.

In 1992, the Greater Vancouver Regional District (GVRD) contracted Forest Technology Systems to develop and install a network of hydro-meteorological monitoring stations (currently 14), to monitor continuously a wide range of water and weather parameters throughout the watersheds. The system measures and records all parameters every 15 minutes, and automatically transmits data back to GVRD headquarters.

Vancouver's continuous monitoring system provides comprehensive information regarding water availability and water quality. The system's data also assists in water supply forecasting and in planning and monitoring for erosion control works. Special features include automatic sampling triggered by turbidity, quick graphing, archiving and data analysis with specialized software. Meteorological parameters are monitored to assess fire hazard in the area and study the impact of rainfall and snow pack on the quantity and quality of water in the city's water supply.

Introduction

The Greater Vancouver Regional District (GVRD) serves a rapidly growing, water consuming population of 1.7 million people; the average daily consumption is over 264 million gallons per day, with a record maximum of double that amount. Two watersheds within the access-restricted area, Capilano and Seymour, supply the bulk of the GVRD's water, while a third, Coquitlam, is primarily used to generate hydro-electric power.

Raw water from these watersheds is not filtered; it is just coarsely screened and lightly chlorinated before entering the distribution system. Thus watershed management is of critical concern. In the late 1980s a series of storms resulted in turbid drinking water in the city, arousing public concern about logging impacts on water quality. A panel of technical experts and a series of public meetings resulted in a logging ban except for specific forest management situations.

These watersheds are located within the Pacific Coastal Range. The mountainous watershed terrain is steep and subject to periods of heavy precipitation, primarily from October to January. The rugged topography varies in height from just over 500 to 5,800 feet above sea level, with annual precipitation up to 200 inches at higher elevations. Winter snow accumulation often exceeds 10 meters. The soils in the Capilano watershed are particularly erodible and constitute a substantial source of turbidity, requiring significant soil conservation measures. Compounding the problems of the rugged topography, much of the watershed lands are accessible by helicopter only, making a traditional monitoring program highly tedious, time consuming and expensive.

The network now totals 14 monitoring stations and tracks the following parameters:

- water level
- water flow
- wind direction
- turbidity
- air temperature
- precipitation
- water temperature
- humidity
- rainfall
- auto sampler
- wind speed
- snow pillow (water equivalent)

Remote, Continuous Hydro-Meteorological Monitoring

Continuous monitoring, achieved through electronic sensors and dataloggers, forms one component of a complete watershed monitoring program. Continuous monitoring captures transient (aperiodic) events which are often missed in traditional grab sample programs. In the GVRD watersheds, during periods of heavy rain, clear peaceful streams can swell into raging rivers. In just 24 hours streams have been known to rise over 18 feet.

Knowing the exact nature, extent, and sources of changes in water quality, whether from natural causes such as storms and landslides or from human causes such as road building and timber harvesting, required extensive and frequent sampling. As well, sampling frequencies needed to be consistent and tied to natural events (a heavy rainfall or high turbidity levels) to ensure an accurate profile of changes in the watershed. For this reason meteorological sensors are used to determine if an extreme reading can be explained by a localized storm, for example. The danger of fire in the watersheds is also of critical concern because of the severe after-effects a fire can have on water quality.

The GVRD required a more comprehensive monitoring program and more immediate information than could be obtained by periodic site visits. Data had to include the extremes or 'highs and lows' of water quality for appropriate decisions to be made and action to be taken. All 14 electronic monitoring stations embody a rugged datalogger, designed for year-round deployment and a radio modem. Each station has a different sensor configuration. GVRD personnel have immediate access to the hydrological data in the dataloggers through the use of radio telecommunications which 'calls' for the data at preset times and converts the data to information displayed in a spreadsheet or graph format using specialized data analysis software.

Monitoring Stations and Sensors

Hydrological data are monitored continuously and automatically downloaded to the GVRD's head offices, 10 miles away, at predetermined times every day. During severe weather systems (or when otherwise required), data are instantly accessible. All sites are solar powered as no AC power exists in the watershed area. Some sites monitor water parameters only, some monitor water and weather, and some measure weather only. Terrestrial radio communication was chosen because mountains obstruct the most appropriate stream side monitoring locations from geostationary satellites. Furthermore, the two-way communications capability or radio is preferred.

The information garnered from these automatic monitoring stations is vital when making decisions as to whether to switch between watershed sources to supply drinking water during periods of turbidity. It also allows the GVRD to track movement of silt in the watershed in order to plan ahead for erosion control activities. A discussion of the key monitored parameters follows.

Turbidity

The GVRD adheres to federal drinking water quality guidelines for turbidity and treatment, as well as provincial regulations governing health concerns such as bacteria levels in the water. Turbidity, measured at five sites, acts as an indication of water quality entering the drinking water system.

Turbidity is a major concern for the watershed management staff and the public. Turbid drinking water is aesthetically unpleasant and when drinking water is turbid the GVRD offices receive hundreds of calls from the public inquiring about the safety of the water. Being able to anticipate high levels of turbidity enables the GVRD to proactively launch public awareness campaigns, accurately explain the causes of the 'dirty water' and, of course, increase chlorination of the unfiltered water to appropriate levels.

Another role of continuous monitoring is to assess whether the 'cause' of turbidity events are human-based or are part of the watershed's natural processes. The GVRD can track stream flow, temperature and turbidity against rainfall. By monitoring air temperature and precipitation, managers know whether it's raining or snowing in the watershed; this is important for estimating summer water supply.

Grab sample programs, while long a standard tool for tracking turbidity, sediment loading, and other parameters, do suffer several basic difficulties. Grab sample programs, which require significant staffing levels, are particularly critical during severe storm events-precisely when access is most difficult, dangerous and expensive. Yet this is exactly when turbidity and sediment are most likely introduced into streams and rivers.

Autosampler

To address this issue of taking samples during extreme conditions, the datalogger takes samples automatically when turbidity exceeds certain predetermined levels.

Five of the streamside sites were equipped with 24 bottle autosamplers. Water samples are either triggered by certain aperiodic events or at preset timed intervals. When the turbidity exceeds specific NTU levels (5, 15, 25, 35, etc.) the autosampler draws a sample. Once a trigger point had been "used", it was disabled until either an increasing or decreasing critical turbidity point had been reached. A value below 2 NTUs was used to re-enable the 5 NTU point when turbidity was decreasing. Every time the autosampler was triggered the datalogger recorded the exact date and time of the sample, which autosampler bottle number was filled and what turbidity reading caused the sample.

By using radio modem telemetry, GVRD staff could keep track of how many bottles had been filled and arrange a timely visit to exchange a new rack of empty bottles. The autosampler goes through long periods without drawing a sample, but when a storm event results in increasing turbidity and sediment, the autosampler draws representative samples on both the rising and falling edge of the hydrograph. Plans are underway to develop a measurement technique to produce flow rating tables to produce a sediment rating curve.

Water Level

Water level is the most basic of water monitoring parameters. It is measured using a variety of techniques at different sites-float gauges, bubbler systems and submersible pressure transducers. Water level is recorded frequently (every 15 minutes) to track the rapid water level changes associated with steep mountain streams. For each of the stream and river sites, data analysis software collects data by radio modem, and also provides the ability to enter equations or rating tables in order to automatically calculate flow. It also has unit conversions built-in to allow depth to be shown as feet or inches, or flow shown as cubic feet per second, cubic feet per day, million gallons per day, etc.

Weather Monitoring

As previously noted, the GVRD uses meteorological sensors to automatically monitor fire hazard. During fire season, the monitoring stations are polled daily and Canadian Fire Weather Indices automatically calculated and made available to fire managers. Forest fires in a watershed can impair water quality, for several reasons:

- Wildfires can greatly increase the amounts of nitrogen and phosphorus entering the water. In great enough quantities, these can cause a community's water supply to become undrinkable.

- Wildfires can alter water temperatures for several years in streams draining from burned areas.

Rain and snowfall data are important for long-term planning and can be used to monitor the effectiveness of erosion control work as well as determining forest fire hazard levels. Snow water equivalent is also measured at two sites using snow pillows.

Data Analysis: Converting Data into Useful Information

With 14 sites, and a variety of sensors at each site, keeping track of the data alone could be challenging. However, the GVRD needs to not only keep track of this data, they have to have it instantly available to help them make resource allocation decisions in a timely fashion. Both facets of data management are covered by specialized data analysis software.

Data are collected from each station daily. Further calculations are performed and the results of these calculations are also stored in the data files. GVRD staff can also call the stations at other than preset times.

Table 1 depicts a partial listing of parameters collected from this site. The data show the onset of a storm event. The Rn_1 column shows the hourly precipitation, derived from the Precip column showing water accumulation inside the gauge. The precipitation is probably rain or wet snow (air temperature 0.4_C). It has not yet started to cause a rise in water level, so it is probably being stored as the snow. Note there is a turbidity spike at 3:00 and 4:00 AM, but this does not continue during the 5:00 AM readings and only has a minimal effect on the average turbidity. Hence the 4:00 AM spike was probably some floating debris passing by the turbidity sensor lens during one of its 'once-a-minute' readings. The final column, Volts, displays the battery voltage level of the datalogger; this information is returned with every call to the datalogger.

Graphing constitutes another aid to clarity-trends and exceptions 'leap out' to a viewer. Graphs can include several parameters from one station or the same parameter from several stations. Indeed, as Figure 1 illustrates, such a comparison helped the GVRD quickly theorize a small landslide may have occurred between two monitoring sites by graphing and comparing their turbidities. The upstream site had very low turbidities, while the downstream site suddenly had turbidities over 18 NTU. This data would be used when making decisions concerning erosion control works for that area. GVRD staff also graph water level, precipitation and turbidity for single sites to characterize the natural processes occurring in a particular watershed.

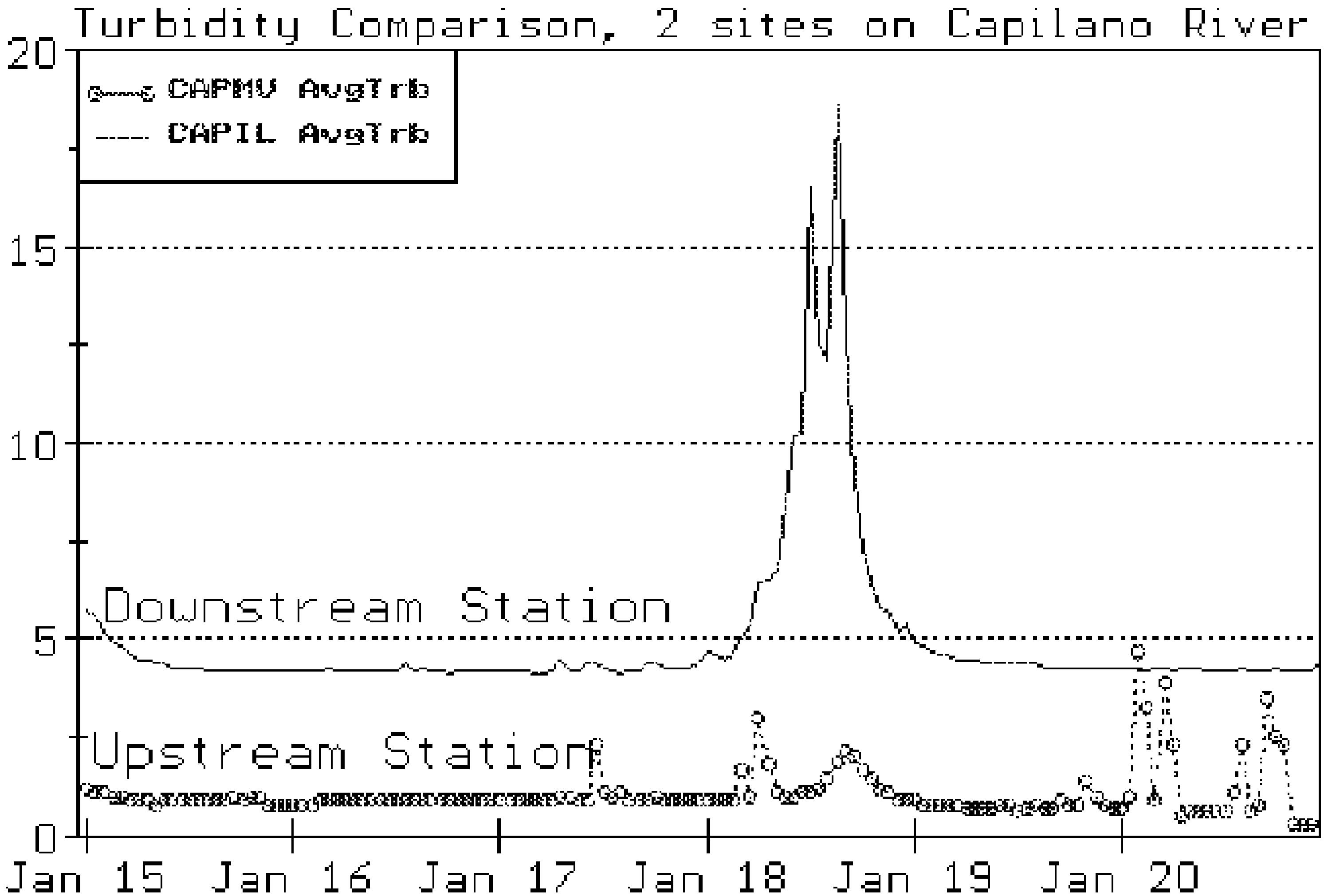

Figure 1. Turbidity Comparison on Capilano River.

GVRD personnel also specify critical criteria. When the computer program identifies a value beyond a user-specified limit, the value is 'flagged' and brought to the attention of the user. Equations and rating tables are also automatically calculated. Water flow, derived from water level measurements are built in and calculate automatically. The flow data is stored together with the rest of a site's data. NOTE: Recently two landslides in the Capilano and Seymour watersheds have resulted in highly turbid drinking water for the citizen's of Vancouver. Turbidity readings and water quality indicators were aired as part of the local, nightly newscasts.

Summary

The network of hydro-meteorology stations that the GVRD operates has helped different divisions plan and monitor erosion control works, forecast water supply information and track raw drinking water quality. Remote, continuous water quality monitoring combined with real time radio access has provided better information on a more timely basis for the GVRD. Offshoots of the system has permitted more effective staff and resource allocation and made the decision-making process in support of the GVRD's primary mandate more effective. Their mandate remains. to manage their protected lands to provide a continuous supply of clean, fresh water. Accuracy, durability and reliability remain key components of this mountainous, urban watershed monitoring system.

Note: This information is provided for reference purposes only. Although the information provided here was accurate and current when first created, it is now outdated.

Miami-Dade Water and Sewer Department's Interactive Weather Radar and Virtual Watershed Management

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

Introduction

The impetus for acceleration of improvements to the Miami-Dade Water and Sewer Department's (MDWASD) sewer transmission and collection system is the result of a negotiated settlement contained within a Consent Decree issued by the United States Environmental Protection Agency (EPA). Regulations and enforcement actions are driven by Dade County's environmentally sensitive features such as the Everglades National Park to the west and Biscayne Bay, an "Outstanding Florida Water", to its east. Dade County is 608,907 hectares (2,350 square miles) in area, of which is 15% water and 16,842 hectares (650 square miles) of Everglades. There are many watersheds which comprise Dade County. Moreover, within Dade County lies the entire MDWASD wastewater collection and transmission system.

In a parallel development, the State of Florida has undertaken its "Ecosystems" initiative which seeks to manage an entire watershed's water quality through an interrelated set of regulatory and planning programs. The concept calls for setting watershed wide environmental goals_including water quality objectives_and then integrating these goals and objectives into the regulations of all pollutant sources within the watershed.

MDWASD has undertaken an improvement program to assure the long-term adequate capacity of the transmission system, including a study to determine rainfall-dependent infiltration and inflow, and procedures for the management of peak flows resulting from rainfall. The County is currently restricted in its ability to issue new building permits when the additional flow contributed by the new sewer connection would result a the pump station violating its operating criteria. Through the use of metered data at representative pump stations, realistic, unique unit influent hydrographs have been developed for each of MDWASD's approximately 900 pump station service areas (PSAs), each PSA acting as a separate subwatershed. Combining the unique pump station hydrographs, a hydraulic model of MDWASD's sewer collection and transmission system, and interactive weather radar/rain gauge results in the ability to predict and prevent sanitary sewer overflows. The goal of the hydrographs, model and radar is to predict and prevent the watershed point source contributions from sanitary sewer overflows.

Collection and Transmission System

MDWASD's sewer system is expansive, providing sewer service to all of Dade County (with the exception of septic systems), 13 volume customers and over 329,000 retail customers. The sewer service area itself covers approximately 104,000 hectare (400 acres) and includes approximately 900 pump stations and 2,414 kilometers (1,500 miles) of force main. The total 1995 plant wastewater treatment plant capacity was approximately 1.34 x 106 m3/day (355.5 MGD). Wastewater from the collection and transmission system flows to one of three wastewater treatment plants. The wastewater treatment plant locations and the forcemain network are shown in Figure 1. Flow has the ability to be diverted between plants using several of its major booster and repump stations. The ability to transfer flow to different areas in the system is critical in preventing sanitary sewer overflows.

Existing Conditions

There are two major aquifer systems in Dade County: the Florida Aquifer System and the Surficial Aquifer System. The Surficial Aquifer is composed of sediments from the water table down to a confining unit. The Floridan Aquifer is found below this confining unit. The Biscayne Aquifer, part of the Surficial Aquifer System, occurs at or near the land surface and is one of the most permeable aquifers in the world. The Biscayne is recharged throughout Dade County by rainfall. Base on a water balance for Dade County, rainfall constitutes the main inflow (73 percent) of the water budget while evapotranspiration and canal discharges represent the main outflows (respectively 38 percent and 35 percent)(SFWMD, 1994).

Hydrographs

Historically, MDWASD's sewer system has experienced surcharging and overflows during wet-weather. Flow monitoring and Sewer System Evaluation Surveys (SSES) performed within the system have determined that the cause of these overflows is excessive infiltration and inflow (I/I) entering the system during wet-weather, as well as, insufficient conveyance and/or system storage capacity. The result of the

Rainfall Dependent Peak Flow Management Study was unique, unit influent hydrographs for the collection and transmission system model, used to perform an evaluation of the adequacy and additional needs of the pump station systems to store and/or convey peak wet-weather flows without system overflows. The 900 pump stations throughout MDWASD's sewer collection and transmission system were grouped into representatively similar categories. The basis for grouping the pump station areas were watershed and collection system characteristics such as: average age of the system, soil type and permeability, groundwater elevations and tidal influence, proximity to surface water bodies, density of service connections, ratio of pervious to non-pervious surface area, land use, historical infiltration/inflow data, system rehabilitation data, seasonal population patterns, and collection system constructions materials.

Development of the hydrographs was based on the above groupings. Dry weather hydrographs were developed for each of the pump station area groupings based on nighttime flows. Rainfall dependent inflow and infiltration (RDI/I) hydrographs were developed for each of the pump station area groupings as well. The composition of the RDI/I hydrograph is shown in Figure 2. The wastewater flow components include: base wastewater flow, groundwater infiltration, and rainfall-dependent infiltration/inflow. The unit hydrograph methodology applied to the systems is based on fitting three triangular unit hydrographs to the actual RDI/I hydrograph. An analysis was performed to determine recession constants and time to peak for three triangular hydrographs which are summed to develop a synthetic hydrograph shape. As a result, the hydrographs for each grouping of PSA's was based on watershed characteristics had similarly shaped hydrographs.

Model Operation

The computer model selected for use by MDWASD was XP-SWMM (developed by XP Software, Inc.), which uses unit hydrographs as input to the model. XP-SWMM is based on EPA's Storm Water Management Model (SWMM) solution module. XP-SWMM is capable of simulating pressures and flows throughout the system, while also having the ability to model gravity and pressure pipe systems simultaneously. The results are real-time flows and pressures. Multiple pumping scenarios can be run prior to implementation to determine effects downstream.

In XP-SWMM, potential overflows can be seen both visually and dynamically. Figure 3 shows a simplified model cross-section of gravity, wetwell, pump, and discharge forcemain which flows to a gravity discharge. The results are played out (in time) in a movie format. When an overflow occurs, water levels at a wetwell will rise above the manhole invert elevation. As Figure 3 illustrates, the pump is currently pumping at a head of approximately 25 meters. Wastewater flows by gravity into the wetwell, and is then pumped into a forcemain which discharges to gravity. The driving force for predicting this sanitary sewer overflow are the inflow hydrographs.

Virtual Rain Gauge (VRG)

Determining the volume of rain within the pump station watershed basin is critical to watershed management and successful operation MDWASD's collection and transmission system. Quantifying the volume of precipitation within the watershed each minute, day, month, or year is necessary. MDWASD, located in South Florida, is susceptible to intense, localized non-uniform tropical storms. Under these conditions, the accuracy of rain gauges is reduced dramatically. Rain gauges measure the rainfall in a small area; however, this data is often taken to be representative of a much larger area. The average size of a rain gauge is eight inches in diameter. There is a general misconception with standard rain gauges that what they measure is representative of what is happening on a much larger scale. Rain gauge accuracy is related to two factors: type of precipitation and rain gauge density (D'Aleo, 1993). Achieving the desired accuracy using rain gauges often becomes cost-prohibitive and impractical. The lack of accuracy is compounded when data from rain gauges is used as input to hydraulic/hydrologic models with inflow assumptions based on gauged information. The watershed approach is not only concerned with what happens in the eight-inch bucket, but what falls over many square miles.

MDWASD is trying an innovative approach by using an interactive weather radar system and Virtual Rain Gauge (VRG). The system used to quantify rainfall is called the VRG, produced by WSI Corporation. VRG is a Windows software which links directly to a satellite and NEXRad radar imagery, then data is downloaded. The VRG operates based on the newest NEXRad filtered satellite imagery with satellite locations at major airports and military installation across the country. The VRG uses filtered radar data to determine the amount of rainfall and intensities within a two kilometer by two kilometer area. The VRG is used by other companies such as the National Weather Service, the National Severe Storms Forecasting Center, and the Weather Channel. Rainfall and intensity data are obtained and used in computer models. As part of an EPA mandated Consent Decree, a hydraulic sewer model was developed for MDWASD which will use the virtual rain gauge data as input. To assist with the model, a virtual rain gauge system is being implemented by Miami-Dade water and Sewer Department to supplement and ultimately replace conventional rain gauges. For large watersheds, the number of rain gauges is no longer a limiting factor.

The output from the VRG can also be used as a direct input to other hydraulic and hydrologic computer models. With input of real hydrologic data into computer models, the predictive capabilities are extensive for fields such as sanitary sewer analysis, stormwater management, water supply, flood plain management, pollutant load studies, and hurricane preparedness studies. Radar is proving to be a more effective and accurate means of determining average rainfall, because it senses average areal conditions as opposed to point data. To operate the system, boundaries of the MDWASD 900 pump station areas are overlayed in Geographic Information Systems (GIS) with the VRG two kilometer by two kilometer grids, as shown in Figure 4. The quantity of rainfall is then proportioned to each PSA watershed. At this point, decisions can be made for each storm event of how to manage flows within the system. When a storm event with overflow potential enters the sewer service area, MDWASD personnel will be able to shift and divert flow with the help of major booster pump stations, to one of its three wastewater treatment plants. A uniform intensity and duration storm throughout the county may require no action. However, localized intense storms may require diverting flow to lines with more capacity.

Watershed Management

Dry and wet weather hydrographs were used as input into the peak flow model. With the data obtained from the VRG and the Model, flow transfer options can be addressed. MDWASD's sewer collection and transmission system has the ability to shift flows between three of its wastewater treatment plants using a combination of pumping scenarios with its major booster and repump stations throughout the system. Preventing sanitary sewer overflows requires predicting the volume of rainfall per each subwatershed (PSA) and determining best management practices based on prior experience and Model results. MDWASD's current application for the VRG is to predict and prevent sanitary sewer overflows; however, this technology may be used to assist in other areas of watershed management as well. The Metropolitan Dade County's Department of Environmental Resource Management (DERM), as part of its continuing stormwater management plan, is developing an approach to establish watershed stormwater quality level of service criteria (Vazquez et al., 1995). However, no criteria is currently imposed.

Conclusions

The complex nature of prevention and management of sanitary sewer overflows requires a watershed approach. Although still in the infancy stage, establishing limits based on total maximum daily loading levels would impose stricter limits on the entire watershed. Imposing watershed limits would allow greater flexibility for sewershed management. The VRG and hydraulic models are innovate management techniques used for watershed management. The technology attained by combination of satellite imagery and on-line computer models can be applied to control other components in the watershed. By combining the VRG and XP-SWMM computer model, MDWASD will have "virtual" watershed management capabilities.

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Watershed Planning System: A Tool for Integrated Management of Land Use and Non-Point Source Pollution

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Introduction

The Watershed Planning System (WPS) is a geographically based decision support system designed to help local governments and State agencies develop coordinated land use and non-point source (NPS) pollution management strategies. The system facilitates a systematic and detailed examination of NPS and land use management issues by (sub) watershed. Managing growth and development, preserving natural areas and agricultural land, and controlling NPS pollution are the primary issues examined in the WPS. The system can be used to select a feasible mix of growth and NPS management alternatives that can be implemented through program changes and best management practices (BMPs). Changes to comprehensive plans, zoning, subdivision regulations, sewer plans, soil conservation and water quality plans, and implementation programs would be achieved by working with local governments and state agencies.

Overview of The Watershed Planning System

The WPS consists of three computer models: the Baseline Inventory Model, the Growth Management Simulation Model (GMS), and the NPS Management Simulation Model (Figure 1). The models use data from composite geographic information system (GIS) overlays. The composite GIS database includes information on land use, soils, streams, watersheds and county boundaries, zoning, sewer service, and agricultural land preservation. Each model combines the basic landscape data with additional watershed information, such as census data and management practices, compiled in cooperation with local governments.

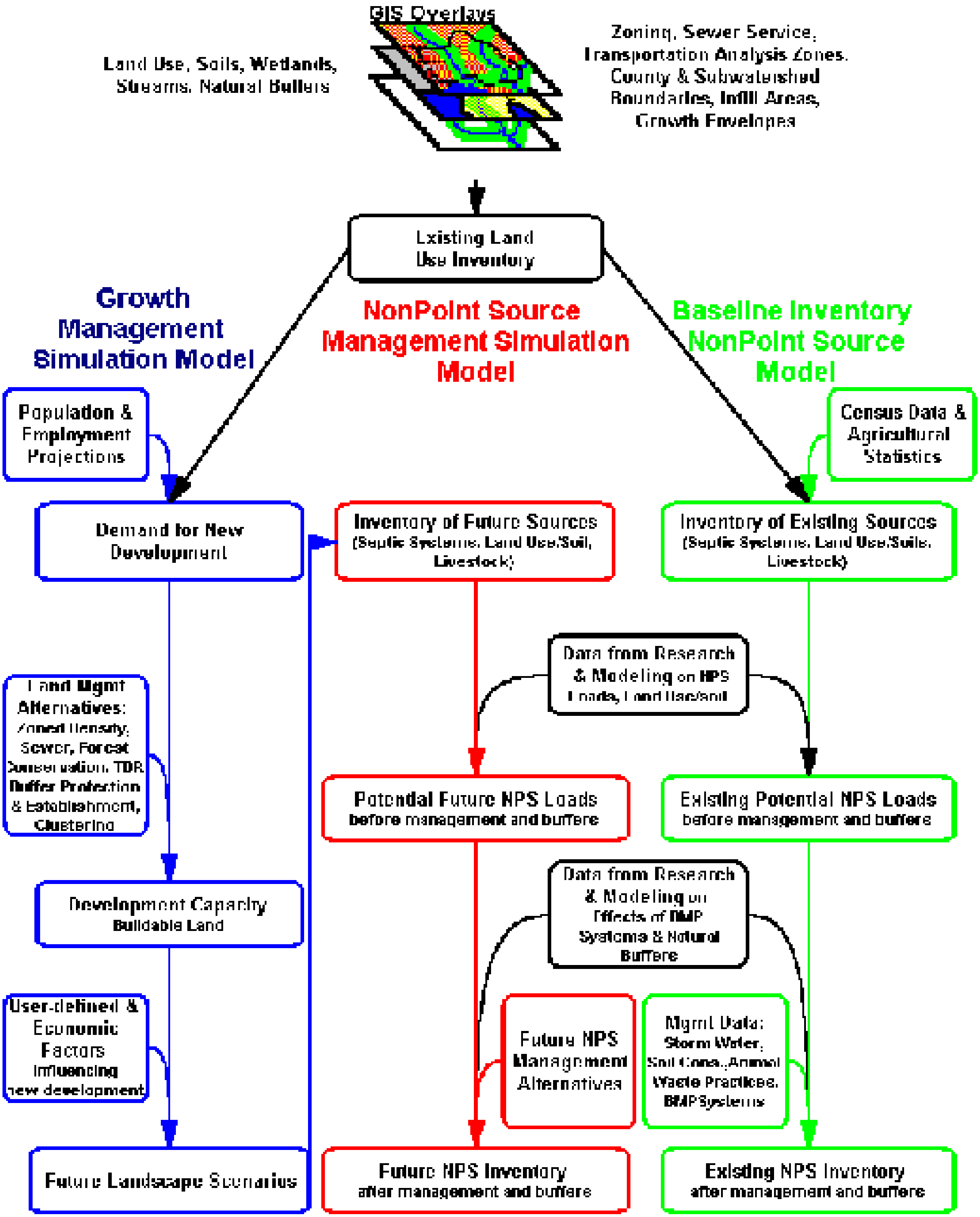

Figure 1:The Watershed Planning System

Figure 1:The Watershed Planning System

The Watershed Planning System estimates the relative nutrient loads from on-site disposal systems (OSDS), land use, and animal facilities. Total nitrogen (TN) and phosphorus (TP) loads from land use sources are calculated using loading coefficients representing the relative potential for small watersheds to discharge TN and TP. Nutrient export coefficients for each land use source are based on a distribution of values that characterized a range of rates that could be reasonably expected in Maryland. To decrease uncertainty and improve reliability, only nutrient export coefficients from locations with climatic conditions, land uses, and soils similar to Maryland are used. Loads from animal facilities are calculated from manure acres (OP, 1994b). Nitrogen loads generated from OSDSs are calculated from the census inventory of septic systems (OP, 1994a), average household size, and the assumption that a percent of the nitrogen leaving the septic tank reaches the subsurface water (Personal Communication,Tom Simpson, Md. Department of Agriculture; U.S. Environmental Protection Agency, 1980). It is also assumed that nitrogen from OSDS will undergo additional reductions prior to reaching surface waters as it moves through subsurface pathways. It is assumed that these reductions are similar to reductions observed for nitrogen leaving agricultural fields (Reneau, R.B., 1979; OP, 1994b).

The estimated TN and TP loads from each source are partitioned among three flow pathways: surface runoff, subsurface flow and groundwater flow. This important feature of the WPS facilitates a more realistic evaluation of the effects of management practices, which act on loads moving through the three pathways in different ways. The models link the effects of management practices and land use alternatives directly to sources, as defined through the GIS. Existing or future management practices are linked to nutrient loading estimates from source categories through their estimated effects on loads moving through one or more of the transport pathways.

Baseline Inventory Model

The Baseline Inventory Model estimates the nutrient loads generated from the current landscape by source category. The landscape is divided into source categories based on OP's 1990 land use and soils (OP, 1973). Data compiled from NPS management programs, research, monitoring, and modeling are then applied to estimate the Baseline Inventory (OP, 1993; OP, 1994b). For each source category the Baseline Inventory estimates the relative pollution loads; the effects of existing management systems and pollution buffers (forest and wetlands); and the loads from reaching surface waters.

Growth Management Simulation Model

The GMS model projects the existing land inventory into a series of possible "future" landscapes, each a function of different land use management alternatives. Land use changes and the loss or gain of pollution buffers depend on the individual county plans, regulations, and management procedures simulated.

Changes in land uses and environmentally sensitive areas are estimated using population projections and growth management factors as independent variables. The model evaluates different possible land use scenarios by changing assumptions about comprehensive plans, zoning plans, sewer service, subdivision and environmental regulations. New development is then calculated as a function of household demand, existing or hypothetical management choices (such as, clustering, transfer of development rights, growth areas, and agricultural land preservation) and user-defined considerations. User-defined considerations allow local concerns, and policies that may influence the type and locations of development to be represented in the model.

Nonpoint Source Management Simulation Model

The Nonpoint Source Management Simulation model estimates the potential impacts of NPS management alternatives (urban and agricultural BMPs) on NPS loads when applied to current land use conditions (Baseline Inventory) or to possible future land use conditions (Growth Management Simulations). The model allows the user to evaluate the relative values of NPS management alternatives under various land use patterns and the importance of the land use alternatives. Thus, a county proposing to use different stormwater management practices can examine the effects on pollution for different possible planning and zoning schemes (such as, traditional versus clustering land use patterns). The effects of stormwater management alternatives can be reviewed in relation to different GMS land use patterns and other NPS controls, such as agricultural controls or pollution buffers. The result is a relatively comprehensive context for watershed planning and decision making.

Conclusion

The key utility of the Watershed Planning System as a planning tool is its ability to readily represent realistic alternatives and management programs. The management scenarios represent the effects of traditional and innovative BMPs, and land management tools. This approach can be applied in any part of the state because the models use standardized GIS layers to characterize important features. The models can also be customized to use more detailed data, where it exists. The requirements and constraints of state and local plans, programs, and regulations are used in the models to determine the potential for development and conservation of resource land and sensitive areas in each (sub) watershed. Following coordination with local jurisdictions and State and local programs, the alternatives evaluated through the models represent feasible program and BMP options.

The WPS is designed to easily incorporate ongoing NPS research and modeling, and can be updated and improved to incorporate new NPS knowledge. To date, the WPS has been applied in the Patuxent River Watershed (OP, 1994c) which covers parts of seven counties, Piney and Alloway Watersheds in Carroll County (OP, 1994b), and in Winter's Run in Harford County (OP and Harford County, in preparation).

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Comprehensive Watershed Analysis Tools: The Rouge Project_A Case Study

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The Rouge River Watershed spans approximately 457 square miles in three counties in south east Michigan and is home to more than 1.5 million residents. Sources of pollution to the river include municipal and industrial permitted point sources, combined sewer overflows (CSOs), storm water runoff and interflow from abandoned dumps. The watershed analysis effort has developed and applied comprehensive computer model of the Rouge Watershed to simulate the water quantity and quality response of the Rouge River system to wet weather events.

Modeling Objectives

The objectives of the modeling work are to:

- Develop comprehensive models of the Rouge River watershed capable of predicting the water quantity and quality response of the Rouge River in response to wet-weather events for existing and future conditions in the watershed, and under various CSO and NPS control alternatives.

- Simulate the Rouge River watershed, using the model, for existing and future conditions, and under various CSO and NPS pollution control alternatives.

- Provide a suite of modeling tools, documentation, and training for future watershed planning.

The models can predict the rainfall-runoff relationship and the water quality response of the river from combined sewer outfalls, non-point source, and point source discharges. Validation of the models use flow and water quality data collected during the Rouge Project.

Approach to Modeling

The approach to simulating the Rouge Watershed with computer models has three tiers. This multi-level approach allows the project to examine and understand, in detail, the various pollutant generation, transport, removal and treatment processes on a small scale and translate the findings to a watershed-wide model. The three tiers are examined below.

The purposes of the Small Area Models (Tier I) are to 1) examine the physical processes of pollution accumulation and transport through simulation and analysis of flows and pollutant loads and concentrations from pilot areas; 2) examine the processes associated with pollution treatment technologies through simulation and analysis of flows and pollutant loads through pilot pollution control projects and 3) develop methodologies for extrapolating the results to the subarea analysis (Tier II).

There are two components to the Subarea Models (Tier II): 1) a simple pollutant loading model, Camp Dresser & McKee's Watershed Management Model (WMM), for screening watershed management alternatives and 2) a complex subarea model, the RUNOFF block of the U.S. Environmental Protection Agency (U.S. EPA) Storm Water Management Model (SWMM), used to develop flows and loads for input into the riverine water quantity and quality models.

There are two components to the Riverine Models (Tier III). The TRANSPORT block of SWMM is used to define river hydraulics to determine river flow, depth velocity, and volume. The U.S. EPA's Water Quality Analysis Simulation Program (WASP) model is used in Tier III to determine river water quality and the fate of pollutants in the river.

Monitoring Program

A comprehensive monitoring and sampling program were designed and carried out to support the Rouge River Watershed analysis activities. This program supports the computer simulation required for watershed analysis and the region's long-term management of the watershed. The monitoring and sampling program are subdivided into three major categories: source characterization, pollution control, and instream characterization. An important tool developed for the Rouge Project was DataView. DataView, a Windows (TM) program, allows display and analysis of the extensive monitoring data collected during the project.

Source Characterization

Flow monitoring and sampling was done at storm drain outfalls and CSO outfalls to characterize the discharge. Sampling was designed and carried out to determine the presence and strength of a first flush and provide guidance on variability of pollutants.

Pollution Control

The influent and effluent of CSO treatment basins were sampled to help determine the pollutant treatment efficiencies. Storm water treatment devices: wetlands, dry and wet basins, swales and others, were also sampled to help determine the pollutant treatment efficiencies.

Instream Characterization

Water Quantity Monitoring. The components of the water quantity monitoring consisted of twenty-three rain gages recording 15 minute precipitation in the watershed. The watershed has seven U.S. Geological Service (USGS) flow gages. For the project, USGS established flow rating curves at ten additional stations on the four rivers.

Water Quality Monitoring. Seventeen continuously recording stations were established that recorded dissolved oxygen, temperature, pH, and conductivity in the Rouge River system. In addition, 16 water quality sampling stations were established. Seven wet weather and two dry weather samplings were done in 1994, and two wet weather and one dry sampling were done in 1995 to established baseline water quality conditions, and to validate the Tier II and Tier III models.

Tier I_Small Area Analysis Modeling Tools

Tier I modeling examine the physical processes of pollution accumulation and transport on the land surface and the processes associated with pollution treatment technologies. The source characterization and pollution control monitoring programs provide data for model validation for Tier I models. Several models have been used for the Tier I analysis. Models included the Program for Predicting Polluting Particle Passage Thru Pits, Puddles & Ponds (P8)_Urban Catchment Model was developed by Dr. William W. Walker for the Narragansett Bay Project (Walker, 1990). The model predicts pollutant load generation and transport in stormwater runoff for urban watersheds assuming contaminants are adsorbed to up to five particle classes. The model was used to predict the pollutants in storm water runoff and to predict the removal efficiency of BMPs. In addition for Tier I, the RUNOFF and TRANSPORT blocks of SWMM were used to examine the buildup and washoff of pollutants on urban land surfaces in combined sewer areas, mix with sanitary flow in sewer lines to determine the characterization of combined sewer overflows (Huber 1988). TRANSPORT and later the STORAGE/TREATMENT block of SWMM simulated the treatment efficiencies of CSO basins. The findings of the Tier I analyses and simulations are a fundamental understanding of the pollutant generation, transport, and removal during treatment process, which can be extrapolated to Tier II analyses.

Tier II_Subarea Analysis

The simple pollutant loading model, WMM, uses event mean concentration (EMC) and annual runoff to predict the load of ten selected pollutants. The EMC for each pollutant was developed for each of the ten different land uses in the watershed (CDM, 1992). The pollutant load model allows many alternatives to be evaluated and permits many users to do the simulations.

A second Subarea Analysis model used is the RUNOFF block of SWMM that simulated the pollutant buildup and washoff in the 460 square mile watershed. More than 350 subareas were developed, varying in size from 50 acres for some small combined sewer areas to more than 2 miles in the undeveloped west portion of the watershed. Flow and pollutant loads for each subarea are simulated using the RUNOFF block for a six-month simulation. Initially, an EMC approach was used to simulate the pollutant generation. This was changed to buildup and washoff after analysis of the source characterization sampling data. For model validation, a six-month continuous simulation was used. In the combined sewer areas, detailed EXTRAN and TRANSPORT models have been developed of the combined sewer collection system by the Detroit Water and Sewer Department for their CSO abatement program. The combined sewer models are called the Greater Detroit Regional Sewer (GDRS) Model. The Rouge Project used the TRANSPORT GDRS model to simulate the combined sewer collection system. In the separate sewer areas (storm water areas) the flow and pollutant time series from RUNOFF is used to provide input to the Tier III riverine TRANSPORT and WASP models. In the combined sewer areas, the flow and pollutant time series from RUNOFF was input into the TRANSPORT combined sewer model, which in turn, provide flow and pollutant time series data to the TRANSPORT riverine model.

Tier III_Riverine Models

The Tier II and Tier III models makeup the watershed models. River cross section data provided the physical data for the TRANSPORT riverine model. An extensive model validation process was undertaken to simulate the hydraulics in the river system accurately. The validation of the models included comparing six months of flow data at 17 flow gaging stations.

The pollutant loads generated by RUNOFF, in the storm drain areas, and by TRANSPORT in the combined sewer areas, are input into the WASP model. WASP also has hydraulic input from the TRANSPORT riverine model. The result is a six-month time series of flow and quality from the WASP model.

Findings

The monitoring data, analysis tools, and subsequent simulation models have allowed insight into the complexities of the sources, processes, and responses in the Rouge watershed. The analysis has uncovered the following findings:

- The poorest water quality occurs in the Rouge River during short intense rainfalls of moderate storm volumes. During these short intense storms, CSO discharges to the Rouge River, which has a low base flow. Larger storm events produce storm water runoff, which "dilutes" the combined sewer discharges in the Rouge River. The dissolved oxygen concentration can drop several mg/l in a matter of hours in the river, and then recover quickly during these storm events.

- The Detroit combined sewer system displays a "first flush" for many pollutants during storm events. The first flush is most pronounced for total suspended solids. Further analysis is underway to discern the causes of first flush in the combined system, land surface runoff or solids' resuspension in the combined sewer or both. The Project is evaluating the effectiveness of CSO treatment basins to store and treat CSO discharges to meet uses in the Rouge River.

- Increasing river peak flows in the Rouge River system from further urbanization of the watershed contributes to many problems. These problems include bank erosion along all branches, high velocity change that severely limits the fish and macroinvertabrate community. Effective watershed management includes not only source and structural water quality controls for storm water areas, but must also include flow controls to restore the uses to the Rouge River.

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Development and Application of a Coupled GIS-Modeling System for Watershed Analysis

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Introduction

In order to facilitate the site-specific, problem-specific development and application of water quality models in Great Lakes watersheds, a modeling support system that links water quality models with a geographic information system (GIS) (ARC/INFO) has been developed. This system, which is called Geo-WAMS (Geographically-based Watershed Analysis and Modeling System), automates such modeling tasks as: spatial and temporal exploratory analysis of watershed data; model scenario management; model input configuration; model input data editing and conversion to appropriate model input structure; model processing; model output interpretation, reporting and display; transfer of model output data between models; and model calibration, confirmation, and application. The design of Geo-WAMS and its feasibility and utility are demonstrated by a prototype application to the Buffalo River (Buffalo, NY) watershed. The prototype provides a modeling framework for addressing watershed management questions that require quantification of the relationship between sources of oxygen demanding materials (biochemical oxygen demand, BOD) in the watershed and distribution of dissolved oxygen in the Buffalo River. It includes a watershed loading model, the output from which is automatically converted to input for a modified version of EPA's WASP4/EUTRO4 model for simulation of dissolved oxygen in the river. In this way the impact of regulatory or remedial actions in the watershed on the dissolved oxygen resources in the lower river can be examined.

The Geo-WAMS Concept

Geo-WAMS was designed by carefully considering the process a modeler goes through in developing and applying a surface water quality model on a site-specific basis. Generally, this process involves a series of steps that include: problem specification, theoretical/conceptual construct, numerical construct, model code development and implementation, model calibration, model confirmation, and diagnostic or management application. In reviewing the modeling process as applied to watershed analysis, two major needs stand out. First, regardless of the level of sophistication, application of water quality models on a watershed basis requires efficient acquisition, storage, organization, reduction and analysis of model input data accompanied by manipulation, interpretation, reporting, and display of model output data. Second, application of mathematical models for analysis of water quality on a watershed scale usually requires a cascading linkage of several models. For example, in the analysis of the impact of land use in a watershed on dissolved oxygen resources in a river that drains the watershed, one might have to run a hydrologic runoff model, a pollutant loading model, and a river dissolved oxygen model in series. Converting output from one model to appropriate format and spatial/temporal scale for use as input for the next model can be a very tedious task.

The Geo-WAMS Modeling Support System was design to facilitate the job of the water quality modeler in accomplishing the various data-interactive and model-application tasks necessary to develop and apply a site-specific, problem-specific, process-oriented mathematical modeling framework. The features built into Geo-WAMS to accomplish these goals include:

- Familiar User Interface;
- Geographic Information System (ARC/INFO);
- Relational Database Management System;
- Process Models and Model-Data Linkages;
- Model Input and Model Linkage Assistance Tools;

- Model Scenario Manager;
- Model Application Tools_calibration, sensitivity analysis, diagnostics, management analysis, etc.;
- Model Output and Field Data Query Module;
- Model Output and Field Data Visualization Tools.

The above features have been built into a software package that integrates five major components as depicted in Figure 1:

- Spatial/temporal database_a database management system that allows modelers to input, store, analyze, retrieve, and display all spatially and temporally referenced data.
- Data-Model management interface (DMMI)_a software interface for the data conversion between spatial database and process models and for the user to access the database, the process models, and the toolkit utilities.
- User interface (UI)_a window and screen menu program written in macro language for the user to visually examine the spatial and temporal data sets and to interactively manage and analyze them through the DMMI. A series of help/explanation windows is also a part of this interface.
- Process models_a group of existing and newly developed mathematical models for aquatic system analysis and management. These models could range from relatively simple conservative substance transport models to complex, high resolution ecosystem food web models.
- Analyst Toolkit Utilities_a library of utilities used for data manipulation, data analysis, model development, and model application.

The conceptualization and functioning of Geo-WAMS is presented in more detail in DePinto, et al. (1994).

Description of Buffalo River Watershed

The Buffalo River watershed is comprised of 430 square miles of mixed land use drainage area contributing flow and pollutants into the lower portion of the river (a Great Lakes "Area of Concern"), which flows through the city of Buffalo and discharges into Lake Erie. The Buffalo River receives BOD loading from point sources, combined sewer overflows (CSOs) discharging directly into the lower six mile urban portion of the Buffalo River, and nonpoint runoff from various types of land use in the watershed. As shown in Figure 2, forest and agricultural land dominate the watershed, with urban land uses concentrated near the city of Buffalo.

There is a long history of industrial activity within the Buffalo River watershed. Although much of this activity has diminished in recent years, low levels of dissolved oxygen (.1 mg/L) are still observed during summer low flow conditions. The extent to which this low dissolved oxygen condition is the result of various ongoing land uses in the watershed is the subject of this demonstration project for the Geo-WAMS concept.

Model Description

The Buffalo River application of Geo-WAMS consists of two linked models (Watershed Pollutant Loading Model (WLM) and WASP4/EUTRO4), the data base necesssary to configure and apply the models, and a number of analysis tools that facilitate the configuration and application of the models. Taken as an integrated unit this program permits analysis of the loading of oxygen-demanding materials from the Buffalo River watershed and its impact on the dissolved oxygen resources in the lower portion of the Buffalo River.

Watershed Pollutant Loading Model

The Watershed Pollutant Loading Model (WLM) makes extensive use of ARC/INFO (a GIS) in storing, generating, and retrieving input data, in calculating pollutant loadings as a function of spatial data and associated attributes, and in displaying spatial distributions of pollutant loadings in a given watershed. In short, the WLM is intimately coupled with, indeed operates within, the ARC/INFO environment. The model functions by first estimating areal distributed precipitation and then calculating runoff quantity and quality; specified point source loading information is also included in model output. The three major elements of the WLM operate as follows (more detail can be found in Sullivan and Song-James, 1995):

- Estimation of Watershed Precipitation: Precipitation is the driving force behind the generation of runoff and associated pollutant loads. Estimation of precipitation across the watershed is based on available precipitation data from rain gages located either within the watershed or in nearby areas. Spatially distributed precipitation or mean areal precipitation is generated using GIS information on the location of rain gages, elevation, and other contributing factors.

- Hydrologic Submodel: The hydrologic submodel of WLM generates runoff flow within the watershed. To fully utilize the power of a GIS and spatially distributed data, a distributed parameter modeling approach based on the USDA's Soil Conservation Service (SCS) Curve Number Model was selected for our prototype application on the Buffalo River watershed. The SCS Curve Number Model requires spatially distributed soils and land use data that was readily available for the Buffalo River watershed.

- Pollutant Loading Submodel: The loading submodel allows for the generation and/or specification of pollutant loadings and their transport and fate within the watershed. Loading sources include point sources, nonpoint sources from rural as well as urban areas, and CSOs. Point source loads are regulated by NYS SPDES permits; therefore, discharge and loading information is reported regularly. Pollution loads from nonpoint and CSO sources will vary depending on precipitation quantity, land-use activities, storage capacities, and watershed topographic features. With this model nonpoint source exports of BOD, TSS, TN (total nitrogen) and TP (total phosphorus) are determined on a daily basis for individual polygons in the watershed based upon runoff calculated by the hydrologic submodel and land use-specific event mean concentrations (EMCs) for the pollutants of interest. To determine the actual loading to the lower river, delivery ratios are applied on the basis of distance from the lower river to account for in-stream losses.

BREUTRO

EUTRO4 is a sub-model of WASP4, the updated version of the Water Quality Analysis Program (WASP), developed in 1981 by Hydroscience, Inc. (Ambrose, et al. 1987). EUTRO4 is a dynamic mass balance model designed to analyze a variety of eutrophication and/or dissolved oxygen problems in surface waters. Because this model is supported by the U.S. Environmental Protection Agency and has been widely used, it was an excellent candidate for integration into Geo-WAMS. BREUTRO refers to the EUTRO4 model configured to address the dissolved oxygen problem in the lower Buffalo River.

Geo-WAMS Application

The linked models described above were run for the growing season (April 1 to October 31) of 1990. This period represented the best data set for precipitation, flow, and water quality data pertinent to our problem. After calibration, the watershed model was used to evaluate the combined and individual effects of various sources within the watershed on BOD and DO in the Buffalo River. The model was also used to determine the impact of changes in land use or implementation of pollution abatement practices (e.g.,Best Management Practices in agricultural areas) on the dissolved oxygen in the lower river.

A very useful analysis that is facilitated by GIS allows the analyst to visualize the spatial distribution of loading of a pollutant of concern througout the entire watershed. Such a visualization for the seasonal yield of BOD5 to the river for the April-October, 1990 period is presented in Figure 3. This display allows one to use the GIS to rapidly determine the relative contributions from different classes of sources during a given period. For example, the model output for this period indicates an average BOD5 loading to the river of 6,850 kg/day, with 53%, 9%, 35%, and 3% coming from CSOs, urban runoff, rural runoff, and point sources, respectively.

Another post-processing capability of GEO-WAMS was used to analyze the output of BREUTRO for the lower Buffalo River. This module also takes advantage of the GIS capabilities of the system to display the model output as a spatial animation. This AML program allows time-dependent simulation model output to be transferred to the GIS for display in two-dimensional map form on the screen. At each time step the spatial variation of any given parameter may be displayed. Dynamic changes with time can then be illustrated by sequentially displaying maps at different time steps. This provides a valuable means of viewing model output.

The Buffalo River watershed analysis performed with Geo-WAMS allows us to make assessments about the relative impact of source management on dissolved oxygen in the river. For example, although CSOs represent the biggest loading of BOD to the river, their impact on dissolved oxygen resources are not as significant as upstream loadings because of their discharge location (lower river) and the fact that they contribute loads only during high flow periods when the BOD does not have much time to exert itself before being discharged into Lake Erie.

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A Wasteload Allocation Modeling Tool for Watershed Management

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Introduction

A numerical tagging technique has been developed to address eutrophication control in watershed management. One of the most recurrent questions in eutrophication control is the fate and transport of nutrients from wastewater discharges. For example, nutrients from point and nonpoint sources could be incorporated into the biomass of phytoplankton, deposited into the sediments, or transported downstream. This tagging technique is developed to address the question: How much nutrients in the algal biomass at a certain location in the receiving water is from a given source?

In BOD/DO modeling, component analyses are routinely performed to quantify the contribution of individual BOD sources to dissolved oxygen deficits (Thomann and Mueller, 1987). The analysis procedure is straightforward: a particular BOD load is removed from the model, the model is rerun, and the resulting DO concentrations are compared to the original results. The difference in dissolved oxygen concentrations between the two model results, before and after removing the BOD load, represents the portion of the overall dissolved oxygen depression in the receiving water attributable to this specific component of the BOD loadings. Such a procedure is not applicable to eutrophication modeling simply because of the nonlinear formulations in the eutrophication models (e.g., algal growth and nutrient dynamics). Removing individual phosphorus sources might result in proportional reductions in river nutrient concentrations but unproportional reductions in chlorophyll a concentrations. Thus, if the sources of a nutrient (phosphorus or nitrogen) were removed one at a time and the reductions in biomass (presumably chlorophyll a associated with that nutrient source) were added together, the sum would not be equal to (most likely, much lower than) the biomass resulting from the analysis in which all nutrient sources are included (Lung, 1996).

The numerical tagging procedure is quite similar to the 32PO4 technique that limnologists used in tracking phosphorus in the natural water system by measuring the amount of 32PO4 in various phosphorus compartments in the system. Instead of a radioactive tracer, a numerical tracer is injected to one of the nutrient sources in the eutrophication model. The model, which is based on the mass balance principle, is used to track the concentrations of this nutrient in the receiving water. The numerical tagging technique has been applied to the Upper Mississippi River and Lake Pepin, MN to track the fate and transport of major phosphorus sources and to the James Estuary, VA to track phosphorus and nitrogen from point and nonpoint sources. Successful applications have demonstrate that the technique is particularly useful in quantifying the contribution of an individual nutrient source or a group of sources to the phytoplankton biomass in the receiving water. This paper presents the concept behind the procedure and displays results from these model applications.

Modeling Framework and Technical Approach

The modeling framework used for developing this tagging technique is the EPA's Water Quality Analysis Simulation Program (WASP). WASP5 is the latest version available from the EPA's Center for Exposure Assessment Modeling (CEAM) in Athens, GA (Ambrose et al., 1993). EUTRO5 is the eutrophication module of WASP, modeling eight water quality constituents in the water column and sediment bed and is probably one of the most commonly used modeling framework used in wasteload allocation studies of nutrients to date (Lung and Larson, 1995; Lung, 1996). Phosphorus is present in three interlinked compartments in the EUTRO5 model: orthophosphate, nonliving organic phosphorus, and phosphorus in the phytoplankton. To track these components in the receiving water, three additional system variables have been added: labeled orthophosphate (variable No. 9), labeled nonliving organic phosphorus (No. 10), and labeled phytoplankton (No. 11). Special care is needed to preserve the nonlinear relationship between algal growth rate and phosphorus concentrations. While the kinetic interrelationships among these labeled compartments are separate, but the same as those for the unlabeled, algal growth rates are calculated based on the total concentration of labeled and unlabeled orthophosphate. When either labeled or unlabeled orthophosphate is exhausted, algal growth and associated phosphorus uptake should shift to the other compartment to maintain the mass balance and avoid negative orthophosphate concentrations. Labeled phosphorus is tracked separately and cycled within the labeled compartment (i.e., variables No. 9-11). Carbon in both labeled and unlabeled phytoplankton biomass is recycled to the common CBOD pool. In tracking phosphorus alone, ammonia and nitrite/nitrate are utilized by both labeled and unlabeled phytoplankton. Nitrogen in the phytoplankton biomass (both labeled and unlabeled) is also recycled to the common nonliving organic nitrogen pool. Although the orthophosphate concentration has been divided into two compartments, labeled and unlabeled, the phytoplankton growth rate must be calculated based on the combined concentrations of these two components, because the phytoplankton should not discriminate between these two phosphorus sources. The phytoplankton growth rate (in day-1) is calculated accounting for the effects of water temperature, light, and the levels of nutrients (phosphorus and nitrogen) in the water column (Thomann and Mueller, 1987). A complete description of the formulations of the equations for the numerical tagging model and the testing of the model can be found in Lung (1996).

Application to Upper Mississippi River and Lake Pepin

The Metropolitan Wastewater Treatment Plant (Metro Plant) is located in St. Paul, MN on the Upper Mississippi River and is approximately 50 miles upstream of Lake Pepin. A recent wasteload allocation modeling study by Lung and Larson (1995) showed that phosphorus load reductions at the Metro Plant would have a minimum effect on reducing the algal biomass in Lake Pepin. The next question is: To what extent is phosphorus from the Metro Plant transported to Lake Pepin under both existing and potential reduced loading conditions? More specifically, how much phosphorus in the algal biomass in Lake Pepin is from the Metro Plant?

Results of the numerical tagging analysis for the summer 1988 condition are presented in Figure 1, showing the fate of different phosphorus sources in longitudinal concentration profiles of total phosphorus, orthophosphate, and phytoplankton concentrations in the river under two loading scenarios: the 1988 loads and the reduced phosphorus (effluent concentration = 0.4 mg/L) loads at the Metro Plant. Figure 1 shows the dominating effect of the Metro Plant discharge on the phosphorus concentrations in the water column during the summer months of 1988. In general, total phosphorus and orthophosphate concentrations are reduced in the downstream direction, indicating loss of phosphorus along the river (due to algal uptake and settling) in addition to dilution by the St. Croix River. Although the Metro Plant effluent contains no phytoplankton biomass, phosphorus from the effluent is gradually taken up by the phytoplankton in the river, leading to the band of phosphorus in algal biomass attributed to the Metro Plant in the lower panels of Figure 1. Results from another model run to quantify the phosphorus components under a reduced Metro Plant phosphorus load are also shown in Figure 1. The reduced loading rates reflect a 10-fold reduction of phosphorus loads at the treatment plant. Total phosphorus and orthophosphate concentrations in the receiving water would be reduced significantly under this scenario. Subsequently, the uptake of this phosphorus by the algal biomass in the water column would be considerably reduced compared with the summer 1988 condition. However, despite the significant reduction of phosphorus loads from the Metro Plant, the phytoplankton biomass reduction would amount to only 10 µg/L of chlorophyll a behind Lock and Dam No. 2 and even less (about 5 µg/L) in Lake Pepin, in agreement with the original modeling results (Lung and Larson, 1995).

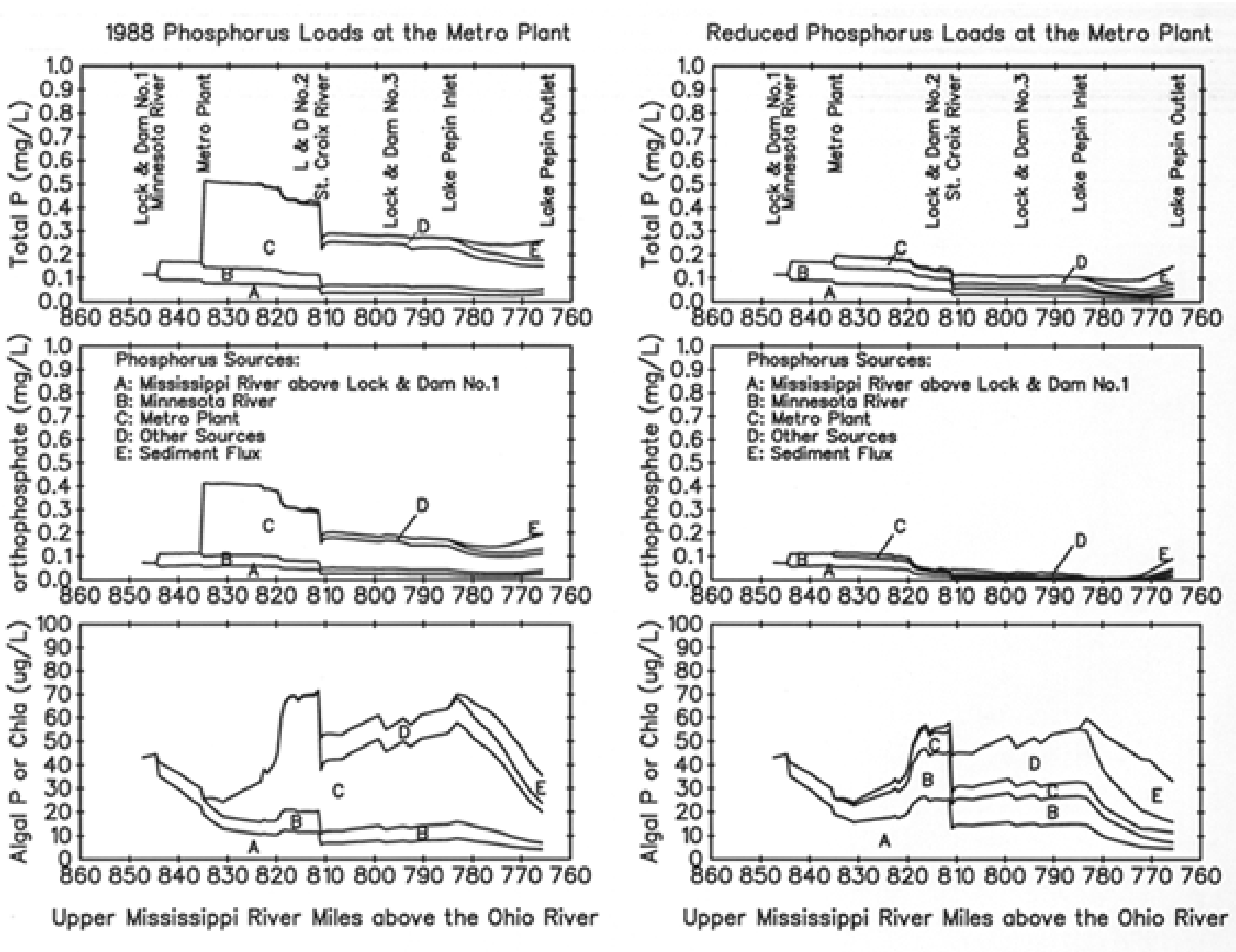

Figure 1. Calculated total phosphorus, orthophosphate, and algal P or chlorophyll a concentration under 1988 and reduced loading rates.

A comparison between the compositions of phytoplankton phosphorus or chlorophyll a (Figure 1) reveals a significant change in the contributions from various phosphorus sources. In fact, phosphorus from other sources would increase its contribution to the phytoplankton biomass in the water column significantly, almost making up the lost contribution from the Metro Plant. While the contribution from the Metro Plant to the phytoplankton phosphorus or chlorophyll a in the water column would be reduced to a narrow band of concentrations in the receiving water, other phosphorus sources would still be available for algal growth in the river (Figure 1).

Application to James Estuary

The James Estuary in Virginia is one of the major tributaries to the Chesapeake Bay. Control measures to reduce phosphorus loads to the bay include a phosphate detergent ban (since January 1, 1988) and an average monthly limit of 2 mg/L of total phosphorus in the effluent of about 40 wastewater treatment plants in the Chesapeake Bay drainage basin. A modeling study by Lung (1986a) indicated that a reduction of nutrient inputs by removing phosphorus at municipal wastewater treatment plants would lead to a phosphorus limiting condition in the James Estuary, thereby lowering the phytoplankton biomass levels.

The numerical tagging was applied to the James Estuary to assess the impact of point source phosphorus controls on eutrophication in the context of the fate and transport of phosphorus from major point sources. The model runs were conducted under the river condition of September 1983 (Lung and Testerman, 1989), which data were available to calibrate the EUTRO5 model. Results of the modeling analysis showing total phosphorus, orthophosphate, and chlorophyll a concentration profile in the James Estuary from Richmond to the mouth of the river under no point source control and point source control scenarios can be found in Lung and Testerman (1989). Due to the significant phosphorus loads from the point sources in the James River basin, reducing the point source loads by removing phosphorus at wastewater treatment plants to an effluent concentration of 2 mg/L would reduce the peak chlorophyll a levels in the estuary by a factor of two. Unlike the case in the Upper Mississippi River and Lake Pepin where nonpoint phosphorus loads are more significant than the point sources, controlling point sources in the James River basin would have a significant impact on eutrophication. This result is consistent with the earlier finding by Lung (1986b) that prior to implementing the control measures, the James River basin was dominated by point source nutrient loads.

The numerical tagging model was also modified to track nitrogen components: nonliving organic nitrogen, ammonium, and nitrite/nitrate nitrogen in the James Estuary (Brown, 1994). The nitrogen tagging model was run under a 7-day 10-year (7Q10) low flow condition with the point source phosphorus and nitrogen loads reduced to levels at concentrations of 2 mg/L. Model results showed that the nitrogen reduction yielded no further reduction in the algal biomass levels, suggesting that the estuary was phosphorus limited. In addition, the results showed that the nonpoint source impact on the chlorophyll a concentrations in the estuary is minor under the 7Q10 low flow condition.

Summary and Conclusions

Results from this numerical tagging analysis demonstrate that the technique is very useful in providing additional insight into the phytoplankton-nutrient dynamics in the Upper Mississippi River and Lake Pepin and the James Estuary in terms of water quality management. The model results are particularly useful in quantifying the contribution of an individual nutrient source or a group of sources to the phytoplankton biomass in the receiving water. Applying the technique on a watershed basis would yield information for developing a sound water quality management strategy, particularly in terms of the trade-off between point and nonpoint loads. It has been demonstrated that the numerical tagging analysis can be instrumental in improving the overall TMDL (total maximum daily load) development of a particular watershed. By adding a sediment system to the model, one could identify the origin(s) of phosphorus in the sediment by quantifying the shares of the contributing sources. Such an analysis would complement field work on finger-printing phosphorus in the sediment. Finally, the principles behind the procedure are not site specific to the Upper Mississippi River or James Estuary, but rather generic enough to apply to any water quality-limited waterbody that requires TMDL development.

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Watershed Based Source Screening Model_An Analytical Tool for Watershed Management in Urban Environments

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***Web Note:** Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

As specified in the 1988 Storm Water Management Plan (SWMP), the Alameda Countywide Clean Water Program (Program) has actively researched urban storm water runoff, the pollution problems it causes and control measures that can be implemented to address the problems. Activities and investigations have included monitoring of water quality in streams and storm inlets; literature reviews to evaluate sources of urban storm water pollution (e.g., pollution in roof runoff and street runoff); pilot studies to optimize solutions for urban storm water problems; development of Best Management Practices (BMPs) to control storm water problems; and evaluation of natural treatment facilities, such as marshes, to cleanse storm water (e.g., DUST Marsh). These investigations have provided the Program with an understanding of urban storm water issues and the effectiveness of treatment measures

The Regional Water Quality Control Board and the EPA are now encouraging urban runoff programs to pursue a watershed-based solution approach, the intent of which is to develop and implement an integrated, holistic strategy to effectively restore and protect aquatic ecosystems and human health. As a result, the Program plans to integrate a Watershed Management Approach (WMA) into the SWMP. One of the elements of the WMA is to assess watershed needs which includes

- Characterization of aquatic resources and beneficial uses
- Identification of existing and potential threats to the resources
- Prioritization of the beneficial uses and threats

As a first step towards assessing the needs of the watersheds in Alameda County, the Program has developed a 'Source Evaluation Method' (SEM), designed to identify satisfy a portion of the watershed needs assessment_evaluate basin-wide sources of water quality problems. As part of the SEM a Watershed Screening Model was developed and tested on a pilot watershed in the City of Oakland (Sausal Creek).

Source Evaluation Method

The objective of the SEM is to qualitatively evaluate basin-wide water quality problems. The method consists of five clearly defined and separable steps which are described below.

Step 1. Compile Known Water Quality Problems In Watershed

This is a critical component in the SEM. The objective is to compile known, direct or indirect impacts on water quality in the watershed. These may include the effects of toxic pollutants such as fish kills, impacts associated with nutrients and eutrophication such as algae blooms or taste and odor problems in reservoirs, and others. Determination of the water quality impacts in the watershed will serve as a road map in conducting the remaining tasks in the SEM.

Sources of information on known water quality impacts include: local regulators (Regional Water Quality Control Board), city and county water quality managers, environmental groups, and local and citizen groups.

Step 2. Characterize the Physical Properties of the Watershed

The physical nature of the watershed such as size, topographic relief, and local hydrologic conditions will determine the runoff and erosion from the watershed. Characteristics such as land use, creeks and storm drainage system in the watershed may be used to delineate sub-watersheds, so that different attributes of the watershed may be clearly differentiated and addressed. Evaluation at a sub-watershed scale is more meaningful for two reasons. First, not all sub-watersheds within an urban watershed will have the same level of development. Second, it is easier to identify water quality problems at a sub-watershed level.

Sources of information on watershed characteristics included available material such as: maps (USGS, city storm drainage, RCDC soils map), aerial photographs, photographs, and previous reports.

Step 3. Inventory Watershed Activities

The objective of this step is to identify activities in the watershed that are potential sources of water quality problems. Such activities include those typically associated with urbanization such as industrial and construction practices; agricultural practices such as herbicide and pesticide application; recreational activities, and transportation. Because identifying every pollutant source-activity is often difficult and time-consuming, an alternative is to use watershed land uses as a surrogate. The advantage of using land use as a surrogate for activity is that data are available for different land uses and many activities are concentrated within certain land uses. The disadvantage is that many sources are lumped together which necessitate further analysis to differentiate between specific sources, and that many activities (e.g., vehicle use) occur in many different land uses.

Sources of watershed activity information include interviews with knowledgeable stakeholders and jurisdictional agencies such as: city and county planning departments, Department of Parks and Recreation, Department of Fish and Game, Department of Forestry and Fire Protection, and Department of Water Resources.

Step 4. Link Watershed Activities to Impacts

The objective of this task is to provide the physical link between the activities identified in Step 3 and water quality impacts. The ideal approach would be to use a physically-based model to simulate the effects of the activity on water quality. For example, the impacts to water quality from parking lot runoff would be estimated by physical relationships between pollutants, runoff and the period and intensity of rainfall, the antecedent dry period, the parking lot surface material plus other factors. However, except for a few activities, the relationship between the activity and water quality is either not very well understood or is too complicated and data intensive to use in a screening model. Therefore, empirical relationships are used to relate activities (or land use) to water quality impacts.

Model Description. The screening level model developed for this task is a simple spreadsheet model which uses empirical relationships to estimate annual pollutant loads. The model is not designed to be used for loads assessment since it only uses loads as a surrogate for water quality impact.

For most activities the relationship between the activity (land use) and the water quality impact is the concentration of pollutants in the runoff. This concentration is not estimated from watershed specific data but is the average from land use specific data collected by the Program and other urban runoff programs. The model compares the loads from the different land use-activities to a baseline value and ranks the severity of the water quality problem into a high, medium or low impact. Input into the model includes watershed reach parameters, soil parameters, land-use breakdown, and precipitation. Figure 1 is a flow-chart of the model-layout.

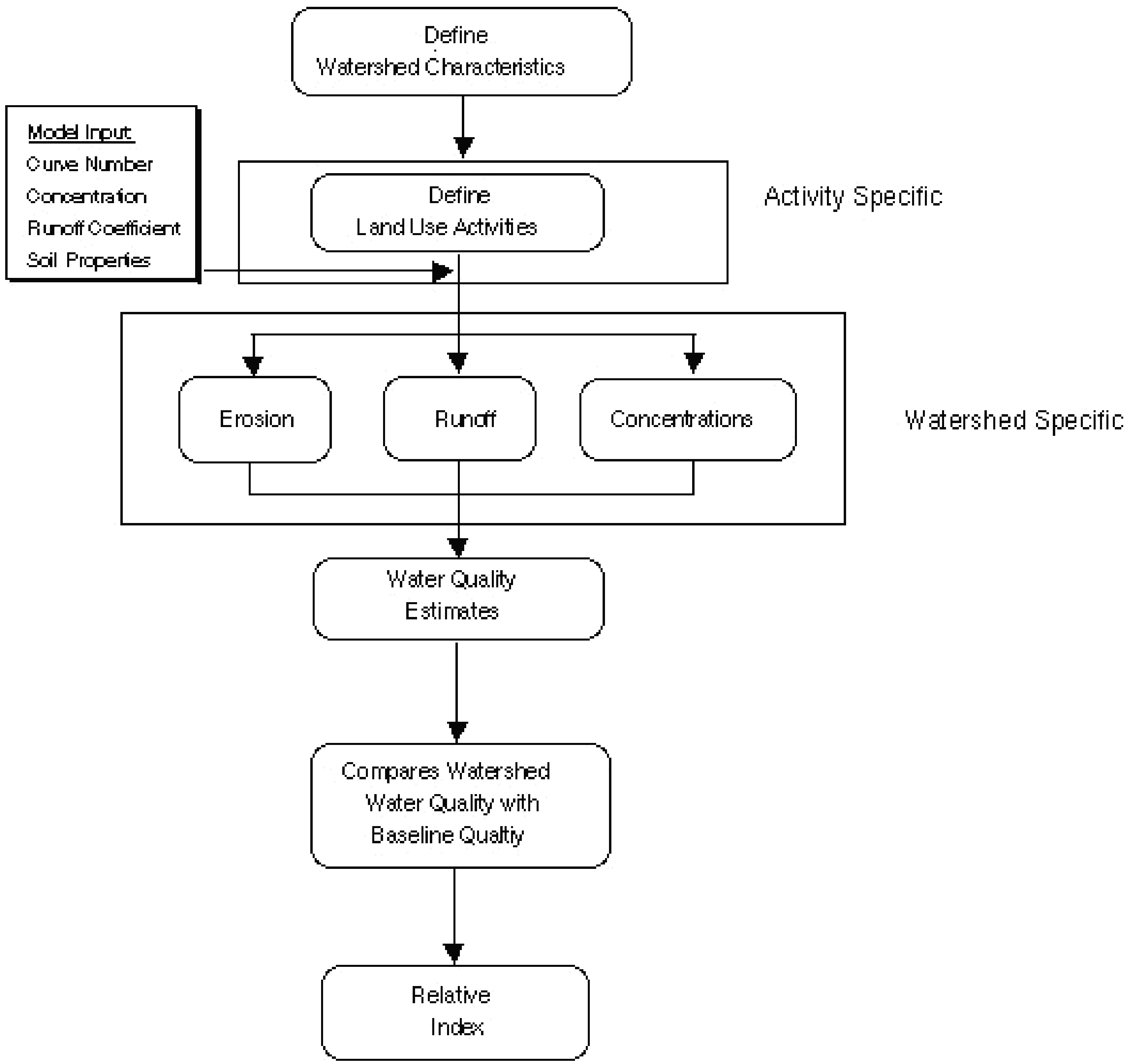


Figure 1. Flowchart of the model layout.

Model Calculations. Runoff and Erosion - The model estimates the erosion from the unurbanized areas using the Universal Soil Loss Equation developed by the Soil Conservation Service (SCS). These areas include the agricultural, forest land, open space, parks, single family residential and construction land use activities. Annual runoff is estimated for each land-use activity as the annual runoff coefficient times the annual rainfall for the subarea. The storm runoff for the ten-year 24-hour storm is calculated using the

SCS method. A curve number is automatically assigned to each land use activity from a lookup table based upon the soil number input by the user. The runoff is given in acre-feet.

The erosion potential for each land use activity is ranked relative to a baseline value (see discussion of model output for description of baseline value). The ranking is based upon a pseudo-average annual concentration calculated as the total erosion mass (i.e., tons) divided by the annual runoff (acre-feet). If this value is greater than two times the baseline value, the land use activity is assigned a high (H) ranking. If it is less than the baseline value it is assigned a low (L) ranking, otherwise it is assigned a medium (M) ranking.

Pollutant Loads - The model calculates the load of nitrogen, phosphorous, copper, lead and zinc for each land use activity. For each of these constituents for each land use activity, both a dissolved and particulate concentration has been assigned in a lookup table based on historical monitoring data. The total load is calculated as the total sediment load times the particulate concentration plus the annual runoff times the dissolved concentration. For the nutrients and metals, the load per unit area is compared to a baseline unit area value (Alameda annual pollutant load per unit area, (WCC 1992)). If either one is greater twice the baseline value the land use activity is assigned a high (H) rank, if both are lower than the baseline value the land use activity is assigned a low (L) rank.

Model Output. Model output is contained on the subarea specific pages and the main output page. On each subarea page a L, M or H is assigned to each land use activity for erosion, nutrients and metals. These are based on the calculations discussed above.

Step 5. Evaluate Pollutant Sources in Watershed

After reviewing model results the user needs to compare these results to the perceived water quality problems in the watershed. The screening model is not designed to determine if a particular land use activity is causing a water quality problem, only if the land use activity is contributing greater than a baseline amount.

Implementation Example Sausal Creek Watershed

The model was used to develop the water quality impacts from land use activities in the Sausal Creek watershed in Oakland California. An impact ranking was developed by comparing the load per unit area for each sub-watershed with the baseline value. If this value is greater than twice the baseline value, the land use activity is assigned a high priority. Conversely, if the value is lower than the baseline value the land use activity is assigned a low priority. For erosion, ranks were assigned by comparing average annual concentrations to a baseline value.

Table 1 shows the sub-watershed characteristics and land-use breakdown for the Sausal Creek watershed. The first two sub-watersheds (Shepherd Canyon and Palo Seco) both drain to Diamond Canyon which drains to MacArthur and Fruitvale. The land-use distribution is typical of watersheds in Alameda County where the upper sub-watersheds are largely open space or parks with increasing residential land-use in the middle sub-watersheds and industrial areas in the lower sub-watersheds.

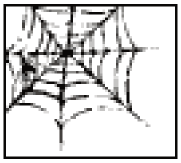
Table 2 shows the severity or impact ranking for each of Sausal Creek's sub-watersheds and for the watershed measured at the base of each sub-watershed.

The results for each sub-watershed indicate activities related to residential, commercial and industrial land uses show a low priority for nutrients and erosion and medium to high priority for heavy metals.

Conclusions and Recommendations

A process for identifying potential sources of urban storm water pollution was developed. As presented in this paper, an integral part of the process is a screening level model that ranks each land use activity from low to high based on its estimated impact on water quality.

Some possible improvements to the model include using concentrations rather than loads to assess short term impacts to creeks using event specific rather than annual average conditions to evaluate the effects of specific storm events. However, more investigation is needed on how this information can be used to direct implementation of Best Management Practices before these effects are incorporated into the model.



Note: This information is provided for reference purposes only. Although the information provided here was accurate and current when first created, it is now outdated.

Successful Restoration of Shellfish Habitat by Control of Watershed Pollution Sources

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Web Note: *Plesae note that images for this session of the Watershed 96 Proceedings are not available at this time, but will be available soon.*

Like many coastal communities, the town of Orleans, Massachusetts, has had its shellfish habitats affected by nonpoint source runoff. Elevated levels of fecal coliform bacteria forced the Cape Cod community to close over 2,500 acres of shellfish habitat during the 1980's. In 1987, the town formed a Water Quality Task Force to identify marine problem areas, determine the causes of the water quality degradation that had necessitated shellfish closures and recommend solutions. A municipal water quality monitoring laboratory was established, staffed by trained volunteers, to test for fecal coliform bacteria using the membrane filtration technique. The volunteers were primarily members of an environmentally active neighborhood association. The task force assumed, and subsequent water sample analyses confirmed, that stormwater runoff was a major factor in shellfish closures.

Pollution Assessment

The town of Orleans is located at the "elbow" of Cape Cod. It has extensive marine shellfishing resources including Town Cove and Meetinghouse Pond (Figure 1). The assessment involved identifying and mapping all existing surface drainage systems which were then prioritized according to the size of the drainage area and the resources affected. Areas were categorized according to shellfish productivity, swimming, and anadromous fish runs. Drainage pipes that discharged into shellfish habitat areas with more than one type of activity or very high productivity were given the highest priority and were recommended for remediation.

The town hired Metcalf & Eddy, Inc. to delineate the watersheds and drainage systems, develop remediation alternatives, design the new retrofit systems selected by the town, and oversee their implementation. The town funded the engineering and construction of the control facilities by a special appropriation of $400,000 approved by the voters, despite difficult economic conditions. Additional support was provided by the Friends of Meetinghouse Pond, the Commonwealth of Massachusetts which retrofitted existing drains with leaching catch basins during a road resurfacing program, and a private corporation that constructed the innovative filter dam system (designed by Metcalf & Eddy) on their property at Jeremiah's Gutter.

Five of the largest drainage systems were identified as having the most severe impact on high priority areas. Remediation projects were recommended for these systems: two in Meetinghouse Pond in the Pleasant Bay estuary and the three in the Town Cove portion of the Nauset estuary (Figure 1). The combined drainage area of the three pipes emptying into the Town Cove encompassed the majority of the business district and impacted some of the town's most valuable shellfish habitats. The other two areas were primarily residential uses.

Remediation Design

The analysis and design process considered a number of factors in selecting the most appropriate method to remediate the bacteria contamination. The process consisted of collecting base data and information; alternative identification and analysis; and detail design.

Bacteria contamination is most effectively treated by filtration. That filtration can be accomplished by subsurface soils (infiltration) or through a surface filter (sand filter). Since filtration in either scenario would be adversely effected by clogging of sediments and debris, those materials must be captured before the filtration occurs. An additional benefit of the sediment capture is that many pollutants are attached to the sediments and are also removed from the stormwater runoff. That pre-treatment process is typically accomplished with the use of settling tanks, or water quality inlets, installed upgradient of the treatment area. If hydraulic conditions would preclude the installation of the tanks, then alternative treatment areas such as a settling pond with baffles would be effective.

Once the priority watersheds and stormwater discharge pipes were selected, base information was obtained and potential treatment areas identified. Site and hydraulic conditions were studied to determine the most appropriate location to construct the treatment systems. The initial site screening conditions were depth to groundwater (must be greater than 10 feet), suitable soils (medium to highly permeable with no confining layers within 15 feet of the surface), and nearby stormwater collection system hydraulics. Secondary considerations were topographic and access conditions which would impact construction costs. Treatment area property ownership (town versus private) was also considered. The groundwater and soil conditions were necessary to ensure that the filtration system would consistently operate with minimum maintenance. Borings and soil testing were utilized to identify suitable soil strata treatment areas. The stormwater collection system hydraulics criteria required the acceptable treatment area to be at least ten feet below the drainage pipe invert. This allows the system to be gravity operated and eliminates the costly capital, operation, and maintenance costs associated with utilizing pumps in the treatment system. The general stormwater system mapping was supplemented with detailed survey to obtain system hydraulic information.

The alternative analysis involved evaluating the base information and determining the most effective treatment system for each watershed. Four acceptable areas were identified for installation of subsurface filtration systems. The systems consist of leaching chambers surrounded by stone. The stormwater entering the leaching chamber percolates through the gravel and sand to the groundwater, where it enters the estuary as underflow in a more diffuse manner. Pretreatment to collect sediments and debris was accomplished with the use of water quality inlet precast concrete tanks. The tanks were designed with a minimum detention time of 2 minutes and ranged in size from 2,500 gallons to 10,000 gallons. Since the majority of the rain events and pollutant generation occurs in the "first flush" or 1 inch of runoff, the systems were designed to treat that stormwater volume. Rain events with greater runoff volumes bypass the filtration system via an overflow weir and discharge directly to the estuaries. The infiltration systems consisted of leaching galleys and drywells. The systems each treated up to 150,000 gallons for the design storm.

A fifth area requiring treatment, Jeremiah's Gutter, has high groundwater (less than 4 feet below the ground surface) and unacceptable system hydraulics to install a treatment system similar to the other four sites. At this location a surface sand filter installed in precast concrete tanks was utilized for stormwater treatment. An existing upstream pond was retrofitted with steel sheeting to encourage sediment settling and trapping of floating debris. Since the treatment area was previously subject to fuel spills, a hydrocarbon containment boon was installed in the pond to further protect the estuaries. The filtration system provided treatment for over 300,000 gallons of stormwater, consisted of five concrete tanks with a 12 inch thick sand and geotextile filter media. An underdrain system was designed to discharge the treated stormwater downstream and allow for convenient water sampling. If the stormwater runoff exceeded the design event or the filter was not properly maintained, excess runoff would discharge directly to the downstream areas via an overflow weir.

System Construction

Because Orleans experiences tremendous tourist activity between April 1 and October 1 each year, no construction could occur during those periods. The design and permitting was completed in the fall of 1992, therefore bidding and construction had to be completed between December 1992 and April, 1993. The construction program consisted of the completion of four treatment systems at three sites: Academy

Place, Main Street and Tonset Road, and Meeting House Pond areas. The fifth area, Jeremiah's Gutter, was constructed by a private corporation at no cost to the town.

The project for the four sites was awarded to the contractor in February 1993 and the work was essentially completed by the April 1, 1993 deadline at a cost of approximately $282,000. Jeremiah's Gutter treatment system was conducted on private property and therefore not subject to the April 1, 1993 deadline.

Operation and Maintenance

Each project included an operation and maintenance program that the town or the private corporation has adopted. The program consists of periodic inspection of key components and removal of sediment and debris which has accumulated in the water quality inlets. Maintenance on the sand filter at Jeremiah's Gutter involves periodic removal of the filter media and is conducted by a private corporation.

Water quality monitoring is continuing to determine the efficiency of the systems. Data from the source monitoring program, four sites constructed by the town, is shown in Table 1. The effectiveness of the stormwater treatment systems are apparent, with substantial reductions in fecal coliform bacteria. Within 15 months of completing construction, all of the shellfish habitat acreage was either successfully reopened or has not been subject to temporary closures.

The filtration system at Jeremiah's Gutter was constructed by a private corporation and initially was not operating correctly. After construction the geotextile on top of the sand filter and through which the stormwater has to percolate was clogged with iron algae. Recently the geotextile was removed as recommended in the operation and maintenance plan and the filter was operable. The town will initiate water quality sampling and analysis of the filter system effluent to determine the effectiveness.

Future Remediation

The town has investigated remaining drains and prioritized them for future remediation based on the success thus far. A grant from the Environmental Protection Agency and Massachusetts Department of Environmental Protection was received from the nonpoint source pollution program. With these funds, an additional four drains will be remediated. Additional work is being undertaken by the town to prevent future contamination problems and avoid the need for additional pollution control retrofits. Actions include preparation of a groundwater table map, flushing analysis of two estuaries, preparation of comprehensive land use and resource management plans and an assessment of nonstructural best management practices for stormwater control. This assessment includes a review of ordinances that would encourage on-site handling of stormwater and discourage direct drainage to marine resources.

Watershed Restoration in Deer Creek, Washington- A Ten Year Review

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Deer Creek is a tributary to the North Fork Stillaguamish River located in the North Cascades of Washington State. The watershed encompasses approximately 67 square miles. Approximately half of the watershed is National Forest land, the rest is in state and private ownership. The major land use is forestry. The topography is characterized by glaciated valleys separated by sharp ridges, with elevations ranging from 1600 to 4900 feet in the headwaters to near 200 feet at the mouth. The mainstem of Deer Creek has a length of 24 miles while 23 individual tributaries total an additional 56 miles of stream channel.. The effect of glaciation, in particular the deposition of lacustrine clays and silts, has strongly influenced the morphology and sediment production of the watershed. These glacial sediments in the steep lower slopes of the valleys of Deer Creek and its tributaries are prone to mass wasting and erosion (Collins et al 1994). Most of the watershed is classified as a temperate evergreen forest with a western hemlock and silver fir vegetation series dominating. Within these two vegetation series the dominant tree species include western hemlock, silver fir, western red cedar, and Douglas fir (Henderson et al 1992). The average annual precipitation ranges from 75 inches in the lower watershed to 110 inches or more at the higher elevations. Precipitation occurs throughout the year, 75 % falls between October and March. In the Washington Cascades, elevation influences whether winter precipitation occurs as rain or snow. Middle watershed elevations (1600-2600 feet) are transitional rain-on-snow zones; snow may build up and melt several times during a winter. Winter storms, often accompanied by heavy rains and wind may melt snow at these elevations causing high flows and subsequent flood damage.

About two thirds of the Deer Creek stream channel network is accessible by anadromous fish and has historically supported runs of steelhead trout (Oncorhynchus mykiss), coho salmon (O. kisutch) and native char (Salvelinus malmo). Based on historical accounts, Deer Creek fish habitat consisted of a variety of riffles and high quality pools formed by a multitude of huge boulders with deep, clear cold water. The wild steelhead run in Deer Creek has evoked strong emotions among past and present generations of anglers and writers. In 1918, while passing through Seattle on his way to the Campbell River in British Columbia, the famous western novelist, Zane Gray fished Deer Creek. His second day on the stream, he hooked his first steelhead. It was the beginning of a long association with steelhead fishing about which Gray wrote extensively about later. In 1937 the Washington State Game Commission closed Deer Creek to all fishing to protect and maintain the natural production of steelhead within the watershed. In 1943, the N.F. Stillaguamish River, downstream from Deer Creek, was designated for fly fishing only. This was probably the first time a western river was restricted to fly fishing (Raymond 1973).

Major timber harvesting began in the watershed in the 1950's. By the mid 1980's the Deer Creek fishery was in decline due to the cumulative effects of the timber harvesting which caused increased land slides, channel sedimentation, and loss of fish habitat The majority of the lower watershed and approximately one third of the federal land has been timber harvested.

The declining fish populations coupled with habitat loss and degradation in Deer Creek made protection and restoration of the remaining habitat a high management priority. The Deer Creek Group was formed in 1984 in response to these concerns. The Group was composed of local landowners and managers, state agencies. Fishing groups and local Indian tribes. Mixed land ownership in the watershed and conflicting mandates of resource management agencies made it imperative that a forum be created where all concerned parties could begin a dialog to address resource issues.

All these efforts still didn't do much to stop or reverse the decline in the adult and juvenile summer-run steelhead populations in Deer Creek; in the fall of 1993 Washington Trout formally petitioned the National Marine Fisheries Service to consider Deer Creek summer-run steelhead as a federally endangered species.

Watershed Assessment and Restoration Strategy Development

Starting in 1984 the US Forest Service and other resource management agencies began to address the concerns in Deer Creek through watershed-wide inventory, monitoring, and identification or restoration opportunities. This major assessment and planning effort led to the identification of the natural landscape interactions (climate, hydrologic response, erosional processes) that had been altered by management activities and subsequently led to the development of the restoration strategy. The scope of this watershed scale assessment was focused mainly on the aquatic ecosystem and was not as broad in scope as is the present federal watershed analysis efforts.

This assessment documented that the various land management activities throughout the watershed over time had contributed to a loss of historic aquatic habitat and became one of the main factors for the decline of the native fish runs, including the watershed's famous summer-run steelhead. In particular, concentrated timber harvest and the associated road building had modified the hydrologic regime that in turn resulted in a increase of mass wasting (landslides) and channel degradation. This was most evident in steep gradient, first and second order channels where these sub-watersheds were usually clear-cut harvested and the heavy density or roads altered the natural drainage pattern. This channels flushed repeatedly during storms and became a chronic source of coarse sediment input to the downstream channel network.

The focus of federal restoration in Deer Creek, over the past 10 years has been to reduce the impact that management activities throughout the watershed and to promote the return to the natural hydrologic and erosional regimes. The ultimate goal has been to restore major portions of the historic aquatic habitat. The restoration strategy had a dual thrust; first employ long term aquatic resource protection followed by a comprehensive restoration program. Resource protection, in particular timber harvest and road building prescriptions and standards, was an early key step of the restoration strategy. Timber harvesting and planning continued during the early phases of watershed assessment and initial restoration implementation. Recognition of the cause and effect relationships of management activities and resource conditions led watershed specialists to identify and study ways to quantify these relationships. The concept of hydrologic cumulative effects was employed to assess and explain conditions across the watershed that contributed to stream channel degradation and fish habitat loss. Thresholds were developed using these cumulative effects models in order for management decision making; based on such thresholds, the US Forest Service in 1986 and again in 1990 deferred any future timber harvesting on federal land in the watershed until aquatic habitat conditions were improved. With natural watershed recovery possible now through these management decisions, the restoration component of the strategy could be developed and implemented. The restoration focused on the erosional process and sedimentation. The general objective was to reduce coarse sediment delivery and to mechanically stabilize hill slopes and streambanks; this would promote stream channel recovery, natural revegetation of riparian and flood plain areas, and to ultimately restored fish habitat. The ultimate goal was the recovery of the depressed native fish stocks, with a particular emphasis on summer-run steelhead trout. The restoration program had 2 elements; (1) implement restoration that involved three categories of treatment (roads, hill slope, and in-channel), (2) carry out these treatments over a multi-year period of time. The restoration treatment objectives were:

- reduce coarse sediment input from road and hill slopes to the downstream channel system
- reduce the risk of catastrophic failure (major landslides from roads and hill slopes)
- reduce sediment recruitment from the stream channel banks
- promote a return to the natural stream channel sediment regime (transport and deposition)

Projects were developed from the watershed assessment and coordinated with other agencies and landowners through the Deer Creek Group. US Forest Service projects were prioritized by treating the sediment source areas (current and potential) first. Individual sites were prioritized by an informal risk assessment looking at the probability of failure and the potential resource impacts if failure occurred. Other site scale factors considered were accessibility to the site, success potential for the treatment, and project cost. With this prioritization of treatments, roads and hill slopes projects were implemented before most of the in-channel work.

Watershed Restoration Implementation

Once the processes were identified through watershed assessment and a restoration strategy was developed, the implementation team had to design and implement specific treatments throughout the watershed which were intended to meet the overall restoration goals through more narrowly defined project site treatment objectives.

Road treatments were one of three types (road obliteration, road storm proofing, road upgrading) and typical treatments included:

- installation of larger or additional culverts, or hardened dipped crossings (concrete fords or open box culverts)
- bridges installed to replace ineffective culverts
- removal of culverts from inactive roads and restoration of the natural drainage
- construction of effective drainage ditches and insloping/outsloping of roads to direct water and reduce road fill saturation that causes road fill failure
- installation of waterbars to intercept water and provide a controlled flow in a drainage ditch
- removal of sidecast or settling road fill materials to reduce the risk of mass wasting
- revegetation of cut banks, fill slopes and or obliterated road beds to reduce surface erosion and to stabilize the soil and ground cover.

Generally hill slope treatments occurred on bare, eroding slopes with the intent of stabilizing and revegetating the site. Typical treatments included installation of retaining structures such as sediment fences and check dams, revetments, drains and trenches on unstable areas to reduce the risk of mass wasting and seeding, mulching and planting of native trees and shrubs. In-channel treatments focused on the location and position of woody debris in the stream channel. The majority of the treatments either featured the repositioning of wood on the lateral margins of the active channel or efforts to decrease the mobility or rapid transport of this wood out of the active channel. Treatments were designed to add structural diversity (roughness) missing from the channel system and then allow time for the channel to adjust. Little mechanical reshaping or regrading of the channel was employed.

Monitoring and Maintenance

Prior to 1984 there were only a few habitat and fish population surveys of a limited nature were conducted in Deer Creek. When concerns about the effects of management activities on fish habitat were raised in the early 1980's, it became clear that there was a need to develop an integrated strategy to monitor key watershed parameters on national forest land and to promote a similar approach by other downstream landowners and resource managers. The US Forest Service initiated the development of a watershed scale interagency multi-resource monitoring program beginning in the summer of 1984. The main objective of this monitoring was to determine avenues for correcting current aquatic resource problems and improving future resource management decisions. Inventories and surveys were coordinated by the US Forest Service and included state agency and tribal fishery personnel; these included stream, fish population surveys, spawning gravel and stream channel morphology assessments, stream temperature monitoring, road and landslide inventories. An initial report was prepared following the first year of monitoring recommending (1) the monitoring effort should be continued and expanded to include the whole watershed, (2) pilot restoration projects be identified, (3) and a hydrologic cumulative effects assessment be conducted for the watershed.

The most intensive monitoring effort in Deer Creek has been on specific project effectiveness. A regular review of site treatment effectiveness aided the scheduling of annual project maintenance. This allowed for the modification of existing projects and adjustments in future project design. Project modifications were common, particularly in the early years of the restoration program; when techniques had to be adjusted to local site conditions or unfamiliar methods required minor redesign. Most projects required annual maintenance since implementation.

Results and Conclusions

Implementation of watershed restoration in Deer Creek has been a major undertaking. The treatment results listed here are general in nature because even with detailed or statistical analysis, it would be difficult to obtain definitive results without conducting cost prohibitive long term research oriented studies. Even with such studies, the complexity and dynamic nature of aquatic ecological interactions at a watershed scale would make it difficult to link the observed results with management actions. Most federal watershed restoration programs, including the Deer Creek restoration have restricted monitoring budgets; monitoring is usually restricted to comparing qualitative data and information. This type of monitoring known as implementation and effectiveness monitoring, is limited to producing trend type information. At a watershed scale, this level of monitoring is intended to show the trend or change in the amount of landslide activity, coarse sediment transport and deposition, road failures, stream channel stability, habitat loss or degradation, stream temperatures, and ultimately, change or trend in fish population status.

The watershed restoration program in Deer Creek is considered successful for the following reasons:

- The program assisted in the development of a watershed restoration strategy now embodied as a component in the aquatic conservation strategy in the Northwest Forest Plan.

- The Forest Service was the initial partner in developing and maintaining working relationships within the Deer Creek Group which became a model for the Washington State Timber, Fish, and Wildlife Program.

- Deer Creek has remained a federal restoration priority for 10 years and a new phase of restoration assessment, planning, and a revised restoration strategy developed on past success is underway.

- The Forest Service has responded with many regional and international requests to share knowledge and skills through numerous field trips and workshops.

- Since the Forest Service declared a moratorium on timber harvest in 1986, significant revegetation of timber stands has occurred, with a resultant partial recovery of the watershed's natural hydrologic function.

- Restoration treatments survived the 1990 and 1995 flood events, some estimated to be 50-year events.

- Relatively high quality fish habitat has been maintained in the upper watershed and is currently serving as refugia habitat for summer-run steelhead, coho salmon, and native char.

- Fish populations in Deer Creek have increased significantly in the last two years. The increase in juvenile fish densities is reversal of a decade long decline. This is in part, attributed to an improvement of the habitat during the past five years.

It may be difficult to view this work as ecological restoration because the intent was not to actually restore the watershed to its pre-management condition. The US Forest Service with its multiple use mandate had the responsibility to develop a restoration strategy that would strike a balance between land use and resource protection and recovery. The emphasis of restoration in Deer Creek has been to accelerate natural recovery through a scope of work that was accessible, affordable, and achievable.

The Deer Creek story is a success story largely due to cooperative efforts both within the US Forest Service and with external partners in the Deer Creek Group. Efforts in Deer Creek served as a model for development of the strategies and techniques necessary to implement a successful multi-year watershed restoration program.

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Watershed Management of Coral Reef Communities

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Introduction

Coral reefs are among the worlds richest ecosystems. They are second only to rainforests in the diversity of plants and animals. Reefs exist in an environment that is narrowly defined by factors of temperature, salinity, light, available oxygen and nutrient regimes. The health of a coral community can be severely disrupted If environmental conditions fall above or below the acceptable range of these parameters.

Coral communities adapt well to acute (short term) disturbances such as tropical storms and hurricanes. The tremendous destruction that can occur to reefs from severe storms is well documented (Woodly, 1981). Recolonization and recovery are a natural process absent any other ongoing stress (Rogers, 1993). However, corals are not faring well where increasing coastal populations and development apply more chronic pressures. It is estimated that some ten percent of the worlds reefs are degraded beyond recovery. Another thirty percent could be lost in the next decade without proper management (Wilkinson, 1993). Solutions to managing these pressures are often found locally. All contributing stressors to the coral ecosystem need to be considered in development of a management plan. It must look beyond the reef proper consider all sources of a watershed which can impact a coral community. Coral reef management plans should be integrated into the planning process of coastal community planners. The goal is to reduce the impacts of coastal watershed activities on reefs. These plans should identify problems and provide solutions which have the commitment of all local interested parties. Developing local partnerships and cooperation are one of the most challenging tasks of ecosystem management. Development of these partnerships are key to the success of coral reef management.

Problems and Threats

Coral reefs exist in zones where powerful storms occur. Reefs are also subjected to adverse conditions which result from seasonality and fluctuating water temperatures. All of these can result in death to corals. However, just as with terrestrial systems this death opens a hole which allows for recolonization and increased diversity. This type of change is natural in biological systems. Corals do not as easily rebound from the impacts of mans activities.

Threats to corals are quite varied. Sources range from alteration of the environmental parameters (Light, temperature, salinity, oxygen,nutrient enrichment), to exposure to toxics and pathogens or the all to common mechanical damage that can result from recreational activities (diving) and boating (groundings, anchor damage). Most of these impacts occur to nearshore, easily accessible reefs. Rarely is just a single stressor involved.

One of the leading causes of nearshore coral decline can be related to land and near shore construction which is not environmentally sensitive. While these activities are removed from the reef proper they are detrimental to the associated communities of mangroves, mudflats and seagrasses. These communities are vital to chemical and energy cycling and also provide important nursery and habitat for a wide array of organisms. Mangroves trap sediment and organic material and allow a slow progressive breakdown. The mudflats act as a storage battery by retaining dissolved nutrients and periodically releasing them. If these communities are altered too much they expose the reef to stress in the form of sedimentation, nutrient enrichment, low oxygen levels or toxics from runoff, as well as the overall decrease in biodiversity.

Looking Beyond the Reef

Reefs have always been recognized as areas of high biological productivity which warrant special protection. Protective measures were often directed solely on the reef with little recognization of pollutant impacts from distant sources. Establishment of National Parks, sanctuaries and biosphere reserves began as a way to gain control over degrading reefs. While this did much to control impacts from recreational activities and fisheries; it did not address pollutants which arrive from distant waters.

The establishment of parks and reserves was an important step in managing reefs, but it did little more than establish "coral islands". Some were large biosphere reserves, established through United Nation activities, or through state activities such as John Pennecamp Coral Reef State Park , in the northern Florida Keys. Others were small like Looe Key Sanctuary in the lower Florida Keys. But large or small they were managed in isolation. What is needed is an integrated approach to gain control over pollutants from distant sources. The biosphere reserves began the process of zonation (Clark, 1996). This consisted of three or more concentric zones that made up the reserve. The least disturbed area is the core. This is adjoined by the buffer zone. The buffer zone surrounds the core and manages activities in this zone so as to buffer the core area from adverse impacts. The transition zone is the outer most area and surrounds the buffer zone. This zone may contain settlements, pastures, forests or any area that contains economic activities which influence the reserve. The transition zone is where efforts of cooperation occur to incorporate the needs of the reserve in the regional planning process. This is a form of integrated coastal zone management. While the success of these reserves may be debated, the plans of incorporating source pollution control is key to the success of any coral reef management.

Watershed Management

Coral reef management must move away from the reef proper and consider all waters and activities which have influence on the system. It is necessary to work at the ground level and form partnerships and cooperation with local communities if we are to integrate the needs and activities of these communities with the needs of the coral ecosystem.

It is noted that in the Florida Keys, reefs only exist in the shadow of islands. They do not occur where the "green water" of Florida Bay flow between the islands. This bay water effects essential environmental parameters that were mentioned early. The bay water is too saline, too turbid, too high in nutrients and too low in available oxygen to sustain reefs. To remove or decrease this stress will require changes in activities which affect water quality. These activities generally occur in communities far from the reef proper.

The Florida Keys National Marine Sanctuary plan (NOAA, 1995) is a vehicle that will attempt to control some of these stressors. This plan was developed in cooperation with state and federal agencies. One of the most important components of the plan, as well will be the development and implementation of a water quality plan for South Florida. This plan will address the difficult water use issues which involve the agricultural and urban communities of South Florida.

Building understanding, cooperation and partnerships with various stakeholders is not easy, however, it is paramount to the final success of any management plan. The Environmental Protection Agency's (EPA) National Estuary Program (NEP) can provide examples of success in developing partnerships. They have published these as NEP success stories (EPA, 1994). The EPA's Ocean and Coastal Protection Division has developed a guidance document on coral reef protection through watershed management (EPA, in prep.). This document is directed toward the non technical user and presents a framework for coral reef management which can be used at the local level.

The heavy rains of 1993 which flooded America's heartland brought large loads of sediment to the Gulf of Mexico. Tons of these sediments were deposited on Florida reefs. This huge freshwater inflow caused the temporary appearance of a freshwater river that pushed northward, with the Gulf Stream, to Maine. It has been suggested that under this scenario Kansas could be considered a coastal state. This natural event would not be as significant if the reefs were not also under stress from anthropogenic sources. As stated earlier with severe storms, reefs can sustain themselves in the face of major perturbations, when other stressors are not present. The Florida reefs may not as easily rebound from this natural disaster since they are under constant stress from other multiple sources. We may not be able to control the weather, but we can direct our actions. We need to build upon the earlier efforts of ecosystem management of reefs and develop integrated management plans which are based upon cooperation and partnership.

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